2.5 GEOLOGY, SEISMOLOGY AND GEOTECHNICAL ENGINEERING

Information regarding the geologic and seismological characteristics of the region and site and site geotechnical engineering conditions are presented in the order outlined in <Regulatory Guide 1.70> (Revision 3), <Section 2.5> and as defined in <10 CFR 100, Appendix A>, “Seismic and Geologic Siting Criteria for Nuclear Power Plants.”

For the initial FSAR development, several consultant organizations were retained to assist in subdiscipline specialties. Their major contributions by section are as follows:

Gilbert Associates Inc. (GAI) of Reading, Pennsylvania had the primary responsibility of directing, coordinating, preparing, and assembling the detailed information and data for this Section. Regional Tectonics and Vibratory Ground Motion were prepared by Weston Geophysical Corporation, Inc., Westboro, Massachusetts. Weston performed and arranged for seismological, geophysical and some aspects of geological studies conducted respective of regional and site conditions.

Stability of Subsurface Materials and Foundations, Stability of Slopes and Embankments and Dams, were prepared by Woodward-Clyde Consultants, Plymouth Meeting, Pennsylvania. Woodward-Clyde Consultants performed and arranged for aspects of geotechnical engineering analyses during preconstruction site investigations and construction activities. Most laboratory testing and analyses were conducted by Woodward-Clyde consultants at their Plymouth Meeting office.

The contributions of independent consultants who contributed to various investigative and analytical tasks or who served in a review capacity are acknowledged within the main text.

For the initial USAR development, incorporating the analysis of the January 31, 1986 Leroy earthquake, Weston Geophysical was retained as they were responsible for all geotechnical studies related to that event.

Description of Region

The site is situated in the central part of the Eastern Stable Platform Tectonic Province, a wide region characterized by an Upper Precambrian crystalline basement complex overlain unconformably by a sequence of Paleozoic sedimentary formations with little tectonic deformation. Basement rocks in the site province are comprised largely of high-grade, regionally-metamorphosed schists, gneisses, marbles, and calc-silicate granulites, which were consolidated to a discrete crustal block during the Grenvillian Orogeny, 950±150 million years ago.

Post-consolidation tectonic deformation in the site province is of minor extent, limited to the development of broad northeast-trending arches of epeirogenic origin along the western portion during Early to Middle Paleozoic time, with localized faulting activity on or near the arches in Middle to Late Paleozoic time. The only tectonic structure within the site province interpreted to be active is the Clarendon-Linden fault zone in western New York, about 160 miles northeast of the site.

The site province is bounded on the west by the Grenville Front and Michigan Basin; on the northeast (beyond the site region) by the Ottawa-Bonnechere graben structure; on the southeast by the moderately-folded sedimentary rocks of the Appalachian Plateau; and on the south (beyond the site region) by the Kentucky River-Rome Trough fault system. The Grenville Front is a profound tectonic boundary in the basement, separating the high-grade Grenvillian terrane of the site province to the east from essentially undeformed felsic intrusives, volcanic flows and sedimentary/pyroclastic rocks of the Keweenawan and

Elsonian Terranes to the west. Along much of the Grenville Front to the west and southwest of the site, the Precambrian basement rocks lie at depths less than 1.24 miles below ground surface.

The residual gravity map was used as an important part of the basis for constructing regional tectonic provinces. Gravity gradients, amplitudes of individual anomalies, and trends of individual anomalies supplemented mapped geology and other data. These gravity data, from about 40,000 stations in the area, 77°-85°W and 38°-48°N, were used to prepare contour maps of the total Bouguer gravity anomaly, and residual Bouguer gravity anomaly.

The site is located in the Eastern Stable Platform Province, where seismic activity is relatively low. Within 200 miles of the site, only two zones of moderate seismic activity can be found. The first is located 160 miles away, in the same province, and is correlated to the Clarendon-Linden structure while the second, in the Central Province, about 185 miles away, near Anna, Ohio, is probably tied to local basement structures in that area (Reference 1) (Reference 2). Within this context the earthquake potential at the site is low, as related to the hypothetical occurrence of an Intensity VI(MM). Such an intensity is estimated from the maximum earthquake, not correlated to structure, experienced in the site province. A safe shutdown earthquake acceleration of 15 percent of the gravity acceleration (g) is selected for the safe shutdown earthquake (SSE). This value is above the mean value of intensity versus acceleration given by Trifunac and Brady for an Intensity VII (Reference 3).

Description of Site

The Perry site is approximately 35 miles northeast of Cleveland on the shore of Lake Erie. The plant site is on nearly level terrain, with the main plant being about 800 feet from the toe of a 45 foot high steep bluff that forms the shoreline. Upper Devonian shale bedrock underlies

the site about 55 feet below the existing ground surface. Bedrock onshore is overlain by approximately 30 feet of very dense till which in turn is overlain by about 25 feet of poorly compacted lacustrine deposits, both of Pleistocene age. Thin layers of glacial till and beach deposits respectively, overlie bedrock at the shore. Shale forms the lake bottom from 1,000 to 1,500 feet offshore in the area investigated. Pleistocene glaciation induced localized shallow faults and folds in the shale strata beneath the site. Last movement on an offshore fault intersecting the cooling water tunnels occurred during Pleistocene time in response to deglaciation-isostatic rebound.

Investigations Performed

The onshore plant site investigation included test borings into bedrock, the deepest of which was 730 feet. Other subsurface site investigative activities included: 42 inch drilled exploratory shafts into the top of bedrock, in situ testing and plate load tests; pressure meter tests; permeability determinations; piezometer installations; seismic analyses, seismic refraction traverses and seismic shear wave determinations; geologic mapping of foundation grades, tunnels and excavation cuts; geologic studies and preparation of subsurface geologic profiles. Offshore in Lake Erie, investigations for cooling water facilities included: ten test borings into bedrock, water pressure tests, gas composition and pressure tests, and probing of the lake to determine both configuration and nature of the lake bottom materials. In addition, the dispersive characteristics of shale and till were investigated to determine any clogging potential of the plant porous concrete underdrain system. Supplemental investigations were conducted on the shallow onshore and cooling water tunnel deformation identified during the geologic mapping program.

Results of Investigations

Subsurface exploration, substantiated by laboratory testing of soil and rock and excavation experience, confirmed that stratigraphically, the subsurface materials and their respective physical properties were similar throughout the plant site. The Upper Devonian shale strata beneath the site dip less than 5 degrees southeast, but the erosional bedrock surface slopes north toward Lake Erie. Small inflows of natural gas were encountered in about a dozen borings penetrating shale bedrock. Groundwater levels ranged between three and five feet below ground surface. The depth to groundwater gradually increased toward Lake Erie.

The bearing characteristics of the lacustrine deposits and upper till with a combined thickness of 35 feet are generally unsuitable for the support of Seismic Category I structures. Support for most Seismic Category I buildings is provided by lower till and Chagrin shale. Seismic Category I structures, such as piping, duct banks, buried fuel oil storage tanks, and the diesel generator building are founded on compacted Class A backfill. Controlled Low Strength Material (CLSM) may be used as a replacement for Class A fill when the Class A fill was used as bedding and backfill for buried piping and ductbanks only, and not as part of the Plant Underdrain system, or as a foundation for safety-related buildings or structures. The lower till exhibits a very low compressibility under static loads up to 6 tsf. The shale is capable of supporting loads to at least 25 tsf without detrimental settlement. Subsurface investigation of the cooling water tunnel alignments indicated that Chagrin shale beneath Lake Erie is relatively uniform and generally competent and free from detrimental soft zones. Site conditions for plant excavation and tunneling were predicted to be favorable.

Construction experience generally was consistent with the exploration results. Material properties and groundwater conditions were as

anticipated. The open excavations were dry, and the radius of monitored groundwater drawdown was less than had been calculated.

Shallow deformation exposed by onshore foundation excavation into Chagrin shale, although unanticipated, was similar in style and origin to that identified on the east bank of Bates Creek during preconstruction site-locale geologic reconnaissance. A similar result was obtained during investigations of geological features at Big Creek, located 22 km southwest of the plant site (Reference 4) following the January 31, 1986 earthquake. In this instance the shallow structures are confined to the Cleveland shale directly overlying Chagrin shale.

An anomalous, small-displacement, thrust fault intersecting the cooling water tunnels, was revealed during tunneling. Studies show that its last movement, an adjustment to glacio-isostatic rebound, occurred in Pleistocene time. Several inflows of methane were encountered without hazardous incident. Tunneling was conducted under characteristically dry conditions. The only wet conditions experienced were a short term, relatively small volume of discharge from the tunnel fault under piezometric pressure and several other minor seeps. None of the site faulting evaluated during initial site investigations, or faults mapped during post January 31, 1986 Leroy earthquake studies, are capable as defined in <10 CFR 100, Appendix A>.

Ohio and adjacent areas are characterized by small infrequent earthquakes with an occasional moderate earthquake. Three moderate earthquakes, one of Intensity VII-VIII (MM) centered in the Anna, Ohio area, 185 miles southwest of the site, one of Intensity VIII (MM) in the Attica, New York area, 160 miles northeast of the site, and the Intensity V-VI(MM) event centered near Leroy, Ohio, 10 miles south of the site, represent the largest earthquakes to have occurred within 200 miles of the site. Acceleration values for the safe shutdown earthquake (SSE) and operating basis earthquake (OBE), are 0.15g and 0.075g, respectively.

Conclusions

Findings of the comprehensive geology, seismology, geotechnical engineering investigations, and construction experience show that the Perry site on the southeast shore of Lake Erie, near North Perry, Ohio, is acceptable from geologic, seismic and geotechnical engineering viewpoints.

2.5.1 BASIC GEOLOGIC AND SEISMIC INFORMATION

Basic geologic and seismic information provided throughout the following paragraphs is discussed in context of a regional, local, site, or plant area connotation and is defined as follows:

a. Regional

A large area within the Central Lowlands Physiographic Province essentially defined by a basic similarity in the spatial distribution, position and geologic history of stratigraphic units, structural features and surface forms. Generally, a reference area within a 200 mile radius of the site is sufficient in developing the regional geologic and seismic characterization.

b. Local

Normally a "localized" area in proximity to the site within a minimum radius of five miles centered at the plant area. Geologic features peripheral to the five mile radius but significant with respect to local geology are necessarily incorporated into this category. Following the January 31, 1986 Leroy earthquake, this area was extended to include features within 15 miles of the site and within 5 miles of the epicenter.

c. Site

An area restricted to the surface property boundaries of the site including the Lake Erie shoreline and the subsurface limits of mineral rights acquisitions.

d. Plant Area

Includes those areas occupied by major plant structures and especially Seismic Category I structures.

All elevations are in feet above mean sea level (MSL), USGS Datum, unless otherwise noted.

2.5.1.1 Regional Geology

Salient aspects contained within the Central Lowlands Physiographic Province as well as contiguous provinces are presented in context of their relationship to the site location and structures.

2.5.1.1.1 Regional Physiography and Geomorphology

The site lies within the Lake Plains Section, a physiographic subdivision of the Central Lowland Physiographic Province. The Lake Plains Section is characterized by a narrow band of very low relief terrain, five to ten miles wide, along the southeast shore of Lake Erie. South of the Perry site, the narrow Lake Plains Section is adjoined by the Glaciated Plateau Section of the Appalachian Plateau Physiographic Province. This boundary, commonly referred to as the Allegheny Escarpment, trends in a general northeast-southwest direction from the Pennsylvania border to north-central Ohio where its bearing changes to a more southerly direction. The Allegheny Escarpment is recognized as an abrupt change in relief, approximately 100 feet, in northeastern Ohio.

In south-central Ohio the Glaciated Plateau Section has a common boundary with the Till Plains Section of the Central Lowland Province. A regional physiographic map showing these physiographic relationships to the site is presented in <Figure 2.5-1>.

The site is on a portion of the Lake Plain that was submerged in the geologic past when the level of Lake Erie was considerably higher than the present level. Approaching the present shoreline of Lake Erie, the flat terrain gives way to a steep bluff that forms most of the shoreline in northeastern Ohio. The average height of the bluff is approximately 45 feet.

2.5.1.1.2 Regional Geologic Features

The site is situated within the eastern portion of the Central Lowland Physiographic Province as previously discussed. This province is founded on a buried supracrustal platform or craton composed of Precambrian crystalline basement rock overlain by variable thicknesses of Paleozoic sediments, generally on the order of several thousand feet. A surficial veneer of Pleistocene glacial and lacustrine deposits are present throughout much of the province, including the site.

The Precambrian crystalline basement is not exposed anywhere in Ohio but underlies the site vicinity, approximately 5,000 feet below surface, as interpolated from drill records and geophysical survey data. Basement structures inferred on the basis of direct and indirect data include both local trends and regional features consisting of the Lake Superior syncline in Wisconsin, Minnesota and Iowa and the Grenville metamorphic or orogenic front presumably traced from eastern Canada southward into Michigan and Ohio (Reference 5) <Figure 2.5-2>, and the Akron Magnetic Boundary representative of regional scale lithologic differences in the crystalline basement.

Distinctive regional Paleozoic structures are principally broad upwarps such as the Cincinnati, Findlay and Kankakee arches, the Ozark uplift and the Nashville dome, with intervening deep depositional basins of Paleozoic rocks including the Michigan and Illinois basins. The development of these uplifts and basins spanned the Paleozoic Era. These areas of uplift and subsidence were accompanied by high-angle faulting and mild folding.

2.5.1.1.3 Geologic Setting

The site is on the northwestern flank of the Appalachian geosyncline. Bedrock directly beneath the site belongs to the Ohio shale formation (Upper Devonian). To the south, these Devonian strata are overlain by successively younger Paleozoic sediments and Pleistocene glacial deposits respectively. These rocks dip gently to the south at a gradient of approximately 20 to 40 feet per mile. This paleotopographic surface was eroded as a consequence of continental glaciation forming Lake Erie along with the other Great Lakes during the Pleistocene Epoch. Lake Erie is the shallowest of the Great Lakes, with a maximum depth of 210 feet and an average depth of 58 feet. The western end of the lake is extremely shallow as much of the lake bottom is immediately underlain by resistant carbonate bedrock. From the general vicinity of Sandusky, Ohio, to the east beyond the Pennsylvania boundary, Lake Erie has been eroded into Upper Devonian shales which overlie the more resistant rocks comprising lake bottom strata of the western portion.

All but southeastern Ohio has been extensively mantled by Pleistocene glacial deposits. Consequently, bedrock exposures are sparse particularly in proximity to the local area of the Perry site. The distribution and southern extent of glacial deposits throughout Ohio are portrayed on <Figure 2.5-3>.

2.5.1.1.4 Stratigraphy

The stratigraphy of Ohio can be readily differentiated into three distinct units which include a basal Precambrian crystalline basement, a sequence of Paleozoic sedimentary rock and a surficial cover of Pleistocene glacial and glaciolacustrine sediments. Soil profiles have developed since the recession of continental glaciation in the upper several feet of the surface veneer. Precambrian rocks are not exposed in Ohio, as the basement complex lies at approximately minus 5,000 feet (Reference 6). Paleozoic sedimentary rocks, essentially Devonian shale, comprise bedrock in the northern region of Ohio, east of Sandusky, including a large portion of the Lake Erie Basin. In the extreme northwestern corner of Ohio, Devonian rocks immediately underlie the outer fringe of the Michigan Basin. A much smaller distribution of Devonian strata occurs as an outlier slightly east of the Cincinnati Arch, approximately 40 miles northwest of Columbus. Limestone and dolomite strata of Ordovician and Silurian ages outcrop in the western half of Ohio. The southeastern portion of the state is immediately underlain by successively younger post-Devonian Paleozoic rocks such that Permian strata are exposed in proximity to the Ohio River segment serving as a mutual boundary with West Virginia. The areal extent of bedrock geology in Ohio is shown on <Figure 2.5-4>, and a statewide composite bedrock stratigraphic column is included as <Figure 2.5-5>.

A Devonian-Mississippian stratigraphic interval dominated by shale forms the bedrock surface of an 8 to 20 mile wide belt contiguous to Lake Erie from the Pennsylvania border to the vicinity of Sandusky and from there southward through central Ohio to the Ohio River. The subdivision of these Devonian-Mississippian shales in Ohio is based on their lithologic character according to Hoover (Reference 7). The precise horizons separating the divisions are somewhat arbitrarily defined because of interfingering facies and their transitory nature vertically from one unit to the next. In the northeastern region, a complete columnar section through the shale sequence in stratigraphic order, oldest to

youngest, would include the Plum Brook (logged in subsurface) Huron, Chagrin, Cleveland, and Bedford shale members (Reference 8). Collectively, these members comprise approximately 1,500 feet of stratigraphic section of the site locale. The Huron, Chagrin and Cleveland shales together are also known as the Ohio Shale, representing most of the Devonian-Mississippian shale sequence in northeastern Ohio. The composite interval is underlain by Middle Devonian, predominantly nonargillaceous, carbonate rocks and capped by Berea sandstone, the latter of which lies on a scoured Bedford Shale erosional surface.

Member subdivisions of the Ohio Shale are accomplished mostly on the basis of color, primary structures and other physical criteria. The Huron shale, stratigraphically averaging 410 feet throughout Ohio, is a black fissile shale containing conspicuous carbonate concretions. It's base is placed at the top of the highest gray shale (or limestone) bed of the underlying Plum Brook Shale. The top of the Huron is placed at the highest black shale where the gray, slightly arenaceous Chagrin begins. In some locales, the base of the Chagrin is conspicuous, beginning at the top of the uppermost layer of carbonate concretions (generally from 1 to 6 feet in diameter, but as large as 15 feet) or at the base of the lowermost Ohio shale cone-in-cone structure. The Chagrin shale is essentially a noncarbonaceous, medium-gray, fissile, clay shale occupying an intermediary position between two highly carbonaceous fissile blue-black shales. The Cleveland shale is readily distinguished from the Chagrin on the basis of darker color and from the Huron on the basis of the absence of large calcareous concretions. Primary and secondary deposits of pyrite, occurring along thin bedding laminae as concretionary masses and/or as finely disseminated pyrite, are best developed in the Cleveland shale. Regionally, the irregular distribution and variable thickness as well as the horizontal gradation and vertical transitory nature, characterizing the stratigraphy of the Ohio Shale, can be readily understood in context of the facies concept.

The Bedford Shale overlies the Ohio Shale. Its stratigraphic base is placed at the top of the uppermost black shale sequence containing a few siltstone beds. The basal sequence of the Bedford consists of a gray-black shale, more frequently interbedded with thin siltstone beds than the Ohio Shale. However, Bedford siltstones exhibit local evidence of bedding plane failure and slump (load casts and flow rolls). In some locales Bedford Shale is predominantly a soft, red clay shale. Erosional channels have completely cut through the Bedford Shale into the underlying Ohio Shale, such that Berea Sandstone, the next youngest stratigraphic unit, is in unconformable contact with Ohio Shale. Generally, the Bedford-Berea contact is very irregular and disconformable even where erosional channels have not been identified. The top of the Bedford, where exposed, has been defined by the base of massively-bedded Berea Sandstone strata. It is generally accepted that the Devonian-Mississippian time boundary should be placed at the Ohio-Bedford contact.

At the site, the Chagrin shale of Upper Devonian age, is the highest Ohio Shale member. The Cleveland and Bedford shales, and the Berea Sandstone outcrop successively higher along the Allegheny Escarpment to the south. Consequently, bedrock reaching the surface in Lake County is chiefly shale and lesser amounts of sandstone. Bedrock exposures are sparse, however, as most of the surface is concealed by glacial deposits. The nearest outcrops to the plant site are situated approximately seven miles southwest along the banks of the Grand River. The areal distribution of the major bedrock units with respect to the Perry site and northeastern Ohio is shown on <Figure 2.5-6>.

Glacial materials cover more than two-thirds of Ohio. In northeastern Ohio glacial drift and glaciolacustrine sediments overlying bedrock reach a maximum thickness of approximately 250 feet. The glacial deposits are dominantly till composed of native material with some ice-transported granitic erratics undoubtedly derived from Canada. Composition of the till varies from place to place but in general is a

heterogeneous, dense, boulder clay with interspersed rock fragments ranging from large boulders, cobbles and pebbles down to sand size. Along the lake front, a layer of glaciolacustrine deposits comprised of clay, silt and fine sand mantle dense tills. Sandy beach ridges located 1.5 to 10 miles inland from the present shore delineate former lake margins. The distribution of glacial and glaciolacustrine deposits in northeastern Ohio are shown on <Figure 2.5-7>.

2.5.1.1.5 Regional Tectonics

2.5.1.1.5.1 Regional Tectonic Elements

The regional tectonic elements are described in the following paragraphs.

a. Grenville Front

The Grenville Front extends southwesterly across eastern Canada for 1,150 miles from the coast of Labrador to the north shore of Georgian Bay, Ontario, where its trace in the Precambrian basement dips beneath Paleozoic sedimentary formations (Reference 9) (Reference 10). Cutting across older structural provinces of the Canadian Shield, the Grenville Front is a tectonic break which defines the northwestern limit of Grenvillian metamorphism and deformation, part of a several kilometer wide shear zone, the Grenville Front Tectonic Zone (GFTZ). The GFTZ is characterized by strongly deformed, locally mylonitic rock exhibiting northeast-trending, gently southeast-dipping tectonic layering and southeast plunging mineral lineations (Reference 293). Seismic reflection profiles in Lake Huron and Central Ohio reveal the subsurface expression of the GFTZ as a zone of east-dipping reflectors ranging from 30 to 50 kilometers in width (Reference 294) (Reference 295).

To the southeast of the Front in Canada, the Precambrian terrane comprises an orogenic belt defined as the Grenville Province and characterized by upper-amphibolite or granulite facies metamorphic rocks having K-Ar radiometric ages of 950±150 million years. There is a systematic decrease in radiometric dates to the southeast away from the Front, from a high of about 1,050 million years along the Front in Ontario to about 850 million years near the St. Lawrence River (Reference 9) (Reference 11).

To the northwest of the Grenville Front, along much of its trace in Ontario and Quebec, there are Early Precambrian (Kenoran, 2,400 million years) rocks of the Superior Province. In southern Ontario, 300 miles north of the site, along the north shore of Lake Huron and northwestern Georgian Bay, kyanite-zone metasediments, minor metavolcanic rocks and related migmatitic rocks of the Grenville Province abut greenschist-facies, sedimentary and volcanic rocks of the Huronian super group of the Canadian Southern Province along a Grenville Front fault boundary (Reference 12) (Reference 13). The Canadian Southern Province is characterized by sedimentary deposition during Lower Proterozoic time (2,400-2,200 million years) and deformation during the Hudsonian orogeny, about 1,700 million years ago (Reference 14) (Reference 15). An intrusive suite of granitic, minor intermediate to felsic volcanic rocks, and subordinate diorite and granodiorite occurs northeast of Georgian Bay near Killarney, Ontario. These 1730-1750 and 1450-1470 million year old granitoids separate the Huronian rocks from the Grenville Front.

Where last exposed at ground surface, the Grenville Front trends southwesterly beneath northwestern Georgian Bay and beneath Paleozoic sedimentary rocks on eastern Manitoulin Island, Ontario. The southerly trend of the Grenville Front, beneath the sedimentary cover in the site region, has been traced by petrographic and radiometric analyses of basement rocks sampled in deep borings.

Bass was the first to define the general position of the boundary in western Ohio by his identification of high-grade metamorphic rocks on the east and unmetamorphosed, nonorogenic igneous and sedimentary rocks on the west (Reference 16). The metamorphic rocks were dated at 900-1,000 million years and classified as part of the Grenville Province orogenic belt. The Grenville Province is presently divided into two principle subprovinces based on recognition of distinct lithologic and structural characteristics. Immediately east of the GFTZ is the Central Gneiss Belt (CGB). The CGB comprises mainly quartzfeldspathic gneissic rocks of igneous origin, generally metamorphosed to upper amphibolite facies. To the southeast, the Central Metasedimentary Belt (CMB) consists of greenschist to granulite metamorphosed marbles, volcanics and clastics. The allochthonous CMB terrane was thrust northwestward onto the CGB along the Central Metasedimentary Belt Boundary Zone which parallels the GFTZ. Recognition of subdivisions of the two major subprovinces, established in areas of Precambrian exposure in Ontario and Quebec, have been extrapolated southward beneath Paleozoic cover by examination of available core and drill cuttings and by aeromagnetic anomaly patterns. Seismic reflection data along transects of Lake Ontario and Lake Erie have confirmed the presence of distinguishable Precambrian features coinciding with the terranes and terrane boundaries (Reference 296).

In his study of basement rocks to the west of the Grenville boundary in Ohio, Kentucky, Tennessee, Indiana, and Illinois, Bass found no regionally metamorphosed rocks. The igneous rocks there are mainly massive to flow-banded (Reference 16).

In the broad area to the west of the Grenville Front in the midwestern United States, Engel used the term “Central Province” to describe basement terrane characterized by felsic igneous rocks of intermediate age (1,500-1,200 million years) (Reference 17). Lidiak et al further defined the Central Province as a “terrane of

granite and rhyolite (which) extends from eastern Iowa to western Ohio, where it is terminated by metamorphic rocks which are the subsurface extension in Michigan and Ohio of the Grenville Province of the Canadian Shield” (Reference 18). Granites were emplaced in the Central Province 1,350 million years or more ago (Elsonian event), while rhyolite and trachyte in western Ohio are dated at about 1,260 million years. They further noted that gravity and magnetic anomalies in the Michigan Basin may reflect Keweenawan (1,200-1,100 million years) igneous rocks. The Keweenawan rocks mark a former rift zone, the Keweenawan rift sequence. Exposures of the rift around Lake Superior consist of basalt flows overlain by a thick sequence of sandstones, shales, and conglomerates (Reference 297). The sequence is termed the Mid-Michigan Rift southeastward through Michigan. Red arkosic sandstones recovered from a deep borehole in central Michigan apparently overlie layered basaltic flows interpreted from COCORP (Consortium for Continental Reflection Profiling) seismic reflection data (Reference 298). The aeromagnetic and gravity pattern of the Keweenawan sequence extends in subdued fashion across the Grenville Front (Reference 299).

Muehlberger et al, in discussing the geologic history of the interior United States, noted that crustal stabilization events occurred about 2,500, 1,700, 1,350, and 1,000 million years ago (Reference 19). During the Nemaha igneous episode (Elsonian, 1,450-1,350 million years), basement rocks from New Mexico to Ohio were consolidated to form the basement for younger, extensive volcanic-intrusive complexes. Bayley and Muehlberger defined the subsurface location of the Grenville Front from southern Ontario through eastern Michigan and western Ohio to northern Kentucky <Figure 2.5-8>, and further described the different lithologies on each side of the boundary (Reference 20). Based on petrographic and radiometric studies of basement well samples, Ammerman and Keller located the Grenville Front in northern Kentucky between little-metamorphosed igneous rocks to the west, and marble and

upper-amphibolite grade, metamorphic rocks (913 and 894 million years, K-AR ages) to the east (Reference 21).

b. Arches

Several broad Paleozoic arches exist in the site region: the north trending Cincinnati Arch of north-central Kentucky and southwestern Ohio (Reference 22) (Reference 23) (Reference 24) (Reference 25) (Reference 26), the northeast trending Findlay Arch of northwestern Ohio (Reference 22) (Reference 26) (Reference 27) (Reference 28) (Reference 29); the north-northeast trending Waverly Arch of west central Ohio (Reference 23) (Reference 25) (Reference 28); the Ohio-Indiana Platform of western Ohio and eastern Indiana (Reference 22) (Reference 26) (Reference 27); and the northeast trending Algonquin axis of south-central Ontario (Reference 30) (Reference 31). Recently the presence of the subtle Waverly Arch has been questioned on the basis of analysis of more borehole logs. Evidence from recent drilling activity in eastern Ohio has revealed a north northeast-trending arch designated the Wooster Arch (Reference 303) (Reference 300).

All arches in the site region rest on a crystalline Precambrian terrane which has been mantled by a relatively thin sequence of gently-warped Paleozoic sediments. The Paleozoic section ranges in age from Cambrian to Carboniferous (Reference 22) (Reference 23) (Reference 25) (Reference 26) (Reference 27) (Reference 28). The arches were formed in response to differential subsidence of the surrounding sedimentary basins (Reference 22) (Reference 23) (Reference 25) (Reference 26) (Reference 28). There are, however, variations in the timing of formation of the various arches and in the development of localized structural features along them.

The Cincinnati Arch began to develop during Late Cambrian and Early Ordovician time in response to subsidence in the Appalachian Basin

to the east, and in the Illinois Basin to the west (Reference 22), (Reference 23), (Reference 25), (Reference 26), (Reference 27), and (Reference 28). The location of the Cincinnati Arch is partially controlled by a basement ridge along the Grenville Front (Reference 6) and (Reference 28).

The Findlay Arch which separates the Appalachian Basin from the Michigan Basin does not show any evidence of development until the Devonian time (Reference 29). The Ohio-Indiana Platform, which is located where the Cincinnati Arch broadens and bifurcates into the Findlay and the Kankakee Arches, began to develop in Ordovician time, with full development occurring with the formation of the Findlay Arch in Devonian time (Reference 26) and (Reference 27).

The structures along the various arches also exhibit local variations. Tobin, Mayhew, Lidiak and Zietz, and Ammerman and Keller have described north trending faults in the surface and subsurface along the east flank of the Cincinnati Arch (Reference 32), (Reference 33), (Reference 34) and (Reference 35). On the other hand, it has been indicated that the Bowling Green fault of northwestern Ohio occurs along the western flank of the Findlay Arch (Reference 36). However, all of the above authors agree that the faulting noted along the Cincinnati and Findlay Arches is basement-controlled and reflective of reactivation of Precambrian structures possibly related to the Grenville Front.

c. Basins

Two Paleozoic basins, the Michigan and Appalachian Basins, exist within the site region.

1. Michigan Basin

The Michigan Basin is oriented slightly northwest-southeast and contains 15,000 feet of sediment (Reference 37) (Reference 38). The basin overlies unmetamorphosed Central Province basement rocks in the west and northwest, and metamorphosed Grenvillian-age basement rocks in the southeast (Reference 18) (Reference 19) (Reference 20) (Reference 39).

The Michigan Basin began to develop in Cambrian time, with full development not occurring until the Middle Ordovician (Reference 29) (Reference 37) (Reference 38). Maximum basin formation occurred during the Middle to Upper Silurian when several thousand feet of sediment were deposited (Reference 29) (Reference 37). The Michigan Basin continued to subside intermittently throughout the Paleozoic, with local areas of differential subsidence in the Chatham Sag (Reference 30).

2. Appalachian Basin

The Appalachian Basin in the site region is a broad northeast trending, southeast dipping homocline overlying metamorphosed Grenvillian basement (Reference 18) (Reference 40).

The development of the basin began in Cambrian time and continued throughout the Paleozoic in response to episodes of Appalachian mountain building. The basin contains a thick sequence of unmetamorphosed Paleozoic shales, sandstone and carbonates which dip gently (25-50 feet per mile) to the east and southeast off the Cincinnati and Findlay Arch systems (Reference 40). Locally within the basin, Rodgers notes the

presence of local faults and a few broad folds (Henderson dome, Cambridge arch and Parkersburg-Lorain syncline) (Reference 40).

d. Faults

Several faults and groups of faults have been defined within the site region: the Chatham Sag faults; the Peck fault and faults associated with the Howell-Northville anticline; the Bowling Green fault; faults near Anna, Ohio; faults along the Cincinnati arch; faults in eastern Ohio; western New York faults; and the Appalachian Plateau and Northern Valley and Ridge faults. Of these faults, the Clarendon-Linden fault system, located in western New York, 165 miles northeast of the Perry site, is currently considered active (Reference 41), and a spatial correlation of earthquakes with the Anna-Champaign, Auglaize and Logan-Hardin faults in west-central Ohio has been suggested (Reference 2).

1. Chatham Sag Faults

The Chatham Sag is a west northwest trending syncline in south-central Ontario and southeastern Michigan. Brigham notes the presence of five normal faults in the area with Ordovician to Devonian ages (Reference 40). The offsets of the faults, commonly down on the south, range from 100 to 300 feet.

2. The Peck Fault and Faults Associated With the Howell-Northville Anticline

These faults are high-angle normal faults located in southeastern Michigan, 160 miles from the Perry site. The faults associated with the Howell-Northville anticline strike northwest and are downthrown to the southwest. The Peck fault

strikes north and is downthrown to the west with a maximum displacement of 300 feet (Reference 30). The faults have been described on the basis of a subsurface stratigraphic data by Brigham (Reference 30) and Prouty (Reference 37). These authors postulate the ages of the two faults to be Ordovician and Mississippian, respectively.

3. Bowling Green Fault

This fault is a north trending, high-angle normal fault zone up to five miles wide, located in northwest Ohio, 170 miles from the Perry site (Reference 36). It has a downward displacement of approximately 200 feet to the west. The Bowling Green fault is interpreted to offset Ordovician Trenton Rocks in a normal sense according to seismic reflection data (Reference 301). A series of high-angle reverse faults and folds is reported to cut Silurian formations in quarry exposures located over the trace of the fault zone (Reference 36) (Reference 40) (Reference 42). Quick et al suggest that the Bowling Green fault is due to reactivation, during Paleozoic time, of Precambrian basement structures along the north trending Grenville Front (Reference 36).

4. Faults near Anna, Ohio

Thompson et al and McGuire have described three normal faults in the subsurface near Anna, Ohio, 185 miles west of the Perry site (Reference 43) (Reference 44). The faults near Anna, which have been mapped on the basis of subsurface geological and geophysical data, have a northwest and north orientation (Reference 43) (Reference 44). The northwest trending Anna-Champaign fault is downthrown to the north with an offset inferred to be 25 to 150 feet (Reference 1). The

north-northeast trending Auglaize and Logan-Hardin faults are downthrown to the west with offsets inferred to be approximately 50 feet (Reference 45). The age of the faulting at Anna is uncertain.

5. Faults Along the East Flank of the Cincinnati Arch

Tobin and Mayhew postulate the existence of north trending normal faults in the subsurface of west-central Ohio, about 175 miles southwest of the Perry site (Reference 32) (Reference 33). These faults are reported to be due to possible Paleozoic reactivation of Precambrian structures along the boundary between Grenvillian age metamorphosed rocks on the east and older Central Province, unmetamorphosed Precambrian rocks on the west (Reference 46).

6. Faults in Eastern Ohio

Several small faults of probable Paleozoic age with variable orientations ranging from northwest to northeast have been noted in the subsurface of northeastern Ohio (Reference 47) (Reference 48) (Reference 49) (Reference 50) (Reference 51).

The faults are of variable angle with throws typically ranging from a few inches to several tens of feet (Reference 51) (Reference 52), and in some isolated cases up to 200 ft.

Four northwest-trending faults (Akron, Suffield, Smith Township, and Highlandtown) are mapped on Packer “Shell”, Onandaga and Berea bedrock structure contour maps, extending from east central Ohio towards Cleveland, Ohio (Reference 52) and are located 50 miles or further from the site. The easternmost (Highlandtown fault) is spatially coincident with the western extension of the Transylvania or Lat. 40 (degree)

fault zone, inferred from a series of east-west trending faults and associated geophysical and well log anomalies, extending through southern Pennsylvania (Reference 53). Several lines of evidence indicate a multiple movement history of the faults in northeastern Ohio. The en echelon fault geometry and apparent associated magnetic anomaly offsets indicate initial Precambrian to Cambrian right-lateral strike-slip motion of the Precambrian basement rocks along the fault zone (Reference 54). The faults are persistent in location and orientation at four stratigraphic levels within the overlying Paleozoic section, culminating in post-Pennsylvanian deformation of coals and limestones. Based on offset structure contours, relative Paleozoic motion on the high-angle faults in northeastern Ohio is up to the northeast, with maximum vertical displacement of 200 feet.

Several high-angle reverse faults in salt mines in the area have been noted (Reference 49) (Reference 50) (Reference 51). These faults are apparently confined to the salt and do not affect the overlying strata. For details on faulting in the immediate site vicinity see <Section 2.5.1.2.3>.

7. Faults in Western New York

Fakundiny and Isachsen and McKendree have discussed the Clarendon-Linden fault system of western New York, located 165 miles east-northeast of the site (Reference 55) (Reference 56). This system is a north trending zone of folds and faults which have been identified on the basis of subsurface geological data. It deforms rocks of Devonian age and older, and is considered to be seismically active (Reference 41).

Sixty-five miles west of the Clarendon-Linden fault, the Chautauqua Anticline/Bass Island structure is mapped (Reference 57). The 100 kilometer long, northeast-trending structure is comprised of at least 47 minor thrust faults upthrown to the northwest. The faulting corresponds to the northwestern limit of Salina Group salt beds which localized decollement sliding of overlying units. At this point, the termination of the easily deformable salt layer forced the leading edge of the detachment upward into overlying units where it eventually dies out in fissile shales of the Hamilton Group. The resulting anticlinal structure is similar to the Burning Springs Anticline in West Virginia. Locally, within these zones and elsewhere along the arcuate terminal margin of the Alleghanian deformation, strike-slip faults perpendicular to the Alleghanian structural front offset the thrust faults. Such a zone of north-south normal faulting (Devonian or older) has been identified in western New York, approximately 210 miles east-northeast of the Perry site. The resulting fault blocks control the curved geometry by differential block transport (Reference 56) (Reference 57).

8. Thrust Faults in the Appalachian Plateau and Valley and Ridge Provinces

The style of faulting in the Appalachian Plateau and the Northern Valley and Ridge provinces, to the southeast of the site, takes the form of north to northeast trending thrust faults dipping east and southeast (Reference 40). The sense of motion on these faults is generally east over west.

The only difference in faulting style between the two provinces is that thrust faults in the Northern Valley and Ridge province are relatively common as compared with the sporadic occurrence of faults in the Appalachian Plateau. The

faulting style noted in the Northern Valley and Ridge province continues southward to the vicinity of the James River and Roanoke, Virginia (beyond the site region) where it undergoes a distinct change. North of the Roanoke area, thrust faults striking N30°-35°E are generally discontinuous. South of the Roanoke area, however, thrust faults striking N55°-60°E are the dominant structural features (Reference 40).

e. Folds

The principal folds in the site region are those developed within the Michigan Basin adjacent to the Findlay Arch and in the Appalachian Basin and its more greatly-deformed eastern extension, the Northern Valley and Ridge province (Reference 22) (Reference 37) (Reference 40).

1. Michigan Basin Folds

The folds in the Michigan Basin generally strike northwest-southeast (Reference 58). The subsidiary fold trends are northeast-southwest, and radial to the basin (Reference 37) (Reference 59). The development of the fold pattern in the Michigan Basin has been suggested classically as reflecting basement structure (Reference 60).

King and Dallmus suggest that fold development within the basin occurred throughout the Paleozoic in response to regional stress (Reference 61) (Reference 62). Prouty reiterated the suggestion of King and Dallmus that some of the major folds of the Michigan Basin (in particular, the Howell-Northville anticline) did not develop until at least Mississippian time (Reference 37) (Reference 61) (Reference 62).

2. Lucas County Monocline

The generally north trending Lucas County monocline is located in northwestern Ohio and southeastern Michigan (Reference 22) (Reference 36) (Reference 58). The structure was initially identified from surface and subsurface data as a gently east dipping Paleozoic monocline with no evidence of faulting. However, studies of surface exposures near the southern terminus of the Lucas monocline have suggested the presence of a high-angle fault; the Bowling Green fault (Reference 22) (Reference 36). See Item d.3 of this section. The age of deformation of the Lucas County monocline is possibly Late Paleozoic (Reference 63).

3. Folds in the Appalachian Basin

The fold pattern in the Appalachian Basin has been described by Rodgers and by Clifford and Collins (Reference 40) (Reference 64). Rodgers indicates that with a few exceptions (notably the Burning Springs anticline, Cambridge Arch, the Parkersburg-Lorain syncline, and the Henderson dome) folds in the Appalachian Basin are generally "planless irregularities, folds of erratic trend, domes, noses, etc" (Reference 40).

According to Clifford and Collins, the Burning Springs anticline and Cambridge Arch are the result of thin-skinned thrusting on a Silurian salt glide plane (Reference 64). These authors also point out that the Parkersburg-Lorain syncline cannot be identified below the salt horizons. Similarly, Rodgers suggests that the Henderson dome has developed, in response to diapiric action of salt, into the overlying Paleozoic section (Reference 40).

4. Folds in the Northern Valley and Ridge Province

The folds in the Northern Valley and Ridge province occur in a series of belts of long, steep sided to slightly overturned parallel folds with a general north-northeast orientation (Reference 40). The wavelength of the longer folds is 3 to 10 kilometers, with an amplitude of 800 to 1,500 meters.

The structural pattern in the Northern Valley and Ridge is the result of "wholesale stripping" of the Paleozoic section from the basement at the level of the lowest incompetent shale of upper Lower Cambrian age (Reference 40). Subsequent to stripping, folding of the Paleozoic section was caused by northwest directed compressive stress during the Alleghenian orogeny, about 250 million years ago. The style of folding in the Northern Valley and Ridge undergoes a distinct and profound change in the vicinity of the James River-Roanoke area of Virginia (Reference 40). Northeast of Roanoke, the style of the deformation is one of long, continuous folds with only minor evidence of thrust faulting. Southwest of the James River-Roanoke area, folds are relatively less important and less continuous (Reference 40).

f. Cryptoexplosive Structure

1. Serpent Mound

The Serpent Mound cryptoexplosive structure is a circular area of disturbed Paleozoic rocks approximately 4 miles in diameter, located in southwestern Ohio (Reference 65) (Reference 66) (Reference 67). The Serpent Mound structure consists of three zones or rings of tilted Paleozoic rocks surrounded by generally flat-lying Paleozoic sediments. The inner zone consists of Ordovician and Silurian rocks which

have been raised well above their normal stratigraphic level (Reference 65) (Reference 66) (Reference 67). This zone is succeeded outward by an intermediate ring of Silurian and Devonian rocks at their normal stratigraphic level, and finally by an outer ring of Devonian and Mississippian rocks, which are at a considerably lower than normal stratigraphic level (Reference 65) (Reference 66) (Reference 67).

The origin of the Serpent Mound structure is described as either the result of a near-surface explosion of volcanic gases or a meteorite impact (Reference 65) (Reference 66) (Reference 68). Recent geophysical studies have tended to support a volcanic origin for the structure (Reference 69) (Reference 70) (Reference 71).

2.5.1.1.5.2 Regional Tectonic Provinces

The geology of the site region is characterized by a wide expanse of flat-lying to gently-dipping sedimentary formations of Cambrian to Permian age, resting on broadly-arched and basined Precambrian crystalline and supracrustal rocks of various Proterozoic age, and overlain by a veneer of glacial sediments of several Pleistocene ages.

The major tectonic elements reflected in the Paleozoic rocks are the Appalachian Basin to the southeast and the Michigan Basin to the northwest, with intervening topographic divides including the Algonquin axis, Findlay arch, Indiana-Ohio platform, and Cincinnati arch. These and other related tectonic features, which developed during Paleozoic epeirogenic crustal movements, are shown on <Figure 2.5-8>, and are discussed elsewhere in <Section 2.5.1.1.5> and also in <Section 2.5.1.1.6>.

The tectonic provinces of the region, derived for purposes of evaluating seismic hazards to the site, are defined on <Figure 2.5-9>. These

provinces are delineated by boundaries along which characteristic regional geologic structural features terminate, or are transected by major tectonic structures of markedly different style. In the western part of the site region, province boundaries are controlled by trends along which major structural changes occur within the relatively shallow Precambrian basement rocks and in the thin cover of less-deformed Paleozoic sedimentary formations. To the north and south, province boundaries are defined by tensional or transcurrent fault zones of regional extent which have intermittently displaced both the Precambrian basement terranes and the overlying younger sedimentary formations. To the east, province boundaries are drawn along zones of significant change in type of compressional deformation in Paleozoic sedimentary rocks resulting from Late Paleozoic orogenic forces.

As shown on <Figure 2.5-9>, the site region is partitioned into five tectonic provinces, each characterized by lithologic and structural geologic features which are unique to it. These provinces are as follows: Eastern Stable Platform - Site Province; Michigan Basin; Appalachian Plateau; Northern Valley and Ridge Province; and Central Province.

The original FSAR (1982) described four tectonic provinces including the Eastern Stable Platform where the site is located. This approach differed somewhat from the approach taken by the NRC Staff, as discussed in Q&R 230.2 and 230.6. In the SER, the NRC Staff places the site within the Central Stable Region, while the CEI approach places the site in the Eastern Stable Platform Region, a smaller, regional province.

After the SER was issued, an Atomic Safety and Licensing Board provided useful guidance on this subject in <u>In Re Consumer's Power Co</u> (Reference 72). In <u>Midland</u>, the ASLB concluded that, on the basis of geology and seismic hazard studies, the Applicant's subdivision of the Central Stable Region into smaller tectonic provinces was proper and in conformance with <10 CFR 100, Appendix A> (Reference 72). On the basis

of criteria set forth in Midland, the Michigan Basin Province is shown on <Figure 2.5-9> as another potential subdivision of the Central Stable Region.

a. Eastern Stable Platform - Site Province

The Eastern Stable Platform tectonic province is generally characterized by a crystalline basement terrane of metamorphic, sedimentary and igneous rocks which last consolidated to a crustal block during the Grenvillian orogeny, during the period 1,100 to 900 million years ago (Reference 19) (Reference 73). The surface of the crystalline basement slopes gently to the southeast from a series of elongate topographic arches along the western part of the province, and is buried beneath a southeast-thickening, little-deformed sequence of Paleozoic sedimentary formations.

The western boundary of the province consists of a series of platforms including the Findlay arch, the Indiana-Ohio Platform and Cincinnati arch where they are coincident with the distinct structural changes in the crystalline basement across the Grenville Front <Figure 2.5-9>. North of Latitude 42° the boundary is considered coincident with the eastern margin of the Michigan Basin. The boundary is generally consistent with that given in the Final Safety and Analysis Report (1982) south of 42° latitude. It is also consistent with the Midland ASLB conclusions that features in the Paleozoic sediments are meaningful for purposes of establishing tectonic provinces (Reference 72).

As stated, this boundary 150 miles southwest of the Perry site, is defined by the coincidence of the structural features in the Paleozoic rocks and the subsurface trace of the Grenville Front. Below the Paleozoic rocks are the metamorphic rocks of Grenvillian age which abut essentially unmetamorphosed granite, rhyolite and supracrustal continental deposits of Elsonian (1,350 million years)

and Keweenawan (1,200-1,100 million years) ages. The northern boundary of the province is marked by west-northwest trending block faulting in the Ottawa-Bonnechere graben, about 320 miles northeast of the site, in south-central Ontario, Canada (Reference 74) (Reference 75). The southern boundary is defined by the east trending Kentucky River fault zone and underlying Rome trough, about 250 miles south of the site (Reference 21) (Reference 34) (Reference 76). The eastern margin of the province is transitional, and is placed along the zone about 80 miles southeast of the site, where gentle open folding and minor thrust faulting become apparent in sedimentary formations of the Appalachian Plateau (Reference 40).

In the Eastern Stable Platform, within the site region, the Appalachian Basin is a broad northeast trending, southeast dipping homocline overlying metamorphosed, Grenvillian age, Precambrian basement (Reference 18) (Reference 40) <Figure 2.5-9>. The development of the basin began in Cambrian time and continued throughout the Paleozoic, in response to Appalachian mountain building.

b. Michigan Basin

The Michigan Basin is a broad, shallow structural depression which underlies the lower Michigan peninsula, part of the Upper Peninsula, eastern Wisconsin, northern Illinois, Indiana, Ohio, and southwestern Ontario. The approximate eastern boundary of the Basin is shown on <Figure 2.5-9>. A maximum thickness of 14,000 feet of Paleozoic sediments (Cambrian-Pennsylvanian), in the center of the basin, overlies a deeply eroded Precambrian basement surface. The perimeter of the Michigan Basin is bounded by the Wisconsin arch and dome to the west, Canadian shield to the north, Indiana-Ohio platform to the southwest, and Findlay/Algonquin arch to the southeast and east. These positive features in the

Precambrian surface acted as relatively stable “platforms” about which the Michigan, Illinois and Appalachian basins subsided. Gravity and magnetic data, and limited borings indicate a complex Precambrian basement including Keweenawan igneous, Grenville and Central terrane lithologies. Precambrian structural zones related to these diverse terranes apparently did not control the overall development of the Michigan Basin.

Within the Paleozoic section preserved in the Michigan Basin, numerous small anticlinal flexures occur, trending predominantly northwest and to a lesser extent northeast. The folding and local faulting is interpreted to have occurred during subsidence of the basin. The uniform, harmonic nature of the deformation throughout the Devonian-Mississippian interval, and localization of the more intense deformation in the center of the basin, suggest that basin subsidence and corresponding intraformational compression produced the structures (Reference 77). The correspondence of the predominant northwest structural orientation with the similar Precambrian trends indicates potential basement control of the Paleozoic flexures. Larger flexures such as the Howell anticline, Albion-Scipio syncline and Lucas-Monroe monocline are faulted along their western flanks. The locally interpreted faulting and widespread associated flexures are thought to have culminated before deposition of the Saginaw formation (Pennsylvanian). The interpretation of basinal subsidence related deformation is supported by this observation, as the Pennsylvanian units are the first non-marine sediments overlying a progressively restricted marine sequence, implying gradual reduction and cessation of basin subsidence and associated deformation (Reference 77).

c. Appalachian Plateau Province

The Appalachian Plateau province in the site region is a broad synclinal basin mainly characterized by a thick section of Upper

Paleozoic red shale and sandstone, overlying Lower Paleozoic shales, carbonate rocks and sandstones. The segment of the province in New York and northern Pennsylvania consists primarily of a homoclinal structure of southward dipping, Paleozoic sedimentary rocks that rest on Grenvillian age, Precambrian basement. In southeastern Ohio and West Virginia, the regional dip swings toward the southeast (Reference 40).

The northwestern boundary of the Appalachian Plateau province is broadly marked by the northwestern extent of gentle folds and small faults that generally occur on a trend normal to the regional dip (Reference 40). The southeastern boundary of the Appalachian Plateau province is defined by the Appalachian Structural Front and the rocks of the Northern Valley and Ridge province.

The structure of the province was formed as part of the Appalachian Mountain deformation, with the tilting and some small faults and folds formed about 250 million years ago. Large scale erosion beveled the ancestral mountains and reduced the surface to a flat plain by Tertiary time. The removal of the thick cover was accompanied by some localized normal faulting and igneous activity, probably during Cretaceous time, in central New York (Reference 78).

Widespread regional uplift of a nontectonic nature occurred again a few million years ago, and the province has undergone a rejuvenation of the erosion cycle since that time. No tectonic deformation is currently known to have occurred within the past tens of millions of years in the province. Small scale, nontectonic deformation in the northern part of the province has occurred in response to continental glaciation.

d. Northern Valley and Ridge Province

The Northern Valley and Ridge province in the site region consists of a thick series of Paleozoic sedimentary rocks which overlie Grenvillian age, metamorphosed, Precambrian basement (Reference 40). The Paleozoic rocks of the Northern Valley and Ridge province have been deformed into a series of north-northeast trending, steeply inclined to overturned folds and associated south-southeast dipping thrust faults. The Northern Valley and Ridge province is separated from the Appalachian Plateau province by the Appalachian Structural Front which is, as described by Rodgers, "the sharp boundary where the nearly flat beds of the plateau give way to steeply dipping or overturned beds of the Nittany arch" (Reference 40).

To the southeast, the Northern Valley and Ridge province is bounded by the Blue Ridge province and, to the southwest, by the distinct and profound structural change which occurs in the vicinity of the James River-Roanoke area of Virginia (Reference 40). Northeast of the James River-Roanoke area, the dominant structural style consists of large parallel folds having considerable continuity. Thrust faulting in the area north of Roanoke is generally subordinate, with only two major thrust faults in the entire province (Reference 40). However, southwest of the James River-Roanoke area, southeast dipping thrust faults dominate through the entire width of the province, and folding is distinctly subordinate.

Deformation in the Northern Valley and Ridge is a result of a sequence of events which commenced with stripping or detachment of much of the Paleozoic section from the underlying rocks at the horizon of incompetent Lower Cambrian shales (Reference 40). The subsequent folding of the detached Paleozoic section seems to have

been in response to compressional stress from the east and southeast during the Alleghenian orogeny, about 250 million years ago (Reference 40).

e. The Central Province

The Central Province extends westerly through western Ohio, Indiana, Illinois, and southern Wisconsin into the west-central and southwestern United States, and is characterized by a Precambrian basement terrane of essentially unmetamorphosed, predominantly felsic, igneous rocks of Elsonian age (1,450-1,350 million years), locally enclosing rift basins and troughs of Keweenawan age (1,140-1,120 million years) (Reference 17) (Reference 18) (Reference 20) (Reference 73). The surface of the crystalline basement over wide areas is nearly horizontal to gently south dipping with local depressions in the Michigan and Illinois Basins, and is buried beneath a relatively thin cover of little-deformed, nearly flat-lying Paleozoic sedimentary formations of platform derivation.

The eastern boundary of the Central province is along the south trending Grenville Front of western Ohio, and northcentral Kentucky and on the westward trending continuation of the front across Mississippi, Louisiana and Texas (Reference 19) (Reference 20) (Reference 73). The eastern boundary of the Central province is approximately 150 miles from the site at its closest approach. The northern boundary of the Central province is the Indiana-Ohio Platform corresponding to the southern boundary of the Michigan Basin.

Within the site region, the basement rocks of the Central province are largely unmetamorphosed, massive to flow-banded intrusive rocks, and supracrustal rhyolite flows and pyroclastic rocks with radiometric ages in the range of 1,500-1,200 million years

(Reference 16) (Reference 20). Included as subprovinces within the older Central province basement are rift basins or troughs of Keweenawan age (1,140-1,120 million years), containing basalt and sediment fillings, derived from crustal rifting of subcontinental dimensions late in Precambrian time (Reference 73). Burke and Dewey ascribe Keweenawan basin development to widespread rifting in the North American shield, with a triple junction in the area of the eastern end of Lake Superior and one arm of the rift zone trending southeasterly into lower Michigan (Reference 79). They further suggest that a Grenville ocean opened on a Keweenawan rift along the present trend of the Grenville Front in east central United States, and upon subsequent Grenvillian plate convergence, the continental crust to the east was thickened and the Grenville Front tectonic boundary formed during Grenville reactivation about 950 million years ago.

2.5.1.1.5.3 Regional and 1986 Epicentral Area Geophysics

Spatial variations in the earth’s gravity, after corrections for the effects of latitude and elevation, and magnetic field, are important guides to geologic structure and lateral changes in rock type. Many data are available for the mid-continent area of the United States and adjacent parts of Canada from previous studies. These data were used to help define the boundaries of regional tectonic provinces and assess potential spatial correlation and extrapolation of mapped and geologic structures <Appendix 2D F>. They are especially valuable for interpolating between observable geologic features.

A review of available published and unpublished seismic reflection data has been made. Available seismic surveys in Lake Erie show no evidence of Paleozoic bedrock structures. Interpretation of the offshore data was affected by poor resolution, due to shallow bottom conditions and nature of bottom material, or limited equipment capabilities (Reference 80). A seismic reflection survey was completed at the ICI

Americas (formally Calhio) waste injection facility located four miles south of PNPP. The purpose of the investigation was to determine the character of the Paleozoic sedimentary section, particularly relative to the potential for anomalous structures capable of transmitting fluids above the injection zone in the Cambrian Mt. Simon and Maynardsville formations. The results of the seismic reflection survey confirm other information, such as structural contour mapping of stratigraphic horizons determined from borehole geophysical logs, that the structure of the area is characterized by local nosings, troughs and terraces likely resulting from variable erosional and depositional causes. No evidence of unusual or significant neotectonic structural features or faulting was reported (Reference 302).

The data base, the methods of data reduction, and the results of the earth gravity and magnetic field studies for the Perry site are described in the following paragraphs.

a. Data Base - Gravity

Approximately 40,000 stations were compiled from two dozen different sources for the area bounded by 77°-85°W longitude and 38°-48°N latitude. The average station spacing is approximately 3 miles, but in some areas, such as western Ohio, the stations are as close as a few hundred feet. In other areas, such as northern Ontario, the station spacing exceeds 10 miles. Within a 200 mile radius of the site, the station spacing is 3 miles or less, with the exception of the region covered by the Great Lakes where the station spacing is approximately 10 miles.

The quality of the data is sufficient for the construction of 2 milligal contour maps. The largest source of error in individual gravity anomalies is the uncertainty in station elevation. Within the 200 mile radius of the site, elevations are known sufficiently

well, generally within ±10 feet, for the precision of the Bouguer anomalies, and quantities derived from them, to be at least 1 milligal.

b. Data Reduction - Gravity

The data reduction for the preparation of maps used in this study utilized the original values of observed gravity, elevation and latitude tabulated by each investigator. The Bouguer gravity anomaly was calculated with Equation 2.5-1.

$$BA = g_{obs} + ah - g_{theor} \tag{2.5-1}$$

where:

BA = Bouguer anomaly, milligals

g_{obs} = Observed gravity, milligals

a = 0.1884; A constant which includes both the free air effects and the Bouguer slab effect for density of 2.67 gm/cm^3

h = Elevation, meters

g_{theor} = $978031.85\ (1 + 0.005278895 \sin^2\theta + 0.000023462 \sin^4\theta)$, milligals

θ = Latitude

The Bouguer gravity anomaly map for the area within 200 miles of the site is shown on <Figure 2.5-10>. Its use in determining the distribution of rock types and geologic structures in the basement can be enhanced greatly by dividing the Bouguer anomalies into two

parts, termed regional Bouguer anomaly and residual Bouguer anomaly, with conventional techniques. The residual Bouguer anomaly map contains those anomalies due to masses that occur relatively near the earth's surface (generally 10 kilometers or less); whereas the regional Bouguer anomaly map contains those anomalies that may be caused by anomalous masses located at relatively greater depths. The regional anomaly for this analysis was calculated at each point by averaging all values of gravity over a 40 kilometer by 40 kilometer area. The residual Bouguer anomaly is the difference between the total Bouguer anomaly and the regional Bouguer anomaly.

The regional Bouguer anomaly map is shown on <Figure 2.5-11>. The residual Bouguer anomaly map is shown on <Figure 2.5-12>.

c. Interpretation of Residual Bouguer Anomaly Map

The residual Bouguer anomaly map is largely controlled by the basement rocks within about 10 kilometers of the earth's surface. It is used as an important part of the basis for constructing boundaries of the regional tectonic provinces. <Figure 2.5-13>, an overlay for the residual Bouguer anomaly map, shows trends of individual gravity anomalies and the province boundaries that have been drawn on the basis of mapped geology (where available); data available from cuttings and cores from drill holes; aeromagnetic data for Michigan gravity gradients and amplitudes of individual anomalies present on the residual Bouguer anomaly map; and trends and changes in direction of trends of the individual gravity anomalies (Reference 63) (Reference 81). The western boundary of the Eastern Stable Platform, the Grenville Front, as drawn on <Figure 2.5-13>, honors all data from wells with two exceptions. Both exceptions are south of Anna, Ohio, where gravitational features are very well defined. The eastern boundary of the

Eastern Stable Platform, drawn chiefly on the basis of mapped geological structure, is confirmed by gravity contours.

Several gravity anomalies noted by Voight <Appendix 2D F> are suggested to be structurally controlled based upon analogy with similar relationships observed in areas where geologic structures are not obscured. Two of the anomalies (13, 15) spatially coincide with features previously interpreted from Paleozoic structure contour maps <Section 2.5.1.2.3.1>. Existing geologic and geophysical information in northeastern Ohio does not allow verification of the occurrence or determination of the extent of potential faulting associated with the described geophysical or structural contour anomalies, in either the Paleozoic section or Precambrian basement rocks.

d. Regional Aeromagnetic Map

Recently, aeromagnetic data have been compiled in several maps covering Ohio <Figure 2.5-14> including detailed maps of northeastern Ohio (Reference 4). Aeromagnetic contour patterns reflect varying amounts of magnetically susceptible minerals, particularly magnetite, in the bedrock. Often, an excellent correlation between the anomaly pattern and the causative lithologic and/or structural features is observed. Typically, exposed and near-surface features are represented in the aeromagnetic data. However, in northeastern Ohio, the magnetic variations are caused by Precambrian rocks buried beneath several thousand feet of magnetically homogeneous Paleozoic sediments. A characteristic, distinctive anomaly pattern can be traced along the trend of the Grenville Province, northeastward to exposures of the Precambrian Grenville rocks in Ontario. In western Ohio the typical north- to northeast-trending magnetic patterns of the Grenville Province are interrupted in the vicinity of the proposed north-south extension of the Grenville Front. A characteristic

“birds-eye” pattern along the basement transition zone is found along sections of the Grenville Front exposed in Canada. To the west, in the Central Province, the magnetic anomaly pattern is subdued with no definite trend.

The aeromagnetic anomaly map of Ohio <Figure 2.5-14> reveals a distinct boundary within the Grenville terrane in eastern Ohio, between a high frequency anomaly pattern to the west and a subdued low frequency pattern to the east (Reference 82). The linear boundary has been termed the Akron Magnetic Lineament (AML). This lineament is typical of other magnetic lineaments and patterns characterizing the Grenville Province. It is likely that the lineament is related to a lithologic boundary defined by mylonitic structures such as those mapped in Precambrian outcrop areas. There exists extremely limited drill data to determine the nature and origin of the lithologic contrast across the AML. A shallow seismic reflection profile across the AML in Coshocton County, Ohio, may suggest an east-dipping thrust fault in the Precambrian basement in the vicinity of the AML (Reference 83). This interpretation is supported by data from a COCORP seismic reflection line extending across central Ohio. The seismic profile shows evidence of prominent west-dipping reflectors at middle to deep crustal levels that are truncated by low-angle east-dipping reflectors at shallow crustal levels beneath the Paleozoic-Precambrian contact (Reference 295). Cross-cutting magnetic alignments and gradients, trending west to northwest, intersect the lineament and segment it.

Specific magnetic anomalies identified by Voight <Appendix 2D F> are interpreted to be caused by intrusive bodies in the Precambrian basement. The resolution of the magnetic data is not sufficient to determine if the intrusive bodies are fault controlled or whether the structures may extend into the overlying Paleozoic rocks.

e. Detailed Gravity and Aeromagnetic Surveys - 1986 Epicentral Area

A detailed gravity survey was conducted in Lake, Ashtabula, Geauga, and Cuyahoga counties in order to assess the cause of a positive gravity anomaly centered in southwestern Lake County (Reference 4). The detailed data reveal a complex gradient and anomaly pattern on the eastern flank of the gravity high, which is responsible for the eastward bulge of the circular anomaly in the 1986 epicentral area. Modeling of an east-west cross-section was conducted through the resulting simple Bouguer anomaly map, utilizing three distinct lithologic bodies within the Precambrian basement. As modeled, within the limits of assumed lithologic density contrasts, the larger western body does not subcrop beneath the Paleozoic sediments. The eastern margin of the body dips to the east. The two bodies to the east, are modeled at the Precambrian surface extending 3,000 and 1,500 feet beneath the erosion surface. Due to the limitations of the geologic data, specifically uncertain lithologic density contrasts, no unique geometry or structural control of the causative bodies can be derived from the interpreted gravity data.

A detailed aeromagnetic survey was conducted over a 20 mile square area, centered on the Leroy earthquake epicenter, to provide a uniform magnetic data base for interpretation of lithologic and structural features in the Precambrian basement. On the resulting aeromagnetic contour map, the January 31, 1986 epicenter coincides with a northeast-trending magnetic low which is deflected eastward by a northwest-trending magnetic high (Reference 4). The series of discontinuous linear northeast-trending lows and highs, with amplitudes of a few hundred gammas, is terminated 5 km east of the epicentral area by the Akron Magnetic Lineament (AML). Based on comparison of the anomalies with similar patterns occurring in exposed Precambrian Grenville lithologies to the northeast, and limited drill data, the pattern is interpreted to represent

alternating bands of gneiss, with varying mafic mineral content. A Werner deconvolution processing of the data was conducted to calculate depth points, dip directions and susceptibility values, assuming a geometric configuration of the causative lithologic bodies. The results indicate that the northwest-trending higher magnetic anomaly, west of the epicenter area, is interpreted as having a large source body at depth, below the Precambrian surface. To the east, the northeast-trending high is interpreted to have a source near or at the Precambrian surface. As with the gravity data, no unique structural control for these interpreted lithologic contrasts can be determined from the available data. However, the anomaly pattern in the epicentral area is pervasive west of the AML and does not represent a unique structural feature within the typical Grenville terrane.

2.5.1.1.6 Geologic History

The Central Lowlands province, predominantly of the United States, together with the Laurentian (Canadian) Shield province are genetically related, forming the Central Stable Region as defined by King (Reference 61). Precambrian crystalline rocks, predominantly metamorphic of granitic composition, are exposed on the shield, but mantled by a sedimentary cover variable in thickness and generally several thousand feet throughout the Central Lowlands. In the eastern portion of the lowlands, the surface rocks are of Paleozoic age whereas further west, in the Great Plains, Paleozoic rocks are overlain by Mesozoic and Cenozoic rocks. The Appalachian and Cordilleran ancestral geosynclines were in contact on the east and west respectively to the lowlands. Several interprovince basinal structures, of regional significance including the Michigan and Illinoisan Basins received the greatest influx of Paleozoic sediments, up to 14,000 feet. In all likelihood, these features represented regions of negative relief during the Precambrian Era undergoing gradual subsidence concurrent with subsequent Paleozoic sedimentation. In contrast interbasinal domes,

arches and other elements indicative of positive structural relief subsided at a considerably reduced rate. The few episodes of Paleozoic deformation mildly affecting the lowlands, were contemporaneous with orogenic activity in the adjacent geosynclines. The site resided on a portion of the lowlands at the conclusion of Precambrian time which did not develop into a region of either positive or negative structural relief. See <Figure 2.5-15> for reference with the following paragraphs regarding geologic time intervals.

2.5.1.1.6.1 Cambrian and Lower Ordovician

Subsurface information, extrapolated from deep well samples according to Janssens, indicates that approximately 1,200 feet of Cambrian and Lower Ordovician sediments were deposited on the Precambrian surface in northeastern Ohio beginning with the Mt. Simon Sandstone of Upper Cambrian age and concluding with the Knox Dolomite (Reference 63). The top of the Knox Dolomite is a regional unconformity serving as a time-stratigraphic boundary between the Lower and Middle Ordovician. Little is known of the depositional environment operative for the Mt. Simon Sandstone. However, the absence of fossils and glauconite in the sandstone prompted Janssens to suggest a nonmarine origin followed by reworking of the sand during the earliest marine transgression (Reference 63). A deltaic depositional environment with recognizable deltaic fan and prodelta marine facies is postulated for the post Mt. Simon and pre-Knox strata. The northerly and northwesterly situated Laurentian Shield could have served as a likely source of these deltaic sediments. Alternatively, sediments may have been derived from an easterly or southeasterly source beyond the contemporaneous Appalachian miogeosyncline. The Knox Dolomite represents a deepening depositional environment, although apparent thinning of the Knox along a postulated Waverly Arch may signify emergence of the arch as a positive feature (Reference 23).

2.5.1.1.6.2 Middle and Upper Ordovician

The deposition of Middle Ordovician sediments was preceded by a hiatus during which the seas regressed and variable thicknesses of Knox strata were differentially eroded throughout the lowlands. Regional thinning along a general northerly traverse across Ohio is expressed on the isopach maps of Janssens (Reference 63). Further to the north beyond Lake Erie in Ontario the Knox strata are missing.

Carbonaceous mud and other carbonate sediments were laid down upon a basal Middle Ordovician clastic deposit of orthoquartzitic sands of the St. Peter Sandstone. This clean sand is ubiquitous throughout the north-central United States and is interpreted as a shallow water deposit whose depositional environment probably was not too dissimilar from that of the Mt. Simon Sandstone. Subsequently, the marine environment deepened in response to continuous subsidence throughout the lowlands as documented by the repetitious occurrence of fine-grained late Ordovician sediments.

During the waning phases of Ordovician sedimentation, episodes of orogenic activity, restricted to eastern North America, were ascribed to as Taconic. In some portions of Ohio and throughout southern Ontario the Upper Ordovician-Silurian datum is defined as an unconformity.

2.5.1.1.6.3 Silurian-Middle Devonian

Silurian time was intermittently characterized by restricted seas, marine waters of exceptionally high salinity; but paradoxically some of the clearest Paleozoic seas similarly prevailed during this period. It was in the context of this variable depositional environment that the development of thick evaporite deposits and growth of carbonate reef structures flourished. Both conditions have demonstrated their economic worth throughout much of the lowlands province.

From the onset of the period a pattern of carbonate sedimentation ensued initially with the Medina units and later by the Clinton. Clinton rocks contain appreciable shale implying a deepening depositional environment. Collectively both units comprise the early Silurian underlying the "Big Lime," a shortened expression for the drillers' term, "Big Niagaran Lime."

"Big Lime" refers to a thick sequence of limestones, dolomites and evaporites of Middle Silurian through Middle Devonian age. Stratigraphically, they can be differentiated into the Lockport Group (Middle Silurian), Salina Group containing exploitable salt deposits and Bass Islands Dolomite (both Upper Silurian), and a Devonian carbonate sequence including Detroit River Dolomite (Helderberg Limestone to the east) Oriskany Sandstone, Columbus Limestone and Delaware Limestone (Reference 84). Although the paloenvironmental setting undoubtedly exhibited tremendous local as well as regional variability, historical developments can be generalized as subsequently discussed.

Lockport deposits are interpreted by some to represent considerable reef bank development (Reference 85). Presumably this is contemporaneous to carbonate platform deposition in clear seas under warm climate conditions (Reference 86). Subsequent deposition of the Salina Group is associated with reef development which accompanied as well as preceded Upper Silurian evaporites. Physical obstruction to free water circulation, attributed to reef structure, may have enhanced conditions optimum for thick evaporite accumulations, particularly rock salt, known to underlie portions of the lowlands province including northeastern Ohio (Reference 87).

Essential requisites for evaporite deposition include isolation, either wholly or partially, of a significantly large body of restricted water and a source continually feeding seawater through a relatively small surface connection. Alternatively, closely spaced interconnected evaporite basins of regional areal distribution may have been spring fed

by marine water seeps under favorable hydrologic conditions. The latter environment is not too dissimilar to that found on the Saudi Arabian coast contiguous to the Persian Gulf (Reference 86). Either of the above could have provided the environmental setting required for the co-generation of sulfate, carbonate and salt mineralization.

An abrupt stratigraphic contact is signified by a change from bedded anhydrite of the Salina strata to dense dolomite of the Bass Islands rocks. Most probably the salinity concentration of the depositional environment returned to a consistently lower level. Emerging land surfaces especially in western Ohio reportedly are recorded as an unconformity defining the top of the Bass Islands Dolomite. This unconformity also serves as a convenient Silurian-Devonian time stratigraphic horizon (Reference 88). Elsewhere in Ohio including the northeastern portion, this unconformable relationship is absent and the advent of the Devonian is defined by basal sands of the Helderberg Limestone deposited by a transgressive sea.

Early and Middle Devonian sedimentation is predominantly limestone with an intervening interval of Oriskany Sandstone (Reference 89). Conditions favoring carbonate deposition are presumed to be similar to that described for the Lockport sequence which included shallow, clear and warm marine seas. Reef and biothermal structures of laterally equivalent strata are exposed and better understood in nearby New York and Canada (Reference 30). The Oriskany sands could represent a minor regression affecting only the northeastern Ohio region, as they are absent throughout much of Ohio but thicken to the east and north. Following this period of general quiescence characterizing Devonian carbonate sedimentation, the depositional environment must have been altered significantly as recorded by the thick, overlying Ohio Shale sequence.

2.5.1.1.6.4 Middle Devonian-Pennsylvanian

A tremendous thickness of fine-grained sediment and intermittent organics was deposited in a vast marine basin which occupied Ohio and adjacent states of the lowlands province. The northern shoreline advanced to the south during this interval such that its position during early Mississippian time nearly coincided with the present Bedford Shale-Berea Sandstone contact in northeastern Ohio. During early Mississippian time deltaic deposits with several dispersal loci controlled the north to south sediment transport (Reference 90).

Subaerial as well as marine facies are included in the deltaic pattern of early Mississippian deposition. Berea Sandstone generally occurs as fluviatile, channel-filling deposits. Arenaceous Berea strata are in contact with Ohio as well as Bedford Shale. In some cases this can be attributed to deep-channel scouring through the Bedford Shale. Alternatively, widespread and prolonged subaerial erosion preceding Berea stream entrenchment could have effectively removed substantial Bedford sediments during a depositional hiatus.

Clastic sedimentation continued during remaining Mississippian time subsequent to deposition of the Berea Sandstone. Although its areal distribution presumably was widespread throughout most of Ohio, erosion removed much of the relatively thin veneer except for two portions. One in the southeast, occupies the ancestral Appalachian geosyncline and the other in the northwest, flanks the Michigan Basin.

2.5.1.1.6.5 Pennsylvanian and Permian

The regional deposition of Pennsylvanian and Permian deposits probably persisted over a much broader area than that presently indicated by the areal distribution pattern limited to southeast Ohio. At the onset of Pennsylvanian time much of the lowlands had emerged, and the ensuing depositional hiatus was accompanied by substantial erosion except for

the submerged interior basins. In the Appalachian geosyncline a repetitious cycle of transgressive and regressive seas controlled the marine-nonmarine sedimentary cycles referred to as a "cyclothems." Predictably, a variety of vertical and lateral lithologic changes, abrupt and gradational, characterize cyclothem-member facies. In fact, the vast economic deposits of bituminous coal profitably extracted from the Illinois Basin and Appalachian Basin were laid down as cyclothem members during the Upper Paleozoic.

Permian sedimentation must have been far less extensive than Pennsylvanian although much of the record may have been eroded. The culminating event of the Paleozoic Era was a tremendous orogenic upheaval which elevated the Appalachian Mountains by the collective processes of folding, faulting and uplift. These processes were attenuated in their northwest propagation so that the strata are only gently folded throughout much of the Appalachian Plateau. Further inland and throughout much of the eastern lowlands province, the seas regressed with widespread, if not total, emergence of the depositional environment.

2.5.1.1.6.6 Mesozoic through Tertiary

There are no Mesozoic or Tertiary deposits in the eastern lowlands although their thickness is considerable throughout most of the Great Plains, west to the foothills of the Rocky Mountains. Summarily, this interval of time was undoubtedly characterized by widespread subaerial erosion.

2.5.1.1.6.7 Quaternary

The events of the Pleistocene and Recent Epochs have had a profound effect on most portions of the Central Lowlands. Beginning approximately 1-1/2 million years ago until 11,000 years ago there were four major stages of extensive continental glaciation, Nebraskan,

Kansan, Illinoisan, and Wisconsinan. Each resulted in the deposition of vast sediment quantities directly attributable to ice sheet advance and recession as well as melt-water streams emerging from ice sheets. The source of these vast ice sheets was located well to the north. Although the precise cause of the ice sheet growth up to continental proportions is not known and many explanatory theories have been advanced, important factors probably included a general emergence and resultant high altitude of the continents.

Most of Ohio, excluding the southwest corner, was probably covered by ice during each glacial stage, for periods up to 50,000 years separated by long interglacial stages (Reference 91). There is no direct evidence for the first Nebraskan stage, in northern Ohio, but deposits in other areas indicate that Nebraskan ice covered part of the state. Ridges of glacial debris or till more than 40 miles south of the site have been identified as end moraine of the Kansan stage. Tills of the Illinoisan stage have been found about 70 miles south of the site. Deposits of the last major advance, the Wisconsinan, are found up to 75 miles south of the site. As the youngest of the major glacial deposits, they are preserved the best and have been further subdivided into successively younger units: Farmdale, Iowan, Tazewell, Cary, Mankato, Valders (Reference 92). These are substages or simply minor advances of the ice sheet. The glacial till at the site is attributed to events of the Cary substage.

The Great Lakes began to develop after the Cary substage. These ancestral Great Lakes were mainly filled by glacial meltwater dammed by the ice front on the north and higher terrain to the south. Outlets to the west, south and east were used at various times, depending upon the position of the ice front. Lacustrine or lake bottom sediments and beach deposits formed in the lake and contiguous to its shoreline respectively. Some of the early lake deposits were formed only to be obliterated or buried by ice sheet readvances. As the ice sheet retreated for the last time, these deposits emerged as lake levels fell.

Many of these features of the ancestral Great Lakes are now found a considerable distance from the present shoreline and 100 feet or more above present lake levels. The present Lake Erie was established about 9,000 years ago.

<Figure 2.5-16> is a generalized subsurface portrayal along a north-south trend through the Perry site showing the southerly inclination and relative thickness of Paleozoic deposition, by period, together with the Lake Plain veneer of glacial and glaciolacustrine sediments.

2.5.1.1.7 Mineral Deposits

Mineral resources in the northeastern Ohio portion of the Central Lowlands province are restricted to nonmetallic occurrences. A considerable quantity of sand and gravel has been obtained regionally from stratified drift and a weathered conglomerate of Mississippian age. Abundant reserves which can be derived from both sources remain. Chagrin shale of the Ohio Shale, which immediately underlies Pleistocene drift and lacustrine overburden along the Lake Plain east of Sandusky, does not have suitable ceramic properties for use in either the pottery or refractory industry. However, this shale is adequate for making common brick and tile. There are no shallow limestone or dolomite resources in Lake County although carbonate strata are interbedded within the Salina Group. Limited limestone and dolomite production, occurring as country rock in the extraction of salt, is considered relatively insignificant. Shallow occurrences of quality carbonate rock elsewhere in Ohio, especially in the western portion, preclude economic extraction of the deeper sources known to underlie northeastern Ohio. The most valuable commodity mined in Ohio is coal, the economic occurrence of which is restricted to Pennsylvania and Permian period strata situated in the state’s southeast portion.

2.5.1.1.7.1 Salt Mining

Salt deposits exist regionally and are being exploited within Cuyahoga and Lake counties, Ohio. Salt beds of the Salina Group underlie all or a part of 23 counties in eastern Ohio. Since 1889, these beds have been commercially developed by both conventional and solution mining. <Figure 2.5-16> shows the location of area mining operations. Within the locale of the Perry site, solution mining was conducted by the Diamond Shamrock Chemical Company, while room and pillar mining is currently being conducted by the Morton Salt Division of Morton Thiocol, Inc <Figure 2.5-17> <Figure 2.5-18>. In the period from 1980 to 1989 rock salt production in Cuyahoga and Lake counties has remained relatively stable (3.3 million tons/year) with the exception of 1983 (1.7 million tons) (Reference 93). The geology and mining techniques prevailing within the area of study and the potential influence of the mining on PNPP are described in the following sections.

2.5.1.1.7.1.1 Local Geology

As discussed in <Section 2.5.1.1.4>, the area of study is immediately underlain by Devonian rocks associated with the Columbus, Delaware and Ohio formations, the latter comprising subjacent bedrock throughout the Perry site. Additional underlying Devonian and Silurian rocks of interest to this study include the Oriskany, Helderberg, Bass Islands, Salina, and Lockport. A typical geologic column, developed from near-site data, is included as <Figure 2.5-19> and identifies the sequence of carbonate and evaporite rocks which is referred to as the "Big Lime" of Ohio. A southwest-northeast trending stratigraphic section from Painesville Township, Lake County to Harpersfield Township, Ashtabula County, Ohio, and a north-south trending section are shown in <Figure 2.5-20> and <Figure 2.5-21>, respectively. These sections have been inferred from examination of available well logs and from publications of the Division of Geologic Survey, State of Ohio (Reference 7) (Reference 94) (Reference 95) (Reference 96). The

following descriptions of the major stratigraphic units of interest are based on the foregoing sources supplemented by communications with geologists and other individuals associated with the local salt mining and gas producing industries.

a. Lockport Group

The Lockport Group includes strata of Niagaran age. The uppermost shale strata of the Rochester shale, considered to be the base of the "Big Lime," are encountered within the site environs at an approximate depth of 2,670 feet. Locally, the overlying Lockport Group is composed of about 250 feet of dolomite. The uppermost strata of the Lockport include as much as 40 feet of finely-crystalline dolomite. Drillers refer to these strata as the "Newburg Sand" which regionally are a source of natural gas and petroleum.

b. Salina Group

The Salina Group, composed of seven units, occupies the basal part of the Upper Silurian, Cayugan Series and contains the salt measures. The interbedded evaporite and carbonate rocks of the Salina are encountered in the site vicinity at depths on the order of 1,750 feet. The local structure contours and isopachous maps of the salt-bearing B, D and F units are shown in <Figure 2.5-22>, <Figure 2.5-23>, <Figure 2.5-24>, <Figure 2.5-25>, <Figure 2.5-26>, and <Figure 2.5-27>. The salt measures are seen to locally dip to the southeast at an average gradient of about 25 feet per mile. The principal salt producing units within the immediate area of study are the B (Ohio No. 4 Salt) and F (Ohio No. 2 and No. 1 Salts) units. Rock salts within the units are usually interbedded with or contain stringers of anhydrite, shale and dolomite. The Greenfield A, C, E, and G units which separate the salt bearing units are primarily composed of interbedded argillaceous dolomite,

anhydrite and shale. <Table 2.5-1> summarizes the depth and thickness of the various units as interpreted from the drill and geophysical logs of two wells penetrating the Salina Group within Perry Township. As shown by <Table 2.5-1> and <Figure 2.5-20>, total thickness of salt beds in Perry Township are on the order of 190 feet and thicken slightly to the southeast along dip. The inferred local structure and stratigraphy correlate well with more generalized published regional data (Reference 97).

The salt beds of the Salina are granular to crystalline with grain sizes ranging from medium to coarse and are usually found to contain from 92 to over 96 percent NaCl. The salts of the B unit contain the highest proportion of impurities.

From interviews with consulting geologists and other individuals associated with the salt mining industry near Painesville and near Fairport, Ohio, the following information concerning the integrity of unmined salt measures has been established (Reference 98) (Reference 99) (Reference 100).

1. No solution cavities within area underground salt workings have been directly observed either during exploration or during mining.

2. Underground mine workings near Fairport, Ohio, are essentially dry and free of any significant groundwater infiltration.

3. No excessive water loss, rod drops or grout take during casing cementing has been experienced during exploration or during solution mining operations.

The foregoing observations are consistent with the geologic process of secondary salt deposition. This process is explained as follows:

> "most rock salt beds, during a part of their post-biogenetic history, have been exposed to some type of solution attack, particularly near the edges of the salt basins. In some margin areas the salt has been completely removed by the geologic process, leaving only the evaporite impurities and interbeds. Down dip in the evaporite basins, this secondary geologic solution process has led to some thinning of the salt deposits and to solution enlargement of joint systems. In most Paleozoic salts at depths of 1,000 feet or more, "solution crevice" structures are common. These represent solution enlargements in which the salt was removed, the impurities dropped to the boundaries of the opening, and after some flow and deformation, the salt was redeposited from groundwater solution within the remaining openings" (Reference 101).

c. Bass Islands Group

Argillaceous, dolomitic limestone and calcareous dolomite belonging to the Bass Islands Dolomite and possibly limestone of the overlying Helderberg Limestone are present within the area of study. These rocks are encountered at depths on the order of 1,600 feet at the base of the overlying Devonian system. Locally, the Bass Islands and Helderberg are estimated to be about 150 feet thick and contain dolomitic shale interbeds in the lower 30 to 40 feet. No solution cavities within these rocks are reported, consistent with low porosity and relative impurity of most of the carbonate rocks.

d. Oriskany Sandstone

The rocks of the Oriskany are usually identified as a fine-grained sandstone and occasionally as a medium to fine-grained sandstone. Primarily because of the very limited local thickness (8 to 17 feet) within the area of study, the sandstone is important only as a marker bed for stratigraphic correlation. This unit is a source of natural gas near Mentor, Ohio, about 14 miles southwest of the site.

e. Columbus/Delaware Limestone

Devonian rocks associated with the Columbus and Delaware Limestone are usually identified as a hard, dense, cherty limestone, or a dolomitic limestone. The lower Columbus is medium to massively bedded and fine-grained in texture, whereas the Delaware is thin to medium-bedded, fossiliferous and more frequently jointed. No evidence of solution voids within the formation is known to have been reported. This is consistent with the low porosity and permeability of most of these carbonate rocks.

f. Ohio Shale

The Chagrin shale member, together with the Huron shale member of the Ohio Shale, is encountered beneath 40 to 50 feet of glacial drift throughout the area of study and extends to depths on the order of 1,250 feet below the ground surface. Within the depth of plant area exploration (730 feet), cores of the noncarbonaceous Chagrin shale are usually identified as dark-gray to medium-gray silty or clayey shale occasionally containing light gray sandy shale laminae whereas the Huron shales are black to dark brown with lesser amounts of thinly bedded light gray silty and sandy laminae.

A predominant joint system was observed in the rock cores to coincide with near horizontal bedding planes. Secondary joints were also observed with joint attitudes ranging from near vertical to 40 degrees.

Two master sets of conjugate joints are reported to be conspicuous throughout the Ohio Shale (Reference 7). Regionally, the master sets both trend north 40° east and 55° west, respectively. Porosity and permeability of the Chagrin and Huron shales are quite low, although very small quantities of natural gas are known to exist within each.

g.   Groundwater System

Major rock aquifers have been identified within the area of study. The shallowest system (other than near-surface groundwater) is primarily associated with the Oriskany Sandstone ("First Water" of the "Big Lime") and is locally encountered at depths on the order of 1,600 feet. Occasional water bearing zones have also been encountered near the base of the Columbus and in the upper part of the Bass Islands and Helderberg. The waters of these and deeper rock aquifers are a natural brine of high salinity which represent solution remnants of water that filled interstices of sediments deposited in seas of Devonian and Silurian age. The Oriskany aquifer is under considerable artesian pressure and rises in communicating wells to within 100 to 150 feet of ground surface, and therefore has an excess pressure head of at least 1,450 feet (Reference 99).

The "Second Water" of the "Big Lime" is regionally encountered below the salt measures at a depth of about 2,600 feet and is associated with porous crystalline dolomite strata of the Lockport Group known as the "Newburg Sand." Newburg water is a natural brine and is one of the chief water bearing horizons in the

deep-seated rocks. The great yield of this aquifer is consistent with artesian pressure sufficient to cause a rise of the brine in wells to within 300 feet of ground surface, demonstrative of an excess pressure head of 2,300 feet (Reference 102).

Supplementing work conducted by the Division of Geological Survey of the State of Ohio, extensive chemical analyses of the Oriskany and Newburg brines have been conducted by CEI (Reference 102). The results of chemical analysis of water samples taken from wells within Lake County and the immediately surrounding counties together with chemical analyses of sea water samples conducted by the United States Geological Survey (Reference 103) are summarized in <Table 2.5-2>.

To investigate solubility of NaCl in the natural brine waters, a solution was prepared to simulate the average Oriskany brine solution. The chemical composition of the prepared solution is summarized in <Table 2.5-3>. Upon addition of salt (NaCl) to the prepared solution, 100 percent saturation was obtained with 193.6 gms per liter of salt. Thus, salt solubility of the solution is 10.5 percent at room temperature. A simulated Oriskany solution compares with a saturation requirement of approximately 359 gms per liter for a freshwater solution at room temperature. The difference between the saturation requirement of the brine and freshwater solution is attributable to a combination of other solution elements combining with available chlorides. Thus, the Oriskany brine (weakest of the natural brines) was found to have a salt solubility of only 10.5 percent as compared to a freshwater salt solubility of about 36 percent, and is not expected to cause significant dissolution of the rock salt in the absence of continuous brine circulation through the salt measures.

Comparison of sea water and brine analyses <Table 2.5-2> shows that chloride and calcium concentrations of the brine are greater than

those of sea water. It is also noted that the brines have a relatively high salinity under prevailing in situ temperature and pressure conditions and that carbonates are found in small quantities in the sea water, but are absent in the brine. Thus, carbonates would be expected to be practically insoluble in the highly concentrated saline solutions comprising the natural brines (Reference 103). The brines are not expected to cause dissolution of the carbonate rocks. This is consistent with the absence of solution cavities.

As discussed in <Section 2.4.13.2> and <Section 2.5.4.6>, a near-surface, fresh groundwater system exists within the glacial drift encountered throughout the plant site. Groundwater was observed to be held primarily within surficial lacustrine deposits which are underlain by a very dense, relatively impervious clay till deposited as ground moraine. Owing to the low permeability of the predominately fine-grained soils, this water system has a very limited yield but has been utilized as a domestic water source. The relatively impervious Ohio Shale, over 1,100 feet thick, undoubtedly acts as an aquiclude which together with the great artesian heads of the brine aquifers, prevents significant downward fresh water percolation.

No aquifers have been locally identified either within the evaporite rocks or the overlying Devonian shales. It is again noted that evaporite rocks of the Salina have a very low porosity and permeability, as demonstrated by direct in situ observation during deep mining operations.

2.5.1.1.7.1.2 Area Mining

The primary salt producing units within the area of study correspond to the B and F units of the Salina Group, although mining of the D unit cannot be discounted. It is probable that if salt mining were to be

conducted closer to the site, mining techniques currently used in the area would be applied. Within the Painesville, Ohio area, salt is recovered by solution mining of the Salina Group at depths below 1,900 feet. Initially, solution mining was conducted by drilling casing into the salt measures, pumping water down an annular space between the casing and a center tubing, and recovering salt brine through the tubing (top injection method). Cross-well pumping combinations were also used after communication was established between adjacent wells. Difficulty with this method was experienced in economically controlling the solution cavity configuration and preventing surface subsidence. Subsequently, an improved solution mining technique was adopted in 1959 and has been utilized in the Painesville, Ohio vicinity since that time.

Area solution mining currently utilizes hydraulic fracturing of strata, usually between two wells, to provide a controlled pumping communication. This is accomplished by inducing directed high pressures at the base of the salt-producing zone. The production wells are usually aligned along dip. After fracturing strata between wells, a solution pipe and eventually a cavity is developed by injecting water in one well and recovering brine from a second well. The hydraulic fracturing technique has been described by Bays, Peters and Pullen (Reference 101).

Area well fields developed since 1960 generally employ lines of production wells (galleries) spaced about 500 feet on center (Reference 98). The galleries are separated by approximately 1,000 feet. With this well configuration, the maximum horizontal dimension of an elliptical solution cavity would be expected to be aligned along the well gallery, not exceeding the distance between communicating wells. The cavity dimension normal to the well line would be expected to be less than the major axis of the cavity. The vertical extent of solution cavities between wells would be less than the cumulative thickness of salt within the B, D and F units, as discussed

in <Section 2.5.1.1.7.1.4>, because insoluble dolomite, shale and anhydrite strata separate salt beds and occur as thin interbeds and stringers within the salt.

The salt measures existing in the vicinity of the site contain reserves which have a potential for commercial development. The location of salt reserves controlled by the Diamond Shamrock Chemical Company is shown in <Figure 2.5-17>. Consideration has been given to the potential for future solution mining or deep-mining operations located immediately adjacent to the boundary of the mineral rights controlled by CEI. As discussed in <Section 2.5.1.1.7.1.4>, only solution mining appears to have a reasonable occurrence potential. To assess the potential for future development of solution mining operations, particularly those which may be conducted by operators other than the Diamond Shamrock Chemical Company, knowledgeable people connected with the salt industry were interviewed (Reference 99) (Reference 104). From these interviews it is concluded that the future market for solution mining in northeastern Ohio is uncertain, with an expectancy that the demand for soda ash will decline and eventually phase out. However, it was also concluded that there would be a continued need for chlorine production and for underground storage of natural gas and petroleum products. The consensus of expert opinion was that development of a new solution mining operation within the immediate vicinity of the plant site by someone other than Diamond Shamrock Chemical Company is not likely, considering the future market potential and development costs. Moreover, CEI has secured mineral rights within a minimum 3,000-foot “protective zone” as shown in <Figure 2.5-18> around Seismic Category I elements of the plant in order to preclude any mineral extraction operations therein.

2.5.1.1.7.1.3 Subsidence History

Subsidence of the surface as a product of underground mining has been well documented in the literature and has occurred during regional

solution salt mining (Reference 105) (Reference 106). Prior to adoption of the hydraulic fracturing method of solution mining, it is reported that surface subsidence was realized during solution mining within the Painesville, Ohio area. The magnitude of this subsidence is unknown. Since initiation of improved solution mining methods, it is reported that monitoring of surface elevations by the Diamond Shamrock Chemical Company to the nearest 0.1 foot at 300 surface monument locations has not detected any surface subsidence (Reference 104).

2.5.1.1.7.1.4 Subsidence Potential

Measurable subsidence within the area of study could be realized, if within the salt measures, cavities of sufficient size closed. Cavities could be produced by conventional deep mining, by solution mining or by inadvertent solutioning due to the intrusion of aggressive waters through abandoned wells. Natural solution cavities would also be a potential source of surface distortion.

a. Natural Solution Cavities

Consistent with the low porosity and low permeability of the carbonate and evaporite rocks, and as demonstrated by local drilling and mining experience, there is no evidence of significant natural solution voids occurring within either the carbonate or evaporite units. The depths of rocks which are potentially susceptible to solution would also preclude concern that natural solution voids could produce surface subsidence, considering the following conditions:

1. More than 1,200 feet of shale overlies the carbonate rocks nearest the surface. Most of the carbonates within the "Big Lime" interval are impure and do not have a high solution susceptibility.

2. A significant stress increase due to surface loading by plant structures is not realized at depths greater than a few hundred feet.

3. There is no local topographical evidence or history of existing surface subsidence features occurring from natural causes.

4. The groundwater environment is not conducive to solutioning.

5. Below and probably well above the brine aquifers, the water chemistry is not conducive to solutioning of either the carbonate or evaporite rocks.

6. Any enlargement of a hypothetical solution cavity in the carbonate or evaporite rocks by natural solution processes would be insignificant during the life of the Perry site.

7. Development of sinkholes by plug subsidence (the drop of an overburden mass into a subsurface opening without bulking) is not consistent with regional geology.

In summary, the probability that detrimental surface subsidence could be produced within the area of study by natural solution cavities is much too low for further consideration.

b. Conventional Deep Salt Mining

Salt is being mined in northeastern Ohio using conventional room and pillar techniques. The closest deep mine operation in the area of study is conducted by the Morton Salt Division of Morton Norwick near Fairport, Ohio about 8 miles from the Perry site. Deep mining is conducted using the room and pillar techniques where pillars are sized and spaced to support overburden loads in a manner to

preclude surface subsidence (Reference 107). As salt reserves controlled by the Diamond Shamrock Chemical Company effectively block eastward expansion of the Morton operations, deep mining within the near vicinity of Perry is not probable (Reference 104). Should such occur, the effects of deep mining could be more readily controlled than solution mining and the mining is conventionally designed so as to preclude detrimental surface effects (Reference 107).

c. Solution Salt Mining

Salt and allied chemicals were extracted by the Diamond Shamrock Chemical Company near Painesville, Ohio. Since 1957-1960, most solution mining within the salt measures of the Salina Group had been conducted using the hydrofracture technique described in <Section 2.5.1.1.7.1.2> (Reference 108). The basal connection feature of hydrofracturing enables effective dissolution laterally through the salt section rather than just vertically at the roof of the cavity. Uncontrolled vertical solutioning was the cause of the detrimental "morning glory" cavity configuration associated with the older top injection mining method. The hydrofracturing solution method reduces, if not eliminates, roof sag and collapse often realized with the single-cavity well mining method.

Although it is believed that the exact configuration of cavities in salt horizons which contain frequent insoluble interbeds cannot be well documented, recent underwater sonar caliper logging has generally been reasonably effective in approximately defining the limits of solution cavities (Reference 109). Sonar caliper surveys are often periodically made to aid in control of the cavity size. Control of cavity size to minimize well damage and to obtain cavities suitable for underground storage upon completion of solution mining is in the best interests of the mining companies.

It is reported that the optimum cavity width for storage is on the order of 200 to 300 feet and that widths in excess of 500 feet are undesirable (Reference 99).

Based on the foregoing considerations and the experience of the Diamond Shamrock Company's current mining operation, the maximum cavity width in a given salt bed which can be reasonably postulated is on the order of 500 feet (Reference 104). In conjunction with area solution mining, it is expected that cavities would be formed in the B and F units. The upper limit of cavity height in the area of study could not exceed the salt thickness, approximately 100 feet and 60 feet in the B and F units, respectively. Actually, this height would be reduced by the insoluble interbeds, inclusions within the salt and maintenance of some bedded salt to facilitate cavity stability. This would result in probable cavity heights of about 75 feet and 50 feet for the B and F units, respectively. Mining of the D unit is less likely but if achieved could produce a cavity height on the order of 20 feet.

Upon completion of solution mining activities, it is probable that the solution void would exist as an irregular opening initially having a ragged "card-deck" appearance about the periphery of the cavity. It is envisioned that the "cards" are represented by the remnants of the less soluble anhydrite, dolomite and shale interbeds. Further, the progressive collapse and settling out of the insoluble strata and stringers within and between the salt beds would be expected to produce a collection of debris at the base of the cavity. Unless sufficient pressure is maintained within the cavity, with time, a gradual closure would be expected due to creep of the supporting salt (Reference 110).

The rate of cavity closure would no doubt be a function of the size and depth of the cavity as well as of the roof and fluid pressure conditions. In larger cavities with poor roof conditions,

progressive roof falls and bulking would partially or completely fill the cavity, reducing but not eliminating the amount of closure and possibly the time of closure. Local experience indicates that solution cavity subsidence is effectively complete about ten years after solution mining (Reference 99). Laboratory model studies conducted under simulated in situ conditions demonstrated a 90 percent closure of cavities at least by the twelfth year after formation (Reference 111).

d. Solutioning Not Related to Active Mining

In conjunction with solution mining, the potential for solutioning of the salt measures and the surrounding evaporite and carbonate rocks within an abandoned well field has been considered. Consideration has also been given to the solution potential offered by an improperly sealed exploration well. Such potentially detrimental solutioning could be induced by the introduction into the salt measures of fluids which are not salt-saturated.

If a fluid in the void were not fully salt-saturated, additional salt solutioning would occur until full saturation of the fluid in contact with the salt is obtained. Because of the very low porosity and permeability of the salt measures, there is no fluid circulation potential and the volume of fluid capable of dissolution is limited to that contained within the cavity.

To investigate the extent of dissolution which could be induced within a salt cavity by an introduction of an aggressive fluid, a study of the possible growth of a hypothetical, spherical cavity within the salt measures was conducted. The first part of the study involved the introduction of a fluid with characteristics of the Oriskany brine as shown on <Table 2.5-3>. The increase in the diameter of the spherical cavity was calculated for a range of initial cavity diameters assuming that the fluid within the cavity

would actively dissolve salts until achieving 100 percent salt saturation and that the cavity would not be subject to loss or gain of fluid. The results of this study for various assumed salt concentrations are shown as <Figure 2.5-28> and demonstrate that the additional growth of a cavity by solutioning in a fluid similar to the Oriskany brine is insignificant even if the initial salt concentration is zero. The effect of introducing freshwater having a salt solubility of about 46 percent was also investigated for a hypothetical, spherical cavity. The results of this study, also shown in <Figure 2.5-28>, demonstrate that even this extreme condition would not cause an important increase in the diameter of an existing salt cavity.

The conservatism of the foregoing analyses is increased when consideration is given to the formation of the insoluble residue which blankets exposed salt surfaces upon solutioning. This residue retards dissolution and must be cleaned by frequent flushing and agitation to permit an active solution process. Further, the Oriskany aquifer above and the Newburg aquifer below the salt measures are under significant artesian pressures which prevent downward movement of aggressive surface waters. For example, should a freely communicating well be drilled into the Newburg aquifer, the brine would stabilize well above the level of the carbonate and evaporite rocks. The prevailing hydrogeologic conditions at the Perry site are unlike that reported in central Kansas when subsidence was caused by dissolution of salt measures as a result of continuous downward movement of groundwater from a surface horizon to underlying porous strata under low fluid pressures (Reference 112).

Consideration has been given to the effect of pumping, from gas or petroleum fields located immediately adjacent to the boundary of the plant site, on the reservoir pressures existing within the Oriskany and Newburg aquifers. The effect of gas well pumping has

also been considered relative to a potential link with local micro-seismicity as observed in the Gobles field in southwestern Ontario (Reference 113). Regional experience, particularly within the Madison Lake field, indicates that gas extraction from the Oriskany and Newburg horizons may have some measurable effect on reservoir pressures at distances between 2,000 and 3,000 feet from an open gas well. However, the drawdown would be limited because wells are routinely shut down when salt water encroaches into the gas field. A similar situation occurs in petroleum production areas. At present, no decisive causal relationship between gas well pumping and micro-seismicity is apparent.

Mineral and hydrocarbon extraction will be prevented for a distance of at least 3,000 feet beyond the onshore safety-related structures and rock salt extraction is precluded by lease agreement with the State of Ohio within approximately 1,800 feet of the offshore safety-related structures during plant operation. It is concluded that the effect of pumping from an immediately adjacent gas or oil field will have no detrimental influence on the solution potential of the evaporite or carbonate rocks existing below the plant site. Further, even if appreciable pressure drawdowns are postulated, significant flow through a cavity existing within the salt measures has a very low order of probability, because production wells would be shut down upon encroachment of formation water.

As exploitation of natural brines could also produce pressure reductions within the Oriskany and Newburg aquifers, the potential for natural brine production in the immediate vicinity of the site has been considered. Although in past years natural brine production was not uncommon, the only natural brine operations which could be located in northeastern Ohio are being conducted by Pinney Dock and Transport Company, in Ashtabula, Ohio and by the Bestone Corporation, near Chardon, Ohio. The Ashtabula operation consists of a single well 1,800 feet deep, which is producing from

the Oriskany aquifer. The three Chardon wells produce about 12,600 gallons per day from the Newburg horizon at a depth of about 3,400 feet.

Other natural brining operations are located in southern Ohio. The natural brine production in northeastern Ohio is generally for use in highway ice control. There are no data concerning formation pressure drawdown due to pumping of the natural brine. However, it is known that only a limited duration of pumping is possible before pumping must be terminated and the aquifer allowed to recharge. This condition demonstrates that the permeabilities of the Oriskany and Newburg aquifers are too low to establish a steady-state drawdown under commercial pumping rates. In the Ashtabula County operations, the duration of pumping before allowing recharge is also limited by natural gas encroachment.

In summary, it is probable that under the most unfavorable circumstances, the distance of pressure drawdown which could be developed during pumping of natural brine is similar to that cited for gas and oil operations. The significant reduction in the number of natural brine operations in Ohio strongly indicates that the economic feasibility of new natural brine operations is not favorable and that the development of such operations within the near vicinity of the site is highly improbable.

Upon completion of mining, the fluid in the cavities is saturated with NaCl, except for a relatively thin zone at the top of the salt which is slightly less saline. Assuming there is no introduction of fluids from above or below the cavity after equilibrium is achieved, it would be anticipated that the void liquid would remain essentially unchanged.

Extensive chemical analysis of the Oriskany and Newburg brines have been conducted by CEI and have been summarized in <Table 2.5-2>

(Reference 102). As shown by the water chemistry, the produced brines would not be expected to cause any significant dissolution of the salt or of the less soluble overlying and underlying limestone, anhydrite and dolomite. A summary of test results on samples of production brine taken from regional solution wells is included as <Table 2.5-4>.

If the cavity and well casing were to be filled with saturated or nearly salt-saturated fluid, migration of the solution down dip within the salt measures would be expected to be very slow, probably occurring primarily as a diffusion phenomena rather than unsteady-state seepage migration. It is noted that the dips are very gentle, averaging only about 25 feet per mile, and that the salt measures are characterized by a very low porosity and permeability. The impervious nature of the salt beds is documented by the direct, long term observations within the underground workings of the Morton Salt Division of Morton Norwick near Fairport, Ohio (Reference 100).

Concerning solutioning of the evaporite and carbonate rocks within the area of study, there are no existing solution wells penetrating the Ohio Shale within 7-1/2 miles of the site area. Further, mineral exploration or production wells which would be drilled through the shale within the vicinity of the site are required by current state legislation to be adequately sealed to prevent infiltration or migration of water, oil and gas from other horizons. Well sealing is conducted in the presence of a state inspector as required by the Oil and Gas Law of the State of Ohio, July 1970 (Reference 114). It is pertinent to note that the Diamond Shamrock procedure of well sealing includes grouting the casing continuously from the surface of the rock at least to the base of the Oriskany and is more complete than required by the State (Reference 98).

Careful observations of the ground surface adjacent to 21 wells during preconstruction studies in the vicinity of the site failed to reveal depressions which could be attributed to surface subsidence as a result of deep-seated dissolution of evaporite or carbonate rocks. The field survey was also extended to include a search within 3,000 feet of the site for any closed depressions which could possibly be interpreted as a reflection of deep-seated dissolution of the carbonate or evaporite rocks. In addition, available topographic maps of the area of study were also examined. Both the field and topographic map searches failed to identify any surface depressions which could be interpreted as being associated with other than geomorphic origins. Subsequent to the January 31, 1986 Leroy event, a site area reconnaissance revealed no evidence of depressions or other indications of disturbance (Reference 4).

e. Angle of Draw

Some surface distortion is inevitable in response to creation of large underground openings (Reference 105). The amount of surface subsidence is primarily dependent upon the depth and configuration of the opening, the competence of the rocks around, above and to some degree below the opening, and the material left or deposited within the opening. It is well documented that the areal extent of potential surface distortions also extends well beyond the limits of the opening (Reference 115). Because of the potential for subsidence to occur during mining over which CEI would not have direct control, it has been concluded that a zone wherein mineral extraction will be barred should be established around the plant and that the width of this “protective zone” should be sufficient to prevent any mining-related surface distortion at the location of the plant elements. The basis and formulation of criteria to dimension the plant “protective zone” is summarized and compared to the actual limits of mineral rights secured by CEI as follows.

Over the past 100 to 150 years, a great volume of data relating surface subsidence to underground mining operations has been accumulated under a variety of geologic and mining conditions (Reference 107). The state of art of subsidence prediction, although primarily empirical, is fairly well advanced. The empirical procedures developed by the National Coal Board (NCB) of Great Britain, primarily based on the depth and the geometry of mine openings, are the most widely accepted of the current methods of subsidence prediction (Reference 115). The NCB criteria are based on careful surveys conducted at 157 collieries in Great Britain and have been claimed to produce subsidence predictions within about 10 percent of actual measurements (Reference 105). Comparisons of subsidence predictions over salt cavities created by solution mining have also shown the NCB criteria to yield a larger prediction of the amount of subsidence than predictions using theoretical elastic or elasto-plastic analyses (Reference 116). Use of NCB experience to aid in the formulation of judgment relating to evaluation of salt mining influences is believed to be appropriately conservative for the purpose of this study.

There are no subsidence records presently available for mining conducted within the proximity of the proposed site. However, analysis of case histories of subsidence occurring within the salt measures of Ontario, Canada, Michigan, Wyoming, and New York has been made (Reference 106) (Reference 117) (Reference 118). The angle of draw computed from three of the case histories, together with similar data derived from measurements over British coal mines, is shown on <Figure 2.5-29> (Reference 119). It is noted that the observed limit angle over the salt mine openings studied is substantially less than recorded over both British and American mine openings having similar width-depth ratios. This observation is explained by the generally greater competence of the rocks overlying the salt measures.

The prediction of a 30° angle of draw to define the limit of potential mining influences in the vicinity of the Perry site is shown on <Figure 2.5-31> to be conservative, considering that probable limit angles would not be expected to exceed about 20 degrees. As shown by <Figure 2.5-18>, the acquisition of mineral rights will provide at least a 3,000 and 1,800 foot "protective zone" around onshore and offshore, respectively Seismic Category I elements of the plant. The extreme conservatism of the mining protection provision can readily be seen by using Equation 2.5-2 for calculating the "available limit angle" (B'). Allowing for a cavity extension of 500 feet beyond the "protective zone" boundary closest to safety class structures:

$$\arctan B' = \frac{3{,}000 - 500}{2{,}350} \qquad (2.5\text{-}2)$$

and B' = 46.8°. A typical section through the site showing the limit angle relationship is shown on <Figure 2.5-29>.

2.5.1.1.7.1.5 Subsidence Monitoring

Should salt mining be initiated within 1,000 feet of the mineral rights boundary, a subsidence monitoring system, independent of the mining operator, will be installed and maintained during the life of the plant. The monitoring system will consist of surface monuments located within the protected area in the immediate proximity of all production wells drilled closer than 1,000 feet to the mineral rights boundary of the plant. Monument location, spacing and the survey frequency would be designed to enable early detection and detailed documentation of any surface subsidence. Should subsidence within the "protective zone" surrounding the plant area be detected, action will be taken immediately to prevent continued operation of the causative mining.

2.5.1.1.8 Oil and Gas Production

Oil and gas production in Ohio is small by comparison with that of the Gulf Coast, southwestern and western United States or Alaskan North Slope. Nevertheless, in 1977 it represented more than a quarter billion dollar industry to Ohio. The area distribution of oil and gas fields in Ohio is shown on <Figure 2.5-30>. This most recent map (1974) was published before drilling activity increased in the late 1970’s and early 1980’s. In addition to the fields shown on a significant portion of eastern Lake County including all of Perry and Madison Townships and the northern one-third of Leroy township is now gas productive. Oil and gas production has also continued to the south into Geauga County. The producing zone is the Clinton. Only a few wells produce from the Oriskany. Most of the extracted hydrocarbons occur in sandstone reservoirs, principally the Silurian “Clinton-Medina,” Devonian “Oriskany” and Mississippian “Berea.” Natural gas has been commercially produced from shallow wells developed in the Ohio Shale along the Lake Plain since 1869. Eastern United States research, in situ testing, demonstration projects and pilot programs, respective of Devonian shale hydrocarbon potential are funded by the Department of Energy and currently in progress. These endeavors ultimately may yield the technology required for this resource to serve as a viable energy alternative. Presently, most of the regional shale gas production is only sufficient for domestic use. A number of shallow and several deep gas wells have been drilled within Lake County.

Natural gas, commercially developed in Ohio since 1869, is currently produced in northeastern Ohio as shown on <Figure 2.5-30>. Producing gas wells are located immediately east and west of the CEI mineral rights boundary as shown on <Figure 2.5-18>. Numerous gas wells are located to the south of the plant, the closest being well Number 179. A number of shale gas wells were drilled in the early 1900’s within

Perry Township. Most of these wells, generally drilled to depths less than 1,100 feet, have been abandoned. There are no known oil fields within 30 miles of the site.

By 1979 economic conditions had become favorable for exploration of the Clinton Sandstone in northern Lake County. Investor backed oil and gas companies began drilling Clinton gas wells near the East Ohio Gas Company main transmission line in northern Lake County. Drilling and production costs were low because the Clinton formation is shallow in the northern part of Lake County and access to the well locations and gas pipeline was very good. The designation of the Clinton as a "tight gas sand reservoir" allowed the producers to receive a much higher price for their gas, making Clinton exploration and production very attractive. As new markets for the gas opened up and gas prices rose, exploration continued further to the south and east. By the end of 1986 virtually all of Perry and Madison Townships and the northern one-third of Leroy Township were gas productive <Figure 2.5-18>. Recent drilling permit data indicate that exploration will continue to the south and east.

A field survey was made to confirm the location, as recorded prior to May 1973 by the State of Ohio, Division of Geologic Survey, of all wells located within Perry Township between Blackmore and Town Line roads and between Lake Erie and U.S. Route 20. This area and the well locations are shown on <Figure 2.5-18>. The field survey documented the existence of all recorded wells, except well L-201, and located two unrecorded wells, L-207A and L-207B, as shown on <Figure 2.5-18>. Property owners were interviewed for information relevant to use, depth and current condition of their wells. The results of these interviews are summarized in <Table 2.5-5> and supplement or supersede the information contained within the records of the State of Ohio. Supplemental data regarding wells permitted subsequent to May 1973 are summarized in <Table 2.5-6> and nearby wells on record with ODNR during the Leroy earthquake evaluation are shown on <Figure 2.5-17>.

Diamond Shamrock Corporation has retained gas rights to a well 1.9 miles southwest of the site along Clark Road. The well is presently producing gas from the Clinton formation. This well is registered with the Geological Survey of Ohio as No. 203. It is noted that the depth of wells L-215 and L-218 are recorded in the state records as "1,000 - 1,200 feet" and "1,000 - 2,000 feet," whereas interviews with John Winter, formerly employed in local well maintenance, reveals that the actual depth of these wells, as encountered during cleaning, is 800 feet and 1,100 feet, respectively (Reference 120). The incomplete and approximate nature of the state records is attributed to the well records first being compiled in 1957 by interviews with some of the property owners who either did not know or could only roughly estimate the well depth. It is concluded that all but wells L-106, L-207A and L-207B were drilled prior to the period 1915-1920 and that the drilling records do not exist or cannot be found. Records of the referenced wells (well data cards) registered with the State of Ohio, are on file in the offices of the Gas and Oil Division of the Ohio Geologic Survey, Columbus, Ohio.

2.5.1.1.8.1 Gas Producing Formations

Gas production in northeastern Ohio is primarily from the "Clinton" sandstone member of the Medina Formation (Reference 121) (Reference 122) (Reference 123) (Reference 124). This producing member is regionally encountered within the Madison Lake Pool at depths on the order of 2,850 feet and in the vicinity of Parmly Road at depths on the order of 2,710 feet. Other, usually less productive commercial sources, have been developed within the Newburg Sandstone of the Lockport Formation which is encountered in the Madison Lake Pool at depths on the order of 2,575 feet. The shallowest gas producing field is associated with the Oriskany Sandstone. The Mentor Pool, located approximately 14 miles southwest of the site, is encountered in the Oriskany Sandstone at a depth of about 1,850 feet. The Concord Pool, located approximately 10 miles southwest of the site, is also located within the Oriskany

Sandstone at depths of about 2,000 feet. It is noted that salt exploration wells drilled in the vicinity of the site penetrating the Oriskany Sandstone did not encounter commercial gas reserves. The locations of the gas pools noted above are shown on <Figure 2.5-30>.

The production of gas wells drilled within the Ohio Shale in northeastern Ohio is sufficient only for domestic use, almost always yielding far less than 50,000 cubic feet per day, a quantity considered the minimum level for commercial exploitation. The East Ohio Gas Company reports a single production well within the Ohio Shale, located in Geneva Township, Ashtabula County. This well was reported to be 471 feet deep and since being brought on-line in August 1971, has produced at a rate of only 5,000 cubic feet per day with an average 150 psig pressure. The only other commercial Ohio Shale gas wells known within 15 miles of the site are reported to be associated with the Geneva gas field located approximately 12 miles east of the site. Most gas production is from the Clinton Sands, at a depth of approximately 2,750 feet. Locally, production is found in the Oriskany at a depth of 1,625 feet. Some limited Ohio Shale gas production is also reported in Summit and Cuyahoga Counties, the closest being more than 30 miles southwest of the site.

Exploration in the Ohio portion of Lake Erie has been historically banned by the Ohio State Legislature. This ban expired July 1, 1978. A State Senate panel did approve gas drilling in Lake Erie late in May 1979. The governmental proceedings necessary for actual legislated approval have been postponed until the completion of an environmental impact study by the Army Corps of Engineers.

Within the vicinity of the site, the greatest potential for the discovery of natural gas of commercial quantity is within the "Clinton Sand," a regional oil and gas producing sandstone of the Silurian Albion Group. This horizon is encountered in northeastern Ohio at depths usually in excess of 2,800 feet. The producing zones within the

“Clinton Sand” are quite erratic and occur as isolated, stratigraphic traps related to ancient shorelines which were formed by the advancing and regressing Silurian sea. Numerous facies changes comprise these ancient shorelines and the producing zones occurring in porous sandstones which change in relatively short distances into nonproducing shales or argillaceous sandstones. In addition to new “Clinton Sand” production within the general site area, there is also the possibility of discovery of new gas fields within the Oriskany Sandstone. However, Oriskany production within the near vicinity of the site does not have nearly as favorable a potential as evidenced by the very limited local thickness of the Oriskany formation.

2.5.1.1.8.2 Subsurface Gas Storage

Research of available data concerning storage of natural gas and liquid petroleum in Ohio indicates that gas storage is primarily within the “Clinton Sand” horizon. Storage within cavities formed within the evaporite rocks of the Salina Group of Ohio has been reported by the Ohio Department of Natural Resources (Reference 124). The closest salt cavity storage area is Lake Underground Storage which is located 8 miles southwest of the Perry Nuclear Power Plant. The material stored at this site is reported to be liquefied propane. The next existing salt cavity storage area is located near Canton, Ohio, approximately 68 miles south of the site. Presently no potential salt cavity storage areas are located adjacent to the site or within a five mile radius. The potential for subsurface gas storage in the site locale is remote. However, CEI has secured mineral rights within the “protective zone” surrounding the site area and can prohibit subsurface gas storage therein.

2.5.1.1.8.3 Subsidence Potential

The occurrence of surface subsidence due to extraction of natural gas or fluids is attributed to a reduction of interstitial pore pressures

within producing zones. Reduced pressure causes an increase in intergranular stress and subsequent consolidation (compaction) of the zone of withdrawal. Gas and oil fields in Texas and California which have experienced significant subsidence are reported to be usually characterized by producing zones in unconsolidated to poorly lithified sands which are generally Miocene or younger in age (Reference 110).

Subsidence due to extraction of natural gas from the Silurian and Devonian rocks underlying northeastern Ohio has not been experienced. These reservoir strata were lithified into a competent rock mass. Moreover, CEI does not intend to drill production wells within the limits of site mineral rights even in the event that a reasonable production could be expected.

2.5.1.1.9 Induced Seismicity Potential

Induced seismicity is a recently recognized phenomenon which results from formation water pore pressure fluctuations, typically caused by injecting fluids under pressure into deep injection wells. During operation of an injection well, natural formation pressures are increased, resulting in an expanding zone of higher pore pressure which migrates outward from the well in all directions. The increased pore pressure within this zone may effectively reduce frictional resistance along fault surfaces by counteracting the confining stress acting normal to the fault plane. If a "locked" fault is favorably oriented to fail in the existing stress field and the pore pressure increase exceeds the frictional resistance to fault slip, motion may occur causing an earthquake. The pore pressure increase serves only as a premature "trigger" to release accumulating energy that would naturally be released at some point in the future regardless.

Several examples of induced seismicity are well documented in the United States (Reference 125) (Reference 126) and elsewhere in the world. Such activity has been reported associated with waste injection wells, brine

solutioning operations (Reference 41), oil and gas extraction, and enhanced recovery pumping (Reference 113), and reservoir flooding. Seismicity is generally closely associated, both spatially and temporally, with the local modification of pore pressure in the bedrock.

Due to the proximity of the Calhio injection wells, the potential for induced seismicity in the case of the Leroy event and subsequent micro seismic events, has been and continues to be investigated (Reference 127) (Reference 128). While not completely ruled out, the January 31, 1986 Leroy event was not likely induced, due to the substantial distance from the operating injection wells, lack of seismic activity in the intervening area, the depth of the event and aftershocks, location in Precambrian basement isolated from the injection zone stress regime, and history of small to moderate earthquakes prior to operation of the injection wells (Reference 127) (Reference 128). Investigations continue on subsequent seismic events recorded in the epicentral area and corridor to the existing injection wells, in order to determine the nature and possible cause of these events.

2.5.1.2 Site Geology

2.5.1.2.1 Site Physiography

Locally, the site is situated on a portion of the Lake Plain Section bordering Lake Erie. The Lake Plain is a subdivision of the Central Lowland Province previously described in <Section 2.5.1.1.1>. Locally, this plain, a remnant lake bottom, is a narrow band of land extending approximately five miles south beyond the present Lake Erie shoreline. Very little relief occurs in proximity to the site within the Lake Plain except for two low, continuous sandy ridges. Each defines an ancestral beach formed during Pleistocene time when the elevation of Lake Erie was considerably higher than in Recent time. The greatest local relief, nearly 70 feet, is associated with one such ridge which is coincident

with Ohio State Highway 84 east from Painesville to Ashtabula. A lower ridge is contiguous to the north side of U.S. Highway 2 east of the Painesville interchange and U.S. Highway 20 further east. Presumably these ridges are laterally continuous to the west and east and more or less parallel to the present Lake Erie shoreline (Reference 129). Other than that which resulted from erosional processes, little change in the site morphology has taken place since the establishment of the present Lake Erie drainage outlet over Niagara Falls.

Steep bluffs along the southeast shoreline of Lake Erie are continuously subjected to wave action resulting in gradual shoreline recession. Two principal agents of bluff erosion occur: (a) undercutting and erosion by wave action and (b) slump and earthflow. At the site the materials in the shoreline bluff consist of lacustrine deposits underlain by highly compacted glacial till. Groundwater seepage from the face of the bluff is the primary contributing factor to instability of the lacustrine deposits. Wave action erodes the toe of the bluff (dense till) adding to instability of the upper section of the bluff, thereby accelerating the recession process. An approximate yearly rate of natural bluff recession of 5 to 15 feet was reported by the Ohio Division of Geological Survey (formerly Division of Shore Erosion) at Perry Township Park about a mile west of the Perry site (Reference 130). The Corps of Engineers reported a landward movement of 35 feet in the vicinity of the Perry site from 1876 to 1948 and 4 feet per year at Perry Township Park (Reference 131). Further discussion on bluff instability at the site is provided in <Section 2.4.5.5> and <Section 2.5.5>.

2.5.1.2.1.1 Topography

Minimal topographic change is evident at the site subsequent to final site grading and construction. Local relief and slope conditions remain essentially the same. The greatest of both is represented by the shoreline bluff. Excavated debris with variable relief estimated to be

100 feet at its zenith was stockpiled in the general vicinity of the Unit 2 cooling tower throughout much of the construction phase. This borrow pile provided the greatest local relief at the site. Excluding the presence of plant structures, permanent alterations to the preconstruction landscape are not readily apparent except for smooth contouring performed at the barge slip, former lakefront emergence for the minor stream. An elongated, discontinuous berm, approximately 100 feet wide at its base with 20 feet of maximum relief, is parallel and adjacent to Parmly Road. Although this berm is consistent with Lake Plain geomorphologic features, it together with the barge slip comprises the major site topographic alterations. <Figure 2.5-32> is a set of aerial photographs documenting construction stages. <Figure 2.5-33> shows final site topography.

2.5.1.2.1.2 Site Drainage

Final site drainage remains essentially the same as that which preceded construction. Eastern, southern and western site drainage occurs via the site storm drainage system to the northwest sediment control dam and to the minor and major stream diversion channels. The minor and major stream diversion channels also provide for sediment control in settling basins preceding their emergence along the Lake Erie shoreline. Details of the site drainage, diversion channels and sediment control dams are discussed in <Section 2.4.1> and <Section 2.4.2>.

2.5.1.2.1.3 Soil Deposits

Soils in the locality of the site are derived predominantly from glaciolacustrine deposits. Lacustrine deposits occur as very fine sandy, clayey silt and silty clay. The lacustrine soil stratum above the till is as much as 30 feet thick. Lacustrine sediment permeability decreases with depth. The base of the till, which rests on shale

bedrock, is as much as 65 feet below ground surface. Lacustrine sediments are exposed along the upper face of the steep bluff that prevails along the lake shore.

The pedological classification according to the U.S. Soil Conservation Service for cultivated soils in the site locale is Lampson Series 9324. These lacustrine soils are reportedly somewhat poorly drained, fine-sandy loam. The dominant color in the upper horizons (A and B) is yellowish-brown grading to brownish-gray in the substratum (C) horizon. The sand and silt content varies both vertically and horizontally. Alkalinity of the soil is moderately high with a pH value of 6.

The prismatic structure of the subsoil causes this soil to have moderately low permeability. Most of the groundwater exists within the lacustrine stratum. The underlying dense, but relatively less permeable till acts as a barrier retarding the downward percolation of groundwater. Groundwater levels observed in exploration borings were generally two to six feet below ground surface.

Trafficability of the soil is very poor when wet. A high seasonal water table is the major limitation to the use of this soil. The soil, if drained, is suited for speciality crops, of which nursery stock is the most prevalent in the locale.

Soils on some portions of the site have been reworked and seeded consistent with final grading and revegetation plans.

2.5.1.2.2 Stratigraphy

In a regional sense, the site is on the western limb of the Appalachian geosyncline. There are no conspicious surficial expressions of strata arches or dislocations. An Upper Devonian shale sequence more than 1,200 feet thick underlies the site foundation. The Precambrian surface in the region is about 5,300 feet below sea level. In northeastern

Ohio, the region is mantled with glacial deposits that have been preconsolidated by ice that overrode the land during glacial time (Pleistocene). Along the lake shore plain, lacustrine sediments were deposited on glacial till when water levels in Lake Erie were considerably higher during glacial ice recession.

In the site vicinity, the same sequence of sediments were present as reported regionally. Stratigraphically, the lowest interval encountered in the exploration test borings documents interfingering of Huron shale within the overlying Chagrin shale. Both are facies members of the Ohio Shale. Beyond approximately 1,000 to 1,500 feet offshore in Lake Erie, the Chagrin shale immediately underlies lake bottom but is not exposed along the shoreline. Chagrin strata characteristically are bluish-gray, clayey and sandy shale. Fresh shale is moderately hard, but upon exposure to weathering it breaks down to clay. Mineralogically, the shales and siltstones are characterized by their illite-chlorite-kaolinite content.

Unconformably overlying the Chagrin shale in ascending order are glacial till of two different ages, relatively younger glaciolacustrine sediments and recent stream channel alluvium and beach deposits. The exact age of the tills has not been determined, but is likely the Cary substage of the Wisconsin stage.

Onshore the combined thickness of the glacial and lake deposits in the plant vicinity ranges from 50 to 60 feet. <Figure 2.5-34> shows the surface distribution of bedrock overburden deposits prior to construction.

The lower till, which unconformably overlies the Chagrin shale is exceedingly dense and contains a basal boulder layer, approximately one foot thick. This boulder layer is comprised of rounded, resident metamorphic and quartzite erratics and lesser amounts of subangular shale fragments, the latter presumably locally derived. Individual

boulder median diameters typically are on the order of one foot. They are contained within a gray, silty clay matrix. Below the boulder horizon to bedded shale, a six to eight feet thick transitory interval has been mapped in which lower till lenses have been incorporated within contorted, blocky and weathered shale. Folding, imbricate thrusting, drag, and other characteristic features of this interval imply shallow deformation of rock synchronous with glaciation and lower till deposition. Above the boulder layer till grades upward to dense gray clay containing 15 to 25 percent sand size particles and infrequent boulders.

The upper till unconformably rests on the lower till. It is composed of gray silty clay with up to ten percent sand size particles. The upper till differs from lower till by having a higher moisture content and percentage of silt and clay, a lower density and an absence of boulders. Upper till and lower till thicknesses range from 3 to 14 feet and 11 to 28 feet, respectively.

Glaciolacustrine deposits overlying till are generally thin interstratified fine-sand, soft silts and clay. In localized areas, within the upper ten feet, thin lenticular accumulations of predominantly sandy silt are present. Glaciolacustrine sediments are the result of fluctuating lake levels produced when retreating glacial ice exposed successively lower outlets. The best example, representing one of the former lake levels, is present as a sandy ridge along U.S. Route 20, 1-1/4 miles south of the plant site.

Deposits of Recent age include beach deposits, contiguous to the toe of the shoreline bluff, and stream channel alluvium. Stream channel diversions and final site grading have resulted in either removal or burial of preconstruction alluvial deposits.

A composite schematic stratigraphic column of site stratigraphy together with data on file at the Ohio Geological Survey for a deep, abandoned

gas exploratory well less than 1-1/2 miles west of the plant Seismic Category I structures is presented as <Figure 2.5-35>.

2.5.1.2.3 Structural Geology in the Vicinity of the Site

In the site area the structure of the rock units coincide with the regional setting. The Chagrin shale member of the Ohio Shale formation, the immediate bedrock beneath the site, dips less than five degrees south, but its paleotopographic surface is inclined northward toward the lake as a result of erosion by Pleistocene glaciation. North of the site, Devonian shale and limestone underlie Lake Erie for as much as one half its width. In the eastern portion of the basin, shales extend to the International Boundary with Canada. Approximately seven to eight miles south of the site Chagrin shale strata are overlain by Bedford Shale and Berea Sandstone, respectively. These relationships are consistent with regional structural setting.

On the basis of geological and geophysical preconstruction site exploration, it was determined that the Chagrin shale contained two major planar elements, jointing and bedding. From recovered core, several poorly developed joint sets were noted at angles of 30, 60 and 90 degrees. Surface expression of joint patterns is obscured by the glacial deposits, cultivation and vegetation (predominantly trees), although some soil zones visible on aerial photographs seem to reflect N40°E and N55°W trends in Conneaut and Ashtabula Counties to the east. Geologic mapping of site excavations confirmed this conjugate joint system. Northeast, northwest, and north-northeast orientations were prominent in planar continuous joints observed during field mapping conducted after the January 31, 1986 Leroy earthquake (Reference 4). Shale bedding laminae in rock cores are 1/16 to 1/4 inch apart. Interbedded within the shale are occasional siltstone to very fine-grained sandstone beds, ranging from less than 1/16 inch to several inches thick. The siltstone and sandstone beds frequently are cross-bedded and show sinuous small-scale ripple mark features.

Abundant micaceous fragments on these bedding surfaces apparently enhance parting of the drill core parallel to siltstone/sandstone-shale bedding contacts. Structural contours of the Chagrin shale are shown on <Figure 2.5-36>.

Although no secondary mineralization occurs within either bedding or jointing, clay seams 1/8 to 1/2 inch thick were encountered within the shale in several test borings. The lenses generally are parallel to bedding and were thought to be deposited by groundwater migrating along fractures. Although some clay seams may be attributed to groundwater processes, others were determined during excavation mapping to be fault gouge and materials from the transitory interval. In addition to the clay seams, tan, very dense layers, probably siderite ($FeCO_3$) or "ironstone bands," are found interbedded in the medium gray shale. The lateral, discontinuous nature of the siderite beds, suspected on the basis of preconstruction test borings, was confirmed during geologic mapping of excavations and tunnels. Lateral thinning is attributed to sedimentological rather than secondary structural control.

The overlying till deposits are unstratified and generally heterogeneous in composition and variable in thickness. Thickness of the lower till ranges from 11 to 28 feet, averaging 20 feet, while the upper till is between 3 and 14 feet, but averages 9 feet thick. This variation presumably results from differential erosion and deposition processes during glaciation. Structural contours of the lower till are shown on <Figure 2.5-37>.

Lacustrine sediments above the tills are stratified, interbedded units of sand, silt and clay. On a small scale, the units are distinguishable and homogenous but vary without consistent order, both vertically and horizontally. The thickness is dependent upon the paleotopographic relief of the upper till and erosion subsequent to deposition.

2.5.1.2.3.1 Northeastern Ohio Folding and Faulting

Secondary structures demonstrative of regional-scale bedrock deformation in the site vicinity as well as throughout northern Ohio are rare. This is attributable to the nearly ubiquitous veneer of glacial deposits obscuring bedrock as well as the minimal effect of the Appalachian Orogeny on Paleozoic strata in this region. As discussed in <Section 2.5.1.1.5.1>, Appalachian orogenic stresses were greatly attenuated during their northwestward propagation beyond the Appalachian Structural Front.

Most of the subsurface structural interpretations for these regions are founded on deep well data. It is reported in (Reference 132), based on personal communication with A. Janssens, formerly employed by the Ohio Geological Survey, that the sedimentary sequence above the Middle Devonian Delaware Formation is affected by folding. Structural contours of the Delaware and Dayton Formations show persistent small structures, probably folds, especially in Portage County, Ohio (Reference 132).

The drilling of numerous gas wells in the past years has allowed construction of new structural contour maps for Lake and Geauga and portions of adjacent Trumbull and Ashtabula counties <Figure 2.5-38> and <Figure 2.5-39>. This task was undertaken to assess any potential association of interpreted Paleozoic structures with neotectonic mechanisms. Accuracy of the new structure contour maps is improved by the addition of numerous well data points. Northeast- and northwest-trending structure are mapped, superimposed on the regional southeast dipping monocline. Typical relief on the features is 20 feet diminishing upsection. These features are typical of numerous similar structures observed in the Paleozoic rocks throughout eastern Ohio. They are interpreted to be related to penecontemporaneous deformation which culminated with late Paleozoic orogenic events originating in the Appalachian orogen to the southeast. Neither of these mechanisms is related to existing neotectonic processes.

Salt mining has exposed deformation within the Salina salt beds. Heimlick describes minor folds, amplitude of six inches and wave length less than twelve inches, locally overturned, in the production interval of the International Salt Company mine in Cleveland (Reference 133). Structural contours of the salt production interval for the Morton Salt Division of Morton Norwick mine in the Painesville area reveal northeasterly trending synclinal troughs interpreted by Jacoby to be salt flowage preceding faulting in response to Appalachian tectonism (Reference 134). However, large scale folding in Lake County of either the salt or overlying shale strata is neither exposed in surface erosional or subsurface excavation exposures, nor interpreted by subsurface geological or geophysical data.

Faulting is nearly as anomalous as fold structures. Regionally, and as discussed in <Section 2.5.1.1.5.1>, faulting does affect Paleozoic strata to the south and also has been exposed in the International Salt Company mine in Cleveland to the west. More locally, Jacoby reports that a high-angle thrust fault intersects the salt production interval of the Morton Salt Division of Morton Norwick mine in Fairport Harbor, approximately eight miles southwest of the Perry site (Reference 134). A small, normal fault described by Voight has been reported in the Grand River Access shaft of the Fairport Harbor Salt Mine (Reference 135). The normal fault is one border of a small graben with easterly strike and apparent offsets of up to 1 foot. The graben affects dolomites immediately overlying the First Salt of the Salina Group. The small thrust (reverse) fault described by Jacoby offsets approximately 25 feet of the underlying Upper Second Salt and a portion of intervening dolomite beds. There is no evidence that the faults are coincident along strike. They may be related in the sense that faults of this scale are reported to be common at the base of dolomites overlying the First Salt. Furthermore, it is not unreasonable to expect some degree of rotational movement in solution-induced faulting. Hence, movements of both normal and reverse senses might be expected in associated faults or even on different portions of a single fault. It is not believed

that these faults are pervasive vertically through the Oriskany Sandstone of Middle Devonian age (Reference 134). The thrust fault, while on strike with the cooling tunnel faults, is at a substantially greater depth below unfaulted post Middle Devonian limestones and shales (Reference 134). No known or inferred relationship of this fault with the tunnel faults is apparent from existing geophysical or geological data.

Rock cores from salt strata exploratory borings in the Painesville area occasionally intersect displacements within the "Big Lime." They are of a very minor nature, are completely healed and amount to a few inches at most. Donald R. Richner, consulting geologist, has examined these discontinuities which range from very minor to miniscule, consisting mainly of stylolites and minor slips with traces of slickensides but having observable displacements of two inches at most. He has not seen any evidence that these discontinuities were of a tectonic origin. Those observed above and below the Salina salt beds appear to result from penecontemporaneous deformation (Reference 135).

Geologists are in agreement that the faulting and folding exposed in the International Salt Company and Morton Salt Division of Morton Norwick mines in Cleveland and Painesville, respectively, are attributable to dissolutioning of the salt during sediment lithification (Reference 132) (Reference 134) (Reference 135). Subsequent failure of the overlying strata resulted in graben structures, slumping and down-warping dependent upon overlying lithology. Locally, salt flowage into fractures and irregularly shaped cavities is evident.

2.5.1.2.3.2 Local Structures

A well documented fault in the geologic literature near the site locale is a relatively minor localized overthrust with approximately one foot of displacement in the Bedford shale (Mississippian age) on Bates Creek, also known as Warners Creek (Reference 136). The fault is eight miles

south of the site. A minor thrust fault matching the one described by Prosser was observed in the field on the east bank of Bates Creek. The strike of the fault is northeast. Three minor superficial faults of limited extent and displacement were found about one mile north of the Bates Creek fault (eight miles south of the site) on the west bank of the Paine Creek. The faults, two gravity faults and a small bedding thrust fault named Hell Hollow 1, 2 and 3, were found to be associated with slumping. These structures are shown on <Figure 2.5-40>.

Field investigations and literature studies were completed to determine the characteristics, origin and age of both the Bates Creek and Hell Hollow faults. The findings and results of the investigations are discussed in <Section 2.5.4.3.6.1>. The Bates Creek and Hell Hollow faults were determined to be of surficial nature, limited in extent and unrelated to deep-seated faulting. Their origin is believed to have been glacially induced at Warners Creek and related to bedrock slumping at Hell Hollow.

Following the January 31, 1986, Leroy earthquake, extensive field mapping was conducted in the epicentral area and extending northeastward to the PNPP site. Previously investigated structures <Section 2.5.4.3.6.1> were reexamined and other outcrops were checked for potential earthquake related structures. Several types of bedrock structures were observed during these field investigations. These include primary sedimentary structures, joints and fractures, anticlinal folds (pop-ups), and normal and thrust faults (Reference 4). Deformation associated with these fractures is generally minor and was typically observed to terminate rapidly both laterally and vertically within a given outcrop. One larger, but obscured structure (Big Creek Structure, <Figure 2.5-40>) was studied in more detail by excavation, seismic refraction, magnetometer survey, and three boreholes. The evidence from these investigations showed that the deformation was confined to the near surface. There was no indication of any significant fracturing or offsets of the essentially flat-lying

sedimentary rocks extending beneath the excavated area. While numerous folds and minor faults, similar to those previously reported in Bates Creek, were mapped during the investigation, all structures are readily associated with widely reported surface deformation mechanisms. These include glacial push, glacial loading and unloading, removal of lithostatic load, and lateral compression coupled with unloading of incised stream valleys. Regardless of the mechanism involved, all structures are limited in lateral and vertical extent to the upper 20 to 30 feet of bedrock exposure, and therefore are judged to be unrelated to deep-seated neotectonic structures (Reference 4).

2.5.1.2.3.3 Onshore Deformation Exposed by Plant Excavations

Geologic mapping, inspection and evaluation of bedrock foundations, including excavation cuts and foundation grades for the Perry structures, were initiated in August 1975. Several localized areas of deformed bedrock were revealed as a consequence of the excavation (see <Section 2.5.4.3.6.2> for investigative program). Three fundamental structural fabrics consisting of folds and faults within the Chagrin shale, trending northwest and north-south, are inferred from the foundation bedrock geologic maps. An excavated thrust fault traversing the southwest quadrant of Reactor 1, a shallow fold traversing Reactor 2 and terminating in the Control Complex and a very shallow fold traversing the northeast corner of Condensate Demineralizer 1 are three elements of the northwesterly fabric. A generally north-south trending fold, traversing the Control Complex, the Radwaste Building and Condensate Demineralizer 1, represents a second fabric. Gentle swells and swales in Reactor 1, portions of the Control Complex, the Radwaste Building and elsewhere north and south of the nuclear island complex trend northeastward.

These smaller structures (approximate wave length of two to three feet and amplitude less than six inches), which terminate with depth on horizontal shale bedding planes, were determined to be either primary,

related to deposition or secondary, related to glaciation. The swell and swale axes lie normal to both regional Upper Devonian sediment transport as well as the general north to south Pleistocene glacial transport direction (Reference 7) (Reference 91). The structural features are shown on <Figure 2.5-41>.

As previously discussed, many of the smaller structures including the northeasterly trending swells and swales, most joints and in addition bedding-plant decollements were effectively removed during the final 0.5 foot of excavation to final foundation grade. Several clay-filled vertical joints with less than one inch separation between parallel faces, extend below final grade. It was determined by probing that the joints close at a depth of one foot. No groundwater was discharged from either tight or clay-filled joints, bedding-plant partings or localized areas of deformation.

A fault traversing the intermediate building was observed intersecting the southwest quadrant of Unit 1 reactor building. It was possible to view a downward projection by which the fault plane became conformable with bedding having a horizontal altitude at Elevation 561.6’ because the reactor building foundation grade lies two feet below that of the intermediate building. A three inch thick gouge layer defining a decollement plane conformable with bedding was removed as a result of excavation to planned final foundation grade. Thirty-five feet beyond the reactor building, the surface expression of the fault trace swings abruptly into a northeasterly trending small-scale anticline <Figure 2.5-41 (1)>.

A small bedding plane thrust fault, trending northeastward intersects the west wall of the Control Complex approximately 20 feet north of the southwest corner. The fault plane is defined by a thin gouge sheet, less than one-inch thick, of tough leathery clay containing angular fragments generally no larger than fine gravel. One segment dips 14 degrees to the south becoming horizontal with depth as observed from

fault-plane projections onto flat-lying strata from which the thin conformable gouge sheet was removed during excavation to final grade. The fault is bounded above by undisturbed horizontal bedding. A southward directed sense of motion is interpreted from disturbed rock along the inclined fault-plane segment.

A step-line pattern was exposed in a near vertical cut along the west wall of the control complex <Figure 2.5-42 (1)>. Gouge defining the fault plane thinned laterally, possibly signifying the limits of appreciable movement.

Another thrust fault, located along the northern wall of the Radwaste Building, strikes generally east, dipping to the north. This structure is bounded vertically by horizontal strata as observed during excavation. A southerly sense of overriding motion is interpreted from disturbed rock along the fault-plane and from drag effects.

Two anticlinal structures, larger scale than the swell and swale features, traverse the Unit 2 reactor building and the control complex in northwesterly and northerly directions, respectively. The approximate width of affected bedrock in the reactor building is 30 feet, and in the control complex it is 20 feet <Figure 2.5-41 (1)>, <Figure 2.5-41 (2)>. As determined by measurements and observations of bedrock at excavation grade and in exploratory test pits and borings, caisson excavations and overexcavated areas, the anticlinal structures are generally steepened on their southerly and westerly limbs. The folded strata exhibited fracturing along their hinge lines, but the rock had not undergone weathering. The hinge lines generally migrate to the south and west with increasing depth. These folds terminated below foundation grade on horizontal bedding-plane decollements characterized by a gouge layer ranging in thickness from one to three inches conformable with immediately subjacent flat-lying, competent shale <Figure 2.5-43> <Figure 2.5-44>. A caisson excavation penetrating the folded strata, extending southeasterly beyond the Unit 2 reactor

building, reached undeformed, flat-lying, competent shale <Figure 2.5-45>. Both condensate demineralizer foundations intersect the northerly trending fold traversing the radwaste-control complex excavation. However, the deeper foundations excavated for the condensate demineralizer penetrate folded strata and extend into flat-lying, competent shale.

Fault-plane material in all cases was a gouge of tough, leathery consistency, composed of a very hard, gray-clay matrix with coarse-grained sand size, angular-shaped shale inclusions. The matrix material resembles the dense lower till derived from Chagrin shale. Unlike the overlying till, it does not contain erratics derived from either the crystalline rocks of the Canadian Shield or any sedimentary rock compositions with the exception of Chagrin shale inclusions. No slickensides, cleavage, groundwater, or secondary mineralization were identified within the fault zones or adjacent country rock. The absence of foreign materials and a similar lack of evidence for either recrystallization of country rock or crystallization of anomalous mineral matter within or adjacent to deformed strata is interpreted as localized, low temperature and relatively low-stress deformation conditions.

Vertically the lower limit of the onshore deformation was established at a horizon defined by the deepest foundation excavations including those for the condensate demineralizer and heater bay buildings. The upper limit of this deformation terminates at the base of a boulder layer which maintains grade at approximate Elevation 570’ and is pervasive throughout the plant site. As discussed in <Section 2.5.1.2.2>, this boulder layer defines the base of structureless lower till. Below the boulder layer and above competent shale, a six to eight-foot thick transitory interval was mapped in which the lower till has been incorporated within contorted, blocky and weathered shale. Shallow folding, imbricate thrusting, drag, and till incorporated into the bedrock all imply deformation associated with lower till emplacement.

The upper till and overlying glacio-lacustrine sediments are not deformed. A complete lens of till integrated within the shale approximately three feet above flat-lying shale is shown on <Figure 2.5-46>.

In summary, the approximate 45 foot thick interval occurring between the excavation grade of the deepest onshore foundation excavations and the base of the boulder layer has experienced deformation consisting of folding and faulting. The northeasterly to southwesterly sense of shove has been interpreted on the basis of structural fabric and symmetry. Bedrock strata were detached along bedding planes with combinations of rotation and buckling as well as slight upward shearing or underthrusting developing in proximity to their leading edges. Movement along bedding-plane decollements resulted in the development of gouge. The mechanism which generated this shallow bedrock deformation, is attributed to late Wisconsinan glaciation.

2.5.1.2.3.4 Offshore Deformation Exposed by Tunneling

2.5.1.2.3.4.1 Intake Tunnel Structures

Tunnel excavation operations during April 1978 in the intake tunnel, at a point about 600 feet offshore and 120 feet beneath the lake, intersected a small displacement, low-angle thrust fault, striking northeast and dipping southeast. The lateral extent of deformation within the tunnel is less than 50 feet.

The fault exhibited less than one foot of throw with a decrease towards the tunnel crown. The brittle nature of this deformation is exemplified by the development of fractured and broken drag folds, kinks, angular/flaggy fragments of siltstone and shale adjacent to and within the prominent gouge zone and dipslip striations. These characteristics

are present within an interval ranging up to three feet in thickness normal to the fault plane trace. See <Figure 2.5-47 (5)> for geologic maps of faulting.

The gouge consists of a light gray, clay matrix containing angular fragments of siltstone and shale derived from the adjacent hanging and foot wall country rock. Thin splays, 0.1 foot thick, originating from the main fault become parallel with bedding plane separations. The thin gouge layers conformable with bedding are not laterally continuous but gradually thin to a zero thickness, generally within ten feet of the fault zone.

Drag folding is both well developed and quite pronounced. Locally, a faint axial plane cleavage is developed at the fold hinges. Drag folds are asymmetric, demonstrating deformation parallel to the fault plane dip direction. Orientations of drag folds are parallel to the strike of faulting.

Numerous striations indicative of fault plane motion are recognized on both the hanging and foot walls immediately adjacent to the fault gouge. Striations indicate the fault movement is parallel to the dip direction. The sense of movement direction cannot be determined on the basis of striations but is readily apparent from stratigraphic offset.

The fault is immediately preceded to the southeast within the intake tunnel by an asymmetric syncline. This gentle flexure is bounded by horizontal strata upward vertically within the tunnel excavation. The base of the structure lies below the tunnel invert elevation. Folding is accompanied by bedding-plane parallel flexural slip and very minor northwest dipping thrusting on its northwest limb. There, too, the thrust merges with bedding planes.

2.5.1.2.3.4.2 Discharge Tunnel Structures

Two discharge tunnel segments exhibiting bedrock deformation were intersected by excavation operations in late August and early September 1978, respectively. See <Figure 2.5-47 (20)> and <Figure 2.5-47 (21)> for geologic maps of faulting.

The first is a distinct, zigzag fracture pattern occurring approximately 700 feet offshore. The general structure attitude is north-northeasterly striking and south-southeasterly dipping. Minor, discontinuous displacements, 0.1 to 0.4 foot, and flexuring of strata which traverse the plane of deformation, have resulted in a cumulative stratigraphic throw less than 0.4 foot at the tunnel invert. Only very gentle strata warping occurs near the tunnel crown, indicating vertical termination of deformation. The relative sense of inferred motion indicates upward and northerly movement of the hanging wall block.

Approximately 150 feet north of the first segment, a small-displacement, low-angle thrust fault, similar to the intake tunnel structure, intersects the discharge tunnel. The lateral extent of deformation within the tunnel is less than 40 feet. The fault plane attitude strikes slightly more easterly and dips less than in the intake tunnel. Associated with the faulting are drag folds fracturing and well developed gouge, as previously described for the intake tunnel.

2.5.1.2.3.4.3 Extent of Tunnel Deformation

Exploratory borings (TX-1 through TX-6) drilled through the intake tunnel invert and confirmatory downhole geophysical logging (low P-wave velocity for deformed rock relative to high P-wave velocity for undeformed rock) established a consistent fault plane dip, essentially 17 degrees toward the southeast. Two deep onshore borings (TX-7 and TX-11, 397 and 730 feet deep, respectively) situated in proximity to the discharge and intake tunnels did not yield definitive evidence of

faulting. This suggests that the fault thins appreciably downdip and is conformable with bedding or dies out. A boring (TX-12), oriented parallel to the intake tunnel alignment and inclined approximately 60 degrees from the horizontal, intersected the fault as interpreted from core. A zone of broken rock and gouge (three seams, 1.5 to 3.0 inches thick) was found between depths of 376.0’ and 380.4’ (elevation approximately 300’) which represents the fault. This interpretation corresponds to a straight-line projection based on tunnel exposure and in-tunnel borings. From these data the fault extends 600 feet southeast of the tunnel exposures.

The intake and main discharge tunnel deformation are separated by approximately 750 feet representing the known distance along fault plane strike. Projections of the tunnel faults to the southwest, using several hypothesized attitudes, extend beneath the bottom elevations of borings TX-8, 9 and 10. As a result, these borings drilled west of the site, on the shoreline projection of the faults, would not be expected to and, in fact, did not encounter evidence of deformation. Nor did shoreline reconnaissance suggest structural deformation in the tills and lacustrine deposits comprising the shoreline bluff. Lateral extension of faulting in a northeasterly direction is purely conjectural.

There is no surface expression of the fault on the lake bottom. Lake bottom reconnaissance and video tape documentation were conducted across the updip fault plane projection. A decreasing deformational gradient in an updip direction has been inferred from tunnel exposure measurements and interpretations of tunnel borings. This gradient suggests that the net slip along the fault plane should reach zero approximately 20 feet above the tunnel elevation.

The conclusions regarding lateral and vertical extent are supported by comparative isotopic analysis of fault zone seepage and Lake Erie water. These analyses show that isotopic ratios of D/H and 180/160 from the intake tunnel differ insignificantly from each other and from the

discharge tunnel. These data are consistent with a single fault intersecting both tunnels. However, water from the fault differs significantly from the lake water. It is therefore concluded that water from the fault in the two tunnels has a common source which is not Lake Erie. All three sample sets are meteoric, that is, they were not derived from an exceedingly great depth, but rather from the atmosphere.

The geometrical relationships interpreted from the laboratory and field data are shown on <Figure 2.5-48> and <Figure 2.5-49>.

2.5.1.2.3.4.4 Tunnel Deformation Origin

Based on structural style, orientation and sense of offset, the thrust fault exposed in each tunnel is apparently the same feature or en echelon. Faulting is distinctly brittle with deformation confined to the immediate vicinity of the fault plane. The zigzag fracture pattern and accompanying evidences of flexure characterizing the more southerly discharge tunnel deformation may be an en echelon structure, but more probably represents a splay from the main fault.

Faulting mechanisms considered included Paleozoic Tectonics, Mesozoic-Tertiary Tectonics and Pleistocene-Recent. Regarding mid-Paleozoic deformation, the concept of soft sediment deformation can be ruled out by the brittle nature of observed deformation. The tunnel fault formed following lithification of the shale sequence. Notwithstanding interpretation regarding age, pre-Pleistocene tectonics are considered primarily in consideration of geometric data on tunnel fault strike and shallow dip. Alleghenian (Appalachian) orogenic compressional stresses propagated northwesterly, employing Salina salt bed decollements would be technically feasible. Upward propagation of faulting at low dip angles, as with the tunnel faulting, would be compatible. Alternatively, southeasterly gravitational movement during late Paleozoic or early Mesozoic time was possible when overburden pressure and formation temperatures were about at peak values. Again, a majority

of the lateral movement would be expected to occur upon the Salina salts. Relatively high loading conditions existing during glaciation with high stress gradients near ice sheet boundaries may have activated flowage deformation within the salt which resulted in underthrusting of the more competent overlying strata. Other mechanisms associated with deeper rooted deformation such as basement-block faulting and differential warping of Paleozoic strata would tend to produce normal faulting in overlying formations, not thrust faults.

Data regarding the age of faulting were derived from field and laboratory studies. An age determination from fault gouge mineralization could not be undertaken because none of the constituent minerals contained radioactive isotopes suitable for dating. However, on the basis of syn and/or post-deformational mineral growth extending completely across fault zone microcracks related to the last movement on the fault, it is concluded that the time of last movement for each of the tunnel fault segments is approximately 1 million years but may be as old as 2 to 5 million years or as young as 0.8 million years.

Comparisons of the microcrack data to similar data from other locales were employed in age determinations. Allowances for variability in factors such as temperature, pressure and chemical environment and uncertainty related to mineral growth rates could suggest a greater range in estimated formation time. Notwithstanding the foregoing consideration, it is not reasonable to postulate a recent age for last fault movement. Microcrack mineral growth bridges, some of which are quite delicate, remained intact and unruptured during the period of historical seismicity discussed in <Section 2.5.2>.

During faulting the orientation of the maximum principal stress was oriented normal to fault strike. In situ stress measurements employing the hydrofracture technique demonstrate that the stress field orientation has changed since faulting <Section 2.5.1.2.5.3> <Appendix 2D E>. The maximum principal stress consistent with the

prevailing regional stress field is parallel to the fault strike. The magnitude of vertical stresses measured is as expected for calculated overburden pressure. Reorientation of the stress field must have occurred during Pleistocene time in response to glaciation. Deposits of three major stages are recognized in northeastern Ohio <Section 2.5.1.2.4>. No Nebraskan stage deposits have been identified in Ohio. It is not known which major ice advance or minor recessional-readvance cycle altered the stress field prevailing during the last fault movement. This method of qualitatively dating the last fault movement is in agreement with the microcrack study conclusions.

It has been hypothesized on the basis of maximum past consolidation pressure of the fault gouge that the associated overburden pressure was not substantial but on the order inferred from an ice sheet considerably thinner than that estimated for northeastern Ohio at the Laurentide maximum. On this basis, the last fault movement is more likely associated with deglaciation-rebound than an ice sheet advance. However, rock-to-rock contacts across the fault zone, as well as the step-like pattern of faulting, were documented during large-scale mapping of the deformed tunnel segments <Figure 2.5-50>, <Figure 2.5-51>, and <Figure 2.5-52>. Extrapolations of fault displacement suggests that approximately 70 feet of undeformed bedrock overlie the updip projection of faulting. Therefore, it is uncertain whether the fault gouge would have experienced maximum overburden loading during glacial advance when ice thicknesses exceeded several thousand feet. Hence, the age of movement for the fault based on gouge consolidation tests is not reliable.

The most reasonable interpretation of all the data is that the tunnel deformation and at least the last movement on the fault was a Pleistocene event associated with glaciation. Candidate mechanisms include ice-sheet traction, differential down-bowing with glacial advance, differential rebound with glacial retreat, surficial stress-relief or "pop-up," and subsurface salt tectonics, the latter as

previously discussed. More probable were glacio-isostatic uplift and surficial stress relief during glaciation rebound. Recurrent movement on deeper-seated pre-Pleistocene structures or faults, either by direct propagation or by en echelon deformation could have been possible. Both of the latter would have been activated by glacial ice loading or unloading. The conclusions of investigations reported in <Appendix 2D> and lack of evidence to the contrary are consistent; the fault is non-capable as defined in <10 CFR 100, Appendix A>.

2.5.1.2.4 Geologic History of the Site

The geologic history of the site is consistent with the regional history described in <Section 2.5.1.1.6>. The site and adjacent areas in northern Ohio are mantled by glacial deposits of Pleistocene age which range in thickness from a few tens of feet to several hundred feet and at the site approximately 55 feet thick. Surface geologic mapping and borings show that the glacial deposits are underlain by a thick series of Paleozoic sedimentary rocks. The Paleozoic rocks are, in turn, underlain by crystalline basement rocks of Precambrian age. The depth to the Precambrian rocks is estimated to be almost 5,000 feet below sea level.

2.5.1.2.4.1 Preglacial

The Precambrian rocks underlying the site are similar to the rocks of the Canadian Shield to the north. Rhyolite and magnetite cuttings are logged for a deep well in Lake County penetrating the Precambrian surface (Calhio No. 1, Permit No. 142). Originally sedimentary and volcanic, these rocks have been changed into metamorphic rocks by folding, igneous intrusion and deep burial. The Precambrian topography was undoubtedly rugged at one time, but prior to the Paleozoic it was eroded to a near level surface.

During Paleozoic time, tens of thousands of feet of sedimentary rocks were deposited in a generally submerged, subsiding basin called the Appalachian geosyncline. The site lies along the western flank of this geosyncline where sedimentation rates were considerably less than to the east along the geosynclinal axis. During this time, the Precambrian basement rocks subsided without major folding or faulting. The rate of subsidence varied with time and location. By the Silurian period, subsidence was slower, the seas were generally more shallow, and the potential for coral reefs rather good. However, locally no major reef development is known. Deposits of evaporite salt and gypsum in the Silurian sequence are thought to indicate the existence of isolated basins. Structural contouring near the base of the “Big Lime” in northeastern Ohio suggests northeasterly trending troughs which may have influenced evaporite deposition. The Cincinnati and Findlay arches are elongated domes of the Precambrian surface marking locations of generally slower subsidence. Early Devonian time marked a return to freely circulating seas as indicated by carbonate deposition.

By mid and especially late Devonian time the paleoenvironmental conditions in northeastern Ohio were undoubtedly characterized by recurrent periods of quiescence and sediment disturbance. The stratigraphic record for this interval, approximately 1,200 feet of interbedded shale and siltstone to very fine-grained sandstone with the former predominant, grades upward from a black and dark gray shale to a light to medium-gray shale. Interfingering of the two basic shale types occurs within the transition. Coarser-grained beds exhibit small scale primary structures including oscillatory rippling, slump, cross-bedding, ripped-clasts, and other evidence of scour. These features are interpreted as evidence of intermittent turbidity. The darker shale section belonging to the Huron shale member and overlying strata of the Chagrin shale member together comprise the Ohio Shale. The uppermost member, Cleveland, is not present at the site but is a facies correlative laterally from west to east with the uppermost Chagrin sediments in northeastern Ohio. Chagrin shale is the youngest bedrock unit at the site.

Approximately seven miles south of the site, Mississippian period rocks comprised of the Bedford Shale and Berea Sandstone are exposed at higher elevations, respectively. Collectively, these sediments may be representative of a deltaic depositional pattern with Bedford Shale transitional from a marine environment of the Ohio Shale to a fluviatile origin for at least some of the coarse-clastic Berea sediments. Pepper and others postulate a northerly source area for the Bedford and Berea sediments (Reference 90). In north-central Ohio channels eroded through the Bedford and occasionally extending into the Ohio Shale are filled with cross-bedded Berea Sandstone. Apparently, some of the Bedford Shale sediments in proximity to definable channels exhibit evidence of a slump. The Chagrin-Bedford-Berea sequence south of the site appears to be conformable, probably occupying an intermediary position between two major sediment dispersal loci.

The Paleozoic Era ended with the Alleghanian (Appalachian) Orogeny during which rocks of the geosyncline were uplifted and accompanied by intense folding and faulting primarily east of Ohio. Several compressional structures in southeastern Ohio, including the Parkersburg-Loraine syncline and the Cambridge arch, have been attributed to tectonic stresses propagated northwesterly during the Appalachian Orogeny. The two structures are contiguous folds striking approximately N10°W, in contrast to the northeast trending Appalachian fold belt axes. These structures occur beyond the Burning Springs Anticline in West Virginia which is suggested to represent the terminal effects of Alleghanian compression. Decollement style deformation employing the Salina salt beds as glide planes was active in West Virginia during the close of the Paleozoic. Following the curved leading edge of the Alleghanian deformation front north and northeastward into western New York, a similar terminal structure, the Chautauqua Anticline/Bass-Islands structure is encountered. It is conjecture to postulate the northwesterly extent of this deformation style. On the basis of geometry alone, it is possible that the small displacement, thrust fault intersecting the cooling water tunnels is a

manifestation of the waning effect of late Paleozoic tectonic stresses attentuated in their northwest propagation beyond the Appalachian Structural Front.

During the Mesozoic and Early Cenozoic Eras, northeastern Ohio underwent active erosion. The region, however, remained a positive feature throughout the interim. It is generally believed that in northeastern Ohio drainage was directed toward the north into the province of Ontario across the area now occupied by Lake Erie. An ancestral Grand River system presumably drained the site vicinity. The gradient of the main Grand River channel probably was much steeper, having undergone significant headward erosion during periglacial and Recent time. Many of its former tributaries are buried by thick glacial deposits. Summarily, the cumulative effect of active processes, dominated by uplift and erosion, subsequent to late Paleozoic tectonism and preceding glaciation, resulted in a general lowering of elevation and reduction in local relief.

2.5.1.2.4.2 Glacial

Beginning approximately two million years ago at the advent of the Pleistocene Epoch and continuing until about 14,000 years ago, there were four major stages of extensive continental glaciation, Nebraskan, Kansan, Illinoian, and Wisconsinan. The individual glacial periods spanned time intervals of approximately 100,000 years and were separated from each other by the following interglacial periods; Aftonian, Yarmouth and Sangamon respectively. During interglacial periods the climates moderated, sea levels rose and the continents were most likely ice free. Also, each of the four major glaciations was interrupted by short term periods or interstades of non-glaciation. During these interstades the glaciers retreated and then readvanced while continuing to cover the main continental mass. Readvances and retreats resulted in partial to complete eradication of previous glacial and interstadial deposits. Parts of Ohio were covered during at least the latter three

stages for periods up to 50,000 years separated by long interglacial stages. Each of the major advances was partly responsible for the formation of the basins of the Great Lakes and the present topography.

There is no direct evidence of Nebraskan stage glaciation in northeastern Ohio, however direct and indirect evidence of the other stages is present. In northwestern Pennsylvania, the Slippery Rock till is assigned pre-Illinoisian, does not outcrop, and is not known beyond the Mapledale (Illinoian) limit. It is correlated with the till in Elkton Rift, 20 miles south of Youngstown, assumed to be Kansan (Reference 137) (Reference 138). Till of the Illinoian stage has been found about 70 miles south of the site. Deposits of the last major advance, the Wisconsinan stage, are found up to 75 miles south of the site.

The extensive deposits of unconsolidated sediments overlying the Chagrin shale at the site, exposed by the plant excavations, include approximately 60 feet of both till and lacustrine sediments. In ascending order a transitory internal, approximately seven feet thick, occurs between competent bedrock and a horizontal boulder layer defining the lower till base. Within the transitory interval, blocks of randomly oriented detached Chagrin shale bedrock are surrounded by a dense, gray clay till not unlike the lower till. The lower till, generally twenty feet thick, is in turn overlain by upper till, approximately ten feet thick, which is less dense and characterized by a slightly reddish hue. The two tills may represent deposition from either distinct substage advances or an advance-retreat-readvance cycle of one substage. The surface deposit, lacustrine sediments, consists of more than 20 feet of thinly stratified clay, silt and occasional sand layers of which the upper five to seven feet are oxidized to a brownish-orange hue.

A radiocarbon date obtained from organic material in lacustrine silt is 14,480±310 B.P. This suggests that the upper till is older than previously presumed. Originally described by White, the Ashtabula till

is the youngest glacial deposit in Ohio, occurring in a very narrow belt parallel to Lake Erie, from two to six miles wide, and traceable from Cleveland along the Lake Shore into New York (Reference 139).

Shane has given the following estimates for the age of the Ashtabula and earlier late Wisconsinan till sheets in the Grand River Lobe of northeastern Ohio (Reference 140):

Ashtabula till	13,000 B.P.
Hiram till	14,500 B.P.
Lavery till	16,500 B.P.
Kent till	21,000 B.P.

Although the site clearly lies within the area of Ashtabula till, the radiocarbon date of 14,480 B.P. is far too old to represent the Ashtabula till, and more probably relates to the earlier Hiram till. The Ashtabula till has probably been removed by early lake erosion. White, Totten and Gross note that in "a belt two to four miles wide between Lake Erie and the Ashtabula moraines, the Ashtabula till has been in part removed by erosion of the higher late glacial levels of Lake Erie, and in part the till is overlain by sand and gravel deposited in the higher levels of the lake" (Reference 141). The date obtained from the organic detritus, interbedded within the site lacustrine deposits, is significant, being the oldest date associated with the retreat of Hiram ice in the northeastern part of the Lake Erie basin. This suggests that the Hiram ice front retreated somewhat earlier than previously suspected, and it supports a White, Totten and Gross contention that the Hiram ice retreated "almost certainly into the Lake Erie Basin" (Reference 141). The radiocarbon date also provides a firm minimum date on the time of the shallow onshore deformation exposed by the site excavations <Section 2.5.1.2.3>. This superficial bedrock deformation, attributed to glacial shove and override, is either associated with Hiram till, or an earlier late Wisconsinan ice advance.

In either case, the deformation must have occurred prior to the 14,500 year-old organic detritus interbedded within lacustrine silts overlying the Hiram till.

Nonresistant upper till sediments were overloaded by an advance of Ashtabula ice. This resulted in differential compaction and development of load casts.

The Great Lakes began to develop after the Cary substage of the Wisconsinan. These ancestral lakes were mainly filled by glacial meltwater caused by ice front damming on the north and high terrain to the south. Outlets to the west, south and east were used at various times, depending upon the position of the ice front. Lacustrine or lake bottom sediments and beach deposits formed in these lakes. Some of the early lake deposits were formed and then obliterated or buried by readvance of the ice sheet. As the ice retreated for the last time, these deposits emerged as the lake levels fell. Different names were applied to each separate lake stage.

Evidence of higher Lake Erie stages are abundant in the locale. Lacustrine sediments were deposited subsequent to the retreat of Ashtabula ice from northeastern Ohio. Several ancestral beaches are preserved south of the site as low continuous sandy ridges generally parallel and subparallel to the present Lake Erie shoreline (Reference 129). Lake Whittlesey beaches are a consistent feature throughout the lake plain area and may be observed at Elevation 735’ between Painesville and Ashtabula along which Ohio State Highway 84 is located. U.S. Highway 20 from Pennsylvania to Lakewood, Ohio follows one of several Lake Warren beach ridges. Discontinuous sediments of beaches associated with Lake Lundy, which developed when the glacial ice began to retreat from southern Ontario, are located between the present Lake Erie shoreline and North Perry, Ohio.

Estimates of the Laurentide ice volumes from its late Wisconsinan maximum suggest that at least 1,000 feet of ice, and possibly up to 5,000 feet loaded the site. The regional response to ice loading was crustal depression and isostatic rebound subsequent to deglaciation. Geomorphologic data indicate that Lake Erie, immediately following deglaciation, drained northwestward and southward. Subsequent to regional rebound, a drainage reversal was effected to its present outlet over Niagara Falls (Reference 129).

Crustal depression induced by these loadings would be expected to contribute to localized stress buildup and vertical movements near the ice margin, probably during glacial advance as well as retreat. These vertical movements at any one place included those associated with ice retreat as well as those attributed to ice loading. The maximum principal compressional stress which caused the faulting exposed in the cooling water tunnels was oriented northwest-southeast during deformation. Although this bearing is consistent with the propagation of tectonic stresses during the Alleghanian (Appalachian) Orogeny, so is the gradient of crustal rebound and the general direction of local ice movement within the Grand River Lobe of northeastern Ohio (Reference 142). Stresses developed during glaciation were reoriented following deglaciation via glacial-isostatic rebound.

Rebound at the Perry site and throughout northeastern Ohio has ceased as determined by recent geodetic releveling reported by Meade, 1971 (Reference 143).

2.5.1.2.5 Engineering Geology of Local Geologic Features

Site grade is at approximate Elevation 620’. In descending order, the stratigraphic units encountered are lacustrine, glacial ground moraine, the latter subdivided into an upper till and lower till stratum, and Upper Devonian Chagrin shale.

The lacustrine sediments consisting of stratified silty and clayey fine sands (SM), (SC) and silts (ML) and silty clay (CL) usually have Standard Penetration Resistance (SPR) values ranging between 5 and 15 blows per foot. Average thickness of lacustrine deposits is 25 feet. Upper till materials with an average thickness of 10 feet, are predominantly fine sandy silty clay (CL) of low plasticity. SPR values of the upper till were variable ranging from 4 to 30 blows per foot, but generally increased with depth. The lower till underlies the upper till at an average depth of approximately 35 feet below the preconstruction ground surface. Its average thickness is 19 feet. The lower till differs from the upper till by having a much lower natural water content, relatively greater density and a boulder layer near its base. The lower till is predominantly fine sandy silty clay (CL) of slight to low plasticity with SPR values usually ranging between 30 and 100 blows per foot.

The Chagrin shale is a member of the Upper Devonian Ohio Shale formation which is more than 1,200 feet thick. The stratum dips slightly to the southeast. The shale is mainly clay shale with thin laminations of very fine sandstone to siltstone. Bedding thicknesses generally range from 1/16 to more than 1 inch. Mineralogically, illite (most abundant), chlorite and kaolinite are the clay minerals. Typically, fresh shale is moderately hard, as it can be scratched but not gouged or carved with a pocket knife. Bedrock conditions both onshore and offshore are similar in that the upper two to five feet of bedrock is somewhat softer, perhaps weathered. Below the weathering zone, the rock is competent and 95 percent or higher core recovery is typical.

Ground water levels usually ranged between three and five feet below existing ground surface. The gradient slopes downward toward Lake Erie. Piezometer data indicate a gravitational groundwater system is present resulting in full hydrostatic water pressures at least down to an average elevation of 555’.

Additional discussion of the engineering and physical properties of founding grade materials is provided in <Section 2.5.4.2>. <Figure 2.5-53> is a plot plan showing the locations of exploration borings, sampling and in situ testing. Logs of the test borings are provided in <Appendix 2E>. <Figure 2.5-42> shows geologic cross sections of the plant site excavation profiles supplemented by test boring information. <Figure 2.5-54> is a map view of the materials underlying the plant structures.

2.5.1.2.5.1 Behavior During Prior Earthquakes

No physical evidence was uncovered during the geologic investigations of the surficial or subsurface materials which would indicate any correlation between historic earthquake activity and site geologic structure. Extensive geologic investigations conducted after the January 31, 1986 Leroy earthquake found no geologic structures that could be related to the Leroy event or any historic activity.

2.5.1.2.5.2 Deformational Zones

As described in <Section 2.5.1.2.3.3> several zones of folded, faulted and otherwise structurally altered bedrock were exposed during foundation excavation operations. It was determined during subsequent field investigations, subsurface exploration and planned caisson excavation through altered bedrock that these zones of bedrock deformation are restricted vertically as well as laterally. No surficial manifestation of these structures was observed. Although the engineering properties of disturbed bedrock are sufficiently conservative and within limits of foundation design criteria, zones of altered bedrock were overexcavated to competent bedrock and backfilled to foundation grade with porous and fill concrete. This was accomplished to preclude any potential for the erosion and ingress of altered shale particles into the porous concrete blanket. A complete description of the plant porous concrete underdrain system is provided

in <Section 2.4.13.5>. Typically, the overexcavated areas were backfilled with 1,500 psi concrete to planned excavation grade. A minimum thickness, one foot, of porous concrete has been placed beneath the nuclear island complex. <Figure 2.5-55> shows the areas and depths of overexcavation.

The plant intake and discharge cooling water tunnels beneath Lake Erie are intersected by low-angle thrust faulting as described in <Section 2.5.1.2.3.3>. Geologic mapping and documentation of the deformation was accomplished during tunnel excavation operations and is included in <Figure 2.5-47>. The tunnel design was not affected by the presence of these bedrock discontinuities. The tunnels are constructed with a concrete liner backed with contact grouting approximately one foot thick to ensure continuity between the liner and bedrock.

2.5.1.2.5.3 In Situ Stresses

Hydraulic fracturing was conducted within borehole TX-11 in order to determine the magnitude and orientation of site in situ principal stresses. The borehole in which measurements were made was 3.65 inches in diameter and was drilled to a depth of 730 feet. This hole was advanced initially through approximately 60 feet of glaciolacustrine and till deposits before encountering bedrock of the Ohio Shale formation. Chagrin shale, predominantly thinly-bedded light to medium grey shale and minor light grey to buff siltstone and/or very fine-grained sandstone, extends uninterrupted to an approximate depth of 463 feet. Below this depth interfingering of the Huron shale begins and increases with depth. This interfingering is demonstrative of the facies concept governing the vertical and lateral distribution of Ohio Shale sediments throughout northeastern Ohio. Huron shale is characterized by predominantly thinly-bedded brown shale and minor light grey siltstone and/or very fine-grained sandstone. The Huron shale is harder than Chagrin shale having higher apparent strength properties. Core recovery

was excellent for both Ohio Shale members, and no faults or major discontinuities were interpreted. (See <Appendix 2E> for TX-11 boring log).

Eight test intervals, ten feet long, were isolated by a double packer assembly and subjected to hydraulic fracturing. The medium depths of the shallowest and deepest intervals, respectively, were 394 and 718 feet. In situ stress measurements were calculated from vertically and horizontally induced fracturing and their respective breakdown and shut-in pressures. Assumptions regarding tensile strength values, either assumed or inferred from breakdown pressures, were confirmed by laboratory hydraulic burst tests. Finally, impression packers recorded bore wall fractures induced by hydraulic fracturing. A Kuster single shot survey instrument was used to orient the fracture traces.

A summary of the field and laboratory in situ stress measurement program results are as follows:

a. The orientation of σ_1 was measured to vary between N67°E and E10°S. This fits well with orientation of stress over a regional basis.

b. The stress measured (the horizontal stresses are the maximum and intermediate principal stresses) fall within the limits of stresses measured in other parts of northeastern and north-central United States and southern Canada.

c. In all cases (eight test intervals) except possibly the uppermost interval, the complete stress Tensor could be defined.

d. The vertical component, minimum principal stress gradient corresponds closely to the anticipated overburden pressure.

At the shallower test depths, the tendency for $\sigma_1 \simeq \sigma_2 \simeq \sigma_3$ is well defined and gradient extrapolations of existing measurements to the

surface are reasonable. No high stress magnitudes were experienced in either the tunnel or plant area excavations or concluded from measurements of extensometers installed in the bedrock walls of the emergency service water pumphouse <Section 2.5.4.13.2> and <Section 2.5.4.13.3>. These conclusions, regarding stresses from plant structure excavations, are consistent with the gradient extrapolation of the deeper in situ borehole measurements. Below a depth of approximately 600 feet, both σ_{Hmax} and $_{Hmin}$ show an increase in gradient, with the gradient for σ_{Hmax} being larger. The gradient increase is attributed to changes in bedrock lithology rather than any structural discontinuities. Huron shale is predominant over Chagrin shale at the deeper borehole depths.

The field and laboratory stress measurement program was directed by Dr. Jean-Claude Roegiers, Department of Civil Engineering, University of Toronto. Data conclusions and an overview of the hydraulic fracturing technique are contained within <Appendix 2D E>.

2.5.1.2.5.4 Unstable Material Mineralogical or Physical Properties

No unstable materials, either soil or bedrock, were anticipated on the basis of geological and geophysical investigations, and none were encountered during foundation excavation and tunneling operations. Material properties are discussed in <Section 2.5.4.2>. X-ray diffraction analyses of representative clay gouge samples obtained from the intake tunnel fault zone revealed a mineralogical assemblage nearly identical and in proportion to that analyzed for the Chagrin shale country rock. In both the fault gouge and country rock illite is dominant, whereas kaolinite and chlorite are subordinate in approximately equal proportions. A significant portion of siliceous material is present in both unaltered and altered rock.

2.5.1.2.5.5 Effects of Mining and Hydrocarbon Storage and Production

Regarding man's activities, salt mining subsidence potential <Section 2.5.1.1.7.1.4>, subsurface gas storage <Section 2.5.1.1.8.2> and hydrocarbon extraction <Section 2.5.1.1.8.3> were investigated.

2.5.1.2.6 Site Groundwater Conditions

A description of regional and local groundwater conditions is presented in <Section 2.4.13.2>. Information pertinent to preconstruction groundwater conditions and supplemental investigations discussing the effect of plant construction and operation onsite groundwater are discussed in <Section 2.5.4.6>. For descriptions of the plant accommodations of groundwater conditions as they exist at the site, see <Section 2.4.13.5>.

2.5.2 VIBRATORY GROUND MOTION

2.5.2.1 Seismicity

2.5.2.1.1 Local and Regional Seismicity

The assessment of the seismicity required to define the maximum earthquake potential will be based on two updated data sets, one regional and the other local. The first set covers a broad region around the site, just in excess of a 200 mile radius. It includes all known earthquakes with an observed magnitude greater than 3.0, without scale differentiation, or an epicentral Intensity I_o greater than III(MM). These thresholds are recommended in <Regulatory Guide 1.70>, (Revision 2), and are more conservative than those in Revision 3 which requires only intensities greater than IV(MM). The cut-off date for including available data in this update is September 1, 1991.

In <Figure 2.5-56>, 50, 100 and 200 mile radii circles centered on the site have been superimposed on the seismicity map to show the spatial relationship of the site to the various zones of seismic activity. <Table 2.5-7> lists available parameters describing all seismic events located between Latitudes 38 to 45N, and Longitudes 77 to 85W, satisfying the thresholds just described. A separate listing of events of non-tectonic origin (i.e., chemical explosions) or with so poorly constrained coordinates that plotting is unwarranted, is given in <Table 2.5-8>.

The second data set covers the same time period, but focuses on the local area contained within a 50-mile radius circle around the plant site. All known events with magnitudes greater than 1.0 and intensity equal to or greater than I(MM) are included. <Figure 2.5-58> and <Table 2.5-9> present the available information of this set. Some date information has been included on <Figure 2.5-58>. It should be noted that many historical events from 1823 to 1976 contained in this second set have been individually investigated in <Appendix 2D D>. The results of this study are still valid and have been integrated to the earthquake data base. They are specifically presented in <Section 2.5.2.1.2.3>.

Two symbols are used to plot earthquake locations on the seismicity maps of <Section 2.5.2>. An octagon indicates an earthquake for which the epicentral location and the size have been originally determined mostly on the basis of intensity felt reports formulated according to the Modified Mercalli scale. Most of the pre-instrumental era earthquakes are represented by octagons. Generally, a square is used to plot epicenters of more recent earthquakes for which both the location and the magnitude were calculated on the basis of instrumental data. A small number of non-instrumentally determined epicenters are also represented by a square if their felt report distribution was sufficiently detailed to permit the calculation of an inferred equivalent magnitude on the basis of empirical relationships, e.g., felt areas versus magnitude. All symbol sizes have been scaled to maintain

some equivalence between intensity and magnitude. The relative size of symbols has also been scaled down for plotting purposes, since magnitudes express a logarithmic relationship. Whenever an earthquake has both intensity and magnitude values assigned, the plotting routine will use the following priority to select the symbol type: m_b, m_{blg}, M_L, M_c, I_o(MM). An event will be included as long as either the magnitude or the intensity is above the desired threshold; a magnitude symbol is used even in cases where the acceptance is based on the intensity threshold.

2.5.2.1.1.1 Data Base

a. Sources

The updated seismicity data sets presented here are taken from Weston Geophysical's earthquake data base. This computerized data base, which covers a much broader geographical region than the one investigated for the Perry site, has been developed through the past two decades by incorporating data from many published sources, and complementing these data with additional research. Through a parallel compilation of major catalogs and listings, typographical errors have been detected, duplications corrected and significant discrepancies identified and noted for further investigation. Major sources included or examined are the United States Earthquakes Series, the Earthquake History of the United States, the Preliminary Determination of Epicenters by the National Earthquake Information Center, the Publications of the Dominion Observatory, and the Seismological Series of the Earth Physics Branch, now the Geological Survey of Canada. The bulletins of major seismic networks such as those of the Lamont-Doherty Observatory, St. Louis University, and the New England Seismological Association. Important listings such as those by Mather and Godfrey (Reference 144), Brigham (Reference 145), Brooks (Reference 146), Docekal (Reference 147), Nuttli (Reference 148),

Nuttli and Herrmann (Reference 149), Hopper and Bollinger (Reference 150), Bollinger and Hopper (Reference 151), Bollinger (Reference 152) (Reference 153) (Reference 154), Barstow (Reference 155), Dewey and Gordon (Reference 156), Gordon (Reference 157), have also been considered. Supplementary information for many historical events has also been collected from newspapers, town histories, private diaries, scientific papers, technical reports, etc. Through a critical review and evaluation of the above material, a selected set of parameters was adopted for each event included in the data base.

In addition, an important catalog of earthquakes in the Eastern United States up to the end of 1982 was compiled by a group of experts for the Electric Power Research Institute (EPRI) as part of the broad scope investigations entitled "Seismic Hazard Methodology for the Central and Eastern United States" (EPRI, July 1986, NP-4726). Special attention was devoted during preparations of this EPRI-catalog to refining the parameters of the larger EUS earthquakes, i.e., greater than 4.5 m_b. The resulting EPRI catalog was compared to the WGC data base for the region of the Perry site; some appropriate changes were made to the WGC catalog to reflect the weight of expert opinions on certain events.

b. Completeness and Reliability

In reviewing the cumulative seismicity of a region in terms of seismic risk assessment, it is necessary to examine the completeness and reliability of the data set. Because earthquakes are characterized either by their epicentral intensity or their magnitude, and are located by analyzing isoseismal contours and/or instrumental recordings, the spatial and temporal distributions of population and seismographic stations influence the number, size and location of reported events. It is almost impossible to get a homogeneous data set over a long period of time, as both factors,

population and networks, constantly change. As long as proper thresholds and uncertainties are kept in mind, the data set is still most informative.

Even though major catalogs carry entries dating back to more than three centuries for some parts of eastern North America, it should not be assumed that completeness was achieved in these early years, except for a very high threshold, i.e., Intensity IX(MM). For the region presently under consideration, it is more realistic to assume that the seismic history is relatively complete over the last 160 to 200 years for events that would be significant in terms of structural design, i.e., with intensities equal to or greater than VII(MM). This period is long enough to provide a good insight on the local seismic regime.

The reliability of early historical data depends greatly on the population density and the construction practices in the areas around the epicenters. A lack of population in the true epicentral area of an event, for example, can lead to that epicenter being mislocated into the populated region where an apparent maximum intensity level was reported. Besides shifting true locations, a lack of an evenly distributed population can also result in underestimated epicentral intensities. The opposite bias can occur in cases where felt reports come only from communities settled along lake shores and river banks which characteristically experience enhanced ground motion due to the soil column, or where poor construction practices prevail. In cases of structural damages, one must remember that construction standards were substantially different two centuries ago. A blind application of the Modified Mercalli scale to reports of fallen chimneys, for example, without due consideration of these basic differences can result in overestimated seismic events.

<Figure 2.5-57> and <Figure 2.5-71> show the progressive historical migration of the population, both in the eastern United States and Canada. Even though the westward migration with time is predominant, the regions around Lake Erie, in both countries, show relatively early settlement. By the early 1800’s, the region in the immediate vicinity of the site was settled, even if not densely populated. It should be noted that the earliest reported events, within 50 miles of the site, occurred in 1823 and 1839, both of Intensity IV(MM). Taking into account the population spreading between settlements, events reported during the first half of the 19th Century must be given an uncertainty in location of the same order (several tens of miles). The assigned intensities may have been the actual epicentral intensities, but conceivably in some cases, they could have been maximum felt reports of slightly larger events located between settlements. Such population bias could not have resulted in an error larger than two intensity units. With the increasing population in the second half of the century, this uncertainty of location and intensity can be safely reduced. In all likelihood, completeness above the Intensity VI(MM) threshold has been achieved for as long as 150 years in the immediate site area.

The instrumental era beginning around 1900 brought a substantial improvement to the quality of seismological data, particularly with respect to epicentral location. Yet, for the first half of the century, epicentral locations continued to depend heavily on felt reports; the seismographic data, sometimes too sparse, provided at least some control on the location and occurrence of the events. Determination of magnitudes for regional events in California was initiated during the thirties, but not used for eastern earthquakes until the forties and fifties. For much of this era, from the start of the century and up to the sixties, only a small number of seismographs were operated simultaneously in the northeast, both in the United States and Canada. These few stations were part of the

national networks, the regional networks operated by the Jesuit Seismological Association (JSA), and some American colleges and universities. In these early decades, numerous factors such as the type of instrumental response, lack of good time control, awkward geographic configuration, use of graphical locationing methods, and limited knowledge of crustal velocities were potential sources of errors and uncertainties in the epicentral coordinates.

From <Table 2.5-10>, which lists the location and date of operation of the JSA stations, it appears at first sight that the Cleveland region was favored with the early opening of the John Carroll University station. The history of the station by Macelwane (Reference 158) indicates that unfortunately the station was continually plagued with difficulties, at least until the forties (traffic noises, vault relocations, water seepage, etc.). The homemade instrument which operated during the first decade should be regarded as unreliable. The Wiechert seismograph, with its low magnification, relatively long period and slow drum speed was not designed for recording local events. In 1947, the station was finally equipped with three short-period instruments.

During the aftershock studies that followed the January 31, 1986 earthquake, it was estimated that the John Carroll University probably had a detection threshold of about Magnitude 2.5-3.0 for events located 40 km away. Microseisms and soil amplification of traffic noise are responsible for this relatively low sensitivity.

In the sixties, some improvements in the coverage came about with the installation of the World Wide Network of Standard Seismographs (WWNSS) <Table 2.5-11>, with the Long Range Seismic Monitoring Program (LRSM), and the expansion of the Canadian Network for the Upper Mantle Project <Table 2.5-12>. The operational characteristics and station distributions of these networks were primarily oriented towards recording large regional

and teleseismic events and studying the internal structure of the earth. The uncertainty to be associated with the epicenters of many local events during the sixties can still reach a few tens of kilometers.

Since the early seventies, there has been an increased interest in studying local seismicity in an effort to understand intraplate activity and define the seismic hazard. Besides the expanded National Seismographic Network operated by the U.S. Geological Survey with central recording center in Golden, Colorado, there now exist numerous regional networks east of the Rockies, particularly in areas where historical seismic activity has been observed. Presently, besides the U.S. and Canadian agencies, seismic data in the northeastern United States are gathered by the Northeastern United States Seismic Network (NEUSSN) and in the southeastern United States by SEUSNN. These regional networks are composed of several subnets operated independently by universities and state surveys, all cooperating in the interpretation of data and publication of bulletins. In the central United States, St. Louis University and the Tennessee Earthquake Information Center located at Memphis State University, also operate large networks. The University of Michigan has been monitoring the seismic activity near Anna, Ohio since 1976 with a nine-station array; in 1981, a four-station net was installed in Indiana by the same group.

In the early eighties, the Empire State Electric Energy Research Corporation (ESEERCO) contracted Woodard-Clyde Consultants to operate two networks in New York state, one in the North Central area and the other in the Mid-Hudson area. The Government of Canada also expanded its network in the East (ECTN), thus improving the coverage in Southern Ontario and Western Quebec.

These new networks have limited aperture centered around specific target areas; nonetheless, in their ensemble they form a vast

network potentially capable of producing, at least for moderate earthquakes, epicentral determinations and fault plane solutions far more accurate than those obtained prior to 1975.

In northeastern Ohio, where the PNPP is located, the instrumental coverage of smaller earthquakes had been dependent mostly on one station at John Carroll University in Cleveland, at least up to the installation of the Anna network and the western New York stations, in the late seventies. More recently, after the Leroy earthquake of January 31, 1986, the John Carroll University (JCU) Observatory has installed, with assistance from CEI, a five-station telemetered array. <Figure 2.5-72> shows the station locations. Details on this net are provided on <Table 2.5-13>. Operation of this new array began at the end of September 1986. The objective of this installation is to improve the detection and location threshold over 400 square km in northeastern Ohio.

Finally, on a temporary basis, CEI has been operating a small aperture network that monitors a short corridor between two ICI America (formerly Calhio) injection wells and the January 31, 1986 epicenter. This five-station digital array employs three-component short period sensors installed in shallow boreholes. In July 1989, a temporary vertical analog component was added in Geneva, Ohio, near Madison-on-the-Lake. Telephone lines connect each station with the Recording Center located at the PNPP site. Locations of the six stations and the two wells are shown on <Figure 2.5-61>. <Table 2.5-14> provides further details on this sensitive microearthquake network installed in April 1987. The purpose of these observations is the acquisition of microearthquake information necessary to study further the probability of induced seismicity in the area, as suggested by the USGS (Reference 128) (Reference 159). Quarterly reports on network operation are submitted to the NRC (Reference 173).

c. Significance of Cumulative Seismicity Data

From the previous sections, it is apparent that the earthquake data is composed of less precise, qualitative historical information spanning nearly two centuries for the site region, and of far more precise instrumental data that span only the most recent decades. Clearly, the recent data is most valuable because of the greater accuracy that it provides for the epicentral locations, focal depths and magnitudes. It has been observed also that, over a relatively short time, e.g., 10 to 20 years, instrumental monitoring of the microseismicity can refine the more diffuse pattern obtained by one or two centuries of historical data. Yet the historical record has its own value, necessary for hazard estimation; it provides the recurrence rate of the moderate and less frequent earthquakes and therefore a good insight on the maximum credible earthquake.

In the present case, the cumulative seismicity data available is of adequate quality: the Nuttli and EPRI catalogs as well as the USAR <Appendix 2D D> cover well the macroseismicity. For the past five years, the immediate region surrounding the PNPP facility rates high among the densely instrumented regions in eastern North America. New information made available through denser coverage is the more accurate determination of focal depths.

One important conclusion from a summary review of the cumulative seismicity for the PNPP site region is that the historical record does not reveal the occurrence of large earthquakes, such as in other recognized high risk zones of eastern North America, e.g., New Madrid and La Malbaie, where deep seated and extensive through-going tectonic structures have been found. In addition, the shallow focal depths presently observed in the site region for moderate earthquakes ($m_b \leq 5.0$) such as at Leroy and St. Marys,

Ohio, or for low level microseismicity (m_b <1.5), do not match the greater focal depth range usually associated with large intraplate earthquakes.

2.5.2.1.2 Spatial Distribution of Seismic Activity

The seismicity data presented in <Figure 2.5-56> and <Table 2.5-7> show two well defined zones of moderate earthquake activity within the 200 mile radius circle around the site. These zones include some of the largest Modified Mercalli Intensities reported, up to VII and VIII, and the largest magnitudes, ranging from 4.5 to 5.2 m_b, observed in the site region. The first of these zones is located around Anna, Ohio; the second comprises the activity near Attica, New York and over the Niagara Peninsula. Two clusters of less dense activity exist in a south-southwesterly direction from the site. The first cluster is situated about 180 miles to the south-southwest in south-central Ohio; the second one, consisting of roughly the southwestern quadrant of the 50 mile radius circle, includes the region of the January 31, 1986 Northeastern Ohio earthquake. Beyond the 200 mile region, but still in the site tectonic province, is located the Sharpsburg, Kentucky earthquake of July 27, 1980, with a magnitude 5.1 m_b and a maximum Intensity of VII(MM).

2.5.2.1.2.1 The Anna, Ohio Seismic Zone

In addition to the March 9, 1937, Intensity VII-VIII event with an instrumental magnitude of m_b = 4.9, four other Intensity VII events have occurred in the Anna area, on June 18, 1875, September 30, 1930, September 20, 1931, and March 2, 1937. The estimated m_b magnitudes of the last three earthquakes on the basis of felt areas were respectively: 4.2, 4.5 and 4.7. The felt area of the June 18, 1875 earthquake is reported to be smaller than that of the September 20, 1931. It could be incomplete because of the sparse population at that time. For this reason, the event size should be characterized by its

Intensity VII. Many smaller events have also been located within 20 miles of Anna, throughout the recorded history. Westland and Heinrich, Bradley and Bennett and Coffman and Von Hake have descriptive materials on many of these events (Reference 160) (Reference 161) (Reference 162). More recently, Nuttli and Herrmann (Reference 149), Nuttli (Reference 148) and Nuttli and Brill (Reference 163) produced several revised versions of an earthquake catalog for the central United States, based on extensive compilation and reanalysis of felt reports and available seismograms.

A significant contribution on the Anna seismicity was made by Dewey and Gordon (U.S. Geological Survey), who relocated three of the larger Anna earthquakes on the basis of instrumental data (Reference 164). These new epicentral locations are quite different from those presented by Bradley and Bennett (Reference 161). They are in better agreement with the isoseismal data. The focal depth estimates (5 to 16 kilometers) suggest ruptures in the basement rocks of the upper half of the crust.

Mauk, et al (Reference 1), and Christensen, et al (Reference 2), have studied the seismicity of the Anna region using the data collected by the new network. They have synthesized <Figure 2.5-62> in several reports, the proposed faults of the region, the new epicentral locations of Dewey and Gordon <Table 2.5-15>, recent epicenters from the Anna seismic array, and some nine other epicenters from Bradley and Bennett (Reference 1) (Reference 161) (Reference 164). Three faults have been proposed for the Anna seismic zone (Reference 2): the Anna-Champaign fault, trending northwest-southeast, the Logan-Hardin fault, trending northeast-southwest, both inferred from proprietary data, and the Auglaize fault, trending northeast-southwest, based on well data. Landsat imagery shows three lineaments which appear to support the first two postulated faults. If the location uncertainty attached to relocated epicenters and inferred faults is considered, the close spatial coincidence of the Anna-Champaign and Auglaize faults with the relocated earthquakes of 1931 and 1937, as well as the seismicity

observed by the recently installed network, strongly suggests a causal relationship. The increasing amount of seismic data and geological information near Anna suggests the existence of a structure with which the seismic activity can be correlated. Nuttli and Herrmann, in their earlier review of the seismicity of the central United States, had considered that the systems of basement arches present in the Anna region could be an adequate cause for strain concentrations and subsequent earthquakes (Reference 149).

On July 12, 1986, a moderate earthquake with m_b = 4.5 occurred near St. Marys, Ohio, causing only the minor damage of an Intensity VI over a small area (Reference 304). The isoseismal map by Stover is presented in <Figure 2.5-63>. The location is considered quite accurate, considering it is within the Anna network aperture. The fault plane solution <Figure 2.5-64> (Reference 2) indicates nearly pure strike-slip motion, with one plane parallel to the proposed Anna-Champaign fault. Stress axes are in the northeast-southwest direction, as expected. The location and the isoseismal data support the fact that this earthquake occurred in a different location than the Anna earthquakes of the thirties. If the location of a smaller earthquake m_b = 3.3, that occurred on June 17, 1977 is also accepted as reliably distinct, it becomes more probable that seismic activity is indeed occurring along a segment of the proposed Anna-Champaign fault.

2.5.2.1.2.2 The Attica, New York and Niagara Zone

Seismic activity in the Attica, New York area has been reported (Reference 165) (Reference 166) (Reference 167) to occur since the middle of last century. The largest historical event in the entire site region did occur near Attica, New York, on August 12, 1929, with an Intensity VIII (MM) and estimated m_{blg} = 5.2 (Reference 170). Several smaller events were also recorded and felt in the nineteen fifties and sixties, with m_b magnitudes ranging from 2.7 to 4.7 and intensities up to VI (MM). These events were considered tectonic in nature, in

contrast with numerous swarms of microearthquakes related to hydraulic mining. Fletcher and Sykes (Reference 41) have analyzed in detail these smaller events, both natural and artificially triggered, in the Attica-Dale area where injection wells are located in the immediate vicinity of the Clarendon-Linden Fault system.

Fault plane solutions obtained by Herrmann (Reference 169) for two 1966 earthquakes offer a nodal plane closely oriented along the Clarendon-Linden fault. This constitutes the major support for associating the 1929 earthquake with the same fault system, given the similarity of epicenters. Herrmann (Reference 169) suggests that the Intensity VIII of the 1929 earthquake, relatively high for a magnitude m_b = 5.2 with a moment M_o = 1.3 x 10^{23} dyne-cm (Reference 170), can be explained by assuming a relatively shallow depth.

At present, there is a consensus of opinions that the seismic activity near Attica, New York is related to an identifiable tectonic structure or fault system, and as such does not characterize or belong to the seismic regime of the Eastern Stable Tectonic Province, the PNPP site province.

Further west of Attica, some low-level activity still remains uncorrelated with faults or mining activities (Reference 41). A rather well defined cluster of small events is present on the Niagara Peninsula and the western end of Lake Ontario. Many of these historical events have limited epicentral accuracy, due to population bias and poor network configuration. For this reason, credibility might be first given to the cluster itself rather than to the individual epicentral locations. Basement structures are not mapped sufficiently well to support any correlation of this seismic activity with local tectonics. The localization of low-level seismicity in the narrow septum between two unequally elevated lakes could be related to differential stress in the horizontal direction. It should be noted that a series of small tremors was observed in the Canadian city of Burlington, Ontario, just

north of Hamilton, at the western edge of Lake Ontario, during the period 1975-1980. Wetmiller (Reference 171) has researched the cause of these events and concluded that they were relatively shallow, not typical of the regional seismicity, and certainly not comparable to the activity at Attica, New York.

An interesting feature of the Peninsula cumulative seismicity is the apparent shift in location between the historical epicenters and the recent instrumentally determined epicenters. The older events, given locations on the peninsula, may be reflecting population distribution as a function of time, while the data from the last decade, in principle more accurate, form little clusters located to the west. Further west, in Ontario, Mereu et al (Reference 113) have reported several hundred microearthquakes in the area of the Gobles Oil Field. These shallow events, most likely triggered by secondary recovery activities, seem to cluster on two faults perpendicular to each other.

2.5.2.1.2.3 Seismic Activity within 50 Miles from PNPP

Some seismic activity is apparent within the southwest quadrant of the 50-mile radius circle around the site. Several of these earthquakes, except the January 31, 1986 event, which will be discussed separately in the next subsection, have produced felt intensities ranging from II(MM) to V(MM). <Figure 2.5-58> presents the locations of these events and <Table 2.5-9> the corresponding parameters. Many of these events are purely historical events, i.e., their locations depend totally or largely on felt reports, by opposition to instrumentally located epicenters. As mentioned earlier, a seismographic station has been operating at John Carroll University for several decades, but with a high detection threshold and limited location capabilities, at least until 1986, when a 5-station array was added. The value of a single station in locating local earthquakes, such as those that occurred in 1943, 1951 and 1955, is restricted to confirming the occurrence,

approximating the epicentral distance and giving a relative estimate of the magnitude. By itself, a single station provides uncertain directional information.

In <Appendix 2D D>, in response to Q&R 230.3, CEI undertook to review individually all known historical earthquakes that had occurred from 1823 to 1978 within 50 miles from the site, without any threshold imposed on intensity or magnitude. In addition to verifying the sources of already catalogued events, the effort consisted in acquiring from local libraries new accounts of felt reports, evaluating their spatial distribution, and for the latest events in examining several seismograms. It was found that some catalogued entries were not true earthquakes, and that some epicenters had been mislocated because of incomplete availability of the data. <Table 2.5-7>, <Table 2.5-8>, and <Table 2.5-9> take into account these findings. In <Appendix 2D D>, location uncertainties were estimated for several events, e.g., 5, 10, 15 miles. These estimates reflected only the relative confidence of the reviewer and were not meant to be interpreted too strictly. These relocations and uncertainties are now presented in <Table 2.5-16>.

Upon completion of the investigations presented in <Appendix 2D D>, it was concluded that 1) the seismicity within 50 miles from the plant was diffuse, poorly defined, and could be best characterized as low; 2) the denser population distribution along the Lake Erie shore and the soil amplification of lacustrine deposits made it difficult to determine epicenters on the sole basis of felt reports; 3) the resulting large uncertainties could not support the correlation of apparent lineation with geophysical anomalies; 4) the size estimates of historical events had been conservative; and 5) that the reported local activity between 1955 and 1980 had been minimal.

Subsequent to <Appendix 2D D>, within the 50 mile circle, several earthquakes have occurred between 1980 and September 1991. The detection of some of the recent events reflects an improvement of the

national network coverage. During 1983, two small earthquakes occurred on January 22 and November 19, within 10 miles from PNPP, with respective magnitudes of 3.3 M_N or 2.7 m_{blg}, and 2.5 M_N. These events, being rather small, were not well recorded at John Carroll and distant stations. Because diverse locations had been calculated by different agencies, CEI was asked in the Spring of 1986 to review the discrepancies and determine if these events could have indeed occurred either near the Calhio wells or near the January 31, 1986 epicenter. By examining some seismograms of both events and performing sensitivity analyses on available arrival times, reading errors and model variations, it was concluded that a single relocation to 41.765°N and 81.110°W with an uncertainty of ±2 km was appropriate for both events, since insufficient data for the smaller event did not support a separate relocation (Reference 4). Average magnitudes of 3.0 and 2.3 m_{blg} have been adopted. Focal depths could not be determined.

The detection and location threshold in the fifty mile radius area has been greatly improved by the installation of the CEI and JCU seismic monitoring networks in 1986. Several microearthquakes, with Mc less than 3.0, but greater than -0.5, have been located in various areas. Those with Mc greater than 1.0 are listed on <Table 2.5-9> and illustrated on <Figure 2.5-58>.

On June 18, 1987, the CEI network detected a small earthquake, m_c = 2.7, in northwestern Pennsylvania, probably located near Adamsville, about 65 km from PNPP. The earthquake has not been reported by NEIS, as it probably was under the detection threshold.

On April 20 and June 27, 1988, several events (Mc between -0.1 and 2.7) occurred offshore north of Painesville, in or close to an area with a long history of underground salt mining. The possibility of cavern collapse was considered, but the mine owners reported no evidence of a collapse.

On July 13, 1987, a small earthquake (m_b = 3.6) occurred 2-3 km east of Ashtabula, Ohio, in the proximity of a deep (2 km) injection well. The aftershock sequence was studied by Armbruster et al (Reference 172). They conclude that this earthquake was likely induced by fluid injection. They cite the spatial proximity to the well (1 km), the large number of aftershocks (at least 36), the lack of historical seismicity in the area and the recent opening of the well as the basis for their hypothesis. The composite fault plane solution shows a vertical east-west nodal plane, chosen as the fault plane since it coincides with an east-west distribution of aftershocks. The seismic activity is spread within a zone 1.5 km long, 2 km in depth and 1/4 km wide.

Several other microearthquakes have occurred in 1989, 1990, and 1991 in the same Ashtabula area. They were clearly recorded by the CEI network which has a detection threshold of approximately Mc = 1.0 for an epicentral distance of 40 km. There is a noticeable tendency for these small events to occur in groups, a characteristic not observed with the purely tectonic activity at Leroy.

Two small events (Mc = 2.4, 1.2) occurred near Madison-on-the-Lake on December 25, 1988 and August 11, 1989. On March 31, 1988, a microearthquake (Mc = 2.8) occurred near Nelson, and on March 12, 1991 another event (Mc = 2.3) occurred between Solon and Aurora, where two events (Mc = 3.5) were reported in May and June 1955.

On January 26, 1991 (03h21 UT), a magnitude Mc = 3.5 event occurred offshore of Euclid, a suburb of Cleveland. It was well recorded by the JCU and CEI networks. The felt reports seemed to be predominately III and IV, although NEIS listed a few intensity V reports at locations far from the epicenter. A telephone survey was conducted to determine the limits of the total felt area. The latter was estimated at 7500 square kilometers, assuming symmetry over the lake. <Figure 2.5-213> illustrates the semicircular pattern around the epicenter. Reports

within Cleveland and immediate suburbs are not plotted. The interesting lesson learned from the data set is the similarity of felt reports collected along the shoreline, i.e. III and IV. Without the instrumental data, the epicenter would most likely have been placed on-land as far as Brecksville, on the basis of the larger felt reports. Once more, seismic locationing with instruments confirms the large uncertainty associated with locationing using low intensity reports, particularly in areas where soil amplification is suspected to take place. This applies to several older events for which reports are sparse and often controlled by a poor distribution of the population and newspapers.

Since the beginning of the monitoring of the corridor between the injection wells and the January 1, 1986 epicenter, from April 1987 to September 1991, CEI has recorded only three events with Mc greater than 1.0. These events (Mc = 1.3, 1.8, and 1.9) occurred on May 1, 1987, January 16, 1988, and March 22, 1989 respectively. They are located within 5 km to the east and south of the wells, and are surrounded by approximately fifty micro events with Mc varying from -0.5 to 0.5. The focal depths of all these events are relatively shallow, less than 2.5 km, compared to the depths observed in the Leroy area of 5 km (+/- 1km). Because of the relative proximity to the wells, the shallowness of depth, the occasional grouping of occurrences, and the fact that seismicity induced by injection has been proposed elsewhere in Northeastern Ohio, CEI considers these events to be potentially induced by the well operations.

Similarly, several events in the same magnitude range have been located by the CEI and JCU networks near Fairport Harbor where other deep injection wells have been in operation. They are also potentially related to injection. These conclusions were expressed in the Quarterly Reports submitted to the NRC (Reference 173).

2.5.2.1.2.4 The January 31, 1986 Earthquake

On January 31, 1986, at 11.46 EST, a moderate earthquake (m_b = 5.0) occurred in Leroy Township, near the boundary of Lake County and Geauga County, in northeastern Ohio. The preliminary epicentral coordinates calculated by NEIS on the basis of worldwide data was 41.649°N and 81.105°W. This location was revised by J. Dewey of the USGS (Reference 174) on the basis of a regional model, to 41.650°N and 81.162°W; these coordinates were confirmed later by the distribution of the aftershocks. The epicentral intensity was VI(MM), as shown on <Figure 2.5-65>, and IV-V(MM) at the plant itself, located 17 km north of the epicenter.

The Leroy earthquake sequence was studied in great detail by the applicant (Reference 4) (Reference 127) and the USGS (Reference 175) (Reference 128) (Reference 159), in an effort to determine the faulting parameters and to understand its tectonic origin and the significance of the high frequency, short duration strong motion observed at the plant site. The monitoring of aftershocks began less than 12 hours after the main event as several teams of observers converged to the epicentral area. The U.S.G.S. sent two groups, one from Menlo Park, California and one from Denver, Colorado. The Lamont-Doherty Geological Observatory, St. Louis University, the Tennessee Earthquake Information Center of Memphis State University, the University of Michigan, and the Electric Power Research Institute deployed field equipment. Two other teams supported by CEI, Weston Geophysical Corporation and Woodward-Clyde Consultants, deployed 13 MEQ-800 seismographs. Dr. R. B. Herrmann from St. Louis University organized an exchange of data between various observers, at least for the first month of monitoring. <Table 2.5-17> lists station codes, locations and periods of operation. To be noted is the fact that some observers stayed in the field for only a few days, some ten days and others one or two months. Only Weston Geophysical carried out prolonged and continuous monitoring for more than one year with portable equipment, under CEI sponsorship. <Figure 2.5-66> shows a

typical portable Weston's network configuration around the epicenter. <Table 2.5-18> gives the location parameters of the 21 aftershocks recorded over 5 years, with 12 occurring within the first three months. <Figure 2.5-67> shows the aftershock epicenters relative to the main shock epicenter. As mentioned earlier, the seismic monitoring of the main shock region since the Fall of 1986 has been assumed by John Carroll University which operates a five-station array, with telephone telemetry to its observatory.

The aftershock sequence of the Leroy earthquake appears to have terminated with the February 12, 1987 event. An eighteen month period of silence followed, after which two very small microearthquakes occurred in August and October 1988, followed by a larger event (Mc = 2.8) on December 28, 1988. This event had an intensity between III-IV near the epicenter and was felt over a relatively wide area for its size. It had no aftershock. A field and questionnaire survey was conducted. <Figure 2.5-214> shows the symmetry in the felt area, except for an anomalous elongation to the northeast, possibly related to rock anisotropy and soil amplification. It is an important finding that such a small event with a well instrumentally determined magnitude be felt so noticeably. This confirms what has been suspected for some time, that some small historical events have been assigned inferred magnitudes that are slightly too large. In September 1991, after twenty months of quietness, another small event (Mc = 1.5) occurred. The events occurring after February 12, 1987 may not be part of the aftershock sequence.

The results from the aftershock studies suggest that the original rupture length was approximately 1-1/2 km. The focal depths of the aftershocks vary from 3 to 6 km, in good agreement with a focal depth of the main shock estimated at 4 km by Herrmann on the basis of surface wave radiation (Reference 176).

The composite fault plane solutions obtained with some aftershock data are similar to a solution prepared for the main shock by the Harvard University group using special instruments around the world. <Figure 2.5-68> illustrates the main shock solution. In both cases, right lateral strike slip motion occurs on a steeply dipping plane, if the north-northeast-south-southwest nodal plane is assumed to be the fault plane. Some of the aftershocks suggest a different type of faulting; this second type shows more dip-slip motion and the compressional axes oriented north-northeast. Studies of both the main shock and aftershock faulting mechanisms have been conducted and are reported in Weston Geophysical (Reference 4) and Nicholson et al (Reference 159), or Wesson and Nicholson (Reference 128).

It should be remembered that fault plane solutions are essentially equivocal. The selection of which nodal plane is the real fault plane usually is based on external data, e.g., the presence of a known fault in the area, or the apparent elongation of the aftershock distribution. For this event, there is no known fault available; the aftershock pattern shows only a slight north-south elongation. The stereo view of the hypocenters gives a three dimensional picture of the aftershock pattern. On <Figure 2.5-69>, one can see the seismic activity along two fracture planes regardless of the nodal azimuths used. This is an important point, as it leaves open the possibility of a rupture along the other nodal plane. The recent Ashtabula (July 13, 1987) earthquake, and the St. Marys (July 12, 1986) event have both been given an east-west preferred orientation of the rupture plane, by Armbruster et al (Reference 172) and Christensen et al (Reference 2), respectively. These different cases imply that in Ohio, current faulting can occur along different orientations.

The January 31, 1986 earthquake is interpreted as being typical of the site tectonic province. It is moderate in size; it has relatively shallow focal depth; it conforms with the known regional stress field; it occurs in an area where no tectonic structure has been clearly

identified through geophysical methods, and where geologic mapping, surficial or stratigraphic, has not revealed any active faulting.

The natural origin of the January 31, 1986 earthquake was questioned by the U.S.G.S. immediately after its occurrence (Reference 128). Considering that two deep injection wells (1,800 meters), owned by Calhio and located 12 km to the north of epicenter, have been operating since 1975 and 1981, it was postulated on the basis of modeling that additional pressure at the base of the Paleozoic could have reached the hypocentral area through a system of cracks and triggered the m_b = 5.0 event. CEI, after reviewing a comparative study prepared by Talwani and Acree (Reference 127) of the Leroy earthquake sequence and that of other classic case histories, has concluded that, at this time, such a triggering mechanism is possible but with only a low probability. To study this question further, the applicant agreed to monitor the corridor between the two Calhio injection wells and the January 31, 1986 epicenter. After five years of detailed seismic monitoring, CEI continues to conclude that the Leroy earthquake was purely tectonic and unrelated to the deep injection wells located 12 km to the north. This conclusion, expressed in the Quarterly Reports submitted to the NRC, is based on several observations: 1. the Leroy epicentral area remains separated from the other cluster of micro events considered to be triggered by injection; 2. the focal depths of the two groups of events are different; and 3. the temporal patterns of occurrences are also different, all facts pointing to two distinct tectonic regimes (Reference 173). CEI has answered the question raised in 1986, regarding whether the Leroy earthquake was induced.

2.5.2.1.2.5 Seismic Activity between 50 and 200 Miles from PNPP

A diffuse cluster of historical seismic activity, centered approximately 185 miles south-southwest of the site, includes about ten events with a maximum intensity of VI-VII. The largest event (VI-VII MMI), on November 5, 1926 is reported to have damaged some chimneys in

Meigs County, Ohio and Letart, West Virginia (Reference 162). The magnitude inferred from the relatively small felt area is only 3.4 m_b. Such an anomaly could be explained by a shallow focal depth. Earthquakes in this area are not yet correlated with known or inferred geologic structures. The earthquake epicenters, however, lie within a northward trending zone of geophysical anomalies (Reference 177).

2.5.2.1.2.6 Seismic Activity beyond 200 Miles from PNPP but in the Site Tectonic Province: the Sharpsburg, Kentucky Earthquake of July 27, 1980

On July 27, 1980, at 18:52:21.8 UTC, an earthquake (5.1 m_b) occurred near Sharpsburg, Kentucky, in an area with no history of seismicity. Mauk et al (Reference 178), calculated the epicentral coordinates: 38.18°N, ±0.56 km, 83.94°W, ±0.46 km and a focal depth of 15.5 km, ±2.6 km. Gordon (Reference 157), in his recent catalog of revisions, gives slightly different parameters: 38.193°N, 83.891°W and a depth of 6.4 km, but points out that the focal depths in this zone are relatively imprecise. Taylor and Herrmann in 1989 (Reference 305) seem to favor the larger focal depth, probably because it was derived from the aftershock survey data. The total area of perceptibility was about 673,000 km sq. About sixty aftershocks were recorded in the first fourteen days. The in-depth analysis of Herrmann et al (Reference 179), gives a moment of 4.1 x 10^{23} dyne-cm, a focal depth estimate of 12 km, a surface wave mechanism with a nodal plane striking N30°E, dipping 50°SE and a nearly vertical nodal plane striking N60°W. The P-wave first motion data indicate a right lateral motion, with pressure axes oriented east-west.

A maximum Intensity VII(MM) was definitely observed at Maysville, Kentucky, about 45 km north of the epicentral area where an Intensity VI(MM) seems to have prevailed, but where some VI-VII and VII intensities were also reported. These differences in I_o are discussed by Mauk et al., and seem related to variations of the questionnaires

used and conservatism of the interpreters. <Figure 2.5-70> shows some isoseismals and data points. Somehow the I_o is currently carried out by several authors as an Intensity VII(MM), most likely because the damage in Maysville can be attributed not only to soil conditions and age of construction but also to rupture orientation, i.e., from southwest to northeast.

Keller et al (Reference 180) has noted the spatial correlation between the epicenter and a potential rift of Keweenawan age. As pointed out by Street et al (Reference 181), the epicenter is not apparently related to the present Lexington Fault Zone, nor the Kentucky River Fault Zone. Street et al (Reference 181) have inferred, from four years of refraction studies using quarry blasts, the presence of a sharp velocity discontinuity (6.15 km/s to 6.9 km/s) in the Precambrian basement near the assumed location of the earthquake rupture plane. They proposed that such a feature could have been the cause of stress concentration, later released by the earthquake. It does not appear that this finding is in opposition to the rift theory.

The Sharpsburg event is located 265 miles from the PNPP; it is in the site tectonic province and, because it is not clearly related to a known fault or structure, is the maximum historical earthquake whose occurrence should be considered possible in the immediate vicinity of the plant.

It should be noted that on September 7, 1988, a moderate size event (M_{blg} = 4.3) occurred about 11 km to the southest of the 1980 Sharpsburg epicenter (Reference 305). Its focal depth was shallow (4 to 7 km), and the rupture motion was right lateral strike-slip on a northwest dipping plane. In January 1990, a smaller event (Mc = 3.1) was also located in the same general area.

2.5.2.2 Geologic Structures and Tectonic Activity

2.5.2.2.1 Introduction

Two nationally recognized studies were underway in the 1980's to examine probabilistic seismic hazard at nuclear power generation sites in the Eastern United States. These studies include: 1) "Seismic Hazard Analysis" prepared for the Nuclear Regulatory Commission by the Lawrence Livermore National Laboratory <NUREG/CR-1582>, LLNL, October 1981); and 2) "Seismic Hazard Methodology" prepared for the Seismicity Owners Group (SOG), a group of supporting Utilities, by a team of consulting groups coordinated by the Electric Power Research Institute (EPRI NP-4726, July 1986). The EPRI Study was developed for SOG as a mechanism to close the "Charleston Issue" which had been raised by the United States Geological Survey (USGS) in 1982.

Both of these studies rely on expert opinions on potential sources of future seismic activity throughout the Eastern United States. Individual experts (LLNL study) and teams of experts (EPRI study) were requested to produce maps of potentially seismically active areas and to estimate the earthquake recurrence frequencies within each mapped seismic source zone. The final EPRI Report (NP-6395-ND, EPRI, April 1989) (Reference 307) was submitted to the NRC for closure of the Charleston Issue in April 1989. This report concluded that the possibility of large earthquakes in the Central and Eastern United States is small and does not significantly increase the seismic risk at nuclear power plant sites. The NRC has reviewed the complete set of EPRI data for 57 nuclear sites and concluded that the Charleston Issue is closed for all plants except 8 "outliers" (PNPP is not an outlier). No further analysis will be required as documented in <Generic Letter 88-20>, Supplement 4, <NUREG-1407> "Procedural and Submittal Guidance for the Individual Examination of External Events for Severe Accident Vulnerabilities."

It is noted that seismic source zonations developed during the courses of these two major projects were done independent of any formal criteria for definition of tectonic provinces or tectonic structures given in <Appendix 2A>. An option was made available for experts, or expert teams, to define seismic source zones purely on the basis of the observed pattern of seismicity, with no attention being paid to consistency of underlying geologic conditions. The EPRI study included an intermediate element of definition of a tectonic framework based on review of an abundance of geologic and tectonic data in an effort to geologically support subsequent maps of seismic source zones. Seismic zonations, however, were not constrained to strictly conform to features identified in the tectonic framework; the zones could, and in many cases did, encompass patterns of seismicity in preference to a mapped tectonic boundary. Based on the specific goals required to formulate input data for a probabilistic seismic hazard assessment, the resulting seismic zonations produced by these studies are not strictly in conformance with the criteria of <10 CFR 100, Appendix A> for definition of tectonic provinces or structures; however they are useful for estimating seismic hazard. Maps of seismic source zones are available in LLNL and EPRI reports and are not further discussed, but may be consulted for a general overview of potential wide scale interpretations of seismic source zones beyond the local region. Results of the EPRI study are provided in <Section 2.5.2.4.3>.

2.5.2.2.2 Regional Provinces

The site is located in the central portion of the Eastern Stable Platform tectonic province <Figure 2.5-59>. Geologically, the province consists of a highly deformed Precambrian basement of Grenvillian age which is overlain unconformably by generally undeformed Cambrian through Permian shales, sandstones, and carbonates (Reference 19) (Reference 73). The western boundary of the Eastern Stable Platform is defined by the coincidence of structures in the Paleozoic rocks and in part by the subsurface trace of the Grenville Front, where low-angle

thrust faulted metamorphic rocks of Grenvillian age abut essentially undeformed unmetamorphosed granites, rhyolite and supracrustal continental deposits of Elsonian (1,450 million years ago) and Keweenawan (about 1,100 million years ago) ages. The northern boundary of the province is marked by west-northwest-trending block faulting in the Ottawa-Bonnechere graben in south-central Ontario, Canada (Reference 74) (Reference 75). The southern boundary is defined by the eastward-trending Kentucky River fault zone and underlying Rome trough (Reference 21) (Reference 34) (Reference 76) <Section 2.5.1.1.5.2>.

The eastern margin of the province is transitional and is placed along the zone where northeastward-trending folding and east over west thrust faulting become apparent in sedimentary formations of the Appalachian Plateau (Reference 40).

Within 200 miles of the site, the following tectonic provinces or parts of tectonic provinces are found: the Eastern Stable Platform (site province); the Michigan Basin; Central Province; Applachian Plateau Province; and the Northern Valley and Ridge Province <Section 2.5.1.1.5.1> <Section 2.5.1.1.5.2>.

2.5.2.2.2.1 Eastern Stable Platform

The Eastern Stable Platform province is generally characterized by a crystalline basement terrane of metamorphic, sedimentary and igneous rocks which last consolidated to a crustal block during the Grenvillian orogeny (1,100 to 900 million years ago) (Reference 19) (Reference 73). The surface of the crystalline basement slopes gently to the southeast from a series of elongated topographic arches along the western part of the province and is buried beneath a southeast-thickening, little-deformed sequence of Paleozoic sedimentary formations of platform derivation. Precambrian, northwestward directed, low-angle thrust faults, which are locally reactivated as normal faults offset down to

the southeast, extend from the eastern boundary of the province to the Grenville Front on the west (Reference 83).

The only faulting in the province which some investigators assume to be active is on the Clarendon-Linden fault zone, near Attica, New York (Reference 40). Seismic activity spatially correlated with the central portion of this fault system is discussed in <Section 2.5.2.1.2.2>. No capable faults or evidence for young deformation or Quaternary movement have been reported.

For further details of the bedrock geology, tectonic elements and geologic history of the province, see <Section 2.5.1.1>, <Section 2.5.1.1.5>, and <Section 2.5.1.1.6>. The bedrock geology of Ohio is shown on <Figure 2.5-4>, and the tectonic elements and province boundaries are shown on <Figure 2.5-59>.

2.5.2.2.2.2 Michigan Basin

The Michigan Basin is a broad, shallow structural depression which underlies the lower Michigan peninsula, part of the Upper Peninsula, eastern Wisconsin, northern Illinois, Indiana, Ohio, and southwestern Ontario. A maximum thickness of 14,000 feet of Paleozoic sediments (Cambrian-Pennsylvanian), in the center of the basin, overlies a deeply eroded Precambrian basement surface. The perimeter of the Michigan Basin is bounded by the Wisconsin arch and dome to the west, Canadian shield to the north, Indiana-Ohio platform to the southwest, and Findlay/Algonquin arch to the southeast and east. These positive features in the Precambrian surface acted as relatively stable “platforms” about which the Michigan, Illinois and Appalachian basins subsided. Gravity and magnetic data, and limited borings indicate a complex Precambrian basement including Keweenawan igneous, Grenville and Central terrane lithologies. Precambrian structural zones related to these diverse terranes apparently did not control the overall development of the Michigan Basin.

For further details of the bedrock geology, tectonic elements and geologic history of the province, see <Section 2.5.1.1>, <Section 2.5.1.1.5>, and <Section 2.5.1.1.6>. The tectonic elements and province boundaries are shown on <Figure 2.5-59>. The distribution of earthquake epicenters within the province appears on <Figure 2.5-56>.

2.5.2.2.2.3 Appalachian Plateau Province

The Appalachian Plateau Province in the site region is a broad synclinal basin feature characterized by Grenvillian-age basement overlain unconformably by a thick section of moderately folded Upper Paleozoic red shale and sandstone overlying Lower Paleozoic shales, carbonates and sandstones.

For further details of the bedrock geology, tectonic elements and geologic history of the province, see <Section 2.5.1.1>, <Section 2.5.1.1.5>, and <Section 2.5.1.1.6>. The tectonic elements and province boundaries are shown on <Figure 2.5-59>. The distribution of earthquake epicenters within the province appears on <Figure 2.5-56>. Historical data suggest that this region is essentially aseismic.

2.5.2.2.2.4 Northern Valley and Ridge Province

The Northern Valley and Ridge Province in the site region consists of very deeply buried, metamorphosed, Grenvillian-age, Precambrian basement overlain by a thick section of Paleozoic sedimentary rocks (Reference 40). The Paleozoic rocks have been deformed into a series of north-northeastward trending, steeply inclined to overturned folds and associated southeastward-dipping thrust faults.

According to Rodgers, deformation in the Northern Valley and Ridge Province is due to a sequence of events which commenced with stripping or detachment of much of the Paleozoic section from the underlying rocks at the horizon of incompetent Lower Cambrian shales (Reference 40). The

subsequent folding of the detached Paleozoic section seems to have been in response to compressional stress from the east and southeast during the Alleghenian orogeny, about 250 million years ago (Reference 40).

For further details of the bedrock geology, tectonic elements and geologic history of the province <Section 2.5.1.1>, <Section 2.5.1.1.5>, and <Section 2.5.1.1.6>. The tectonic elements and province boundaries are shown on <Figure 2.5-59>. The distribution of earthquake epicenters appears on <Figure 2.5-56>.

2.5.2.2.2.5 Central Province

The Central Province is characterized by a Precambrian basement terrane of essentially unmetamorphosed, predominantly felsic, igneous rocks of Elsonian age (about 1,450 million years ago) locally enclosing rift basins and troughs of Keweenawan age (about 1,100 million years ago) (Reference 18) (Reference 20) (Reference 73). The surface of the crystalline basement over a wide area is nearly horizontal to gently southward-dipping, and is buried beneath a thin cover of relatively little-deformed, flat-lying Paleozoic sedimentary formations of platform derivation.

Within 200 miles of the site, the only faulting in the central province which investigators believe could be active is in the vicinity of Anna, Ohio, where two north-northeastward trending normal faults and one northwestward trending normal fault have been mapped on the basis of subsurface data (Reference 44) (Reference 1) (Reference 43) (Reference 2). Seismic activity correlated with these faults is discussed in <Section 2.5.2.1.2.1>.

For further details of the bedrock geology, tectonic elements and geologic history of the province, see <Section 2.5.1.1>, <Section 2.5.1.1.5> and <Section 2.5.1.1.6>. The bedrock geology of Ohio is shown on <Figure 2.5-4>, and the tectonic elements and province

boundaries are shown on <Figure 2.5-59>. The distribution of earthquake epicenters in the zone is shown on <Figure 2.5-56>.

2.5.2.3 Correlation of Earthquake Activity with Geologic Structures or Tectonic Provinces

The seismicity of the site region was described in <Section 2.5.2.1.2> as occurring in several distinct clusters, rather than being uniformly distributed. These zones of low to moderate seismic activity can be seen on <Figure 2.5-60> as more prominent than the surrounding background which appears to be almost aseismic in many areas of the region.

Because these clusters have been active at some point during historical or recent times, their locations are indicative of zones of crustal weakness where accumulated strain energy is periodically released. They indicate structural and/or lithological inhomogeneities which may or may not be revealed by geophysical investigations. For the most part, magnetic and gravity anomalies do not correlate with seismic activity.

In the Attica, New York area, seismic activity has been positively correlated with a section of the Clarendon-Linden fault system (Reference 1) (Reference 182) (Reference 169) on the basis of a spatial coincidence of epicenters with known zones of faulting, and the agreement of fault plane solutions with fault orientations. With respect to the seismicity near Anna, Ohio, inferred faults in basement rocks are found in close spatial relation with epicenters of the larger earthquakes, suggesting an explanation for the repeated seismic activity (Reference 1) (Reference 2). In the area of northeastern Ohio no structural correlation with seismic activity has been made.

2.5.2.4 Maximum Earthquake Potential

The selection of the maximum earthquake potential at the site is made in a two-step consideration. First, the earthquake catalog and related seismological data, such as isoseismal maps, are analyzed in order to estimate the highest seismic intensity experienced at the site. Second, the maximum intensity at the site, expected from the occurrence of maximum hypothetical earthquakes in the site province and in adjacent provinces, is determined using the tectonic province approach as defined in <10 CFR 100, Appendix A>. The largest intensity assessed using these two methods will provide a basis for selecting the maximum earthquake potential for the site.

2.5.2.4.1 Site Intensities from Historical Events

In <Section 2.5.2.1.2>, the length and usefulness of the historical seismic record was discussed. Even though a period of two centuries constitutes a short sampling of geological time, it provides a valuable insight of regional seismicity, with respect to both its level and spatial distribution. <Table 2.5-19> lists the location, epicentral intensity, distance to the site, and site intensity for historical earthquakes known to have occurred in the 200-mile radius region, and of other large earthquakes farther away, which may have been felt at the site with an intensity greater than III. In some cases where many events are clustered together, only the larger events from each cluster of repeated activity are listed.

Intensities at the site resulting from historical earthquakes have been estimated using alternative attenuation models and through interpretations of published isoseismal maps. The first attenuation model used (Reference 183) predicts the intensity at a given distance based on the maximum epicentral Intensity I_o. This relationship, presented on <Figure 2.5-73>, in comparison with other relationships, can be evaluated as predicting conservative estimates of site intensity.

The conservatism results from the manner in which the model was conceived, namely by interpreting isoseismal maps to measure the maximum distances at which various intensity levels were observed for a set of historical Eastern U.S. earthquakes. The resulting model provides an estimate of the maximum intensity at a particular distance, because the observations of a given intensity level at distances shorter than the maximum distance were not included. The resulting model, therefore, is well suited to estimate intensities at sites that may characteristically have amplified seismic ground motions, such as on soft alluvial deposits.

An alternative method of interpretation of intensity attenuation is to perform statistical analyses directly on the original felt report data sets (Reference 184), in a manner identical to that generally employed to derive attenuation functions for instrumentally-measured ground motion parameters, such as peak acceleration (Reference 185) (Reference 186). This direct assessment of intensity attenuation (i.e., it does not depend on prior isoseismal contouring), produces a model that predicts a median estimate of intensity at a particular distance and an uncertainty bound. In addition, this direct interpretation can provide intensity attenuation scaled to the earthquake size, specified in terms of magnitude m_b rather than to the maximum intensity, which is an observed effect. Models developed by this direct statistical approach are useful for determining the average (median) intensity at a particular distance from an earthquake of known or estimated magnitude. Therefore, such models are useful for estimating intensities at sites founded on firm or rock foundations, such as the foundations present at the PNPP site.

Site intensities resulting from all events in the earthquake catalog for the site region are estimated using a model developed on the basis of statistical interpretations of several Central and Eastern U.S. earthquakes for which both instrumental magnitudes and extensive felt report data were simultaneously available (Reference 187)

(Reference 188). Median predictions of site intensity for catalogued earthquakes, based on this model, are compared in <Table 2.5-19>, to those made by the more conservative isoseismal-based Gupta and Nuttli model. Site intensities predicted by the two attenuation models are compared on <Figure 2.5-74>. Shown on this figure are attenuation curves for an event similar to the January 31, 1986 Northeastern Ohio earthquake with a magnitude of 5.0 mb and a maximum epicentral intensity of VI. The Gupta and Nuttli (1976) model is illustrated to overpredict the maximum intensity of V (at an epicentral distance of 17 km) observed at the PNPP-1 site by one intensity level. The alternative attenuation model, however, is shown to provide a more accurate estimate of the observed site intensity.

Finally, site intensities observed from available published isoseismal maps are compared, where applicable, on <Table 2.5-19>, to intensities estimated using the two attenuation models. These isoseismal maps are presented on <Figure 2.5-75>, <Figure 2.5-76>, <Figure 2.5-77>, <Figure 2.5-78>, <Figure 2.5-79>, <Figure 2.5-80>, <Figure 2.5-81>, <Figure 2.5-82>, <Figure 2.5-83>, <Figure 2.5-84>, <Figure 2.5-85>, <Figure 2.5-86>, and <Figure 2.5-215>. A list of newspapers consulted to verify some of the intensities for major events is presented in <Table 2.5-20>.

Following the occurrence of the January 31, 1986 northeastern Ohio earthquake, detailed intensity surveys were conducted for the region of northeastern Ohio surrounding the epicenter and for the immediate site locale. Based on these surveys, it was concluded that the highest epicentral intensity was VI (MM Scale), and the maximum site intensity was V (MM Scale). The isoseismal map for the January 31, 1986 earthquake is shown on <Figure 2.5-65> (Reference 189). Intensities at the PNPP site were carefully studied by contacting numerous personnel that were on site during the earthquake’s occurrence. It was concluded, based on this detailed investigation, that the maximum intensity at the site was V (MM Scale). The predominant intensity (approximately 75% of

the 80 site intensity reports collected) observed on site was IV. Maximum effects, evaluated as Intensity V (MM Scale) were reported for temporary structures, such as trailer offices or at upper levels of pre-fabricated, metal office structures. Lower intensities were generally reported for permanent, well-built or engineered structures. A map of intensities documented for the PNPP site for the January 31, 1986 earthquake is shown on <Figure 2.5-87>.

Seismic ground motions generated by the January 31, 1986 earthquake were instrumentally-recorded at several points on the PNPP reactor containment building (Reference 190). These broad-banded (i.e., frequency resolution to 40 Hz) accelerogram recordings illustrated an enriched high-frequency spectrum in comparison to the available data set of worldwide recordings for similar magnitude earthquakes at similar epicentral distances of nearly 20 km. The ground motions recorded at the plant illustrated prominent peaks at frequencies greater than 20 Hz, whereas the available worldwide accelerogram data, would suggest dominant spectral peaks at frequencies less than 10 Hz and little spectral energy at frequencies greater than 15 Hz. Given that the spectral shape employed during seismic design and licensing proceedings for the PNPP site relied entirely on statistical analyses performed on available worldwide accelerogram data (Reference 191) (Reference 192) (Reference 193), the resultant design spectral shape illustrated low amplitudes of high frequency ground motions. The enriched high frequency spectrum for the January 31, 1986 earthquake, which is not characteristic of the worldwide set of accelerograms, therefore, exceeded the original design basis at frequencies greater than 15 Hz; the amount of this exceedance is illustrated on <Figure 2.5-88>. This high-frequency exceedance of the design basis response spectra is addressed further in <Section 3.7>. The short duration, high-frequency nature of the January 31, 1986 accelerograms is clearly illustrated by comparison on <Figure 2.5-89> to the PNPP design time history, characterized by long duration and high energy content.

Low-frequency components, less than 10 Hz, were extracted from the January 31, 1986 accelerograms using digital filtering techniques. Response spectra for the low, and intermediate frequency horizontal component records are compared on <Figure 2.5-90> to response spectra derived for worldwide accelerograms recorded in the vicinity of Intensity V (MM Scale) effects (Reference 194). This comparison illustrates a good agreement of the lower frequency spectral amplitudes observed for the January 31, 1986 earthquake and spectral amplitudes typical of Intensity V effects. The recent earthquake's observed effects can thus be entirely attributed to the lower frequency ground motion components which are associated with longer durations and higher particle velocities and displacements. The observed high frequency ground motion components, characterized by short durations and extremely small displacements, are unrelated to the Intensity V effects observed at the plant site during the January 31, 1986 earthquake as identified in the analytical studies described in <Section 3.7>.

The highest seismic intensity observed or estimated for the vicinity of the PNPP site resulting from known earthquake activity is Modified Mercalli V. This level is believed to have occurred during the largest of the New Madrid earthquakes on February 7, 1812, and also during the recent January 31, 1986 earthquake. Several estimates of site intensity, based on the conservative Gupta and Nuttli attenuation model (Reference 183), exceed V and range to maximum of VI. These conservative estimates, however, are illustrated on <Table 2.5-19> to overestimate observed intensities for events that have published isoseismals. Intensity estimates derived on the basis of the alternative median attenuation model, however, agree well with the few published isoseismal maps. Thus, relying on the median site intensity estimates and the published intensity maps, it is concluded that the maximum intensity at PNPP site is V, and that this level occurred twice during the historical period.

2.5.2.4.2 Site Intensities from Hypothetical Events

The Perry site is located in the Eastern Stable Platform Province. On the basis of lithological differences in basement rocks, the Eastern Stable Platform is considered to be a separate tectonic entity from the Central Stable Province <Figure 2.5-8> and <Figure 2.5-59>.

The seismicity of the site province has been discussed in <Section 2.5.2.1.2.2>, <Section 2.5.2.1.2.3>, and <Section 2.5.2.1.2.4>. In summary, the largest historical event (based on observed MM Intensity = VIII) near Attica, New York, and some nearby seismic activity have been correlated to the Clarendon-Linden fault system. Within the site tectonic province, the remaining clusters of seismicity in northeastern Ohio, and in south-central Ohio and northeastern Kentucky (Sharpsburg earthquake epicentral area) remain uncorrelated to specific tectonic structures. Seismic activity in western Ohio, near the town of Anna, is situated in the Central Stable Platform tectonic province. As for the case of the activity near Attica, New York, the seismicity near Anna, Ohio, is spatially correlated to a set of intersecting faults and remotely sensed lineaments (Reference 2).

Available geologic and seismologic data for the predominant zones or diffuse clusters of seismicity in the site region, located in the Eastern Stable and Central Stable Platform tectonic provinces have been described in previous sections. These data reveal certain similarities and some differences among these concentrations of historical seismic activity. First, the local crustal structure for each of the regions includes a relatively thin Paleozoic sedimentary section overlying Precambrian basement. Three of the clusters are located in Grenvillian basement; while the last cluster at Anna is located west of the Grenville Front in a transitional terrain between Grenvillian and Central (Superior) Province basement lithologies.

The entire site region is currently being subjected to a continental-scale stress field, wherein the principal stress component is horizontal, compressive and oriented in a northeast to east-northeast direction (Reference 195) (Reference 196). The region encompassing the clusters of seismicity, in addition, is characterized by numerous geophysical anomalies and lineations with intersecting trends observed using remote sensing techniques. These anomalies and lineaments suggest a complex, heterogeneous basement structure underlying the site province and adjacent Central Stable province. The pattern of historical seismicity suggests further that the region is capable of producing moderate magnitude seismic events ranging to slightly greater than 5.0 m_b during the historical period. <10 CFR 100, Appendix A> provides alternative approaches for establishing the maximum earthquake potential at a particular site. The tectonic province approach is applicable to the PNPP site.

Seismic activity near Attica, New York, (largest event of Intensity VIII (MM Scale), Magnitude 5.2 m_b, in 1929) is associated with the Clarendon-Linden tectonic structure (Reference 197). Recent seismic activity, accurately located using a local seismographic network, indicates a close spatial association of activity with the Anna-Champaign Fault, a northwest-trending fault mapped in the basement and overlying Paleozoic section. This local region includes other faults including the Auglaize and Bowling Green Faults, and pronounced lineaments interpreted from satellite images.

Although the Attica seismicity has been associated with a local tectonic structure, and the Anna activity can similarly be associated with locally-identified structures, the present state of knowledge on these buried features does not permit an accurate estimation of the maximum earthquake potential attributable to these structures, based on their physical dimensions and characteristics. Gross dimensions of affected crust can be inferred from the nature of geophysical anomalies, geophysical modeling studies, and from earthquake main shock and

aftershock hypocentral distributions. None of these available techniques, however, can presently provide the necessary detailed information on fault rheology (i.e., strength characteristics) and geometries, most critically, on fault segmentation, which are required in order to determine theoretical maximum earthquakes for a tectonic structure on the basis of physical, dimensional arguments.

Presently available data that are attributed significant value for estimating earthquake potential are focal depths of seismicity accurately determined by local monitoring networks. Recent seismicity in the clusters of activity in the site region have generally illustrated focal depths in the upper 10 km of the crust. The deepest activity is evidenced for the Anna, Ohio, and Sharpsburg, Kentucky, epicentral regions where focal depths have ranged to around 15 km. Available hypocentral information for the Attica and northeastern Ohio regions reveal shallower focal depths near 5 km.

Maximum earthquake potential is directly related to the dimensions of fault surface capable of failing in a single earthquake event (Reference 198). It is presently well-documented through regional and local seismographic monitoring for the past decade that regions of eastern North America, including La Malbaie, Quebec, Canada, and New Madrid, Missouri, which have experienced large historical events (Magnitude 6.5 and greater) presently generate earthquake activity at hypocentral depths ranging from near surface to depths of 20 to 30 km (Reference 199) (Reference 200) (Reference 201) (Reference 202). This focal depth information illustrates the necessity of deep crustal involvement for the potential of generating large intraplate earthquakes. It is important to note that such deep crustal involvement is not observed in the site region based on the available shallow focal depths determined by recent seismologic studies supported by dense seismographic monitoring.

The maximum earthquake potential for the PNPP site is established using the "tectonic province" approach. This approach is supported on the basis of the consistency of geologic conditions throughout the site region, a consistent regional stress field, patterns of geophysical anomalies, and the diffuse pattern of seismicity that includes several clusters of increased activity observed historically. Frequency of earthquake activity, determined from the available earthquake history is similar for the clusters of increased activity. The maximum historical event in the adjacent tectonic province within 200 miles is an estimated 5.3 m_b for the 1875 Anna, Ohio, earthquake. Re-evaluations of magnitudes of the Anna, Ohio, events (Reference 163) suggest that none of the historical events exceeded 5.0. In addition, the maximum Attica earthquake of August 1929 is assigned a magnitude of 5.2 m_b. The recent Sharpsburg, Kentucky, and Northeastern Ohio earthquakes have instrumentally-determined magnitudes of 5.1 and 5.0, respectively. The maximum earthquake potential for the site is represented by the occurrence, at the site, of a moderate magnitude event, slightly larger than the maximum historically observed event.

For the purpose of establishing seismic design response spectra, the maximum earthquake potential is characterized by a magnitude of 5.3 m_b and a maximum site intensity of VII. These characteristics of the maximum earthquake potential equate to an event containing approximately twice the seismic energy (approximately twice the amplitude of lower frequency ground motions), and seismic intensities two full increments greater than that associated with the occurrence of the northeastern Ohio earthquake of January 1986.

2.5.2.4.3 EPRI Seismic Hazard Study Results

Both the LLNL and EPRI probabilistic seismic hazard investigations identified in <Section 2.5.2.2.1> are now completed. In both of these

studies probabilistic seismic hazard has been computed for the approximately 70 nuclear plant sites located in the central and eastern United States.

Final results of these investigations are published in the following reports: 1) "Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains," <NUREG/CR-5250>, UCID-21517, LLNL, January 1989; and 2) "Probabilistic Seismic Hazard Evaluation at Nuclear Plant Sites in the Central and Eastern United States: Resolution of the Charleston Issue," NP-6395-ND, April 1989 (Reference 307).

In addition to EPRI's NP-6395-ND report on generic topics, such as descriptions of input assumptions and computational methodologies, individual site reports were published to document seismic hazard results for the various plant sites. For the case of the Perry Nuclear Power Plant site, EPRI issued a report entitled "Probabilistic Seismic Hazard Evaluation for the Perry Nuclear Power Plant," Project RP 101-53, EPRI, April 1989 (Reference 308). Probabilistic seismic hazard at the PNPP site provided in the site report was computed using the EQHAZARD computer package developed for the EPRI project and input parameters supplied by six earth-science expert teams that participated on the project.

Probabilistic seismic hazard is defined as the annual probability of exceeding a particular ground motion amplitude at the site. Typically, probabilistic seismic hazard is defined over broad ranges of annual exceedance probabilities (i.e., 10^{-2} to 10^{-5}), and ground motion amplitudes (i.e., .01g to 1.0g) to establish seismic hazard curves in the form of uniform hazard spectra for selected annual exceedance probabilities. The uniform hazard spectra for PNPP at three annual probabilities of exceedance (10^{-3}, 10^{-4}, 10^{-5}) are shown on <Figure 2.5-212> with selected points highlighted on <Table 2.5-74>. The annual probability of exceeding varying levels of Peak Ground Acceleration (PGA) are shown on <Figure 2.5-211> and selected points in

<Table 2.5-73>. The results indicate that the annual median probability of exceeding 150 cm/sec^2 (about .15g) PGA is 4.25 x 10^{-5}, which is not considered an increase in seismic hazard for PNPP.

2.5.2.5 Seismic Wave Transmission Characteristics of the Site

The plant foundations are underlain by bedrock consisting of Chagrin shale. Compressional wave velocities of the bedrock materials range from 9,000 to 11,000 feet per second, and shear wave velocities range from 4,000 to 4,900 feet per second. <Table 2.5-21> is a summary of the seismic velocities and the resultant modulus values. The complete report of the in situ velocity measurements is included as <Section 2.5.4.4>.

There are no unusual conditions at this site which would affect seismic wave transmission. This was verified following the January 31, 1986 event by analyzing aftershock spectra and comparing these to the main shock spectra. Similarities were observed among spectra at the remote locations for the aftershocks and for the plant main shock records. These similarities (Reference 4) indicate that ground motion transmission characteristics are consistent throughout the site region and that no unusual condition exists specifically at the PNPP-1 site.

2.5.2.6 Safe Shutdown Earthquake (SSE)

From the site intensities either observed or postulated in <Section 2.5.2.4.1> and <Section 2.5.2.4.2>, an Intensity VII (MM) is chosen for the maximum earthquake potential. On the basis of the intensity acceleration relationships of Gutenberg and Richter, Neumann, and Trifunac and Brady, presented on <Figure 2.5-91>, an acceleration in the range of 0.07g to 0.13g corresponds to such an Intensity VII (MM) (Reference 203) (Reference 287) (Reference 3). If the larger value is accepted, the present design value of 0.15g is adequately conservative under <10 CFR 100, Appendix A>, "Seismic and Geologic Siting Criteria."

Three artificial ground motion time histories, two for horizontal motion and one for vertical motion, were generated using a procedure described below. The acceleration time histories for the motion H1, H2 and V are shown in <Figure 2.5-92>, <Figure 2.5-93>, and <Figure 2.5-94>, respectively. Each has a maximum acceleration exactly equal to 0.15g (i.e., the SSE peak acceleration) and a total duration of 22 seconds. The corresponding velocity-time and displacement-time histories are shown in <Figure 2.5-95> and <Figure 2.5-96> for horizontal motion H1, in <Figure 2.5-97> and <Figure 2.5-98> for horizontal motion H2, and in <Figure 2.5-99> and <Figure 2.5-100> for the vertical motion. The computed response spectra of the artificial motions closely match the design response spectra published in the Nuclear Regulatory Commission (NRC) <Regulatory Guide 1.60> (Reference 191). The SSE response spectra for 0.5, 2, 5, 7, and 10 percent damping are shown in <Figure 2.5-101> for horizontal motion, and in <Figure 2.5-102> for vertical motion. The computed response spectra (for 2, 5, 7, and 10 percent damping) are shown together with the corresponding design response spectra, in <Figure 2.5-103> and <Figure 2.5-104> for horizontal motion H1, in <Figure 2.5-105> and <Figure 2.5-106> for horizontal motion H2, and in <Figure 2.5-107> and <Figure 2.5-108> for the vertical motion. The response spectra in <Figure 2.5-103>, <Figure 2.5-104>, <Figure 2.5-105>, <Figure 2.5-106>, <Figure 2.5-107>, and <Figure 2.5-108> were calculated at 200 period values T_i equally spaced on a logarithmic scale and ranging from T_i = 0.02 seconds to T_{200} = 4 seconds.

For those few period values between 0.02 seconds and 1 second where the computed response spectra lie below the design response spectra, the differences in the values of the response spectra are always less than 6 percent for the first horizontal motion time history, less than 6.5 percent for the second horizontal motion time history, and less than three percent for the vertical motion time history.

The procedures used to develop standardized response spectral shapes, such as U.S. NRC <Regulatory Guide 1.60> (Reference 191), are viewed to result in conservative predictions of lower frequency, and potentially more damaging seismic ground motions, than the design intensity of VII that was originally being modeled. This conservatism is illustrated by comparison of the PNPP SSE response spectrum to actual spectra derived for strong motion recordings in areas of Intensity VIII effects (Reference 194). These comparisons, shown on <Figure 2.5-109>, support the conclusion that the original design basis is a conservative representation of seismic ground motion associated with the selected maximum earthquake potential of 5.3 m_b and site intensity of VII. The design basis is shown on this figure as exceeding the average spectrum for Intensity VIII effects produced at relatively short distances by earthquakes in the magnitude range of 5.9 to 7.1 M_L (Reference 194).

The apparent conservatism of the procedure used to develop the SSE response spectrum is further illustrated by Site Specific Response Spectra (SSRS) derived in response to Question Q230.6. One SSRS derived at that time in response to the NRC's question is illustrated in comparison to the PNPP SSE. This comparison shows the SSE to be near the 84th percentile of the SSRS for frequencies in the range of 5 to 20 Hz, and well above the 84th percentile at frequencies lower than 5 Hz. It is noted that several differing sets of earthquakes were analyzed during preparation of responses to Q230.6. The SSRS shown on <Figure 2.5-110> is for the most conservative set of magnitudes and epicentral distances; the average magnitude of that particular set of earthquakes is 5.7 (±.37) at an average distance of 12.9 (±5) km. The earthquake magnitudes ranged to 6.1 M_L.

It is evident from the comparisons shown on <Figure 2.5-109> and <Figure 2.5-110> that the approved SSE response spectrum, modeled for the selected maximum earthquake potential of a 5.3 m_b (±.5) and Intensity VII, can, in fact, accommodate the local occurrence of a theoretically remote earthquake (i.e., move a large regional event to

the site locale) significantly larger than any observed during the historical period. On the basis of the results shown on these figures, it is concluded that the PNPP design basis can resist intermediate and lower seismic ground motion frequencies associated with locally occurring events with magnitudes significantly greater (a minimum 0.5 m_b units) than the selected maximum earthquake potential of 5.3 m_b.

2.5.2.6.1 Motion Generation Procedure

The basic parameters needed to generate samples of artificial earthquake records are the general level of intensity of the motion, its duration, the variation of motion intensity with time (the function I (t)), and its frequency content (Reference 204) (Reference 205). The intensity can be expressed as the (expected) peak ground acceleration (Reference 206). In this case, the maximum ground acceleration, 0.15 g, is used. The duration and relative variation of the intensity during the earthquake were estimated using methods developed at Massachusetts Institute of Technology (Reference 206) (Reference 207). The specification of relative frequency content is in terms of the power spectral density function, $G(\omega)$, which expresses the relative value of the expected "power" at each frequency, ω. The first estimate of the shape of this function, $G^{(1)}(\omega)$, can be derived from the desired 2 percent (design) response spectrum S_V (Reference 205).

The ground motion characteristics estimated above become the input to a computer program which generates samples of a random process having the same basic properties. Sinusoidal waves corresponding to a large set of frequencies are superimposed to form the total motion. The relative magnitudes of the (squared) amplitudes of the waves are determined, from $G^{(1)}(\omega)$. The phase angles of each sinusoidal wave are chosen at random on the interval 0 to 2π. The wave form generated in this way is then multiplied by the intensity function, I(t), and by a scale factor which causes the peak ground acceleration to be exactly equal to 0.15g. The peak response $S_V^{(1)}$ of a one-degree-of-freedom system to such an

artificial motion may considerably deviate from the design peak response S_v, and is likely to be different for different sample functions with the same general characteristics. This problem is partly overcome by a response spectrum smoothing procedure described below.

The computed response spectrum $S_V^{(1)}$ of the sample time history obtained by the procedure described above is compared with the desired smooth design response spectrum S_V for each frequency. A new input spectral density function, $G^{(2)}(\omega)$, is obtained by multiplying the initial choice, $G^{(1)}(\omega)$, by the square of the ratio $S_V/S_V^{(1)}$. The original set of random phase angles is used to generate a new motion with power spectral density function $G^{(2)}(\omega)$ and response spectrum $S_V^{(2)}$. This procedure can be repeated several times, until a response spectrum $S_V(n)$ sufficiently close to the design spectrum S_V is obtained. Different sample functions, each having relatively smooth computed response spectra that are in close agreement with the prescribed response spectra, can be obtained by generating different sets of random phase angles.

2.5.2.7 Operating Basis Earthquake

The operating basis earthquake (OBE) response spectra are one-half the SSE response spectra as shown in <Figure 2.5-111> and <Figure 2.5-112>, and the same relationship holds for the artificial time histories and for the corresponding computed response spectra.

Based on a preliminary assessment, provided in response to Q&R Question 230.01, the occurrence of the OBE at the site was associated with a mean annual probability of 2×10^{-3} or less. This annual probability was estimated, to a first approximation, by interpreting the recurrence frequency of earthquakes, scaled to maximum Modified Mercalli epicentral intensity, in the region of the site. This site region was bounded by the following coordinates; 38°-45°N, 77°-86°W.

At the time of preparation of the response to Q&R 230.01, there existed in the catalog for the site region 24 events with maximum epicentral intensity of ≥VI, and seven events with maximum epicentral intensity of ≥VII. Upon an assumption that the earthquake catalog was complete for 160 years for these largest earthquakes in the site region, the annual frequencies of events with epicentral Intensities ≥VI and ≥VII were derived for the entire region that covers an area of approximately 6.0×10^5 km^2. The probability of exceeding the OBE was then estimated by calculating the product of the annual frequency of earthquakes ≥VI and the ratio of area of Intensity VI effects for the occurrence of a given earthquake to the total area of the site region. Areas affected by Intensities VI for various size events were derived from published attenuation models. The result of this preliminary assessment, which treated the site region as a zone of uniform seismic frequency, in as much as no seismic source zonations were assumed for activity at Attica, New York or Anna, Ohio, was an estimated probability for OBE exceedance at the PNPP site of 2×10^{-3} per year, or less.

The calculation supporting this estimate of OBE exceedance is shown below.

Mean annual recurrence rates in site region include:

1. 24 events ≥VI MM in 160 years = 0.150/yr.

2. 7 events ≥VII MM in 160 years = 0.044/yr.

These rates are determined for the entire site region with an approximate area of 600,000 sq km.

Using published attenuation models <Figure 2.5-73>, the radius of perception of Intensity VI effects, for an event with a maximum epicentral intensity also of VI, is 25 km; the resulting perceptible area is 2,000 sq km.

The annual probability of exceeding an Intensity VI is:

$$P \geq OBE = \frac{0.15/yr \times 2{,}000 \text{ sq km}}{600{,}000 \text{ sq km}}$$

$$= .0005/yr$$

The OBE intensity of VI can also be exceeded during occurrence of an earthquake with a maximum epicentral intensity of VII. Relying again on published attenuation models, the area of Intensity VI effects for such a larger event is 30,000 sq km.

The annual probability of exceeding an Intensity VI, in this case, is:

$$P \geq OBE = \frac{0.044/yr \times 30{,}000 \text{ sq km}}{600{,}000 \text{ sq km}}$$

$$= .0022/yr$$

Because the OBE can be exceeded by occurrence of either an Intensity VI or Intensity VII event, the cumulative probability of OBE exceedance is derived as the summation of the individual probabilities calculated above; hence, the annual probability of exceeding the OBE at the PNPP site is (.0005 + .0022) or 0.0027. Due to some conservative aspects of this computation, namely 1) counting all events in the site region, even though many are associated with local structures at Attica, NY and Anna, OH, and 2) employing conservative attenuation models, the annual probability of exceeding the OBE was stated in response to Q&R 230.8 to be 0.002.

The probability of exceeding the OBE at the PNPP site is re-examined using a formal probabilistic seismic hazard methodology (Reference 291) (Reference 292). Two alternative seismicity recurrence scenarios are analyzed. The first scenario is identical to the one employed previously, namely, a specification that the site region (38°-45°;

77°-86°W) is characterized by a uniform likelihood of recurrence of future seismicity. The second scenario is an hypothesis that future seismicity will recur in the immediate site region (defined by the surrounding 1° block), with a frequency that is consistent with that determined from the historical catalog, including the recent seismic activity near the site. The basic difference between these scenarios is that future seismic activity will be dispersed throughout the site region (scenario 1) or concentrated in clusters of seismicity that are evident from the historical and recent earthquake records (scenario 2). The observation has been for episodes of seismicity to shift to new locations throughout the site region during the historical period, which is appropriately modeled using the first scenario.

Probability of exceeding the OBE is made equivalent to an occurrence of an Intensity VI (which is consistent with the threshold of damage to unreinforced structures) or greater earthquake at the site. The probability of exceeding the OBE at the PNPP site was computed using the input seismicity and ground motion attenuation data listed on <Table 2.5-22>. Results of the formal probabilistic assessment are listed on <Table 2.5-23>. These results include an annual probability of exceeding the OBE of 7.2×10^{-4} for the first seismic scenario and 2.1×10^{-3} for the second scenario. These probabilities of exceeding the OBE intensity of VI can also be associated with likelihoods of exceeding the OBE response spectrum at lower ground motion frequencies. From previous discussions in <Section 2.5.2.4.1>, it was illustrated that for the January 31, 1986 earthquake, the high-frequency region of the design spectra were exceeded and that intermediate and lower frequencies (<10 Hz) were well below the OBE spectral level. The seismic intensity was evaluated to be V, also below the OBE design intensity of VI. Due to the presently recognized deficiency of <Regulatory Guide 1.60> in emulating the high frequency seismic spectrum of EUS events, it is likely that the high frequency portions of the design spectrum will be exceeded with a higher probability than the annual probabilities of exceeding the design intensity of VI given in

<Table 2.5-23>. These possible high frequency exceedences (at frequencies >10 Hz) however likely will result in low intensities, as was the case for the occurrence of the January 1986 earthquake. It is also noted that the probability of exceeding the OBE at 2.5 Hg is about $1x10^{-5}$ (from the EPRI Hazard Study (Reference 308)), very similar to the earlier site specific calculations.

Recalculation of probabilities of OBE exceedance at PNPP are consistent with those previously provided in response to NRC Questions Q&R 230.1 and Q&R 230.8. In both, a similar conclusion was reached that the probability of exceeding the plant's OBE intensity of VI (MM Scale) is on the order of 2×10^{-3}/year. This estimate results from the formal probabilistic assessment which considers that future seismic activity may be localized in the immediate region of the site (e.g., 50 km radius). A similar result was obtained in response to the NRC's questions, not from an assumption of higher seismicity near the site, but rather from the usage of conservative attenuation models. For the consideration that future seismicity would recur randomly throughout the broader region surrounding the site (e.g., 200 mile radius), the probability of exceeding the OBE, as obtained by the recalculation is reduced to approximately 7×10^{-4}/year.

2.5.3 SURFACE FAULTING

Based on the findings of the geological, geophysical and seismological investigations, no capable faults are present at or near the site. Investigations and findings relevant to surface faulting are described in <Section 2.5.1.2.3>, <Section 2.5.1.2.4>, <Section 2.5.1.2.5>, and <Section 2.5.4.3.5>. Regional and site investigations have included literature review, subsurface investigations, interpretation of subsurface data, geologic mapping, and reconnaissance, and laboratory analyses. The following sections summarize the pertinent findings and conclusions from these studies.

2.5.3.1 Geologic Conditions of the Site

The lithologic, stratigraphic and structural conditions of the site and site locale are described in <Section 2.5.1.2>.

2.5.3.2 Evidence of Fault Offset

Within the site locale vicinity, minor displacements were identified during preconstruction mapping of bedrock outcrops, during small-scale geologic mapping of the onshore and cooling water tunnel excavations and during geologic mapping of the 1986 Leroy earthquake epicentral area.

Site locale displacements consist of thrust faults and vertical faults primarily exposed in stream channel outcrops, located over a wide area south of the site. Displacement along the thrust faults reaches a maximum of approximately 10 feet, however, the majority are less than 1 foot. One gravity-fault slump block overrode an adjoining slump block for a horizontal distance of several feet. Vertically, faults terminate along bedding planes of flat-lying, undeformed shale both above and below. Lateral and vertical terminations are generally observed in outcrop, however, as in the situation encountered in the cooling tunnel excavations, additional excavation, mapping, drilling, and geophysical evidence were necessary to establish the extent of deformation in the Big Creek area (Reference 4). All observed structures are shallow and apparently unrelated to tectonic deformation from depth. The thrust faults are often overlain by undeformed surficial sediments. These minor faults generally do not extend more than 200 to 300 feet laterally. No lineaments coinciding with any of the fault strikes were discernible on aerial photographs (1:4,800 scale). In one location, an accurate trace of a slump scarp is evident on aerial photography. The width of fault zone deformation excluding slumping is variable, on the order of several inches to several feet, measured normal to the plane of deformation in near-vertical natural and excavated outcrops. The origin of these superficial minor faults was concluded to be related to glacial

stresses (Pleistocene) and to movement of localized bedrock masses due to slumping. <Section 2.5.4.3.6.1> and Weston Geophysical (Reference 4), 1986 report on detailed geologic investigations conducted in the site locale and epicentral area of the 1986 Leroy earthquake. A map of the outcrops is shown on <Figure 2.5-40>.

Faults exposed within the onshore plant excavations consisted of decollement style, glide-planes conformable with bedding. Gouge up to three inches thick comprised of gray clay having a tough, leathery consistency and containing sand-size, angular, Chagrin shale fragments, define the basal plane of localized deformation. This interval of deformation is bounded vertically upward by an undeformed boulder horizon pervasive throughout the site at approximate Elevation 572’ at the base of the structureless lower till. The lowest elevation of onshore bedrock deformation was exposed in Unit 1 condensate demineralizer building excavation at approximate Elevation 534’.

The distance of lateral transport along the decollements may have been on the order of several feet, possibly exceeding ten feet, inferred from strata shortening taken up by folding. A southerly sense of lateral shove is inferred from structural fabric. Leading edges of decollement glide planes exhibit lateral thinning conformable with bedding, and termination by upward imbricate thrusting, underthrusting and buckling. The origin of the compressive stresses which caused this deformation is attributed to loading and lateral shove of late Wisconsinan glaciation and specifically Hiram ice which overrode the site approximately 14,500 years B.P. (See <Section 2.5.1.2.3.3> for additional descriptive information of onshore deformation.)

Thrust faulting, striking northeasterly and dipping 17 degrees toward the southeast intersects the cooling water tunnels beneath Lake Erie approximately 120 feet below lake bottom. Net displacement along the fault ranges from 1-1/2 to 2-1/2 feet. Throw for a probable minor splay from the main fault is 0.4 foot. Deformation within the fault zone

measured normal to the plane of faulting is generally one foot thick. Additional descriptive information is contained in <Section 2.5.1.2.3.4.1>, <Section 2.5.1.2.3.4.2>, <Section 2.5.1.2.3.4.3>, and <Appendix 2D>. Extrapolation of the displacement gradient data suggests faulting terminates in an updip direction well below lake bottom. No fault scarps, abrupt changes in relief or fault traces are evident on the lake bottom. The fault zone was intersected by invert borings on a straight-line, down-dip, fault plane projection. An onshore angle hole intersected the fault at approximately 290 feet below lake bottom. Between the tunnels, the fault strike measures about 750 feet. Extrapolation northeasterly and southwesterly beyond the tunnels is conjecture. However, borings located to intercept an updip projection of fault plane at a shallow depth within bedrock did not reveal evidence of faulting southwest of the plant site. Hypothesized northeasterly extensions of the faulting along strike intersect seismic track lines of the Department of Army, Coastal Engineering Research Center. Between navigation survey Fixes 610 and 640 in the vicinity of the site, no abrupt elevation changes in the lake floor or acoustic contrasts of sediment, both potential indications of faulting, are reported by Mr. S. Jeffress Williams, Marine Geologist, Geotechnical Engineering Branch (Reference 208) (Reference 209). Reconnaissance of glacial and lacustrine deposits comprising the lake bluff did not reveal evidence of faulting southwest or northeast of the site.

Earth Resources Technology Satellite (ERTS) imagery (Bands 4, 5 and 7) was examined for evidence of lineaments within the immediate vicinity of the Perry Nuclear Power Plant site. No lineaments were observed on the ERTS imagery within a 5 mile radius of the site. Twenty lineaments located within 75 miles of the PNPP site were observed on the ERTS imagery <Figure 2.5-113>. Only one lineament (50 miles southwest of the site) coincides in both trend and location with known structure. The remaining 19 lineaments can be associated with a combination of glacial, contemporary and paleo drainage, and vegetation effects. No lineaments

were observed on the ERTS imagery which indicate conditions posing a potential hazard to the PNPP site.

“A lineament is a mappable, simple or composite linear feature of a surface, whose parts are aligned in a rectilinear or slightly curvilinear relationship and which differs distinctly from the patterns of adjacent features and presumably reflects a subsurface phenomenon” (Reference 210). The lineaments identified during the analysis of ERTS imagery transparencies were plotted on an acetate overlay and compared to available surface and subsurface geological and geophysical data for northeastern Ohio and adjacent Pennsylvania. This comparative analysis included the interpreted anomalies of Voight Figure 13, <Appendix 2D F>. The geologic setting, which provided the framework for assessing and interpreting the lineaments, is discussed in <Section 2.5.1>. Individual lineaments are described in the following paragraphs.

a. Lineament 1

Lineament 1 is a discontinuous tonal variation trending northeastward for approximately 50 miles from a point 14 miles south of Cleveland to 20 miles east of Perry. The three southwestern lineament segments correspond in part to the contact between isolated upland remnants of Pennsylvanian sandstone, shale and limestone (Pottsville and Allegheny Formations), and underlying Mississippian shale, sandstone and limestone (Waverly and Maxville Formations) (Reference 211) enhanced by stream segments of the Chagrin River and Big Creek which cut valleys through the essentially horizontal bedrock strata. The northeastern segment of Lineament 1 corresponds to Coffee Creek which does not correspond to any mapped lithologic contacts. No mapped faults or fold axes (Reference 212) coincide with Lineament 1. No gravity anomaly or gradient parallels Lineament 1 <Figure 2.5-12> and <Figure 2.5-13>. These lineament segments are, therefore, attributed to drainages that are variably controlled by the underlying lithology.

b. Lineament 2

Lineament 2 traces a discontinuous curvilinear path along a generally northeastward trend from a point 16 miles east of Cleveland to 5 miles south of Perry and then southward to approximately 15 miles south of Perry. The tonal change occurs as a discontinuous dark band of variable width. This lineament corresponds mainly with northeast-trending stream channel sections of the Chagrin, Big and Grand drainages and the north-south trending Paine, Bates and East Branch Cuyahoga drainages which cut through the Pennsylvanian Pottsville and Allegheny coal, sandstone, shale, and limestone into and through the Mississippian Waverly and Maxville, shale, sandstone and limestone into the underlying Devonian Olentangy and Ohio shales (Reference 211). The stream erosion of resistant sandstones and limestones results in narrow steep-walled valleys which are responsible for the lineament segments. No mapped fold axes or faults (Reference 212) coincide with Lineament 2. Also no gravity anomaly or gradient parallels Lineament 2 <Figure 2.5-12> and <Figure 2.5-13>. The lineament is, therefore, attributed to a number of steep-walled valleys cut by streams through essentially horizontal bedrock.

c. Lineament 3

Lineament 3 is a broad dark-toned band which corresponds to an east-west trending, meandering segment of the Grand River. The dark-toned floodplain is composed of Wisconsin age alluvium filling this section of the Grand River Valley. The Wisconsin age Lake Escarpment moraine parallels and may topographically control the alignment of the drainage in this area (Reference 91). No fold axes or faults are mapped along Lineament 3 (Reference 212). No gravity anomaly or gradient is associated with the lineament <Figure 2.5-12> and <Figure 2.5-13>. Lineament 3 is attributed to

the contrast between alluvium associated with the Grand River floodplain and the contiguous Lake Escarpment moraine.

d. Lineaments 4 and 5

Lineaments 4 and 5 trend northeastward parallel to the Lake Erie shoreline east of Perry, Ohio, occurring as slight tonal variations. The abandoned beach ridges of Wisconsin age Lake Warren correspond with these lineaments (Reference 91). Bedrock topography may influence the orientation of the strandlines; however, no fold axes or faults are mapped coinciding with Lineaments 4 and 5 (Reference 212). No gravity anomalies or gradients are associated with the lineaments <Figure 2.5-12> and <Figure 2.5-13>. Lineaments 4 and 5 are attributed to the topographic expression of the beach ridge deposits.

e. Lineament 6

Lineament 6 is a light-toned, curved lineament extending from Meadville, Pennsylvania, northwestward along Cussewago Creek, then northwestward to westward along Conneaut Creek. The northwest-trending lineament coincides with a segment of the Cussewago Creek cutting Pocono Group conglomerates and sandstones down to the Oswayo Formation shales, siltstones and sandstones (Reference 213), forming steep valley walls. Minor synclinal and anticlinal axes are mapped in the area; however, their limited extent and the lack of any associated gravity anomaly or gradient <Figure 2.5-12> and <Figure 2.5-13> indicate that these possible structures would be limited in scale as commonly reported for this region. The lineament is attributed to narrow stream valleys cutting through the essentially horizontal bedrock.

f. Lineament 7

Lineament 7 trending northwestward, coincident with a segment of Muddy Creek, is of the same origin as Lineament 6.

g. Lineament 8

Lineament 8 extends northwestward from the upper Shenango River in Pennsylvania to Geneva on the Lake, Ohio. The discontinuous lineament occurs as a faint light tone which does not coincide with topographic alignments. This lineament possibly connects southeastward with an area of hypothesized structural discontinuities (Wagner-Lytle lines), described as "narrow zones or trends along which fold axes terminate, diminish or change direction" (Reference 214). It is reported that no surface faulting has been recognized along the hypothesized Wagner-Lytle lines (Reference 215), which suggests that deformation took place in broad zones over long periods of time during which the rocks were able to adjust to stress with many minor fractures rather than mappable faults. Lineament 8, if related to the above described Wagner-Lytle lines, could be attributed to possible enhanced fracturing resulting in associated anomalous groundwater conditions.

h. Lineament 9

Lineament 9 has been eliminated.

i. Lineament 10

Arcuate Lineament 10, a curvilinear tonal variation, coincides with a section of Crooked Creek extending from Greenville, Pennsylvania, northward and northwestward to the Pymatuning Reservoir on the Pennsylvania-Ohio border. Wisconsin age kame deposits and Recent

alluvium fill this section of the Crooked Creek Valley (Reference 216). The lineament is attributed to Wisconsin age glacial and Recent alluvial valley fill deposits.

j. Lineament 11

Lineament 11 is a discontinuous dark-toned line which extends northwestward from Mercer, Pennsylvania, into Ohio. This lineament appears to connect to the southeast with an area of hypothesized structural discontinuities (Wagner-Lytle lines) as described for Lineament 8. Therefore, if Lineament 11 is related to the above-described Wagner-Lytle lines, it could be attributed to possible enchanced fracturing, resulting in associated anomalous groundwater conditions.

k. Lineament 12

Lineament 12 is a discontinuous, light tonal variation which extends from south of Ravenna, Ohio, along a section of the West Branch of the Mahoning River, northeastward to south of the Pymatuning Reservoir. The southwestern segments correspond in part to buried river valleys filled with Recent alluvium and Wisconsin age “valley train” deposits (Reference 217). The northeastern segment appears to correspond to the strike of lithologic contacts between the upland Sharon Conglomerate/Connoquessing Sandstone and the lower Cuyahoga Group shales in the valleys (Reference 210). The middle segments of Lineament 12 appear to correspond to a section of the Mahoning Creek and a tributary of Mosquito Creek northwest of Cortland, Ohio. Structural discontinuities (fold axes or faults) (Reference 212) are not reported parallel to or coincident with the trend of Lineament 12. No gravity anomaly or alignment parallels the trend of Lineament 12 <Figure 2.5-12> and

<Figure 2.5-13>. This lineament is attributed to the coincidental alignment of buried river valleys, existing drainage systems and lithologic contacts.

l. Lineaments 13, 14, 15, and 18

These lineaments are the stronger of many generally north-trending lineaments forming one axis of a rectilinear pattern in northeastern Ohio, resulting from variations in vegetation (wooded versus open). This pattern abruptly terminates at the Pennsylvania border, indicating that the pattern is controlled by culture. In one case, (Lineament 15), the vegetative lineament corresponds with a lobe of Wisconsin age lacustrine deposits filling the buried Grand River valley (Reference 91). No mapped structural alignments (fold axes or faults) (Reference 212) or gravity anomalies correspond to these lineaments <Figure 2.5-12> and <Figure 2.5-13>.

m. Lineament 16

Lineament 16 is a faint discontinuous tonal pattern, trending northeastward. This lineament cuts across lithologic contacts. The more distinct sections coincide with linear glacial outwash deposits (valley trains) preserved as terraces in the Cuyahoga River valley (Reference 217). The northeastern section parallels an end moraine deposit south of Ashtabula, Ohio (Reference 91). No fold axes or faults are mapped corresponding to Lineament 16 (Reference 212). No gravity anomaly or gradient correlates with the trend of the lineament, <Figure 2.5-12> and <Figure 2.5-13>. This lineament is attributed to the alignment of linear glacial deposits.

n. Lineament 17

Lineament 17 is a dark-toned line trending north-eastward coincident with the Upper Cuyahoga River. The river valley is probably controlled in part by the strike of lithologic contacts in this area, cutting through upland Pottsville and Allegheny shale, sandstone and limestone to Waverly and Maxville shale, sandstone and limestone (Reference 211). A buried river valley filled with Recent alluvium (Reference 217) is likely responsible for the location of the existing Cuyahoga River. No fold axes or faults are presently mapped (Reference 212) parallel to the trend of the lineament. No gravity anomaly or gradient correlates with the trend of Lineament 17 <Figure 2.5-12> and <Figure 2.5-13>. Lineament 17 is attributed to the coincidence of an existing stream segment flowing along a buried river valley controlled and enhanced by lithologic contacts mapped in the area.

o. Lineament 19

This lineament is mapped as a tonal change which in part corresponds with segments of Eagle Creek and the Grand River. Coinciding with the lineament to the southeast are sections of end moraine and valley train deposits (Reference 91), while to the northwest the contact between Pottsville and Allegheny sandstone, shale and limestone and Waverly and Maxville sandstone, shale and limestone forms the tonal patterns (Reference 211). The axes of minor synclines and anticlines are mapped in the area (Reference 212); however, their limited extent and the lack of any associated gravity anomaly <Figure 2.5-12> and <Figure 2.5-13> indicate that these possible structures would be limited in scale as commonly reported for this region and would not be responsible for Lineament 19. This lineament is, therefore, variably attributed to glacial deposits, lithologic contacts and existing drainages.

p. Lineament 20

Lineament 20 occurs as an abrupt tonal change from light to dark along a short linear alignment approximately parallel to the railroad right-of-way between Warren and Ravenna, Ohio. The Ravenna Arsenal is an area of distinct tone located south of the railroad between Ravenna and Warren. A segment of the south fork of Eagle Creek also coincides with the lineament. No structures (fold axes or faults) are mapped which correspond to Lineament 20 (Reference 212). No gravity anomaly or gradient corresponds to the lineament <Figure 2.5-12> and <Figure 2.5-13>. This lineament is attributed to cultural features and possibly to drainage.

q. Lineament 21

Lineament 21 is traceable as a faint light tonal variation trending northwestward between Alliance and Akron, Ohio. This lineament is nearly coincident with a N54°W trending high-angle bedrock fault mapped in the subsurface <Figure 2.5-114>; the subsurface fault is limited in extent, as mapped, and no surface escarpment or rupture is reported. The maximum vertical displacement is approximately 100 feet upthrown on the southwest side. Structural contours and isopachs of the Middle Devonian age Delaware-Dayton Formations confirm the existence of the fault (Reference 212) (Reference 217). The location, subsurface occurrence and limited extent of this fault and the lack of any known associated seismicity indicate no potential hazard. There is no evidence to indicate that the subsurface fault is responsible for Lineament 21, and no correlative fault scarp or surface rupture is reported (Reference 212).

As part of the investigation of the 1986 Leroy earthquake, an examination of Synthetic Aperture Radar (SAR) imagery covering the two degree Cleveland map sheet was undertaken. Of the linear features

observed, several northwest-trending lineaments in Ashtabula and Trumbull counties extending southeastward into Pennsylvania are note worthy. The radar lineaments are, in part, spatially correlative to ERTS imagery Lineaments 8 and 11 discussed above <Figure 2.5-113>. The characteristic linear changes in image tone density cut cultural features such as field and roads. They may represent subtle soil moisture and/or bacterial anomalies related to local variations in bedrock fracture intensity. Prior to this investigation, no tectonic structures have been mapped in the vicinity of these features. Field reconnaissance in eastern Geauga county, along the trend of one lineament, revealed no outcrop for examination of potential bedrock structures.

While the general northwest trend of the ERTS and SAR lineaments corresponds in orientation with northwest-trending disruptions in northeast-elongated gravity and aeromagnetic gradients and anomalies (e.g., Akron aeromagnetic lineament), a one to one spatial correlation does not exist. Even a tentative relationship is only conceivable by extrapolation of the lineament trends northwestward from Ashtabula and Trumbull counties into Geauga and Lake counties. Other than representing further indirect evidence of possible northwest-trending structural discontinuities originating in the Precambrian basement, no direct indication of mappable structures involved with the Leroy seismic activity is suggested by the ERTS and SAR lineaments.

Linear features and lineaments interpreted from these investigations <Figure 2.5-113> have also been compared with structural and lithologic alignments and boundaries, derived from various geological and geophysical data discussed elsewhere in this document. These include the Akron Magnetic Lineament, local northwest-trending disruptions in the magnetic pattern, features interpreted from structural contour maps of two Paleozoic units and shallow bedrock structures mapped in outcrops in the epicentral area. No direct spatial correlation of either ERTS or SAR lineaments is noted with the Akron Magnetic Lineament or

northwest-trending disruptions. In general, no specific correlations are noted between the lineamemts and features interpreted on the Packer shell and Delaware limestone horizons. However, a general spatial correlation exists between the broad ERTS Lineament 15 (Grand River Valley) and a north-south-trending feature apparent on both horizons in southwestern Ashtabula county <Figure 2.5-38> and <Figure 2.5-39>. Finally, no bedrock structures, either previously reported or mapped during the 1986 earthquake investigation, were found to uniquely coincide with the ERTS and SAR lineaments.

2.5.3.3 Earthquakes Associated with Capable Faults

No capable faults, with the possible exception of the Clarendon-Linden fault zone near Attica, New York, have been identified within the site region. Seismic activity spatially correlated with the central portion of this fault system is discussed in <Section 2.5.2.1.2.2>. As discussed in <Section 2.5.2.1.2.4> and <Section 2.5.2.1.2.5>, the alignment of other regional or local epicentral distribution trends is purely conjectural. None of these trends can be directly related to existing structure.

2.5.3.4 Investigation of Capable Faults

The only possible capable fault(s) within the site region have been identified as the Clarendon-Linden fault zone as described in <Section 2.5.2.1.2.2>.

2.5.3.5 Correlation of Epicenters with Capable Faults

No capable faults, with the possible exception of the Clarendon-Linden fault zone near Attica, New York, have been identified within the site region. Seismic activity spatially correlated with the central portion of this fault system is discussed in <Section 2.5.2.1.2.2>. As discussed in <Section 2.5.2.1.2.4> and <Section 2.5.2.1.2.5>, the

alignment of other regional or local epicentral distribution trends is purely conjectural. None of these trends can be directly related to existing structure.

2.5.3.6 Description of Capable Faults

No capable faults have been identified within the Perry site local.

2.5.3.7 Zone Requiring Detailed Faulting Investigation

The site is located within a zone which does not require detailed faulting investigations in accordance with <10 CFR 100, Appendix A>.

2.5.3.8 Results of Faulting Investigation

Detailed faulting investigations are not required as discussed in <Section 2.5.3.7>. Investigations conducted to document the evidence of offset and to determine the origin and age of offset are summarized in <Section 2.5.4.3.6>. Details of faulting intersecting the cooling water tunnels are contained in <Appendix 2D>.

2.5.4 STABILITY OF SUBSURFACE MATERIALS AND FOUNDATIONS

2.5.4.1 Geologic Features

2.5.4.1.1 Areas of Subsurface or Surface Instability

Areas of actual and potential surface or subsurface subsidence, uplift or collapse have been considered. There are no features such as cavernous terrain or tectonic-related relief (passive or active) in the plant site vicinity. Regarding naturally occurring conditions, the following were investigated: (1) integrity of unmined salt (<Section 2.5.1.1.7.1.1>, Salina Group), (2) brine solutioning potential (<Section 2.5.1.1.7.1.1>, Groundwater System), (3) natural solution

cavities subsidence potential (<Section 2.5.1.1.7.1.4>, Subsidence Potential, Natural Solution Cavities). Regarding man's activities, the following were investigated: (1) salt mining subsidence potential (<Section 2.5.1.1.7.1.4>, Subsidence Potential), (2) subsurface gas storage <Section 2.5.1.1.8.2> and (3) hydrocarbon extraction <Section 2.5.1.1.8.3>.

2.5.4.1.2 Loading History

The site area was subjected to extensive glaciation during the Pleistocene Epoch. It is known that several glacial advances overrode the site area. Till deposits from the early advances would have been consolidated by the successive glacial advances. Based on ice thickness estimates by Carney, a basal pressure of 115.5 kips on bedrock during glacial override was calculated (Reference 218). A review of the site glacial history is presented in <Section 2.5.1.2.4>. A preconsolidation pressure of 12 ksf for lower till based on laboratory testing was assumed for design. Subsurface material properties are discussed in <Section 2.5.4.2>.

2.5.4.1.3 Deformation Zones

As described in <Section 2.5.1.2.3.2>, several zones of folded, faulted and otherwise structurally altered bedrock were exposed during plant construction.

No zones of weakness that could affect the bearing for Seismic Category I structures were encountered within the lower till or the Chagrin shale. The thin discontinuous zone of weathering at the top of the Chagrin shale was removed during excavation. Weathering along joints and fractures within the shale was too limited in extent and frequency to affect supporting ability. The limited deformation zones were concluded to have no significant or detrimental influence on the plant structures <Section 2.5.4.3.6.2> and <Section 3.8.4>. As a

conservative measure, the deformed bedrock encountered in the plant excavation was overexcavated and backfilled with lean concrete having a 28-day compressive strength of at least 1,500 psi. <Figure 2.5-55> delineates the areas overexcavated and treated as such.

2.5.4.1.4 Residual Stress

Refer to <Section 2.5.1.2.5.3>.

2.5.4.1.5 Unstable Rock and Soil Composition

The lower till and the Chagrin shale units supporting plant foundations are not susceptible to detrimental consolidation, densification or liquefaction under either static or dynamic loading.

2.5.4.2 <u>Properties of Subsurface Materials</u>

As described in detail in <Section 2.5.4.3.3>, four stratigraphic units were encountered by subsurface exploration at the site. In descending order, these units are identified as lacustrine sediments, two distinct glacial ground moraine deposits which are denoted as upper till and lower till and finally, an Upper Devonian shale identified as the Chagrin shale. The properties of these materials are described in the following sections. The test methods used to determine the properties are summarized in <Table 2.5-24>.

2.5.4.2.1 Properties of Soil Materials

2.5.4.2.1.1 Physical Properties

Physical property tests conducted on representative samples of the soils at the site include natural water content, Atterberg (liquid and plastic) limits, unit weight, specific gravity, and grain size distribution. The results of these tests are presented in

<Table 2.5-25>, <Table 2.5-26>, and <Table 2.5-27> and are summarized in <Table 2.5-28>. Grain size distribution curves are presented in <Figure 2.5-115>, <Figure 2.5-116>, and <Figure 2.5-117>. The range of gradations of the upper till and lower till are shown in <Figure 2.5-118> and <Figure 2.5-119>.

2.5.4.2.1.2 Drained Deformation Properties

One-dimensional oedometer (consolidation) tests were performed on relatively undisturbed samples of the soils to determine drained deformation properties. The tests were conducted using both conventional double-load increments and by constant rate of strain loading techniques (Reference 219). The results of the test are tabulated in <Table 2.5-29>. For the lower till, the constrained modulus and deformation modulus have been interpreted from the consolidation test results for stresses less than the preconsolidation pressure of each sample. These values are presented in <Table 2.5-30> and were calculated by using Equations 2.5-3 and 2.5-4.

$$E_d = \frac{(1 - \varepsilon_o)\,\bar{\sigma}_{avg}}{0.435\,C_r'} \qquad (2.5\text{-}3)$$

$$E_s = \frac{(1 + \mu)(1 - 2\mu)}{(1 - \mu)} \cdot E_d \qquad (2.5\text{-}4)$$

where:

E_d = Constrained modulus

E_s = Deformation modulus

ε_o = Initial strain

$\bar{\sigma}_{avg}$ = Average stress within recompression load range

C_r' = Recompression index, unit strain basis

μ = Poisson's ratio

Typical consolidation test curves in the form of axial strain versus consolidation pressure and compression versus time are presented in <Figure 2.5-120>, <Figure 2.5-121>, and <Figure 2.5-122> for each of the three soil units.

2.5.4.2.1.3 In Situ Undrained Deformation Properties

Field testing was performed to investigate the undrained load-deformation properties of the lower till. These procedures included pressuremeter tests and plate-loading tests, which are described in the following sections.

2.5.4.2.1.3.1 Pressuremeter Tests

Ten pressuremeter tests were conducted at various locations within the lower till. As shown in <Figure 2.5-123>, the pressuremeter consists of an expandable cylindrical probe connected by high-pressure tubing to a water and gas pressure source at the surface. The center portion of the probe is expanded in the hole by water pressure whereas the ends of the probe (guard cells) are expanded by gas pressure to effect essentially a two-dimensional radial stress condition around the water loaded, central portion of the pressuremeter probe. The amount of expansion of the center of the probe is measured by a volumeter which records the change in the volume of water contained within the pressuremeter system. The amount of water pressure within the probe and its volumetric expansion is recorded and used with appropriate corrections to characterize the compressibility or soils or soft rock. A more detailed discussion of the apparatus is given by Menard (Reference 220).

Borings drilled to accommodate pressuremeter probes in the lower till were drilled in three stages. First, the hole was drilled “dry” to a depth of about 3 feet above the test level by advancing a continuous hollow-stem auger containing rubber O-rings or gaskets between the auger sections to prevent infiltration of groundwater. Subsequently, the dry

hole was continued by utilizing a 2-5/8-inch diameter, 3-foot long flight auger which was telescoped through the larger diameter hollow-stem augers. The smaller diameter auger holes were usually advanced to about 5 feet below the bottom of the larger hole. Finally, the side walls of the hole were smoothed and enlarged by inserting a 2-7/8-inch diameter split-barrel sampler with a cutting shoe. The pressuremeter tests were conducted immediately after hole preparation to preclude hole softening.

After inserting the probe, pressures were applied in increments of about 3 kilograms per square centimeter. Before and during application of the load, volumeter readings were recorded at time intervals of 15, 20 and 60 seconds. Upon reaching the end of the test or upon initiation of plastic behavior, the applied pressure was reduced in decrements of about 3 kilograms per square centimeter to zero pressure, allowing a 60-second lapse between each decrement. To investigate the recompression characteristics of the material tested, cyclic loading was also conducted at selected locations.

The pressure-volume curves were interpreted as described by Menard to determine the undrained modulus of compressibility (also termed deformation modulus) applicable to the following conditions (Reference 220):

a. At stress excursions less than the preconsolidation pressure of the till.

b. At stress excursions above the preconsolidation pressure.

c. During an unloading (swell) or reloading cycle.

These load ranges are shown on typical pressure-volume curves on <Figure 2.5-124> for the lower till. The interpretation of the stress at which plastic behavior first initiates and the ultimate stress at

plastic yield are also indicated on that figure. A summary of the pressuremeter test result interpretations in the lower till is presented in <Table 2.5-31>. Evaluation of the results of the pressuremeter tests, together with the results of the modulus values determined by other testing techniques, indicate that undrained modulus values determined from cyclic or rebound measurements are more representative than those calculated from first load measurements. It is postulated that the lower modulus values determined from first load measurements are reduced by the effects of the side wall disturbance of the drill hole.

The undrained modulus derived from pressuremeter tests is a function of the ratio of the change in cell pressure to the change in the volume of the measuring cell. Before the test, the initial volume reading at zero pressure is recorded upon stabilization of the volumeter under the hydrostatic pressure prevailing at the level of the cell. By this means, the effect of piezometric pressure is considered in the calculation of undrained modulus from the pressuremeter test.

2.5.4.2.1.3.2 Plate Loading Tests

Down-hole plate loading tests were conducted in two large diameter (42 inches) drilled inspection shafts. These tests were conducted in order to minimize disturbance effects associated with laboratory and pressuremeter testing. The inspection shafts are described in <Section 2.5.4.3.2>.

The load test reaction system consisted of two 30-inch O.D. reaction caissons offset at least 5 feet from each test hole. Reaction caissons were drilled to about Elevation 583’ and mechanically under-reamed to a diameter of 40 inches. The cross beam and deflection measurement system used for vertically loaded bearing plates are shown on <Figure 2.5-125>. Six vertically oriented load tests were conducted using a 22-inch rigid plate seated within the lower till at successively lower elevations.

The plates were seated and leveled on an undisturbed bearing surface using a quick-set “hydrostone” as a leveling material. Load was applied by a remotely controlled 100-ton jack and the plate deformations were measured by extensometer gauges with scale divisions of 0.0001 inch.

In addition to the vertically oriented load tests, five tests oriented in the horizontal plane were also conducted at various elevations within the lower till. As shown in <Figure 2.5-125>, the horizontal load tests were conducted using 13.55 inch diameter (one square foot) steel plates in pairs. The loading was applied by a 50-ton capacity hydraulic jack. The side wall surfaces were prepared by the application of “hydrostone” as a leveling material.

Vertically oriented loading of the bearing plates was conducted in general accordance with the Standard Method for Repetitive Static Plate Load tests as described by ASTM Test Designation D 1195-64. Further discussions of load testing procedures used are given by Coates and Gyenge (Reference 221). After setting of the “hydrostone” leveling course, a seating load of 500 pounds was applied and the measurement system was calibrated for the initial deformation. Within the lower till, 20 to 25 equal load increments and decrements were applied to achieve a maximum load of 22.6 tsf. During each of the loading increments, deformation readings were taken after elapsed time of 1/4, 1/2, 1, 2, 4, 8, and 16 minutes. Cyclic loading was also conducted at selected test levels with the lower till.

Horizontally oriented test plates were loaded to a maximum pressure ranging from 24 to 47 tsf using 13 to 29 load increments and decrements. Time deformations at each of the load increments were maintained for a period up to at least two minutes. The weight of the horizontal load test assembly was independently supported so as not to impose shear stresses on the test surface.

The modulus of compressibility of the lower till was derived from the load versus settlement test curves, assuming the test materials to react as an elastic material in accordance with Equation 2.5-5:

$$E = \frac{q\left(1 - \mu^2\right) d\, C_1\, C_2}{\Delta} \qquad (2.5\text{-}5)$$

where:

E = Modulus of compressibility

q = Applied pressure

μ = Poisson's ratio

d = Plate diameter

C_1 = Shape coefficient (Reference 222)

C_2 = Test depth correction (Reference 223)

Δ = Plate deformation

The modulus was interpreted with the foregoing formula for stress ranges both below and above the apparent preconsolidation pressure of the till. The preconsolidation pressure is interpreted to be the point of maximum curvature on the pressure-deformation curve. The modulus was also calculated from cyclic loading tests which would more closely approximate dynamic loading conditions. Results of the lower till plate loading test interpretations are presented in <Table 2.5-32> and <Table 2.5-33> for the vertical and horizontal tests, respectively. A typical load-deformation curve for the plate loading tests is shown in <Figure 2.5-126>.

2.5.4.2.1.4 Strength Properties

Tests conducted to investigate the shear strength of the subsoils consisted of the following:

a. Unconfined (U) uniaxial compression.

b. Unconsolidated-undrained (UU) triaxial compression.

c. Isotropically consolidated-undrained triaxial compression with pore pressure measurements (CIU).

d. Isotropically consolidated-undrained triaxial compression with pore pressure measurements, consolidated and loaded in stages without intermediate stages being loaded to failure (CIU_s).

The results of the compression tests on each soil stratigraphic unit are presented in <Table 2.5-34>, <Table 2.5-35>, and <Table 2.5-36>. The effective stress parameters interpreted from the CIU and CIU_s tests are summarized in <Table 2.5-37>. Typical stress paths and stress-strain curves for each soil unit are presented in <Figure 2.5-127>, <Figure 2.5-128>, <Figure 2.5-129>, <Figure 2.5-130>, <Figure 2.5-131>, and <Figure 2.5-132>.

2.5.4.2.1.5 Dynamic Properties

Shear modulus and damping values for dynamic response analyses were determined as a function of shear strain and consolidation pressure by cyclic torsion (resonant column) tests conducted on representative samples. Also, estimates of shear modulus at very low strain levels were determined from in situ shear wave velocities measured by seismic cross-hole and down-hole testing. Results of the cyclic torsion tests together with pertinent physical properties of the test specimens are presented in <Table 2.5-38>, <Table 2.5-39>, and <Table 2.5-40> for each soil unit. The results of the in situ testing are described in detail in <Section 2.5.4.4> and are summarized in <Table 2.5-41>. The value of K_2 was determined for each test using Equation 2.5-6.

$$G = 1000\, K_2 \left(\sigma'_m\right)^{1/2} \qquad (2.5\text{-}6)$$

where:

- G = Shear modulus
- K_2 = Shear modulus parameter
- σ'_m = Mean effective principal stress

The damping value and K_2 from the cyclic torsion tests are plotted versus shear strain for each soil type in <Figure 2.5-133>, <Figure 2.5-134>, <Figure 2.5-135>. Also shown on these figures is the damping and K_2 relationship derived by Hardin and Drnevich (Reference 224). Comparison of the K_2 values interpreted from the in situ shear wave velocity measurements with an extrapolation of the laboratory K_2 measurements indicates that the wave velocity measurements are excessively high, particularly for the upper and lower till. Therefore, the seismic wave velocities were not heavily weighted in the formulation of the dynamic properties of the subsoils.

2.5.4.2.1.6 Permeability

The permeability of the subsoils was investigated using laboratory and in situ testing methods. The test methods and results are described in <Section 2.5.4.6>.

2.5.4.2.1.7 Dispersion Characteristics

Three types of dispersion tests were conducted on each of five samples of lower till. These tests consisted of the pinhole test, the Soil Conservation Service (SCS) laboratory dispersion test, and the measurement of dissolved cations in a saturation extract (Reference 225) (Reference 226) (Reference 227). The pinhole test results are shown in <Table 2.5-42>, the SCS test results in <Figure 2.5-136> and the saturation extract results in <Table 2.5-35> and <Figure 2.5-137>. It

was indicated by 14 of the 15 tests that the lower till is nondispersive. The result of one pinhole test which indicated that the sample was dispersive is considered to be questionable.

2.5.4.2.1.8 Petrographic Analysis

Four samples of lower till were subjected to petrographic analysis. All four samples were found to have similar mineralogy and to contain the same variety of rock fragments, varying only in the relative amounts of these constituents. A gray-brown silt and clay matrix was found to be the dominant component, ranging from approximately 40 to 70 percent of the volume of each sample. Numerous individual shale fragments were almost optically indiscernible from the surrounding matrix material, suggesting inplace breakdown of these rock clasts. By far, the most common mineral was found to be euhedral and anhedral quartz, often occurring with crystalline inclusions. A likely source for this material is from the well sorted quartzose laminae in the shale clasts. A summary of the approximate compositions of the samples is presented in <Table 2.5-44>.

The depositional fabric of the samples was granular and heterogeneous without discernible mineralogic or textural banding. The general character of the sediment was a chaotic mixture of diverse mineralogy and rock clasts in a matrix of very fine silt and clay size materials. Brown and black organic material was common in both shale clasts and matrix material. It occurred in irregular, translucent, lenticular, and globular masses. Some of this organic material may have been carbonaceous debris derived from nearby source areas at the time of sediment deposition. Opaque material present in thin sections was chiefly pyrite and magnetite, but no concentrated effort was made to attempt to identify all opaque materials. Not all shale clasts exhibited bulk polarization under crossed Nicols, but became extinct in

globular patches. All samples contained trace amounts of hornblende, enstatite, augite, epidote, rutile, and zircon, suggesting a metamorphic or igneous source rock area.

2.5.4.2.2 Properties of Chagrin Shale

2.5.4.2.2.1 Physical Properties

Physical property tests conducted on core samples of Chagrin shale included natural water content and unit weight. In addition, representative samples were pulverized and determinations made of Atterberg (liquid and plastic) limits, specific gravity and grain size distribution. The results of these tests are presented in <Table 2.5-45> and are summarized in <Table 2.5-46>. Grain size distribution curves are presented in <Figure 2.5-138>.

2.5.4.2.2.2 Petrographic and X-Ray Diffraction Analyses

Petrographic and X-ray diffraction analyses were conducted on shale samples, and the results are presented in <Table 2.5-47>. The dominant clay mineral found to be present was illite, which is considered to be a "normally active" clay mineral. The activity of illite (ratio of plasticity index to the percent finer than two microns) is reported to be 0.9 (Reference 228). The average activity of the Chagrin shale samples tested was found to be 0.33, which indicates that the shale on the whole may be classified as "inactive" and that the plasticity indices measured are reasonably consistent with the clay content and composition of the shale, considering the inclusion of other minerals less active than illite.

2.5.4.2.2.3 Slaking Durability

To investigate slaking durability of the shale, wet-dry cycle slaking tests using procedures described by Franklin (Reference 229) and

essentially constant emersion ("jar slaking") tests were conducted. In the wet-dry slaking test, the percent by dry weight of the shale samples retained by a No. 10 mesh at the end of each cycle is reported as a slaking durability index. The test results are shown in <Figure 2.5-139>. The shale test specimens are rated as having "medium" to "high" slaking durability, with most of the data indicating a "medium high" rating. The results of the jar slaking test are presented in <Table 2.5-48>. Three specimens showed slight to negligible slaking loss and one specimen experienced a moderate slaking loss.

2.5.4.2.2.4 Unconfined Compression Properties

The compressive strength of NX size core samples of the shale was investigated by uniaxial (unconfined) compression tests. The results of these tests are summarized in <Table 2.5-49>. Typical stress-strain curves obtained from the tests are shown in <Figure 2.5-140>. The Deere-Miller strength-modulus classification of the shale samples are shown in <Figure 2.5-141> (Reference 230).

2.5.4.2.2.5 Drained Deformation Properties

Drained deformation characteristics of the shale were investigated by one-dimensional oedometer (consolidation) and swell tests. The swell potential was investigated by immersing the test specimens in the oedometer and adding load until the sample swell was arrested. This load is denoted as the "swelling pressure". Recompression characteristics were investigated by cyclic loading. The oedometer test results, together with the pertinent physical properties of the test specimens, are presented in <Table 2.5-50>. Where samples were subjected to more than one cyclic loading, the recompression and swell indices are reported as maximum, minimum and average values. Drained constrained and deformation moduli, as defined in <Section 2.5.4.2.1.2>, were computed from the oedometer tests and are presented in <Table 2.5-51>.

2.5.4.2.2.6 Triaxial Compression Properties, Drained and Undrained

Stress-controlled, drained triaxial compression tests on core specimens were used to simulate construction and service loading conditions by following predetermined stress paths (Reference 231). The results of these tests, including both compression and swell drained deformation moduli, are presented in <Table 2.5-52>. Cyclically loaded, undrained stress-controlled triaxial compression tests were also conducted to investigate undrained recompression characteristics of the shale. These test results are presented in <Table 2.5-53>.

2.5.4.2.2.7 In Situ Undrained Deformation Properties

Field testing was performed to investigate the undrained deformation characteristics of the shale. These procedures included pressuremeter tests and plate loading tests. The results are described in the following sections.

2.5.4.2.2.7.1 Pressuremeter Tests

Eighteen pressuremeter tests were conducted at various elevations within the shale. The test procedure was essentially identical to that used in the lower till, which is described in <Section 2.5.4.2.1.3.1>, except that test holes in the shale were drilled using an NX core barrel, taking special precautions to obtain a smooth, undisturbed hole surface. Coring was conducted subsequent to casing the bore hole to the top of the rock. No precautions were taken to prevent water accumulation within the test interval.

Typical test results are shown in <Figure 2.5-142>. A summary of the pressuremeter test results interpretations is presented in <Table 2.5-54>.

2.5.4.2.2.7.2 Plate Loading Tests

Two vertical plate loading tests were conducted in drilled shafts just below the surface of the shale. The tests were conducted in the same manner as those in the lower till, described in <Section 2.5.4.2.1.3.2>, except that the maximum loading was increased to 37.7 tsf. The test results are presented in <Table 2.5-55>.

2.5.4.2.2.8 Dynamic Properties

Dynamic deformation parameters were investigated in the laboratory by sonic velocity tests on core samples. The dynamic shear modulus, Young’s modulus and Poisson’s ratio interpreted from the measured laboratory compression and shear wave velocities are presented in <Table 2.5-56>. The corresponding values obtained from field seismic velocity interpretations are also included in <Table 2.5-56>.

2.5.4.2.2.9 Permeability

The permeability of the shale was investigated by in situ testing. The test methods and results are described in <Section 2.5.4.6>.

2.5.4.2.3 Selection of Design Parameters

The shear strength and unit weight values conservatively adopted for design analyses are summarized for each of the four stratigraphic units in <Table 2.5-57>. Parameters adopted for one-dimensional consolidation analyses are presented in <Table 2.5-58>. For finite element analysis

of static deformations, Equation 2.5-7 was used to characterize the deformation modulus of lower till and the shale:

$$E_s = kp_a\left(\frac{p_c}{p_a}\right)^n \qquad (2.5\text{-}7)$$

where:

E_s = Deformation modulus

k = Modulus parameter

n = Modulus parameter

P_a = Atmospheric pressure

P_c = Preconsolidation pressure

The values of the modulus parameters and Poisson's ratio adopted for both drained and undrained deformation analyses are summarized in <Table 2.5-59>. Dynamic soil properties adopted for seismic response analyses are summarized in <Table 2.5-60>.

2.5.4.3 Exploration

Exploration of the subsurface conditions at the site included test borings, large diameter inspection shafts, geophysical surveys, and the installation of piezometers and observation wells. In addition, in situ testing was conducted which consisted of permeability tests, pressuremeter tests and plate loading. The test borings and inspection shafts are described in <Section 2.5.4.3.1> and <Section 2.5.4.3.2>, respectively. The geophysical surveys are described in <Section 2.5.4.4>. The piezometer and observation well installation and in situ permeability testing are described in <Section 2.5.4.6>. The pressuremeter and plate loading tests are described in <Section 2.5.4.2>. The subsurface stratigraphy disclosed by the borings is described in <Section 2.5.4.3.3>.

The offshore subsurface investigations are discussed in <Section 2.5.4.3>. Other supplementary exploration activities performed in conjunction with investigations of the site-locale faults, the shallow bedrock deformation exposed in plant excavation, and the bedrock deformation intersected by tunnel excavations are discussed in <Section 2.5.4.3.6>.

2.5.4.3.1 Test Borings

The locations of onshore and offshore test borings are shown on <Figure 2.5-53>. Logs of the borings are presented in <Appendix 2E>.

The test borings were generally advanced through overburden using six- or nine-inch O.D., continuous, hollow-stem, flight augers. Through boulder zones, borings were advanced by using a 3-7/8-inch O.D. tri-cone roller bit. Where necessary, flush-joint steel casing was placed through the hollow-stem auger or four-inch O.D. steel casing was driven to maintain the stability of the bore hole. The borings were continued into rock using diamond core techniques.

Samples of the subsoils were obtained in the test borings generally at intervals of three to five feet, and occasionally continuously, using a two-inch O.D. split-barrel sampler driven 18 inches by means of a 140-pound hammer freely falling 30 inches, conforming to ASTM Test Designation D 1586. The Standard Penetration Resistance (SPR) for each sample was recorded as the number of hammer blows required for the last 12 inches of sampler penetration. Where less than 12 inches of sampler penetration was obtained, the amount of penetration was recorded together with the corresponding number of blows. Samples recovered from drive sampling were preserved in airtight jars for further classification and laboratory testing.

Relatively undisturbed samples of the subsoils were obtained by means of thin-wall (Shelby) tubes (ASTM D 1587) having a nominal diameter ranging

from 3 to 4-1/2 inches O.D. In the less dense subsoils, the Shelby tubes were continuously advanced using the hydraulic system of the drilling rig. In subsoils where the density or consistency prevented hydraulic Shelby tube sampling, relatively undisturbed samples were obtained by means of a Pitcher sampler (Reference 232). This sampler includes a spring-loaded Shelby tube whose penetration is facilitated by rotary drilling with an outer barrel just behind the leading edge of the Shelby tube. The undisturbed samples were sealed within the Shelby tubes by removing soil at the end of the tube and sealing the ends with nonshrink paraffin or wax. Material removed from the ends of the tubes were sealed in glass jars for identification purposes and the tubes were transported to the laboratory for testing.

Cores of the shale bedrock were obtained using a standard NX double-tube core barrel and a diamond bit, recovering a 2-1/8-inch diameter core sample (ASTM D 2113). Upon encountering bedrock, rock was cored in one, two, five, or ten foot runs, depending upon the quality of the rock. Upon retrieval, the core was placed in core boxes in a manner to separate each core run and to indicate the depth interval. The amount of core recovery per run was recorded together with a description of the rock. The accumulative length of core segments at least four inches long (and including shorter pieces segmented by drilling effects) was also recorded as the Rock Quality Designation (RQD) (Reference 233). It is noted that the utility of RQD classification for thin bedded shales is questionable because of the difficulty of determining natural versus drilling effect on the core segmentation. Selected core samples were wrapped in a membrane and sealed with wax to preserve the natural water content of the specimens for laboratory testing.

2.5.4.3.2 Inspection Shafts

Two inspection shafts, TC-1 and TC-2, located as shown on <Figure 2.5-53>, were drilled by means of a crane-mounted Calweld Drill, Model No. 150 CH, capable of developing a maximum Kelley bar torque of

105,000 ft-lbs. Initially, 60-inch O.D. shafts were drilled to approximately Elevation 589', corresponding approximately to the top of the lower till. Subsequently, 54-inch I.D. casing was lowered to the bottom of the hole and drilled into the dense till to effect a water seal. The hole was then extended by a 48-inch O.D. earth auger in stages to accommodate inspection and in situ testing. The in situ testing is described in <Section 2.5.4.2>.

Nine undisturbed "block samples" of the lower till were secured from the two inspection shafts. The block samples were obtained by using an "air spade" to cut the soil specimen from the inspection shaft side walls at the elevations indicated on the test shaft logs in <Appendix 2E>. The block samples were trimmed to cubes approximately ten inches on each side. The block samples were wrapped in aluminum foil and waxed immediately after sampling to preserve the in situ water content. The samples were then packed with insulation in 12-inch cube plywood boxes for transport to the laboratory.

2.5.4.3.3 Subsurface Stratigraphy

The stratigraphic units encountered in the explorations at the site, in descending order, are lacustrine sediments, ground moraine deposits subdivided into an upper till stratum and a lower till stratum and an Upper Devonian shale identified as the Chagrin shale. Stratigraphic sections through the plant area, as determined from the exploratory program, are shown in <Figure 2.5-143>. A summary of the pertinent stratigraphic data is given in <Table 2.5-61>. These stratigraphic conditions were confirmed by geologic mapping of excavations shown on <Figure 2.5-42>.

Below approximately one foot of organic-rich topsoils, glacial lake deposited sediments, usually identified as stratified silty and clayey fine sands (SM, SC), silts (ML) and silty clay (CL), are encountered. Based on Standard Penetration Resistance (SPR) values usually ranging

between 5 and 15 blows per foot, the lacustrine deposits are rated as generally having a firm to stiff consistency or a medium dense relative density. Usually the upper five to ten feet of the predominantly gray and brown soils are oxidized to orange-brown, presumably indicating a seasonal fluctuation in the groundwater level.

At an average depth of approximately 20 feet, the lacustrine sediments grade into a thin horizon of laminated red and gray silty clay (CL) and clayey sand (SC) containing a small percentage of shale fragments. The stratified nature indicates that this portion of the deposit may be a water-worked phase of the upper till unit. Beneath this thin zone, the upper till stratigraphic unit is encountered at an average depth of approximately 28 feet.

Upper till materials are identified predominantly as gray coarse to fine sandy silty clay (CL) of low plasticity, occasionally containing a trace of gravel. The upper till differs from the underlying lower till by having a higher natural water content, a lower consistency, a higher percentage of silt clay and no boulders. The penetration resistance within the upper till was found to be variable, but to generally increase with depth. Based on an undrained shear strength range of 0.38 to 1.60 tsf, the upper till is rated as stiff to very stiff. As indicated by <Table 2.5-61>, the thickness of the upper till unit is variable and averages about eight feet.

The lower till stratigraphic unit underlies the upper till at an average depth of approximately 36 feet below the existing ground surface. This stratum has an average thickness of approximately 21 feet. The lower till materials are identified as predominantly coarse to fine sandy silty clay (CL) of slight to low plasticity, usually containing a trace to little, angular to subrounded gravel-sized rock fragments. Occasional metamorphic boulders, usually less than one foot thick, were encountered in clusters near the base of the lower till deposit. From SPR values usually ranging between 30 and 100 blows per foot, the till

is rated as a "very dense" noncohesive soil or, on the basis of the measured undrained shear strength of 5.5 tsf (average), as a "hard" cohesive soil.

The lowest stratigraphic unit is identified as the Chagrin shale, which is the eastern member of the Upper Devonian Ohio Shale. The Chagrin shale is encountered at an average elevation of 565.0' and is reported to reach a thickness of about 900 feet, as described in <Section 2.5.1.1.7>. The Chagrin shale is classified as a "compaction shale" containing laminations identified as gray/blue-gray silty shale (predominant laminae), medium gray/black clayey shale and, infrequently, light gray sandy shale. Cross bedding and ripple marks are common in the silty and sandy lamina.

Visual examination of core samples revealed a limited, discontinuous surficial zone to be of poorer quality than the underlying shale. The shale within this weathered zone was found to contain frequent to occasional fractures and joints. Below this zone, a uniformly high core recovery was obtained and core samples appeared to be generally sound, with only infrequent fracturing and jointing. The joint system includes a dominant bedding plane set, generally dipping less than five degrees; a near vertical set; and, an infrequently encountered joint set dipping between 45 and 60 degrees. Core samples exhibited a tendency for delayed separation ("checking") along bedding planes after being exposed to the atmosphere.

2.5.4.3.4 Site Geophysical Exploration

Seismic refraction measurements were taken along the seismic lines indicated on <Figure 2.5-144>. More than 6,200 feet of seismic profiling was accomplished in order to determine the depths to bedrock, the thickness of various seismic layers overlying rock and the seismic velocity values of these soil and rock materials. In situ velocity value measurements by cross-hole and down-hole techniques were made in

order to determine the in situ elastic moduli values and Poisson ratio for the various soil and rock strata under the site. Results of these surveys are discussed in <Section 2.5.4.4>.

2.5.4.3.5 Preconstruction Offshore Exploration

Subsurface geologic investigations conducted for the proposed cooling water tunnels and offshore structures were conducted in phases (I and II). Phase I operations consisted of six core borings to assess anticipated tunneling conditions and 55 probes to determine water depth and the lake bottom characteristics, especially in the vicinity of the offshore riser shafts. Core borings were drilled by a truck-mounted drill rig on a drilling platform. Probes were made by lowering a drill rod from a derrick mounted on a small boat. The boring locations (5-1, 5-2, 5-3, 5-4, 5-5, and 5-8) were offset 100 feet from the proposed alignments of the intake and discharge tunnels <Appendix 2E>. After the borings were completed, one to six pumping-in permeability tests were performed within each borehole. Procedures employed in rock coring and permeability testing were similar to those of the onshore program. Thereafter, the open bore hole was backfilled with cement grout and the casing removed.

Results of the Phase I explorations indicated that offshore bedrock conditions were comparable to those onshore. A relatively uniform and generally competent rock mass, Chagrin shale, was encountered. Rock core recovery typically was 95 percent or higher except for the initial upper several feet, presumably subjected to weathering. No evidence of significant zones of close-spaced jointing or faulting was found. Groundwater inflows at tunnel level, approximately 100 feet below the top of rock, were expected to be generally low.

It was predicted that small, persistent inflows of natural gas would be locally encountered during tunnel excavation operations, necessitating continuous monitoring and stringent ventilation requirements. Results

of representative rock core samples selected for laboratory testing are provided in <Table 2.5-62>. The borings and probes confirmed earlier diving reconnaissance of lake bottom conditions. The lake bottom from the shore to approximately 1,500 feet offshore is mantled by a thin veneer of sediments; beyond 1,500 feet, it is mainly bedrock.

Phase II operations were conducted mainly to furnish supplemental quantitative information regarding the groundwater inflows and natural gas potential anticipated during tunneling. Secondary objectives were two-fold: (1) continuously sample the rock mass, and (2) evaluate the lake bottom characteristics in the vicinity of the intake and discharge tunnels and offshore riser shafts relocated subsequent to Phase I exploration. Four borings (5-6, 5-7, 5-9, and 5-10) were drilled and numerous probes conducted <Appendix 2E>. Procedures implemented during these operations were similar to those employed for Phase I. The notable exception involved determination of gas flow rates and shut-in pressure for selected bore hole intervals. This was accomplished by isolating test intervals with an inflatable double-packer assembly which could be moved vertically within the bore hole to the desired test interval. Tubing connected the test interval to monitoring instrumentation, pressure gauges and flow meters, located on the drilling platform.

Results of the Phase II explorations demonstrated lake bottom and bedrock conditions comparable to those previously experienced. Rock core recovery percent remained high except for the first several feet. The rock mass consisted of flat-lying, fissile, shale interbedded with occasional thin, fine-grained sandstone to siltstone bed sets. The rock cores were mostly hard and competent with rare instances of thin soft shale. Coefficients of permeability calculated from the pumping-in tests ranged from a minimum value of 2.31 x 10^{-5} cm/sec to 10^{-6} and 10^{-7} order of magnitude. In several instances, no water flow was achieved.

On this basis it was predicted that groundwater inflows during tunnel excavation would be low and of minor significance. Lake bottom conditions were as previously encountered.

Anomalously high gas flows were encountered from an interval in Boring 5-6, beginning more than 30 feet below a lateral projection of the tunnel invert elevation. A mean flow rate of 32 cubic feet per minute was calculated from data obtained over a 16-hour test period. Instantaneous monitoring of shut-in pressure never exceeded 17 psig. A second significant gas flow occurred in Boring 5-10 test intervals below the tunnel invert elevation projection. In several of these intervals, shut-in pressures reached 45 psig. However, after monitoring flow rates, which generally decayed rapidly with time (7 cubic feet per minute, maximum flow rate), secondary shut-in pressures were monitored. The secondary pressures for each respective interval did not attain the magnitude experienced during their initial shut-in. Methane concentrations for two samples ranged from 88 to 94 percent. Even though hazardous gas flows were not encountered above tunnel invert elevations, the hazardous potential of methane gas during planned tunnel operation, anticipated during Phase I, was confirmed and considered in preparing construction specifications.

2.5.4.3.6 Supplemental Geologic Investigations

Supplemental investigations and analyses of site and site-locale fault offsets were conducted. It was concluded that none of the faults was capable under the criteria of <10 CFR 100, Appendix A>.

2.5.4.3.6.1 Site Locale

On November 29, 1973, during a site visit prior to construction, members of the regulatory staff were shown several minor geologic faults located seven to eight miles south of the site in Lake County, Ohio. After reviewing the faults, members of the NRC regulatory staff recommended

that further investigations be conducted by CEI in order to learn more about the origin, extent and age of these dislocations.

Investigations of the Bates Creek, also known as Warners Creek, thrust fault and Hell Hollow faults included the following:

a. Personal communications with knowledgeable university geologists including:

   Prof. Eugene J. Synuk, Kent State University
   Prof. Murray R. McComas, Kent State University
   Prof. Tom Lewis, Cleveland State University
   Prof. Charles M. Somerson, Ohio State University

   Their opinions as to the origin and ages of the faults uncovered south of the Grand River were similar. From their experience and knowledge, they indicated such features were minor, limited in extent and likely occurred at or near time of deposition or possibly as the result of glacial ice loads and movements. None of the professors contacted had any knowledge of possible deep-seated faulting existing in Lake County.

b. A review of the geologic literature, which included Lake County and the surrounding area, was conducted to assure that no known faults were overlooked. No new information was uncovered.

c. Reconnaissance was conducted to inspect numerous Chagrin and Bedford shale exposures south and west of the site vicinity for evidence of other deformations and age of faulting (including that cited in the literature) in Lake County (<Figure 2.5-145>, <Figure 2.5-146>, <Figure 2.5-147>, <Figure 2.5-148>, and <Figure 2.5-149>, published photographs of representative secondary structures exposed in northeastern Ohio).

d. Mr. James Murphy, recognized as knowledgeable in local area geology (formerly affiliated with Case Western Reserve University and presently with Ohio Historical Society, Columbus, Ohio) was retained to investigate and report on the origin and age of faulting in Lake County.

e. The fault exposures were excavated, mapped and photographed. <Figure 2.5-40> shows the location of faults and outcrops in the site locale. <Figure 2.5-150> and <Figure 2.5-151> are aerial photos of the fault areas. <Figure 2.5-152>, <Figure 2.5-153>, <Figure 2.5-154>, <Figure 2.5-155>, and <Figure 2.5-156> are geologic sketches and <Figure 2.5-157>, <Figure 2.5-158>, <Figure 2.5-159>, <Figure 2.5-160>, <Figure 2.5-161>, <Figure 2.5-162>, <Figure 2.5-163>, <Figure 2.5-164>, <Figure 2.5-165>, <Figure 2.5-166>, <Figure 2.5-167>, <Figure 2.5-168>, and <Figure 2.5-169> are photographs of the site locale faults.

The basic conclusion of the fault investigation and Mr. James Murphy's report was that no evidence of deep-seated faulting has been found in Lake County. This conclusion was reached as a result of an extensive review of available geologic literature, discussions with knowledgeable university geologists, field investigations conducted at Bates Creek and Hell Hollow and field observation of approximately 75 percent of good Chagrin and Bedford shale outcrops in Lake County.

Faults exposed in outcrop in Lake County have been attributed to vertical movements or slumping of bedrock masses along joint planes and minor thrust faults related either to slumping or loading effect of the ice sheet and ice movement during Pleistocene glaciation. Slumping as evidenced at Hell Hollow could have occurred subsequent to the final deglaciation event.

The faults at Bates Creek and Hell Hollow probably have occurred in the last 35,000 years. On the basis of similar type faults found elsewhere and the opinions of knowledgeable geology professors, these minor faults are not expected to be greater than 200 to 300 feet in lateral extent. Excavation completed along the strike of the faults was not sufficient to determine the actual length with certainty. The Bates Creek thrust fault with 12 inches of displacement trends N30-40°E. The faults at Hell Hollow strike N80°E and dip near vertical with displacements of 30 inches at Hell Hollow No. 1 and approximately 12 inches at Hell Hollow Nos. 2 and 3.

At Bates Creek, continuous bedding lies above and below the thrust fault. The Hell Hollow Fault Nos. 1, 2 and 3 terminate downward vertically and are underlain by continuous, unfaulted Bedford or Cleveland shale and become indistinguishable within residual material above the rock/soil interface.

Numerous examples of the type of minor thrust fault investigated at Bates Creek were observed during reconnaissance mapping for structures potentially related to the 1986 Leroy earthquake (Reference 4). These structures varied in offset from a few inches to 10 feet. Even the larger structures typically terminate into bedding plane over short lateral and vertical distances. Excavation, drilling and geophysical surveys conducted over one complex folded and faulted structure near Big Creek showed that the deformation was confined to the near surface. The most likely mechanism for these structures, as previously stated, is glacio-tectonics, either ice traction or loading/unloading phenomena.

The faults investigated at Bates Creek and Big Creek are located in the Bedford/Cleveland shales (Mississippian age). These shales, approximately 45 feet in thickness, are not present at the site. Faults that occur in the Bedford/Cleveland shales are randomly located and are few in number (as evidenced from the field surveys and the literature). Evidence of faulting in Chagrin shale exposures along the Grand River in

Lake County has not been found in the literature search, nor was any observed in the field survey. Similarity of evidence of glacially induced deformation was found in the Chagrin shale within Lake County. The possibility of faulting as a result of slumping was not considered to be present at the site because of the absence of sufficient relief. It was therefore concluded that it would be unlikely that minor surficial faults would exist at the Perry site.

2.5.4.3.6.2 Onshore Deformation Exposed by Plant Excavations

Deformation, as described in <Section 2.5.1.2.3.2>, was exposed within the transitory interval and the upper 30 feet of Chagrin shale. The presence of this superficial bedrock deformation is consistent with the conclusions regarding the origin and age of the glacially induced Bates Creek thrust faults, eight miles south of the site. The deformation is shown on geologic maps and structure sections prepared from the foundation mapping program (<Figure 2.5-41> and <Figure 2.5-42>, respectively).

In addition to the collection of field data accumulated as a consequence of the planned, small-scale, foundation mapping program, independent field and literature reviews were conducted by two independent geologists. One was Mr. James Murphy, who had functioned in a similar capacity in an aerial bedrock geology review of Lake County and adjacent areas. Mr. Murphy also arranged for the submission of a representative, comminuted plant material sample obtained from the site lacustrine deposits for radiocarbon dating by Mrs. Irene Stehli, Radioisotopes Dicar Laboratory (Case Western Reserve University). A second external field review was performed independently from Mr. Murphy by Dr. Charles E. Herdendorf (Director, Center for Lake Erie Area Research, Ohio State University) who had field mapping experience of glaciated terrain in northern Ohio, west of Cleveland in Erie and Huron Counties (Reference 234).

The weight of evidence demonstrating the shallow nature of deformation was cumulative throughout the plant excavation phase. Immediately preceding the initial identification of bedrock deformation within the nuclear island complex, overexcavation below preliminary grade to final foundation grade was undertaken. The basal decollement, glide-plane of one-thrust structure was removed in this manner. Test trenches and exploratory borings, EX-series <Appendix 2E> demonstrated similar evidence for an asymmetric fold traversing the Unit 2 reactor building. Caisson and deep building excavations beyond the nuclear island complex demonstrated both lateral and vertical limits of deformation.

It is concluded, on the basis of data obtained from the mapping program, planned and unplanned excavation, and overexcavation and opinions of two independent reviews, Mr. James Murphy and Dr. Charles E. Herdendorf, that the onshore deformation was shallow and caused by late Wisconsinan and glacial shove and loading. A radiocarbon date obtained from organic material in the site lacustrine silts is 14,480 years B.P. This date suggests that the deformation was associated with an advance of Hiram ice. Dr. R. G. LaFleur (Geology Department staff, Rensselaer Polytechnical Institute) recognized for his expertise in Pleistocene geology and sedimentology, reviewed the reports (submitted to the NRC regulatory staff) and concurred with the statements of fact, interpretations and conclusions regarding origin and age.

The influence of the bedrock deformation on the foundation design analysis and performance of underdrain system were considered. It was determined that neither inclined nor fractured strata could contribute to a bearing capacity failure. Even conservatively assuming that 30 feet of deformed bedrock has properties equivalent to lower till, a deformation analysis demonstrated that the maximum total ultimate settlement would be between 1/3 and 1/2 inch, and a maximum angular distortion (1 in 1,500) would not be exceeded. Clogging of porous concrete by dispersion of soil material into the plant pressure relief underdrain system was considered in a safety evaluation. Neither the

shale mineralogical composition nor cation exchange capacity (maximum value <6.76 MEQ/100 grams) nor exchangeable sodium (maximum value <1.83 MEQ/100 grams) suggested a dispersion potential (see <Section 2.4.13.5.5>, especially Items 4 and 7). Notwithstanding the foregoing analyses, the Applicant committed to the removal of degraded bedrock as described in <Section 2.5.1.2.5.2> and <Section 2.5.4.1.3>.

2.5.4.3.6.3 Offshore Deformation Exposed by Tunneling

A comprehensive investigative program evolved as a result of the bedrock deformation exposed during the tunnel excavation phase (see <Section 2.5.1.2.3.4.1> and <Section 2.5.1.2.3.4.2> and <Appendix 2D> for descriptive information of deformation). Deterministic fault study objectives, extent, origin, and age were realized as a consequence of a series of interrelated geologic and geophysical research and engineering reviews. The nature of fault-plane geometry and its gouge and mineralogical as well as chemical constituents were studied. After site specific data had been assembled, the localized anomalous deformation was interpreted in context of its regional geologic setting.

The extent of faulting, as discussed in <Section 2.5.1.2.3.4.3>, was defined on the basis of the following: (1) tunnel mapping program <Figure 2.5-47>, 24 sheets, Scale 1:120); (2) detailed mapping of tunnel deformation segments (<Figure 2.5-50>, <Figure 2.5-51>, and <Figure 2.5-52>, Scale 1:12); (3) exploratory borings <Appendix 2E>, <Figure 2.5-48> and <Figure 2.5-53>; (4) geophysical logging of selected TX-series borings; (5) shoreline reconnaissance; (6) offshore magnetic survey; (7) lake bottom reconnaissance mapping and seismic track line data; and; (8) comparative isotopic analyses of Lake Erie water and fault seepage.

Fault zone gouge and fractured rock samples were obtained for X-ray diffraction, for clay-mineralogical determinations, SEM (scanning electron microscope) microcrack analysis, and miscellaneous engineering

property determinations including consolidation pressure analysis. No radioactive isotopes, which could have been dated, were identified in fault zone samples.

With respect to the site area and locale studies, the following were performed or prepared: (1) in situ borehole (TX-11) stress measurements to determine existing site stress field orientation and magnitude; (2) structural contour maps of "Big Lime" upper and basal (-50 ft) horizons and isopachous map of intervening interval for Lake and portions of adjacent Ashtabula and Geauga Counties, (3) evaluation of microseismicity in northeastern Ohio and, (4) literature and field review of area salt mines and interviews with mine personnel (Mr. Jaroslav Vaverka, resident mining engineer, Cleveland Mine, International Salt Company, and Mr. B. C. Cummings, resident chief engineer, Painesville Mine, Morton Salt Division of Morton Norwick).

Independent opinions, based on their field inspection of the tunnel deformation and literature review, were obtained from the following geologists recognized for their expertise in the indicated disciplines:

Dr. Robert G. LaFleur
Pleistocene Geology and Sedimentology
Rensselaer Polytechnical Institute

Mr. James Murphy
Area Geology and Stratigraphy of Northeastern Ohio
Ohio Historical Society

Dr. Barry Voight
Structural Geology
Pennsylvania State University

It is concluded, on the bases of data and interpretation of the aforementioned studies and other site and regional geological, geophysical and seismological information discussed in <Section 2.5.1.2.3.4.4> and <Appendix 2D>, that the last movement on the cooling water tunnel bedrock deformation was not tectonic. It occurred

during Pleistocene time probably associated with deglaciation-rebound rather than ice advance compression. On the basis of geometry alone, it is possible that the initial deformation was a pre-Pleistocene event. The presence of the fault deformation intersecting the tunnels was considered during design review and redesign was not required (Reference 235).

2.5.4.3.7 Site Shale Gas Investigation

Natural gas was encountered within the Ohio Shale formation during subsurface exploration for the Perry site and shale gas is known to exist throughout the area of study in quantities sufficient for domestic use. Field testing has been conducted to monitor gas pressure and flow within the site.

2.5.4.3.7.1 Gas Producing Horizons

Natural gas has been commercially developed in Ohio since 1869. The gas horizons in northeastern Ohio that are suitable for modern commercial production are primarily developed below the Ohio Shale and include the Oriskany (±1,600 feet), the Newburg (±2,600 feet), and the Clinton Sand (±2,800 feet) horizons. Presently, there is very little commercial production of gas from the Ohio Shale in northeastern Ohio. Ohio Shale gas and/or oil production is primarily located in southeastern Ohio where shale wells are generally drilled in excess of 2,000 feet. As the shales have a low primary porosity, gas-producing zones are believed to be principally coincident with well fractured zones but may also be associated with occasional sandy shale strata. Within the immediate area of study, gas zones suitable for domestic production are usually encountered at depths below 500 feet.

Although shale gas production rates are quite low, gas wells have proven to be long-lived and production periods for as long as 30 years are not uncommon. Gas pressures within producing zones are known to be under

relatively high gradients which have caused blowouts in drill holes upon a reduction in piezometric pressure. Piezometric pressures in the lower part of the Ohio Shale are less than pressures existing within the underlying Oriskany and Newburg brine aquifers.

2.5.4.3.7.2 Field Investigations

Preconstruction gas sampling as well as monitoring of gas pressure and flow initially were conducted in onshore Boring 1-55, drilled to a maximum of 210 feet below the existing ground surface. Sampling was also conducted in onshore Boring 1-56. Gas monitoring within Boring 1-55 was achieved by terminating NX coring operations at successive depths and bailing water from the hole. Subsequently, a test interval (usually 10 to 20 feet) extending from above the bottom of the hole was isolated by a hydraulic packer system. Gas in this interval was tapped by means of 3/8-inch O.D. tubing leading to a valve arrangement at the ground surface. The gas shut-in pressure and flow were monitored by opening valves leading to a pressure gauge and flow meter. Relatively uncontaminated samples were also obtained through the valve arrangement.

Results of typical shut-in pressure measurement versus shut-in time data are shown on <Figure 2.5-170>. Isolated test intervals extended from 158 to 210 and 106 to 120 feet below the ground surface. The gas pressure in the 158-210 test interval is shown to reach a maximum of 43.8 psi after 40.3 hours of measurement. After depressurization, the initial buildup in pressure was observed to be quite rapid and most of the pressure buildup was noted to be realized after approximately a 15-minute shut-in. Successive venting was also observed to significantly reduce the pressures which could be recovered within a subsequent shut-in.

The measured gas pressures in Boring 1-55 are shown on <Figure 2.5-171>, as a function of the depth of measurement together with the projected

piezometric profile within the shale, assuming an increase of 0.43 psi per foot (the piezometric pressure gradient). The trend of the pressure measurements indicates that the "discovery pressure" of the gas probably approaches the in situ piezometric pressure within the test interval. Gas flow rates do not represent initial discovery rates or even long term steady-state conditions. Steady flow is a function of well size, the length of the producing interval and time from initial gas escape to pressurization. The measured gas flow rates and attendant test data are summarized in <Table 2.5-63>. Although gas was sensed by a methanometer when releases occurred at depths less than 100 feet, the flow was too low to measure. The gas flow was measured over relatively short test periods, and steady-state flows measured during venting over a period of years probably would be significantly less as demonstrated by production gas wells. The limited variation in flow data from Hole 1-55 was consistent with the infrequent fractures identified from the core recovery.

Gas samples were collected from Holes 1-55 and 1-56 for laboratory analysis. The results are shown in <Table 2.5-64>. The principal constituent of the two test specimens was methane. Reported specific gravity is related to a specific gravity of 1.000 for dry air.

Gas testing was also conducted in onshore Boring 1-72, drilled to a depth of 100 feet below existing ground surface. After test interval 140-160 feet had been isolated, shut-in pressures were monitored. Prior to depressurizing this test interval, a second boring, 1-72A offset 15 feet from Boring 1-72, was drilled to the base test interval elevation of Boring 1-72. The 140-160 feet test interval was isolated and shut-in pressures monitored. Depressurization was alternated between the holes. In this way, lateral communication between the holes could be evaluated. Following this demonstration, testing was continued in Boring 1-72 at progressively deeper test intervals. Gas samples from both holes were collected for laboratory analysis.

It was concluded that very little, if any, communication existed between the two holes. Depressurization of one hole did not effect a reduction in shut-in pressure for the other. The gradient of the shut-in pressure versus depth for Boring 1-72 was comparable to that demonstrated for Hole 1-55 which approximated piezometric pressure, 0.43 psi per foot of depth. Composition analyses for all gas samples were virtually identical to those shown in <Table 2.5-64>.

During Phase II offshore exploration, gas testing, similar to that conducted onshore, was performed in the four exploratory Holes 5-6, 7, 9, and 10. Very little gas was present in holes 5-7 and 9, and no quantitative data was collected. The pressure and flow data obtained from Hole 5-10 indicated conditions comparable to the onshore testing. A significant volume of gas was monitored flowing from Hole 5-6.

Field testing indicated that gas could be anticipated during construction. For the relatively shallow onshore excavations, no significant seepages were expected under site piezometric conditions. Any seepages which could have occurred were not considered to represent an explosive hazard. However, potentially hazardous conditions were considered for tunnel operations under piezometric or anomalous pressure conditions. Therefore, very conservative measures regarding monitoring, ventilation, machine shutdown, and evacuation were incorporated into the tunnel bidding and construction specifications.

2.5.4.3.7.3 Gas Migration

The effects of gas migration were considered for the long term performance of the plant during its operating life.

The migration of shale gas, either under the influence of a pressure gradient or by diffusion, is a function of transport media properties. For percolation through intergranular (primary) and fracture (secondary) space, these properties include the Coefficient of Permeability (k),

methane viscosity (μ) and Threshold Pressure (P_t) (Reference 236) (Reference 237) (Reference 238). Threshold pressure is synonymous with pressure or pressure gradient differential which is the force required to initiate water drive in a saturated material. The diffusion analysis requires evaluation of the Diffusion Coefficient. Dr. D. L. Katz, Professor of Chemical Engineering, University of Michigan, recognized for his expertise in natural gas development and storage, was retained to assign transport media properties for the Chagrin shale and plant concrete <Table 2.5-65>.

2.5.4.3.7.4 Analysis of Gas Percolation Potential

It was concluded that a single 4-foot thick zone of shale, not extensively fractured, would be sufficient to reduce the seepage rate to a relatively negligible amount using Equation 2.5-8.

$$q = \frac{ka(P_1 - P_2)}{\mu L} \qquad (2.5\text{-}8)$$

where:

q = Flow rate, mean pressure (L^3/T)

k = Permeability (L/T)

A = Cross-section area of flow (L^2)

P_1 = Upstream pressure (F/L^2)

P_2 = Downstream pressure (F/L^2)

L = Flow path (L)

μ = Viscosity (CP)

During construction dewatering operations, groundwater levels within the excavation were depressed by as much as 55 to 60 feet, creating a piezometric pressure differential (threshold pressure) as much as 26 psi at foundation grade.

The groundwater level will be established above the shale rock surface, maintaining a saturated shale condition during plant operation. Any upward gas seepage through water saturated shale strata, not excessively fractured, would require a pressure differential on the order of 1,000+ psi to initiate displacement of the pore water by the natural gas.

In considering a more conservative assumption, percolation of gas seepage through Chagrin shale could occur if continuous communicating fractures are pervasive throughout the entire shale mass. However, a maximum pressure differential (threshold pressure) of 26 psi would not be sufficient to exceed the threshold pressure of 60 psi for saturated concrete. It is concluded that saturation of uncracked concrete mats and the use of waterproofing membranes will preclude whatever gas infiltration could occur by the percolation mechanism during plant operation.

2.5.4.3.7.5 Analysis of Gas Diffusion Potential

The rate of gas diffusion from storage horizons to the base of overlying substructures is a function of gas pressure, temperature, length of travel, gas diffusibility as well as other gas properties, expressed by Equation 2.5-9:

$$N_A = \frac{P\,D_e}{RTL} \ln \frac{1-.256\,Y_{A2}}{1-.256\,Y_{A1}} \qquad (2.5\text{-}9)$$

where:

N_A = Rate of gas diffusion (lb moles/L^2/T)

T = Temperature (T)

R = Gas Constant (FL/lb moles T)

P = Pressure (F/L^2)

L = Length of path(L)

D_e = Diffusion coefficient (L^2/T)

Y_{A1} = Mole fraction of methane at entrance

Y_{A2} = Mole fraction of methane at exit

Upper limit diffusion rates through unsaturated concrete mats, having a thickness of four and ten feet respectively, assuming an infinite gas source at the base of the mat, have been calculated using Equation 2.5-9 and the material properties given in <Table 2.5-65>. The results of these calculations indicate that methane under a pressure of one atmosphere would diffuse through the two postulated concrete mats thicknesses at rates of 2.3×10^{-6} and 9.2×10^{-7} cubic feet per minute per square foot of mat area, respectively. These thicknesses are typical of plant substructure fill concrete. Thus, for the plant substructure area of 30,000 square feet, 0.07 and 0.03 cubic foot of methane per minute is predicted to enter the building, by diffusion alone, through the 4-foot and 10-foot thick concrete mats, respectively.

These calculations also show that only 0.001 cubic foot per minute of methane would diffuse through a 4-foot layer of dry shale. The actual rates would be significantly less than the predicted rates on the basis of saturated shale strata and concrete during plant operation. The use of waterproofing membranes is expected to reduce diffusion rates through concrete by at least two orders of magnitude. In summary, it is concluded that diffusion rates are too low to enable gas accumulation sufficient to form a hazardous condition, considering that all substructure spaces will have ventilation systems with an air circulation rate many times greater than the rate of gas diffusion.

2.5.4.4 Geophysical Surveys

A standard seismic refraction survey was performed with seismic lines profiled both in the vicinity of the plant site and along the edge of Lake Erie. Subsequent to the refraction survey, in situ velocity measurements were made using some of the test borings at the plant site.

These measured values of the compressional and shear wave velocities and unit weight values were then used to calculate the elastic moduli values.

2.5.4.4.1 Seismic Refraction Survey

Refraction profiles were operated with SIE, twelve-channel system using a photographic recording oscillograph with two-millisecond timing lines; four shot points were made for each spread, one at each end and two along the spread for maximum near-surface velocity control. Continuous profiling was accomplished by "tying-in" the end point of the spread with the starting point of the next spread; also, checking was accomplished by intersecting profiles at selected locations. Closer spacings of geophones (10 or 20 feet) near the end point locations and greater spacings of geophones (20 or 40 feet) along each spread were utilized to achieve velocity control, layer resolution and depth of penetration.

Cross-hole measurements were made with three-component geophones (two orthogonal horizontal and one vertical element) in four holes of a multi-hole array with the shot point in the fifth hole; all elements were placed at the same elevation level for each particular measurement. Geophones were located at distances varying from 25 to 187 feet from the shot point in order to achieve control in determining wave velocity values and in distinguishing the "P" wave arrivals from "S" wave arrivals. Measurement procedures were rotated and reversed by interchanging the shot point and detector positions. The intervals of measurement were 10 feet, except for thin layer observations where a 5-foot separation was utilized.

As a matter of standard procedure, all profiles were reversed. All reported "S" wave data represented direct wave arrival observations. Refracted wave arrival data were also observed; they were used to determine boundaries of layers and to verify the direct wave arrivals.

A sample set of refracted and direct arrival-time curve data is included as <Figure 2.5-172>. Electric blasting caps (either singularly or in groups) were used for the borehole measurements.

2.5.4.4.2 Results - Seismic Refraction Survey

A total of seven seismic lines were profiled. The locations of these lines are shown in <Figure 2.5-144>. The results of the seismic survey are shown in profile form on <Figure 2.5-173>.

With the exception of Line E, which was profiled along Lake Erie, the seismic lines show four different velocity layers. The top layer velocity of 1,000-2,000 ft/sec is indicative of an unconsolidated overburden which is identified by boring logs as "lacustrine sediments" and "lacustrine deposits." The second layer velocity of 5,000 ft/sec is characteristic of a saturated overburden. The water table is close to the surface at this site and the 5,000 ft/sec velocity correlates with saturated "lacustrine sediments" and "lacustrine deposits" shown on the test borings.

The third layer velocity of 7,500 to 8,000 ft/sec is characteristic of very dense overburden and correlates with the "lower till" material shown on the boring logs. The fourth layer is rock with a velocity of 10,000 to 11,000 ft/sec; the boring has identified rock as the "Chagrin shale." This velocity value correlates with the top of high recovery rock (recovery greater than 70 percent).

Line E, which was profiled along the edge of Lake Erie, shows a thin top layer of 5,000 ft/sec material corresponding to saturated "lacustrine deposits" overlying material with velocity of 7,500 to 8,000 ft/sec. Borings 1-27 and 1-28 confirm the existence of the more compact, high-velocity material and identify it as the previously mentioned "lower till."

2.5.4.4.3 In Situ Velocity Measurements

In situ "P" wave and "S" wave seismic velocity measurements were made in the boreholes, as shown on <Figure 2.5-144>, using the following measurement techniques.

2.5.4.4.3.1 Cross-hole Measurements

These measurements were made by using three-dimensional geophones, containing one vertical and two horizontal elements. Seismic energy was generated in one borehole and detected by the geophones at four remaining boreholes at the same elevation level. This procedure was repeated using different distance combinations of source and detector arrays and at different elevation levels.

2.5.4.4.3.2 Down-hole Measurements

These measurements were made with four, three-dimensional geophones positioned at 20-foot intervals in Boring 1-33. Energy was generated near the top of bedrock at Elevation 560.0', just below the casing of an adjacent hole (15 feet away), Boring 1-34. Measurements of the "P" and "S" wave arrivals were made down the length of the hole by overlapping geophone positions each time the array was lowered.

2.5.4.4.4 Results of In Situ Seismic Velocity Measurements

The results of the in situ "cross-hole" and "down-hole" velocity measurements are shown on <Table 2.5-21>. It should be noted that from approximate Elevation 595' to 583' a "P" wave velocity of 5,900 ft/sec and an "S" wave velocity of 1,900 ft/sec were measured. These velocities correlate well with the "upper till" layer which is too thin to be detected by the seismic refraction survey.

The “P” and “S” wave velocities are used with the unit weight values to calculate elastic moduli values. These results were also presented in <Table 2.5-21>. Also, included in <Table 2.5-21> is a generalized geologic correlation based on Boring 1-33.

The results of the “down-hole” measurements <Table 2.5-21> for rock show a “P” wave velocity of 9,000 ft/sec and an “S” wave velocity of 4,000 ft/sec. These are slightly lower velocity values than the cross-hole measurements indicated. In the cross-hole measurements, data recorded parallel to bedding planes, and in the down-hole procedures, the measured velocity data are obtained nearly perpendicular to the bedding plane. The elastic moduli, based on the down-hole velocity measurements, are also shown on <Table 2.5-21>.

2.5.4.5 Excavations and Backfill

2.5.4.5.1 Excavations

Excavations for plant structures extend as deep as Elevation 531.0’. This is well into the Chagrin shale. All Seismic Category I structures are supported either on porous concrete placed directly on shale, on drilled piers bearing within the shale, or on Class A fill bearing on the lower till. As described in <Section 2.4.13.5>, the porous concrete in the main plant area serves as a drainage medium to relieve hydrostatic pressures. Typical design cross sections of the plant excavations are shown in <Figure 2.5-143>. The results of geologic mapping of the excavations are shown in <Figure 2.5-41> and <Figure 2.5-42>.

Special subgrade protection and treatment procedures which were employed during and after foundation excavation are discussed in <Section 2.4.13.5.5.c.4.(a)>, <Section 2.5.4.12.1> and <Section 2.5.4.14.1>. In addition, preparation of rock surfaces was accomplished by applying high pressure air to remove loose and weathered

debris as well as till and lacustrine sediments which may have adhered to the bedrock. In some instances manual removal of these materials was employed where required due to inaccessibility or in wet rock conditions. All bedrock surfaces were mapped by the Project Geologist or his designated representative, after which the Resident Geotechnical Engineer approved the foundation surface just prior to the placement of porous concrete. In the case of soil subgrades, the Resident Geotechnical Engineer approved the foundation surface just prior to the placement of porous concrete.

Heave gauges and extensometers were used to monitor rebound of the Chagrin shale due to excavation stress relief, as described in <Section 2.5.4.13.2> and <Section 2.5.4.13.3>. Settlement and/or rebound of structures during and after construction have been and will continue to be monitored by survey elevation markers as described in <Section 2.5.4.13.4>.

The excavation side slopes were inclined at a nominal ratio of 1.5 horizontal to 1.0 vertical through the lacustrine sediments, 0.5 to 1.0 through the upper till and lower till and 0.25 to 1.0 through the shale. A bench was constructed at the top of the upper till with a drainage ditch in order to intercept and collect groundwater seepage emanating from the lacustrine sediments.

The plant excavations are backfilled to an elevation at least two feet above the top of upper till with Class A fill and then to finished grade, Elevation 620.0’ with Class B fill. Some Class C fill (nonsafety) may be found between approximate Elevation 615.0’ and finished grade. A typical section of the backfill is shown in <Figure 2.5-174>.

2.5.4.5.2 Class A Fill

Class A fill consists of clean, durable, free-draining sand and gravel obtained from commercial quarries. During initial design studies, the strength and deformation characteristics of a locally available crushed limestone was investigated to establish design parameters for the Class A fill. The crushed limestone was furnished by a quarry of the Marblehead Stone Division of the Standard Slag Company, near Sandusky, Ohio, and was assumed to be typical of material which could also be supplied by other quarries. Soundness and durability tests on the sample gave a Los Angeles abrasion loss of 29.5 percent and a sodium sulfate loss of 5.2 percent. The grain size distribution of the quarry sample is shown in <Figure 2.5-175>, which also shows the grain size distribution of the reduced sample used for testing. The results of static triaxial compression tests are shown on <Figure 2.5-176>. The initial tangent modulus from the tests is shown by Equation 2.5-10.

$$E_i = 700\, P_a \left(\frac{\sigma_3}{P_a}\right)^{0.5} \qquad (2.5\text{-}10)$$

where:

E_i = Initial tangent modulus

P_a = Atmospheric pressure

σ_e = Confining pressure

Dynamic properties of the Marblehead crushed limestone were investigated by two four-inch diameter resonant column tests using a high-amplitude torsional device of the University of Michigan. Typical test results are shown in <Figure 2.5-177>. The shear moduli computed from the measured shear velocities were normalized for a shear strain level of 10^{-4} percent to determine the maximum shear modulus (G_{max}) (Reference 239). The G_{max} values were plotted as a function of confining pressure, as shown in <Figure 2.5-178>, and the shear modulus parameters

K_{2max} and n were determined graphically to be 72 and 0.52, respectively. For dynamic response design analyses, a value of n = 0.50 was used while K_{2max} was varied from 75 to 95.

The Class A fill which was actually used in construction was obtained from the Bestone Quarry, Chardon, Ohio, and the R. W. Sidley Quarry, Thompson, Ohio. Prior to use, samples of the material from each quarry were tested to certify compliance with specifications and the design parameters. A summary of the specified properties and the certification test results are presented in <Table 2.5-66>. It is noted that some of the material submitted by the Bestone Quarry was outside of the grain size distribution specification range. This deficiency was corrected during actual fill placement. Also, the coefficient of permeability of the Bestone Quarry material was below that originally specified. However, an analysis was performed which demonstrated that the Class A fill would have sufficient drainage capacity with a reduced permeability of 0.2×10^{-3} cm/sec, and the material was accepted. The minimum specific gravity requirement was also reduced to 2.60 during the plant construction phase.

Class A fill placement specifications required an average and minimum relative density of 85 and 80 percent, respectively, in load-bearing areas, where structures are founded above the fill, and 80 and 75 percent, respectively, in areas outside of building lines. Minimum and maximum density tests were performed for each 4,500 cubic yards of fill placed, and inplace density and grain size distribution tests for each 150 cubic yards or once per lift, whichever was more frequent. However, in confined areas, where the volume of each lift was less than 50 cubic yards, inplace density tests were performed once every third lift or every 50 cubic yards, whichever was more frequent. Beginning in May 1994, the frequency of minimum and maximum density, grain size distribution and specific gravity testing was changed to once every 250 cubic yards of fill placed.

The maximum and minimum density standards used to compute the relative density of each inplace density test were the averages of the 15 most recent maximum and minimum density tests performed prior to the inplace density test. However, if a maximum and minimum density test was performed on an inplace density test sample, then that single determination of maximum and minimum density was used to compute the relative density of the inplace density test. Alternatively, for yard area backfill placed after May 1994, use of Relative Compaction, (Rc, the ratio of inplace dry density to the maximum dry density) was allowed, provided the maximum density value was obtained using the same method which is used to obtain the relative density for the fill and consistent relationship between the relative compaction and relative density so obtained can be established for the fill.

Through the end of July 1981, approximately 437,000 cubic yards of safety-related Class A fill have been placed, and approximately 6,170 inplace density tests and grain size distribution tests have been performed. The gradation range of the Class A fill which has been placed is shown in <Figure 2.5-179> and <Figure 2.5-180>. A summary of field density tests obtained for quality control during the placement of Class A fill is shown in <Figure 2.5-181>. Reasons why 47 relative density tests of Class A fill are documented below the 75% minimum specified are as follows: (a) certain areas after recompaction were visually accepted by the Resident Geotechnical Engineer (RGE), with no further tests taken; (b) scattered isolated failing tests were accepted by the RGE because all surrounding density tests were satisfactory; and (c) some tests were taken in nonsafety-related fill used for laydown areas and as backfill around nonsafety pipe.

A total of 181 laboratory constant-head permeability tests have been performed on material removed from the fill with the lowest coefficient of permeability obtained being 2.16×10^{-3} cm/sec and the average 1.69×10^{-2} cm/sec. Also, 51 inplace falling head permeability tests have been performed with the lowest coefficient of permeability obtained being

9.45×10^{-3} cm/sec and the average 3.77×10^{-2} cm/sec. The minimum required coefficient of permeability is 2×10^{-4} cm/sec.

Based on U.S. Department of Agriculture, Soil Conservation Service (Reference 240), the Class A fill which was placed is a suitable filtering medium for drainage of the lower till and most of the upper till materials. The SCS method reduces the stringency of the filtering requirements when the base materials exhibit plasticity. Approximately one-third of the grain size distribution tests on the upper till showed results which are finer than that recommended for filtering by Class A fill. However, as described in <Section 2.5.4.6.3>, the seepage from the upper and lower till strata are negligible and undetectable. Therefore, filtering of these strata are not required. Class A fill is generally not a good filtering medium for Lacustrine soil. Therefore, a minimum three feet wide filter zone of Class B fill is placed between the Class A fill and the Lacustrine soil, as shown on <Figure 2.5-174>. This Class B fill filter zone is restricted such that at least 15 percent of the particles are retained on the No. 200 sieve.

2.5.4.5.3 Class B Fill

Class B fill was used for nonload bearing backfill around Seismic Category I structures as shown in <Figure 2.5-174>, and consists of lower till soil which was removed and stockpiled during plant excavation. A typical compaction curve is shown in <Figure 2.5-182>. The maximum dry density (ASTM D 1557) has been found to range from 128.6 to 137.5 pounds per cubic foot and the optimum moisture content from 7.4 to 13.0 percent. Class B fill is compacted to not less than 92 percent of the maximum dry density, at a moisture content not less than three percentage points below nor four percentage points above the optimum moisture content. Through the end of July 1981, approximately 286,000 cubic yards of Class B fill have been placed and approximately 380 inplace density tests have been performed. The gradation range of the Class B fill which has been placed is shown in <Figure 2.5-183>. A

summary of field density and moisture tests taken for quality control during placement of the Class B fill is shown in <Figure 2.5-184> and <Figure 2.5-185>. Reasons for 11 of the density tests being recorded below the 92% minimum specified are that some were in isolated areas surrounded by fill with passing tests, and other tests were taken in nonload bearing backfill areas.

Once the Class B stockpile is depleted, off-site material can be used. This material is approved by the site Resident Geotechnical Engineer based on evaluations which confirm that the off-site material has properties similar to the excavated lower till material originally used as Class B fill.

2.5.4.5.4 Field Testing of Backfill

An onsite testing laboratory was established to perform all field testing. A defined Quality Assurance Program and approved procedures were implemented to assure that proper testing methods, procedures and equipment were used in field testing.

2.5.4.5.5 Controlled Low Strength Material (CLSM)

Controlled Low Strength Material (CLSM) may be used as a replacement for Class B and Class C fill, and as a replacement for Class A fill when the Class A fill was used as bedding and backfill for buried piping and ductbanks only, and not as part of the Plant Underdrain system, or as a foundation for safety-related buildings or structures. Since the CLSM is equivalent to or better than Class B Fill in bearing capacity and impermeability, this change has no effect on the results of USAR <Section 2.5.4.5.1>, <Section 2.5.4.5.2>, and <Section 2.5.4.5.3>.

2.5.4.6 Groundwater Conditions

2.5.4.6.1 Preconstruction Groundwater Conditions

The surficial stratum of lacustrine sediments is the principal water-bearing zone at the plant site. The underlying, relatively impervious till retards the downward percolation of groundwater. Observations made in the test borings at the site indicate groundwater levels usually ranging from three to five feet below the ground surface in the main plant area with the depth gradually increasing to 6 to 11 feet in the close vicinity of Lake Erie. Within the plant area, the groundwater level was observed to generally range between Elevations 613' and 624'. Regional groundwater conditions are described in <Section 2.4.13>.

Pneumatic, Casagrande (double-tube) heavy liquid-type piezometers and standpipes were utilized to monitor the groundwater conditions. The piezometers were installed at five locations throughout the plant site, as shown on <Figure 2.5-53>. At the three pneumatic piezometer locations, the piezometers were installed and sealed at three levels within the glacial till and the underlying shale. The piezometer readings are summarized in <Table 2.5-67> and indicate essentially full gravitational hydrostatic pressure to the maximum depth investigated, i.e., Elevation 555'.

2.5.4.6.2 Permeability of Subsurface Materials

2.5.4.6.2.1 Initial Investigations

During initial investigations, a limited number of in situ permeability tests were conducted to aid in the evaluation of groundwater infiltration to be expected into excavations for plant foundations during construction. In addition, the coefficient of permeability was also estimated from laboratory consolidation test results.

Two rising-head permeability tests were conducted within the lacustrine stratum in boring RC-2 at a depth of 20 feet. The mean coefficients of permeability determined from the two tests were 3.12 x 10^{-5} cm/sec and 2.33 x 10^{-5} cm/sec. The mean coefficient of permeability is defined by Equation 2.5-11.

$$k_m = (k_h \cdot k_v)^{1/2} \qquad (2.5\text{-}11)$$

where:

k_m = Mean coefficient of permeability
k_h = Horizontal coefficient of permeability
k_v = Vertical coefficient of permeability

The vertical coefficient of permeability of the lacustrine soil was calculated from the results of two consolidation tests using Equation 2.5-12.

$$k_v = \frac{c_v a_v q_w}{1 + e} \qquad (2.5\text{-}12)$$

where:

k_v = Vertical coefficient of permeability
c_v = Coefficient of consolidation
a_v = Coefficient of compressibility
q_w = Unit weight of water
e = Void ratio

The resulting vertical coefficients of permeability were determined to be 1.8 x 10^{-5} cm/sec and 2.8 x 10^{-5} cm/sec for the two tests. Assuming the ratio of the horizontal to vertical coefficients of permeability to be 10, the average horizontal coefficient of permeability was calculated

to be 2.3 x 10^{-4} cm/sec. The resulting mean coefficient of permeability is 7.3 x 10^{-5} cm/sec as compared to an average of 2.7 x 10^{-5} cm/sec from the in situ tests.

One in situ rising head permeability test was conducted in the upper till in boring RC-1 at a depth of 30 feet. Assuming the horizontal and vertical permeabilities to be equal in the till, a coefficient of permeability of 2.6 x 10^{-7} cm/sec was computed from the test results. The coefficient of permeability was also calculated from three consolidation tests, yielding values ranging from 1.8 x 10^{-5} cm/sec to 6.2 x 10^{-6} cm/sec, with a logarithmic average of 1.0 x 10^{-5} cm/sec.

The permeability of the lower till was estimated from five consolidation tests. The results ranged from 1.1 x 10^{-6} cm/sec to 2.4 x 10^{-6} cm/sec and had a logarithmic average of 1.6 x 10^{-6} cm/sec.

A total of 23 constant head, pump-in (pressure) tests were conducted in the upper 20 feet of shale in Borings 1-68, 1-70 and 1-74. Single and double packer systems were employed to isolate potentially pervious sections. Flow rates were measured using a water meter. However, the flow rates were so small that in most tests no flow was recorded by the meter. It was then determined in the laboratory that a minimum flow rate of 13.87 cm^3/sec was required before the meter would register consistently. Therefore, in all tests where no flow was recorded, it was conservatively assumed that the actual flow rate was 13.87 cm^3/sec. For measured flow rates greater than zero, the calibration curve determined in the laboratory was used to determine the actual flow rate.

The results of the in situ test in the shale are presented in <Table 2.5-68>. Because most of the test results over-estimate the permeability of the shale, due to the inability to measure very low flow rates, a coefficient of permeability of 5.0 x 10^{-6} cm/sec was chosen to characterize the upper 20 feet of shale.

2.5.4.6.2.2 Supplemental Investigations

Extensive supplementary investigations of the permeability of the subsoil and shale at the site were conducted and reported in 1975 in order to verify the parameters used in design of the plant underdrain system <Section 2.4.13.5> and to determine the effect of the permanent groundwater drawdown at the plant on the surrounding groundwater regime (Reference 241).

The additional testing included 78 falling-head and rising-head permeability tests in seven boreholes (PT-1, PT-1A, PT-2, PT-2A, PT-3, PT-4, and PT-4A), and six laboratory constant-head permeability tests on relatively undisturbed samples obtained from the borings. The results of the field tests are summarized in <Table 2.5-69> and those of the laboratory tests in <Table 2.5-70>.

The supplemental investigations also included a long term pumping test using a six-inch diameter deep well, DW-1. The well was drilled to a depth of 71.4 feet, penetrating about 15 feet into shale. A three-inch diameter well casing was used, perforated the entire length, with filter sand placed between the casing and the soil. A bentonite seal was placed near the ground surface to prevent intrusion of surface water.

Five 20-foot deep observation wells were aligned at distances from 15 feet to 530 feet from the pumping well to determine the influence of the well on the lacustrine groundwater level. Also, piezometers had previously been installed in Boring 1-75, located 30 feet from the pumping well. This boring contained three piezometers, one each in the upper till, lower till and shale strata. Groundwater monitoring locations are shown on <Figure 2.5-53>.

The deep well was pumped for a period of 24 days at an average rate of about 0.12 gallon per minute. The water level in the well was maintained at an average elevation of about 565’. It was found that the

pumping had no discernible effect on the observation wells in the lacustrine stratum, even at a distance of only 15 feet from the pumping well. However, a significant drop in piezometric head occurred in the piezometers in the lower till and shale in Boring 1-75, 30 feet from the pumping well. It was concluded that this reduction of head was caused by very thin seams of comparatively high permeability, such as horizontal joints in the shale, and that no significant quantity of seepage would be derived from these seams.

2.5.4.6.3 Seepage During and After Construction

Based on the initial investigation of the permeabilities of the subsurface materials, it was conservatively estimated that total seepage into the plant excavation during construction would be in the range of 40 to 80 gallons per minute. Based on the more detailed supplementary investigations, it was concluded that the seepage rate would be on the order of one-tenth of the original conservative estimate. It was further concluded that most of the seepage would be derived from the lacustrine stratum and that the seepage from the glacial till and shale would probably evaporate and not be detectable.

During construction, the seepage estimate described above was confirmed. The seepage collected in the peripheral ditch from the lacustrine stratum was estimated to be less than ten gallons per minute. No seepage was detected in the till strata or shale, and the excavation bottom was dry. Seepage into the plant underdrain system after the excavation is backfilled will be essentially the same as that experienced during construction.

As described above, no seepage was detected in the lower till stratum of shale and the plant excavation bottom was dry. The estimated mean coefficients of permeability for these materials are 2.0×10^{-7} cm/sec and 8.0×10^{-8} cm/sec, respectively. The corresponding seepage velocity in these materials is less than 4 feet per year, for gradients as large

as 4. This amount, which is consistent with the lack of observable seepage, is far too small to cause erosion which could contaminate and/or clog the Class A filter.

2.5.4.6.4 Radius of Groundwater Drawdown

In order to monitor the long term effect of the plant dewatering system on the local groundwater levels, four lines of well-point piezometers were installed as shown in <Figure 2.5-186>. The piezometer lines extend 1,000 feet from the plant in the east and south directions and 550 feet in the north and west direction. The average monthly readings for each piezometer are shown in <Figure 2.5-187>. Groundwater drawdown profiles along the piezometer lines are shown on <Figure 2.5-188>. (Some of the piezometers were removed and replaced at various times due to construction activity conflicts.) It is concluded that the groundwater level within the lacustrine stratum is not affected beyond a radius on the order of 500 feet from the plant, as anticipated. In most piezometers, the groundwater drawdown appears to have already (March 1979) stabilized to a steady-state condition.

The piezometers sealed within the lower till and shale <Figure 2.5-188> generally indicate piezometric levels within about three feet, above or below, the lacustrine level. However, in piezometers E-3B and N-4B, both in shale, the piezometric levels (March 1979) are 7.0 and 4.3 feet below the lacustrine water level, and are continuing to decline. The same phenomenon occurred during the pumping test, as described in <Section 2.5.4.6.2.2>, and is attributed to very thin seams of high permeability, such as horizontal joints in the shale. No significant amounts of seepage would be expected from these joints.

The frequency of groundwater monitoring will continue on a once per month basis throughout construction and until one year after plant startup, at which time the frequency will be reduced to once every three months (quarterly). In addition to the four lines of well point

piezometers shown on <Figure 2.5-186>, new piezometers will be installed prior to startup in the plant backfill zone, as shown on <Figure 2.5-174>, one on each side of the plant. These four new piezometers will be monitored at the same frequency as the other piezometers. The purpose of these four piezometers is to monitor the effectiveness of the Class A Fill during the life of the plant.

Since the underdrain system manholes are an integral part of the underdrain system (i.e. porous concrete and Class A Fill), indications of groundwater elevations immediately adjacent to the plant will be noted in the control room. The control room computer will print-out a notification that the manhole service pumps turn on when the manhole water levels reach the high level setpoint. A control room alarm will sound if the water levels reach an elevation of 568.5 feet. The complete pressure relief underdrain system is discussed in <Section 2.4.13.5.1>. Hydrostatic pressures beneath foundation mats will also be indicative of groundwater fluctuations and will be monitored by means of standpipes installed through the safety-related building mats into the porous concrete as described in <Section 2.4.13.5.3d>.

Due to the very small quantity of seepage entering the underdrain system, as described in <Section 2.5.4.6.3> no significant fluctuation in groundwater level within the backfill around the plant is anticipated. Within the natural soils and rock, which support safety-related pipelines surrounding the plant, some seasonal groundwater fluctuation will occur due to variations in precipitation. Based upon historical records, such fluctuations are not expected to exceed about five feet and will not cause measurable subsidence under safety-related facilities.

2.5.4.6.5 Stability of Seismic Category I Structures

As described in <Section 2.4.13.5>, the plant underdrain system is designed to maintain the groundwater level immediately surrounding the plant at Elevation 568.5'. A discussion of the resultant hydrostatic forces is presented in <Section 2.4.13.5>.

2.5.4.7 Response of Soil and Rock to Dynamic Loading

Most of the primary structures for the Perry site are supported on shale bedrock. Lower till and Class A fill soils are also used for support of Seismic Category I and other plant structures. The lower till and Class A fill bearing materials will not be susceptible to liquefaction, as described in <Section 2.5.4.8>, or significant compression due to SSE motions. The shale is not susceptible to loss of strength during cyclic loading. The seismic responses for structures founded above the shale are described in <Section 3.7.1.4>.

2.5.4.8 Liquefaction Potential

2.5.4.8.1 Class A Fill

An analysis of the liquefaction potential of Class A fill was conducted in accordance with the procedures recommended by Seed and Idriss (Reference 242). The method of analysis and the results thereof are described as follows.

The dynamic response of the load-bearing fill, having properties described in <Section 2.5.4.5>, was investigated using the SHAKE IV computer solution to the one-dimensional wave equation (Reference 243). The strain dependent dynamic properties, described in <Section 2.5.4.5> for the Class A fill and in <Section 2.5.4.2> for the lower till, were

incorporated in the program using the average shear modulus reduction and damping versus shear strain relationships recommended by Seed and Idriss (Reference 239).

The SSE artificial time history was developed for the top of the dense till layer or as described in <Section 3.7.1>. This was input at the shale surface level and in accordance with the following:

a. The horizontal shear stress time history at various levels below the free surface was calculated.

b. The average equivalent uniform shear stress was derived for each level by appropriate weighting of the shear stress amplitudes, considering the number of significant stress cycles of the SSE.

c. The induced shear stress was plotted as a function of depth.

The number of cycles (N_c) of stress (σ_{dc}), required to cause initial liquefaction of granular soil during cyclic shear testing and the relationship of laboratory and field behavior, has been studied by Seed and his co-workers (Reference 244) (Reference 245). From this work, it has been concluded that given N_c, σ_{dc} can be predicted as a function of confining pressure (σ_3), the d_{50} grain size and the relative density of the granular soil. The N_c versus $\sigma_{dc}/2\sigma_3$ relationship used to characterize the Class A fill is shown in <Figure 2.5-189>. The number of significant cycles of the SSE, a function of the intensity and duration of the strong motion of the earthquake, was taken as $N_c = 10$. As reported by Idriss and Seed, the assumed N_c corresponds to a Richter Magnitude 7 earthquake, whereas the SSE (Intensity VII) corresponds to approximately Magnitude 6 and represents a significant degree of conservatism (Reference 247).

For the free field case, the ratio between the shear stress required for initial liquefaction to the developed shear stress was found to be

greater than one, and to increase with depth, even though the increase in confining pressure afforded by the stresses imposed by foundations and adjoining fills is ignored. The results of this analysis are shown in <Figure 2.5-190>. A second analysis, considering the influence of a uniformly applied pressure of 5.0 ksf, simulating the foundation mat interaction, predicts a minimum stress ratio of 2.2.

It is pertinent to note the extreme conservatism implicit in the initial liquefaction criterion used to express the “failure” of very dense granular soils. As demonstrated by Seed and Lee, as the number of stress cycles exceed that required for initial liquefaction of dense granular soils, the strains do not increase abruptly, but only gradually (Reference 244). Thus, it is reasonable to set a “limit strain” criteria such as 5 to 7.5 percent single amplitude. According to Wong, this would increase the 10-cycle shear strength by at least 10 percent (Reference 246). Even a greater increase would be justified if consideration is given to an effective principal stress ratio (k_o) greater than is predicted for a normally consolidated state. As vibratory compaction of the fill to a relative density of 85 percent will produce a principal stress ratio (k_o) of at least one, k_o is significantly greater than $k_o \underset{\sim}{\ }0.45$, the value applicable to the field behavior correction factor (C_r) which was used in the liquefaction analysis. It has been shown by Seed and Peacock that an increase in k_o from 0.45, the normally consolidated condition, to $k_o = 1$ increases C_r from 0.7 to 1.5 (Reference 245). Even allowing for a k_o after compaction of only 0.6, C_r becomes 0.90. This increase is about 28 percent greater than assumed in the liquefaction analysis appropriate to $k_o \underset{\sim}{\ }0.45$. Therefore, the minimum ratio of the shear stress required for initial liquefaction to the maximum shear stress developed during the SSE is greater than 1.28 without consideration of other accumulative conservatisms cited previously. This stress ratio is shown as a function of the depth of fill in <Figure 2.5-190>. In summary, there can be no reasonable doubt that Class A fill, conforming to the

specified quality and compaction criteria, will not be susceptible to even initial liquefaction under the postulated SSE ground motions.

The conservatism used in the development of the Class A fill cyclic shear characteristics shown in <Figure 2.5-189> and the similitude of the test sample to the Class A fill utilized in construction are further discussed in the following paragraphs.

The ratio of the laboratory cyclic shear stress ($\sigma_{dc}/2$) to the effective consolidation pressure (σ_3) required to induce initial liquefaction in ten stress cycles (N_c) was conservatively extrapolated from Figure 6, page 1257 of Seed and Idriss, using a median grain size (d_{50}) of 10 mm (Reference 247). The d_{50} value corresponds to the quarry-run Class A fill sample identified in <Figure 2.5-175>. Correspondingly, the stress ratio $\sigma_{dc}/2\sigma_3$ was found to be 0.37 for a relative density (D_r) of 50 percent. For Class A fill with D_r = 85 percent, the field behavior correction factor is 0.70 and the corrected stress ratio is calculated by Equation 2.5-13.

$$\left(\frac{\tau}{\sigma_o}\right)_f = 85/80 \times 0.70 \times 0.37 = 0.44 \qquad (2.5\text{-}13)$$

for N_c = ten cycles to initial liquefaction.

With the exception of the foregoing cyclic shear stress analyses, all static and dynamic analyses involving Class A fill properties were based on the results of laboratory tests conducted on the sample described in <Section 2.5.4.5>. This sample was submitted by the operators of a regional fill source to meet the gradation requirements specified for Class A fill. The dynamic properties of the actual Class A fill materials used were determined by certification testing to be within the design range, as described in <Section 2.5.4.5>.

In summary, the analyses conducted confirm existing precedent and expectation that dense, relatively coarse-grained, free-draining

materials will not experience excessive deformations induced by liquefaction during strong motion earthquakes such as are postulated for the SSE. Thus, it is concluded that Class A fill placed and compacted to a minimum relative density of 80 percent, and an average relative density of 85 percent, will provide adequate support of foundation systems under both dynamic and static loading conditions.

2.5.4.8.2 Lower Till

Liquefaction potential analyses were conducted to study the behavior of the lower till during the SSE. The procedure used has been described in detail by Seed and Idriss and in <Section 2.5.4.8.1> (Reference 242). Three general cases were analyzed: Case I represents the lower till inplace beneath load-bearing fill; Case II, the lower till as a free field surface; and Case III, the lower till supporting a 5-ksf uniform load of infinite extent. Stresses induced within the lower till due to the SSE for Case III, which represents the case of a mat resting directly on the lower till, were calculated using the simplified procedure recommended by Seed and Idriss (Reference 247). The results of Case III demonstrate that a more rigorous approach is not required to assess the dynamic bearing capacity of the very dense, heavily preconsolidated glacial till.

For the response analysis, the maximum shear modulus of the sandy silty clay till was calculated using Equation 2.5-14.

$$G_{max} = 1{,}000\, K_{2\,max} (\sigma_m)^n \qquad (2.5\text{-}14)$$

where:

G_{max} = Maximum shear modulus
$K_{2\,max}$ = Shear modulus parameter
n = Shear modulus exponent
σ_m = Mean principal stress

In this expression, the exponent n was taken as 0.5 and the dimensionless parameter K_{2max} was taken as 100 and 250 to bracket the values derived from cyclic torsion tests. These tests were conducted on undisturbed block and thin-wall tube samples. The strain dependent shear modulus and damping properties, described in <Section 2.5.4.2> for the lower till, were incorporated in the computer program SHAKE IV using the average shear modulus and damping versus shear strain relationships recommended by Seed and Idriss (Reference 239) (Reference 243).

The relationship between stress ratio and the number of stress cycles required to initiate liquefaction of the till is shown as <Figure 2.5-186>. This relationship is derived from the median grain size, d_{50}, of the till, after Seed and Peacock and Lee and Seed (Reference 244) (Reference 245). It is noted that the derivation is predicated on an effective principal stress ratio (K_c) of 1.0, whereas, in the field K_c of the till is approximately 1.7. Therefore, the computed resistance of the lower till against liquefaction, as shown in <Figure 2.5-186>, is conservative.

The results of these analyses are expressed in <Table 2.5-71> in terms of the minimum stress ratio, defined as the ratio of the cyclic shear stress required to cause initial liquefaction in 10 cycles (τ_{cd}) to the shear stress imposed by 10 cycles of the SSE (τ_{hs}). As shown, the minimum stress ratio is greater than 1.0 and, as would be expected, confinement increases this ratio. Considering the conservatisms inherent in the initial liquefaction criterion, in the number of significant stress cycles of the SSE selected (N_c = 10), and in the initial stress conditions assumed (K_c = 1.0), it can be concluded that a wide margin of safety exists against excessive shearing deformation of the lower till bearing strata during the postulated SSE.

2.5.4.8.3 Lacustrine Sediments

An analysis of the liquefaction potential of the lacustrine sediments was conducted because certain Seismic Category I pipes are founded within this stratum. The analysis was conducted in accordance with the simplified procedure by Seed and Idriss (Reference 248). The analysis conservatively assumed that the lacustrine materials would behave as a poorly graded fine sand, whereas, these materials are predominantly silts and clays which would have a greater resistance to liquefaction.

Based on the SSE of Intensity VII <Section 2.5.2.6>, the corresponding horizontal acceleration at the ground surface is 0.13g (Reference 3). However, an acceleration of 0.15g was used in the analysis for conservatism. Intensity VII is equivalent to a magnitude of 5.25 according to correlations by Nuttli (Reference 249) for the eastern United States. The appropriate mean number of cycles, plus one standard deviation, is $N_c = 5$ (Reference 250).

Using the Seed and Idriss approach (Reference 248), the relative density required with depth for factors of safety of 1.0 and 1.2 were determined as shown on <Figure 2.5-191>. Also shown on this figure is the relative density determined for each Standard Penetration Resistance Test blowcount from 65 borings on the site, using the Gibbs and Holtz (Reference 251) correlation for sand. This comparison of the in situ relative density with the required relative density, together with the conservatism of the analysis, indicates that liquefaction of any significant portion of the lacustrine deposit will not occur.

2.5.4.9 <u>Earthquake Design Basis</u>

The basis for establishing the SSE is described in <Section 2.5.2.6> and that for the OBE in <Section 2.5.2.7>.

2.5.4.10 Static Stability

2.5.4.10.1 Foundation Conditions

Consistent with the properties of the primary stratigraphic units described in <Section 2.5.4.2>, support for Seismic Category I and other primary plant structures is provided by the lower till and the underlying Chagrin shale.

a. Lower Till

Since the lower till has been consolidated during the geologic past under loads significantly greater than imposed by the existing overburden, these materials exhibit a very low compressibility under static unit loads up to at least 12 ksf. The lower till was also found to mobilize a high shearing resistance within the range of stress changes imposed by plant foundations.

b. Chagrin Shale

Where not altered by excessive weathering, the shale is capable of supporting unit loads up to at least 25 ksf without detrimental settlement and is rated as having a slight to moderate swell potential upon unloading. Limited deterioration of the shale surface by slaking was expected upon exposure and was not found to be significant during construction. The shale surface was always cleansed prior to placement of concrete or fill.

c. Bearing Grades

As discussed in <Section 2.5.4.3.3>, and as shown on <Figure 2.5-143>, the surface of the lower till within the plant area ranges from Elevations 582′ to 589′ and the surface of the underlying shale varies between Elevations 556′ and 572′. The

bearing grades of the primary Seismic Category I structures are given in <Table 2.5-72>. All Seismic Category I structures, except for the diesel generator building, the offgas buildings and the fuel handling area of the intermediate building are founded on porous concrete fill bearing on shale. The diesel generator building and offgas buildings are founded on Class A fill bearing on lower till and the fuel handling area of the intermediate building is founded on caissons extending into the shale.

d. Groundwater

Piezometric levels within the plant site indicated that the base grades of most of the power plant structures extend well below the phreatic surface. As the piezometer observations indicated the existence of a gravitational groundwater system within the depth of excavation, the plant substructures were designed with a permanent underdrain system to reduce hydrostatic pressure.

2.5.4.10.2 Bearing Capacity

The ultimate bearing capacity of foundations based on the lower till and shale is expressed by Equation 2.5-15.

$$\sigma_o = 6.0\, s_u \; 1 + 0.2 \frac{D}{B} \qquad (2.5\text{-}15)$$

where:

σ_o = Ultimate bearing capacity

s_u = Undrained shear strength of bearing materials

D = Depth of foundation

B = Width of foundation

Ignoring the width and confinement effects, the ultimate bearing capacity of the lower till and shale can be very conservatively calculated from Equation 2.5-15 as 33 and 780 tsf, respectively. The factor of safety for the maximum transient loading condition of the reactor building mat is greater than 60. For a 5 ksf of the lower till, the factor of safety against a bearing capacity failure is greater than 13.

The ratio of the shear strength of the subsoils to the imposed shear stress has also been used to define zones of potential overstress, that is, where the "stress ratio" is less than one. Because the extent of overstress which would correspond to a limiting plastic equilibrium condition cannot be defined, a conventional factor of safety cannot be expressed by this method. However, the safety of foundation elements against excessive shear deformation can be assured if there is no overstress or if the zone of overstress is very limited. Correspondingly, a plane strain, finite element deformation analysis was conducted according to (Reference 246).

The procedure followed in the finite element analysis was to determine the maximum shear stress beneath the mat foundation and to compare this imposed stress with the undrained shear strength of the bearing materials. For the reactor building analysis, the shear strength of the shale was determined from uniaxial compression tests on core samples, conservatively reduced for the discontinuity effects of the rock mass. The minimum stress ratio derived from this analysis was found to be greater than five under operating conditions and greater than two during the transient, accident condition loading of 25 ksf. Thus, both conventional bearing capacity analyses and the stress comparison method indicate that a wide margin of safety against excessive shear deformation is provided for the reactor building. Similar analyses support this conclusion for all Seismic Category I structures founded on either the lower till or shale bearing materials.

2.5.4.10.3 Deformation Analyses

An investigation of the potential total and differential deformation of the foundation system under static loading was made by both one-dimensional consolidation and finite element methods of analysis (Reference 246). The results of these analyses indicate that the ultimate post-construction settlement or heave at any location within the power plant other than the pumphouses will not exceed a maximum of about 1/3 inch and that angular distortions are less than one in 1,500 within any individual unit or between adjacent plant units. The corresponding maximum differential movement between the centers of adjacent Seismic Category I structures would not be expected to exceed 1/2 inch and differential movement across interstructure connections would be negligible. Distortion of safety class piping due to volume change of shale will not occur as this piping is not founded in shale.

<Figure 2.5-192> demonstrates the results of the combined one-dimensional and elastic deformation analysis of the reactor building complex. A swell (heave) of the bearing surface is shown to occur during the excavation phase, followed by compression during the erection of the structure. The compression due to long term consolidation continues at a very slow rate after construction is completed, as shown on the figure. The magnitude of this long term settlement will be quite small.

A plane strain, finite element program, LOCKS, was used to conduct a supplemental foundation deformation analysis as a check on the one-dimensional deformation method used as the primary analytical technique (Reference 252). The program accommodates nonlinear material properties and enables the simulation of dewatering, incremental excavation and incremental loading. However, unlike the one-dimensional analysis, time-dependent consolidation or heave cannot be directly accommodated by the program and was necessarily simulated in a step-by-step procedure.

<Figure 2.5-193> summarizes the results of a plane strain, finite element analysis of the Emergency Service Water Pumphouse which extends an average of 23 feet below the shale surface (Reference 252). The analysis included a ten-step simulation of the dewatering, excavation and construction sequence. It is noted that one-third of the shale swell has been conservatively assumed to occur prior to placement of the foundation mat and that the angular distortion across the mat is on the order of 0.0024 radians. This is the critical design case since the service loading of this structure will reduce the heave deformation. Wall pressures derived from the pumphouse analysis are described in <Section 2.5.4.10.4>.

For both the combined one-dimensional plus elastic and the plane strain, finite element analyses of foundation deformation, the time dependent compression and swell characteristics of the shale were estimated using the results of oedometer tests, presented in <Section 2.5.4.2>, and the records of monitored excavations in stiff clays and shales, reported by Moorhouse (Reference 253). Selection of the amount of swell occurring before backfilling of the Emergency Service Water Pumphouse was very conservatively chosen to be one-third of the predicted ultimate swell of the excavation (the maximum possible) by assuming an interval of only 1 year between excavation and backfilling. Both theoretical and case history considerations predict from 1/2 to 7/8 of this ultimate swell would be expected within the 1-year period. This was confirmed by monitoring of shale movements during construction, as described in <Section 2.5.4.13>.

The drained and undrained volume change characteristics of the shale chosen for the deformation analyses were conservatively weighted towards the properties of the surficial shale zone. Because unsuitable shale has been excavated and mat foundations have been used, no attempt was made to model any localized variations in the properties of the competent shale which might be attributed to random differential weathering effects.

2.5.4.10.4 Lateral Earth Pressures

The magnitude and distribution of lateral earth pressures were formulated for application to the design of both nonyielding and yielding walls, the former typified by restrained substructure walls and the latter by cantilever retaining walls. The typically massive foundation walls of the Seismic Category I structures indicate that the nonyielding assumption is appropriate for these elements. The formulations in the following sections are conservative because the properties of Class B rather than Class A fill have been used throughout.

2.5.4.10.4.1 At-Rest Earth Pressure

Earth pressure, such as would be imposed against nonyielding walls, can be conservatively expressed above the groundwater by Equation 2.5-16.

$$p_o = 69.1\,Z + 0.54\,p_s \qquad (2.5\text{-}16)$$

where:

p_o = Lateral earth pressure at rest, psf

Z = Depth below horizontal backfill surface, ft

p_s = Surface surcharge loading, psf

The value of 0.54 used for the coefficient of earth pressure at rest was determined from the formula:

$$K_o = 1.0 - \sin \Phi'$$

where:

K_o = Coefficient of earth pressure at rest

Φ' = Effective angle of internal friction

The value of Φ′ was assumed to be 27 degrees, which is a conversative value for the effective friction angle of Class B fill and totally ignores any contribution of effective cohesion for the fine-grained Class B materials. The 27 degrees friction angle results in a higher at rest earth pressure coefficient (0.54) than would be determined for Class A fill, which has a minimum design Φ′ value of 35 degrees and an equivalent at rest earth pressure coefficient of 0.43.

The groundwater level is Elevation 590.0′ for normal operation and 618.0′ for massive spill conditions for all structures except the Emergency Service Water Pumphouse; for this structure the groundwater level is Elevation 557.0′. A surface surcharge loading of 100 psf was used for the construction loading condition to account for pressures due to construction equipment.

Below groundwater level, the effective weight of the backfill soil is reduced by buoyancy and a hydrostatic pressure component also acts on the wall. The two components of wall pressure are calculated in accordance with Equations 2.5-17 and 2.5-18.

$$p_o = 69.1\,Z_w + 35.4\,Z_o + 0.54\,p_s \qquad (2.5\text{-}17)$$

$$p_w = 62.4\,Z_o$$

where:

Z_o = Depth below groundwater level, ft

Z_w = Depth from surface to groundwater level, ft

p_w = Water pressure, psf

It is likely that compaction of the backfill adjacent to walls imposed pressures on the walls which were initially somewhat greater than the at-rest condition. However, the additional pressure would be expected to have dissipated within a relatively short time and, thus, is not a design condition. The conservatism in the design soil parameters and

the various combinations of temporary loadings, as described in the next paragraph, would provide adequate reserve for any residual long term compaction induced earth pressures.

Plots of the maximum earth pressure vs. depth used to design rigid subsurface walls for static and dynamic loads are provided in <Figure 2.5-194> and <Figure 2.5-195>. Diagrams in <Figure 2.5-194> are applicable to all Category I structures, except for the Emergency Service Water Pumphouse which is shown in <Figure 2.5-195>. Each structure was analyzed to determine the maximum design stresses resulting from the following earth pressure loading conditions:

a. construction loading,

b. normal operating conditions,

c. normal operating conditions plus the SSE event increment, and

d. massive spill conditions.

Additional loadings due to surcharge from such items as cranes, railroads and adjacent foundations were added as necessary, on a case-by-case basis.

2.5.4.10.4.2 Active Earth Pressure

Active earth pressures appropriate to the design of yielding walls are conservatively expressed above groundwater level by Equation 2.5-19.

$$p_a = 47.4\,Z + 0.37\,p_s \qquad (2.5\text{-}19)$$

where:

p_a = Lateral earth pressure, active condition, psf

Z = Depth below horizontal backfill surface, ft

p_s = Surface surcharge loading, psf

Below groundwater level, the effects of buoyancy and hydrostatic pressures are accounted for in the active earth pressure case by Equations 2.5-20 and 2.5-21.

$$p_a = 47.4\,Z_w + 24.3\,Z_o + 0.37\,p_s \qquad (2.5\text{-}20)$$

$$p_w = 62.4\,Z_o \qquad (2.5\text{-}21)$$

where:

Z_w = Depth from surface to groundwater level, ft

Z_o = Depth below groundwater level, ft

p_w = Water pressure, psf

2.5.4.10.4.3 Passive Earth Pressure

Passive earth pressure, together with the frictional resistance on the base of foundation elements, is used in calculating the resistance of retaining walls to lateral translation under static load. Conservatively assuming that passive resistance is mobilized by Class B backfill materials bearing against wall footings, the ultimate sliding resistance is expressed by Equation 2.5-22.

$$p_r = C_1\,d_s^2 + 0.5\,\sigma_o\,B \qquad (2.5\text{-}22)$$

where:

p_r = Ultimate sliding resistance, pounds per foot

B = Footing width

d_s = Height of footing in tight contact with the backfill

σ_o = Average bearing pressure of footing due to actual imposed load

The coefficient C_1 is 140 for submerged backfill and 170 for a backfill above groundwater level. Consistent with the amount of movement required to develop passive resistance, the factor of safety used in connection with Equation 2.5-22 is not less than 2.5.

2.5.4.10.4.4 Dynamic Earth Pressure Increment

For horizontal backfill surfaces, the added lateral load due to earthquake loading on retaining walls can be approximately expressed (Reference 254) by Equation 2.5-23.

$$\Delta p_{ad} = \frac{3}{8} \gamma H^2 k_h \qquad (2.5\text{-}23)$$

where:

Δp_{ad} = Additional lateral load due to earthquake (pounds per foot of wall)

γ = Unit weight of backfill, pcf

H = Height of wall, ft

k_h = Seismic coefficient

The seismic coefficient for the SSE condition is taken as 0.15 and the average design unit weight of the backfill as 128 pcf; therefore, the added dynamic earth load in pounds per foot of wall is expressed by Equation 2.5-24.

$$\Delta p_{ad} = 7.2\, H^2 \qquad (2.5\text{-}24)$$

The dynamic load is distributed in a trapezoidal manner such that the pressure is 11.52 H at the top of the soil and 2.88 H at the base of the wall. The additional dynamic lateral soil pressure due to surcharge loads is calculated by Equation 2.5-25.

$p_{ds} = 0.54\, p_s k_r$ (2.5-25)

where:

p_{ds} = Dynamic lateral pressure due to surcharge, psf

p_s = Static surface surcharge loading, psf

k_r = Seismic coefficient

To investigate the conservatism of the design method, a dynamic response analysis proposed by Scott, was conducted for a rigid wall employing the dynamic fill properties and soil-structure interaction considerations (Reference 255). Using a shear modulus coefficient (K_{2max}) of 70 for the backfill and assuming an average first mode damping of six percent, total horizontal pressures imposed during the SSE were found for a typical 50-foot high wall to be 78 percent of that predicted by the foregoing conservative design criteria. The Scott method also predicts a similar base moment if the combined static (Equations 2.5-19, 2.5-20 and 2.5-21) and dynamic (Equation 2.5-24) resultants are applied at a distance of H/2 above the base of the wall and not 0.6 H as recommended by Seed (Reference 256).

2.5.4.10.4.5 Lateral Pressures in Shale

As described in <Section 2.5.4.10.3>, a plane strain, finite element analysis of the Emergency Service Water Pumphouse has been conducted. Because this structure extends approximately 23 feet into shale which has a low to moderate swelling potential, this analysis was also used to evaluate lateral pressures imposed on the structure. The analytical model used assumed that excavations down to the shale surface would be sloped, but that cuts within the shale would be essentially vertical, the excavation face being offset away from the substructure walls. The backfill material above the shale level was assumed to be predominantly granular and well compacted. Backfill below the shale level was assumed to be either lean concrete or granular material.

The computer program used, LOCKS, incorporated nonlinear properties for the backfill and subsoils, the shale being conservatively characterized as an elastic medium (Reference 252). The mesh used extended 605 feet below the ground surface and 1,000 feet laterally from the centerline of the ESW Pumphouse. Swelling of the shale after placement of the backfill was simulated by calculating, at the cut face boundary <Figure 2.5-193>, the difference of the boundary distortions obtained from solutions for elastic rebound and for rebound plus ultimate excavation swell. The distortion differential, reduced by the estimated amount of swell occurring before backfill, was subsequently reapplied at the cut face boundary with the backfill in place. As discussed in <Section 2.5.4.10.3>, a reduction of one-third was conservatively chosen.

The volume change properties of the shale utilized in the analysis conservatively assumed the horizontal swell to be equal to the vertical swell characteristics as measured in the one-dimensional swell tests, reported in <Section 2.5.4.2>. Unlike some active clays, the actual horizontal swell would be expected to be less than the amount of vertical swell because of the greater restraint afforded by the horizontal shale laminae and the orientation of the clay mineral particles. The influence of incremental wall construction simulation was also investigated, as shown on <Figure 2.5-196>.

The predicted lateral wall pressures and the adopted design pressure envelope are shown on <Figure 2.5-196>. However, construction schedules permitted excavations to remain open for periods sufficiently long to allow the time-dependent swell of the shale to be essentially complete before backfilling, and the structures will experience only the at-rest lateral earth pressures previously described. Both theoretical and case history considerations predicted that the swell of shale excavations would be essentially complete within a period of 12 to 18 months after completion of excavation. This was confirmed by monitoring of shale movements during construction, as described in <Section 2.5.4.13>.

Hydrostatic pressures are not included in the earth pressure design envelope. Dewatering will be continued until the service pool elevation is established within the ESW Pumphouse. The hydrostatic loading considered in design was, therefore, due to the differential head existing between the service pool and groundwater levels.

2.5.4.11 Design Criteria

2.5.4.11.1 Bearing Conditions

Foundations for Seismic Category I structures are based either on Chagrin shale or on Class A fill over lower till. The bearing elevations and materials for each structure are summarized in <Table 2.5-64>.

2.5.4.11.2 Foundation Mat Design

Mat foundations for Seismic Category I structures bearing on either the lower till or Class A fill are proportioned so as not to exceed an average contact pressure of eight kips per square foot (ksf) under total dead load plus live load, with localized maximum contact pressures not exceeding 12 ksf. These mats were designed as rigid elements and include the diesel generator building, offgas building and condensate storage tank dike.

Foundation mats bearing on shale were designed for a maximum average contact pressure of 12 ksf with local maximum contact pressure not exceeding 25 ksf. The reactor building mats, which are in this category, were designed as rigid elements. The remaining structures in this category including the auxiliary buildings, control complex, fuel handling/intermediate building, radwaste building, and Emergency Service Water Pumphouse, were designed as elastic foundations (Reference 257). The design value for the coefficient of sub-grade reaction for the shale was based upon field values determined from vertical plate loading tests

<Section 2.5.4.2.1.3.2>. The modulus of compressibility measured in the plate loading tests were converted to the coefficient of subgrade reaction (for a 1 foot diameter area) by Equation 2.5-26 (Reference 258):

$$K_{v1} = \frac{E}{I\left(1 - \mu^2\right)} \qquad (2.5\text{-}26)$$

where:

K_{v1} = Coefficient of subgrade reaction, kci
E = Modulus of compressibility, ksi
μ = Poisson's Ratio
I = Plate rigidity and shape factor, 0.79

The values computer were conservatively reduced by at least one-third to account for construction disturbance, with the resulting design value being 46 kips per cubic inch for shale.

2.5.4.11.3 Lateral Earth Pressures

Foundation walls for Seismic Category I structures are considered to be nonyielding and are designed for the at-rest conditions, as described in <Section 2.5.4.10.4>.

2.5.4.12 Techniques to Improve Subsurface Conditions

2.5.4.12.1 Protection of Bearing Surfaces

In order to prevent the deterioration of bearing surfaces due to exposure, excavations were limited to 12 inches above the final excavation grade in lower till and six inches above the final excavation grade in shale, until just prior to the placement of the protective cover. After approval of the final excavation to competent bearing

materials by the Resident Geotechnical Engineer, the exposed surface was expeditiously covered either with porous concrete (over shale) or Class A fill (over lower till).

2.5.4.12.2 Pressure Relief Underdrain System

Refer to <Section 2.4.13.5>.

2.5.4.13 <u>Subsurface Instrumentation</u>

2.5.4.13.1 Piezometers

Four rows of well-point piezometers were installed extending to 1,000 feet from the main plant excavation in the east, south and west direction and 550 feet in the north direction, as shown in <Figure 2.5-183>. The purpose of the piezometers is to determine the extent of the influence of the permanent plant underdrain system on the surrounding groundwater regime. The piezometric levels which have been measured are shown in <Figure 2.5-187> and <Figure 2.5-188>. The piezometer data indicates that the significant influence on the surrounding groundwater levels is only within the lacustrine stratum and the measurable drawdown extends outward on the order of 500 feet or less from the permanent drainage system. In addition, as discussed in <Section 2.4.13.5.3>, pressure monitoring piezometers have been installed through each of the building mats for the auxiliary buildings, control complex, intermediate building, and radwaste building to measure hydrostatic uplift pressure.

2.5.4.13.2 Shale Heave Gauges

In order to measure the rebound of the shale subgrade due to stress relief, nine heave gauges were installed within the shale prior to excavation. The heave gauge locations are shown in <Figure 2.5-197> and

a typical heave gauge detail is shown in <Figure 2.5-198>. Monitoring data of the heavy gauges are shown in <Figure 2.5-199>.

As shown in <Figure 2.5-199>, the heave measured in gauges HG-2, 3 and 4 was very small, about 1/4 inch of immediate rebound and essentially no time-dependent heave. Gauge HG-7, in a deeper excavation, experienced about 2/3 inch immediate rebound and an additional 1/4 inch of time-dependent heave. Heave gauge HG-8, in a still deeper excavation, experienced about 1.5 inches of immediate rebound. Gauges HG-8 and HG-9 experienced no time-dependent heave. (Heave gauge HG-9 was bent during excavation, so only post-excavation movements could be determined.) The heave measured in gauges HG-1A and HG-6 were somewhat larger, 2.6 and 1.2 inches of immediate rebound, followed by 1.2 and 0.7 inch of time-dependent heave, respectively. These two gauges were located within a bedrock deformation zone consisting of an anticlinal fold traversing Unit 2 reactor building, striking northwesterly and bounded vertically on competent rock. Heave of fractured rock in the deformation zone, exposed to extreme climatic conditions, has been attributed to post-excavation stress reduction and swell associated with shale weathering. Heave gauge HG-5 was destroyed during excavation; hence, no data was acquired for this gauge.

2.5.4.13.3 Shale Extensometers

Six extensometers were installed in the sidewalls of the Emergency Service Water Pumphouse, as shown in <Figure 2.5-200>, to monitor horizontal movements of the shale. A typical installed detail of an extensometer is shown in <Figure 2.5-201>. Monitoring results are shown in <Figure 2.5-202>.

The shale movements measured by the extensometers ranged from essentially 0.0 to 0.1 inch and were judged to be essentially completed about 10 months after the completion of excavation. Although some later movement was detected in extensometers EX-2 and EX-5 during the last

4 months of monitoring, it is likely that at least some of that movement can be attributed to vibrations or other disturbance relating to an increased level of construction activity in the ESW Pumphouse excavation during that period.

2.5.4.13.4 Settlement Monitoring

Settlement monitoring points were established in the interior of the reactor buildings, diesel generator building and offgas buildings, and on the exterior walls of these and various other Seismic Category I structures. The settlement monitoring points were typically designated by pencil or paint marks on poured concrete or steel frame structural elements. The locations of currently monitored points are shown on <Figure 2.5-203>.

The interior reactor points were located near the outer circumference of each reactor building, with eight points in each building spaced 45 degrees apart. <Figure 2.5-204> shows the recorded movements of the settlement points within the reactor buildings, together with the approximate time history of the percentage of structural concrete which was placed in these structures. It is noted, however, that these recorded movements are with reference to a monument within the control complex which experienced a settlement of 0.64 inch during the period from November 1976 through February 1981. Therefore, the average actual settlement for Unit 1 reactor is about 0.53 inch and that for Unit 2 reactor is about 0.67 inch, through December 1980. Monitoring of the interior of the reactor buildings was discontinued after December 1980, due to inaccessibility. However, monitoring of the exterior reactor points will continue.

<Figure 2.5-205> shows the results of settlement measurements through August 1981, at points SP-1, SP-2, SP-3, SP-4, SP-6, and SP-7 shown on <Figure 2.5-203>. Settlement points were initially established at low elevations when the lower portions of the walls were cast (elevations

ranging from about 563' to 574'). As the walls were raised and backfill placed around the structures, the settlement points were also raised to higher elevations. The settlement data obtained is conservative because the settlement of the higher points includes the elastic deformation of the underlying concrete walls. Occasionally, settlement points were covered by construction activities before the next higher corresponding point was established. Gaps in the settlement records occur at these times and the settlements which occurred during these periods have been estimated, as shown in <Figure 2.5-205>.

The maximum settlement recorded to date is about 0.9 inch. It should be noted, however, that in some cases substantial amounts of structural concrete was placed prior to the start of monitoring. Permanent brass settlement markers are installed at each location as the walls are extended above finished exterior grade (about Elevation 620'). Continuous post-construction settlement records will be obtained from these markers on a monthly basis until Fuel Load occurs, at which point they will be maintained on a quarterly basis throughout the life of the Plant. Construction details of the settlement monitoring points are shown on <Figure 2.5-206>.

Six settlement monitoring points were established on the diesel generator building in June 1979, shortly after the structural mat was cast. Seven new points were established at a slightly higher elevation in June 1980, and the old points were subsequently abandoned. The monitoring results, shown on <Figure 2.5-207>, indicate that the average settlement through September 1981 was slightly less than one-half inch. From June 1980 through January 1986 average settlement was only 5/32"; therefore, monitoring at the seven construction points was discontinued in January 1986 and replaced by monitoring at one permanent marker installed at point SP-9 as shown on <Figure 2.5-203>.

At the request of NRC, settlement points were established on the offgas buildings after the structural concrete for these structures had been

completed. Four points were established within the Unit 1 structure and three points within the Unit 2 structure. As shown in <Figure 2.5-208>, the maximum average settlement of these structures during the period from June 1980 through September 1981, was about 0.04 inches and 0.12 inches, respectively. The maximum settlement of any individual monitoring point through September 1981 was 0.07 inches for Unit 1 and 0.16 inches for Unit 2. From June 1980 through January 1986 average settlement for Unit 1 was less than 1/32" and for Unit 2 was approximately 3/32"; therefore, monitoring at the construction markers within each of the Offgas buildings was discontinued in January 1986 and was replaced by monitoring at one permanent marker in each building (points SP-8 and SP-10 as shown on <Figure 2.5-203>.

The installation of Safety Class piping between structures began after September 1977. Based on the building settlement data which is available, it is estimated that differential settlement between adjacent Safety Class structures since that time has been about one-quarter of an inch or less, and very little or no additional differential settlement is anticipated. Based on these minimum differential settlements there should be no detrimental effects resulting to the piping connections between buildings.

2.5.4.13.5 Comparison of Actual and Predicted Deformations

<Figure 2.5-189> shows the anticipated deformation behavior of the Unit 1 reactor building, as discussed in <Section 2.5.4.10.3>. The deformation consists of three phases: heave of the shale bearing surface during the following excavation, rapid compression during construction and backfill of the structures and finally, long term post-construction consolidation at a very slow rate. The calculated deformation behavior for the reactor building is typical of all of the structures on the site.

The computed heave of the shale within the main plant excavation ranged from about 1/2 to 3/4 inch. As discussed in <Section 2.5.4.13.2>, the actual heave was only about 1/4 to 1/2 inch, except within the area of a bedrock deformation zone which was subsequently excavated.

The computed immediate settlement for the auxiliary buildings, radwaste building and control complex was about 1/2 inch in the interior and about 1/4 inch along the edges of the buildings adjacent to the toe of the plant excavation. The analysis method, however, did not account for structural rigidity of the foundation mats which would tend to decrease the interior settlement and increase the edge settlement. The actual immediate settlement of these structures, as measured at settlement points SP-1, SP-4 and SP-6, plus the disk in the control complex, has been about 1/4 to 3/4 inch, averaging about 1/2 inch, through February 1981. Long term settlement after completion of construction is expected to be on the order of 1/10 inch.

The calculated immediate settlement of the reactor buildings was about 3/4 inch in the interior and 1/3 to 1/2 inch along the edges. Again, the structural rigidity of the mat would tend to increase the settlement of the edges. The actual settlement, as measured at the 16 interior points on the reactor mat, as well as settlement points SP-2 and SP-3, has been about 1/2 to 1 inch through February 1981. Long term settlement, after completion of construction, is expected to be on the order of an additional 1/10 inch.

It is concluded that settlement of the Seismic Category I structures is very small and of the magnitude anticipated. Post-construction differential settlement is expected to be negligible.

2.5.4.14 Construction Notes

2.5.4.14.1 Shale Deformation

The onshore geologic structures mapped and investigated at the site had little impact on the plant foundation as designed. To preclude the possibility of fines infiltrating porous concrete, the following additional construction measures were taken. Degraded material was overexcavated and replaced with lean concrete having a 28-day compressive strength of at least 1,500 psi. Exposed joints, open or filled, were cleaned and filled with slush grout.

The deformation intersected by the cooling water tunnels had no impact on the tunnel as designed. Additional temporary liner supports were installed in order to maintain safe working conditions through parts of the tunnels. In addition consolidation grouting was performed above the liner to control groundwater inflow.

2.5.4.14.2 Contamination of Porous Concrete

During June 28 and June 30, 1976, severe thunderstorms and torrential rains, totaling 3.33 inches, created excessive runoff into the excavation of the construction site, resulting in the infiltration of sediment into unprotected areas of the porous concrete. The primary purpose for the underdrain system beneath the foundation base mats is to preclude pore pressure buildup.

An evaluation was conducted of the potential for porous concrete clogging. The evaluation included performing an extensive exploratory program of suspect areas in order to delineate the extent of siltation into the porous concrete. This program was coupled with laboratory testing of contaminated porous concrete, engineering analyses of pore pressure buildups and an engineering evaluation of the porous concrete

permeability. The latter was accomplished to assess the influences of silt contamination on the performance of the porous concrete drainage blanket.

The field studies indicated that the most severe contamination occurred at exposed and unprotected edges of the porous concrete blanket. Generally, these exposed edges existed in Unit 1 auxiliary building, Unit 1 heater bay pit, control complex, radwaste building, Unit 2 turbine power complex trench, Unit 2 condensate demineralizer pit, Unit 2 auxiliary building, and several underdrain manhole bases. In addition, the detailed investigations revealed a limited degree of contamination within localized zones beneath both reactor buildings.

The areas affected were corrected in all cases by one of two methods: complete removal and replacement with new porous concrete, or continuous flushing with water. Generally, areas determined to be heavily contaminated were removed. The areas found to be less contaminated were subjected to the flushing method.

Based upon the results of the testing and analyses, the following conclusions evolved. The infiltration of silt which occurred in localized areas of the then existing portions of the porous concrete blanket would have a negligible effect on the future performance of the underdrain/pressure relief system. Laboratory testing confirmed that significant pore pressures cannot build up in even highly contaminated porous concrete.

2.5.5 STABILITY OF SLOPES

The plant is constructed on an essentially level site and the final grades are similar to the preconstruction grades. All excavations for Seismic Category I plant structures have been backfilled and, hence, there are no man-made slopes which could fail and adversely affect the

safety of the plant. The only natural slopes which could affect the safety of the plant are a bluff along Lake Erie which is described in the following sections.

2.5.5.1 Slope Characteristics

A steep bluff which forms the shoreline of Lake Erie is located approximately 300 feet north of the Emergency Service Water Pumphouse. The lower portion of this slope is periodically subjected to erosion due to wave action. In addition, some slumping of the upper bluff materials due to groundwater seepage and frost action has been observed. The resulting estimated average recession rate is two feet per year, as described in <Section 2.4.5.5>. The bluff is about 45 feet in height and has an average slope inclination of about 2 horizontal to 1 vertical, as shown in <Figure 2.5-209>.

2.5.5.2 Design Criteria and Analyses

Stability analyses have been conducted to determine the amount of bluff recession which can occur before the Emergency Service Water Pumphouse would become endangered. The subsurface stratigraphy of the bluff was determined from observations of the exposed bluff slope and from nearby test borings. The stability analyses were conducted using the LEASE-I and LEASE-II computer programs, which utilize the simplified Bishop circular arc method (Reference 259) (Reference 260) and the Morgenstern-Price method (Reference 261) (Reference 262), respectively. For the seismic condition, a seismic coefficient of 0.15 was used for pseudostatic analyses. The groundwater level was taken to be Elevation 615’ near the Emergency Service Water Pumphouse, exiting the bluff slope at Elevation 590’.

The soil strength parameters used in the stability analysis were determined based upon CIU triaxial compression tests on the lacustrine and upper till soils which are summarized in <Table 2.5-37>. Three sets

of strength parameters were utilized in the analysis: "lower bound" values equal to the lowest strength envelopes measured, "upper bound" values equal to the highest strength envelopes, and "design" values, which represent intermediate strength envelopes and which are believed to be representative of the actual soil strength. These parameters are summarized as follows:

	Lacustrine		Upper Till	
Analysis	Cohesion (psf)	Friction Angle (degrees)	Cohesion (psf)	Friction Angle (degrees)
Lower Bound	0	35	0	35
Upper Bound	240	33.5	660	24
Design	240	31	240	31

To stabilize the bluff slope against wave action and against slumping in the zone of groundwater emergence, a flattened slope with rip-rap slope protection is required. The results of Bishop method stability analyses using the "design" strength parameters and with bluff slope inclinations ranging from 1:1 (horizontal:vertical) to 3:1 are shown on <Figure 2.5-209>.

It was determined in this analysis that a 3:1 slope was required for the minimum desired factors of safety. For this slope, factors of safety of 1.68 and 1.09 were determined for the static and seismic conditions, respectively. However, the presence of the rock rip-rap slope protection materials were not considered in this analysis, which would add to the overall stability of the slope.

A parametric study was also conducted using the 3:1 slope and the lower bound and upper bound soil strength parameters. For the upper bound analysis, minimum factors of safety of 2.10 and 1.34 were determined for the static and seismic conditions, respectively. For the lower bound case, wherein the lacustrine and upper till soils are considered to be cohesionless, the static factor of safety is 1.09, with the critical

failure arcs representing shallow, sloughing failure along the slope face below the groundwater level. For deep circles which would influence the crest of the bluff, the minimum static factor of safety found was 1.28. With the addition of seismic forces on a 3:1 unprotected slope, the factor of safety for shallow, sloughing failure was found to be about 0.70. However, all deep failure arcs that daylight more than about 60 feet behind the crest of the bluff were computed to have a factor of safety of more than 1.00 during seismic loading.

Observation of the lacustrine and upper till materials on the bluff face and in excavations on the site indicate that these materials do indeed possess some cohesion. Thus, the lower bound analysis described above is unduly conservative. In any event, final design of a permanent slope protection system will be initiated if the toe of the bluff encroaches closer than 250 feet to the Emergency Service Water Pumphouse. At this time, the crest of the bluff would be expected to be located about 115 feet (assuming a 3:1 slope) from the pumphouse. Thus, any failure which might occur during a seismic event prior to that time would not extend sufficiently far behind the bluff crest to influence the structure.

A Morgenstern-Price stability analysis was also conducted on the 3:1 slope, using the design strength parameters. The results of this analysis are shown in <Figure 2.5-210> in comparison to the Bishop method results for the same slope. The Morgenstern-Price analysis yielded somewhat higher factors of safety than the Bishop method for failure surfaces passing through the upper till (note that only the most critical failure surfaces are shown out of many trial surfaces). Failure surfaces passing only through the lacustrine stratum were also evaluated, and resulted in considerably higher factors of safety than those also passing through the upper till.

Stability analyses have also been conducted on the final slope protection design configuration, which is shown in detail in <Figure 2.4-39>. The results of this analysis, which incorporated a friction angle of 38 degrees for the rip-rap, are shown below and indicate that the stability of the final design is satisfactory:

	Factor of Safety	
Analysis	Static	Seismic
Design	2.33	1.44
Upper Bound	2.49	1.51
Lower Bound	2.12	1.34

These factors of safety are with respect to deep-seated failures. For shallow, sloughing failure the rip-rap was found to have factors of safety of 1.56 and 1.16 for static and seismic conditions, respectively. The unprotected 3:1 slope in the upper portion of the lacustrine stratum was found to have factors of safety for shallow, sloughing failure essentially the same or greater than those shown in the table above, for both static and seismic conditions.

The results of the various stability analyses determined that the toe of the bluff could recede about 200 feet before a potential failure arc of the bluff would approach within 40 feet of the Emergency Service Water Pumphouse. However, as discussed in <Section 2.4.5.5>, if the shoreline recedes approximately 130 feet, protective measures will be initiated.

A monitoring program has been established to measure the bluff recession. This program is described in <Section 2.4.5.5>.

2.5.5.3 Logs of Borings

Boring logs are presented in <Appendix 2E>. <Figure 2.5-53> shows the locations of the borings.

2.5.5.4 Compacted Fill

There is no compacted fill associated with the Lake Erie bluff.

2.5.6 EMBANKMENTS AND DAMS

There are no Seismic Category I embankments or dams associated with the Perry Nuclear Power Plant.

2.5.7 REFERENCES FOR SECTION 2.5

1. Mauk, Frederick J., 1978, Geophysical Investigations of the Anna, Ohio, Earthquake Zone, Annual Progress Report: prepared for the U.S. Nuclear Regulatory Commission by the Department of Geology and Mineralogy, University of Michigan, Ann Arbor, UMGM-NUREG-78/03.

2. Christensen, D. H., Pollack, H. N., Lay, T., Schwartz, S. Y., 1986, Geophysical Investigations of the Western Ontario-Indiana Region, Final Report, October 1981 - September 1986, prepared for the U.S. N.R.C., <NUREG/CR-3145>, Department of Geological Sciences, the University of Michigan.

3. Trifunac, M. D. and Brady, A. G., 1975, "On the Correlation of Seismic Intensity Scales with the Peaks of Recorded Strong Ground Motion", Bulletin of the Seismological Society of America, V. 65, No. 1, pp. 139-162.

4. Weston Geophysical Corp., 1986, Investigations of confirmatory seismological and geological issues, Northeastern Ohio earthquake of January 31, 1986, prepared for Cleveland Electric Illuminating Co., Weston Geophysical Corporation.

5. Sims, P. K. and Morey, G. B., eds., 1972, Geology of Minnesota; A Centennial Volume in Honor of George M. Schwartz: Minnesota Geological Survey, 632 pages.

6. Owens, Gorden L., 1967, The Precambrian Surface of Ohio: Ohio Division of Geological Survey, Report of Investigations No. 64, 30 pages.

7. Hoover, Karl V., 1960, Devonian - Mississippian Shale Sequence in Ohio: Ohio Division of Geological Survey, Inf. Circ. No. 27, 154 pages.

8. Rector, Glasco W., 1950, Paleontology and Straitigraphy of a Well Core from Ashtabula, Ohio: Michigan Univ. Master's Thesis (unpub.), 37 pages.

9. Wynne-Edwards, H. R., 1972, "The Grenville Province," Variations in Tectonic Styles in Canada: The Geological Association of Canada Special Paper No. 11, pp. 264-334.

10. King, Philip B., 1969, Tectonic Map of North America: U.S. Geological Survey, Scale 1:5,000,000.

11. Wanless, R. K., 1970, Isotopic Age Map of Canada: Canadian Geological Survey Map 1256A, Scale 1:5,000,000.

12. Ayres, L. D., Lumbers, S. B., Milne, V. G., and D. W. Robeson, 1971a, Ontario Geological Map: Ontario Department of Mines and Northern Affairs Color Map 2196.

13. Ayres, L. D., Lumbers, S. B., Milne, V. G., and Robeson, D. W. 1971b, Ontario Geological Map - East Central Sheet: Ontario Department of Mines and Northern Affairs Color Map 2198, Scale 1" = 16 miles.

14. Frarey, M. J. and Roscoe, S. M., 1970, "The Huronian Supergroup North of Lake Huron", Basins and Geosynclines of the Canadian Shield: Canadian Geological Survey Paper 70-40, pp. 143-158.

15. Stockwell, C. H., 1969, Tectonic Map of Canada: Geological Survey of Canada Map 1251A, Scale 1:5,000,000.

16. Bass, M. N., 1960, Greenville Boundary in Ohio: Journal of Geology, V. 68, pp. 673-677.

17. Engel, A. E. G., 1963, Geologic Evolution of North America: Science, V. 140, No. 3563, pp. 143-152.

18. Lidiak, E. G., Marvin, R. F., Thomas, H. H., and M. N. Bass, 1966, Geochronology of the Midcontinent Region, United States: Part 4, Eastern Area: Journal of Geophysical Research, V. 71, pp. 5427-5438.

19. Muehlberger, William R., Denison, Roger E. and Lidiak, Edward G., 1967, Basement Rocks in Continental Interior of United States: American Association of Petroleum Geologists Bulletin, V. 51, No. 12, pp. 2351-2380.

20. Bayley, R. W. and Muehlberger, W. R. (compilers), 1968, Basement Rock Map of the United States, Exclusive of Alaska and Hawaii; U.S. Geological Survey, Scale 1:2,500,000, 2 sheets.

21. Ammerman, Michael L. and Keller, G. R., 1976, "A Gravity and Tectonic Study of the Rome Trough:" Geological Survey of America Abstracts with Programs, V. 8, No. 2, p. 124.

22. Green, Darsie A., 1957, Trenton Structure in Ohio, Indiana, and Northern Illinois: American Association of Petroleum Geologists Bulletin, V. 41, No. 4, pp. 627-642.

23. Woodward, Herbert P., 1961, Preliminary Subsurface Study of Southeastern Appalachian Interior Plateau: American Association of Petroleum Geologists Bulletin, V. 45, No. 10, pp. 1634-1655.

24. Biggs, Maurice E. and Pincus, Howard J., 1961, Geophysical Studies in the Indiana-Ohio Portion of the Cincinnati Arch Province in Geological Society of America, Special Paper No. 68, p. 135.

25. Calvert, William, 1964, Pre-Trenton Sedimentation and Dolomitization, Cincinnati Arch Province: Theoretical Considerations: American Association of Petroleum Geologists Bulletin, V. 48, No. 2, pp. 166-190.

26. Bristol, H. M. and Buschbach, T. C., 1971, Structural Features of the Eastern Interior Region of the United States in Bond, D. C., (Chairman), Background Materials for Symposium on Future Petroleum Potential of NPC Region 9 (Illinois Basin, Cincinnati Arch and Northern Part of Mississippi Embayment): Illinois State Geological Survey Petroleum Series No. 96, pp. 21-28.

27. Atherton, E., 1971, Tectonic Development of the Eastern Interior Region of the United States in Bond, D. C., (Chairman), Background Materials for Symposium on Future Petroleum Potential of NPC Region 9 (Illinois Basin, Cincinnati Arch and Northern Part of Mississippi Embayment): Illinois State Geological Survey Petroleum Series No. 96.

28. Calvert, Warren L., 1974, Sub-Trenton Structure of Ohio, with Views on Isopach Maps and Stratigraphic Sections as Basis for Structural Myths in Ohio, Illinois, New York, Pennsylvania, West Virginia, and Michigan: American Association of Petroleum Geologists Bulletin, V. 58, No. 6, pp. 957-972.

29. Fisher, James H., 1976, Structural History of the Michigan Basin: Middle Ordovician Through Silurian Time: North-Central Section Geological Society of America Abstracts with Programs, V. 8, p. 477.

30. Brigham, Robert J., 1971, Structural Geology of Southwestern Ontario and Southeastern Michigan: Ontario Department of Mines and Northern Affairs, Petroleum Resources Section Paper, 71-2, 110 pages.

31. Judge, A. S. and Beck, A. E., 1973, Analysis of Heat-Flow Data-Several Boreholes in a Sedimentary Basin: Canadian Journal of Earth Sciences, V. 10, pp. 1494-1507.

32. Tobin, Don Graybille, 1961, Subsurface Structure from Reflection Seismology in Clinton, Fayette, Highland, Pike, and Ross Counties, Ohio: Ohio State University Master's Thesis, 77 pages.

33. Mayhew, George Herbert, 1969, Seismic Reflection Study of the Subsurface Structure in Western and Central Ohio: Ohio State University PhD. Thesis, 77 pages.

34. Lidiak, Edward G. and Zietz, Isidore, 1976, Interpretation of Aeromagnetic Anomalies between Latitudes 37°N and 38°N in the Eastern and Central United States: Geological Society of America Special Paper 167, 37 pages and 1 plate.

35. Ammerman, Michael and Keller, G. R., 1978, Delineation of the Rome Trough in Eastern Kentucky with Gravity and Deep Drilling Data: American Association of Petroleum Geologists Bulletin preprint.

36. Quick, R. C., Pawlowicz, E. F. and Hinze, W. J., 1976, The Bowling Group Fault - A case of Resurgent Tectonics?: American Association of Petroleum Geologists, Eastern Section Meeting, Lexington, Kentucky, p. 20.

37. Prouty, C. E., 1972, Michigan Basin Development and the Appalachian Foreland: International Geological Congress Abstracts, p. 97.

38. Prouty, C. E., 1976a, Michigan Basin - A Wrenching Deformation Model: Geological Society of America Abstracts with Programs, V. 8, p. 505.

39. Hinze, William, Kellog, Richard, and O'Hara, Norbert, 1975, Geophysical Studies of Basement Geology of Southern Peninsula of Michigan: American Association of Petroleum Geologists Bulletin, V. 59, No. 9, pp. 1562-1584.

40. Rodgers, John, 1970, The Tectonics of the Appalachians: New York, Wiley-Interscience, 271 pages.

41. Fletcher, J. B. and Sykes, L. R., 1977: Earthquakes Related to Hydraulic Mining and Natural Seismic Activity in Western New York State: Journal of Geophysical Research, V. 82, No. 26, pp. 3767-3780.

42. Ohio Edison Company, 1977: Preliminary Safety Analysis Report, Erie Nuclear Plants, Units 1 and 2, Section 2.5, Geology and Seismology.

43. Thompson, Stewart N., Peck, John H., Patterson, Arleigh R., and Willis, David E., 1976, Faulting and Seismicity in the Anna, Ohio, Region: Geological Society of America Abstracts with Programs, V. 8, No. 6, p. 1139.

44. McGuire, Donn, 1975, Geophysical Survey of the Anna, Ohio, Area, Bowling Green State University Master's Thesis, text only.

45. Stone & Webster Engineering Corporation, 1976, Faulting in the Anna, Ohio, Region: W.U.P. Preliminary Safety Analysis Report, Koshkonong, Amendment 12, Appendix 21.

46. Rudman, A. J., Summerson, C. J. and Hinze, W. J., 1965, Geology of Basement in Midwestern United States: American Association of Petroleum Geologists Bulletin, V. 49, No. 7, pp. 894-904.

47. Versteeg, Carl, 1944, Some Structural Features of Ohio: Journal of Geology, V. 52, pp. 131-138.

48. Lockett, J. R., 1947, Development of Structure in Northeastern United States: American Association of Petroleum Geologists Bulletin, V. 31, pp. 429-446.

49. Jacoby, C. H., 1969, Correlation, Faulting and Metamorphism of Michigan and Appalachian Basin Salt: American Association of Petroleum Geologists Bulletin, V. 53, No. 1, pp. 136-154.

50. Jacoby, C. H., 1970, Faults in Salt Mines - their Impact on Operations in Rau, J. L. and Dellwig, L. F. (eds.), Third symposium on Salt: Northern Ohio Geology Society, Cleveland, Ohio, pp. 447-452.

51. Jacoby, C. H., 1979 personal communication.

52. Gray, J. D., Struble, R. A., Carlton, R. W., Hodges, D. A., Honeycutt, F. M., Kingsbury, R. H., Knapp, N. F., Majchszak, F. L., and Stith, D. A., 1982, An integrated study of the Devonian-age black shales in eastern Ohio, U.S. Department of Energy, Final

Report: Contract DE-AS21-76ET-12131 1399 (DE 83011204), National Technical Information Service, U.S. Department of Commerce, Springfield, VA.

53. Root, S. I. and Hoskins, D. M., 1977, Lat 40 degrees-N fault zone, Pennsylvania: A new interpretation, Geology, Vol. 5, pp. 719-723.

54. Root, S. M., Angerman, S. H. and MacWilliams, R., 1986, Tectonics of the Suffield-Highlandtown Faults, Ohio, North Central Section GSA abstracts with programs, p. 321.

55. Fakundiny, R. H., 1978, Clarendon-Linden Fault System of Western New York: Longest and Oldest Active Fault in Eastern United States: Geological Society of America Abstracts with Programs, V. 10, No. 2, p. 42.

56. Isachsen, Y. W. and McKendree, W., 1977, Preliminary Brittle Structures Map of New York, and Generalized Map of Recorded Joint Systems in New York, New York State Geological Survey Map and Chart Series, No. 31.

57. Beinkafner, K. J., 1983, Terminal expression of decollement in Chautauqua County, New York: Northeastern Geology, Vol. 5, pp. 160-171.

58. Newmann, E. A., 1940, Trend Map of Anticlinal Folding: Michigan Geological Survey, Department of Conservation Map 3527.

59. Prouty, C. E., 1976b, Implication of Imagery Studies to Time and Origin of Michigan Basin Linear Structures: American Association of Petroleum Geologists Bulletin, V. 60, No. 4, p. 709.

60. Pirtle, G. W., 1932, Structural Basin of Michigan: American Association of Petroleum Geologists Bulletin, V. 16, No. 2, pp. 39-41.

61. King, P. B., 1951, The Tectonics of Middle North America: Princeton, New Jersey, Princeton University Press, pp. 39-41.

62. Dallmus, K. F., 1958, Mechanics of Basin Evolution and its Relation to the Habitat of Oil in the Basin: Habitat of Oil; A Symposium, Lewis G. Weeks (ed.), American Association of Petroleum Geologists Special Publication, pp. 883-931.

63. Janssens, A., 1973, Stratigraphy of the Cambrian and Lower Ordovician Rocks in Ohio: Ohio Geological Survey Bulletin No. 64, 195 pages and 9 plates.

64. Clifford, M. J. and Collins, H. R., 1974, Structures of Southeastern Ohio: A.A.P.G. Eastern Section Meeting, American Association of Petroleum Geologists Bulletin, V. 58, No. 9, p. 1891.

65. Bucher, W. H., 1935, Cryptovolcanic Structures in the United States: in 16th International Geological Congress, 1933, V. 2, pp. 1055-1084.

66. Galbraith, R. M., 1968, Peripheral Deformation of the Serpent Mound Cryptoexplosion Structure in Adams County, Ohio, University of Cincinnati Master’s Thesis, Cincinnati, Ohio.

67. Reidel, S. P., 1972, Geology of the Serpent Mound Crytoexplosion Structure: University of Cincinnati Master’s Thesis, Cincinnati, Ohio.

68. Dietz, R. S., 1960, Meteroite Impact Suggested by Shatter Cones in Rock: Science, V. 131, No. 3416, pp. 1781-1784.

69. Batsche, Ralph William Jr., 1963, Field Study and Geological Interpretation of a Gravity Anomaly Located in the Fayette County, Ohio, Area: Ohio State University Master's Thesis, 116 pages and 3 plates.

70. Zahn, Jack Cowley, 1965, A Gravity Survey of the Serpent Mound Area in Southern Ohio: Ohio State University Master's Thesis, text only, 37 pages.

71. Flaugher, David Michael, 1971, A Gravity Survey of the Serpent Mound Cryptoexplosion Structure and Surrounding Area in Southern Ohio: Wright State University Master's Thesis, 113 pages.

72. United States Nuclear Regulatory Commission, Atomic Safety and Licensing Board, 1985, (Midland Plant, Units 1 and 2), LBP-85-2, 21 NRC 24 (1985), vacated as moot, on procedure ALAB-842, 24 NRC 197 (1986) ("Midland"). Review declined by Commission, Memorandum to Board and Party, dated December 12, 1956 (unpublished).

73. King, P. B., 1976, Precambrian Geology of the United States: An Explanatory Text to Accompany the Geologic Map of the United States: U.S. Geological Survey Professional Paper 902.

74. Kay, G. Marshall, 1942, Ottawa-Bonnechere Graben and Lake Ontario Homocline: Geological Society of American Bulletin, V. 53, No. 4, pp. 585-646.

75. Kay, Marshall, 1975, Ottawa-Bonnechere Graben: Tectonic Significance of an Aulacogen: Geological Society of America Abstracts with Programs, V. 7, No. 1, p. 82.

76. Hinze, W. J., Braile, L. W., Keller, G. R., and Lidiak, E. G., 1977, A Tectonic Overview of the Central Mid-Continent: Nuclear Regulatory Commission Report, <NUREG-0382>, 106 pages.

77. Weston Geophysical Corp., 1982, Description and evaluation of bedrock structure in the vicinity of Midland Plant - Units 1 and 2, Midland Michigan, Prepared for Consumers Power Company.

78. Broughton, J. G., Fisher, D. W., Isachesen, Y. W., and Rickard, L. V. 1966, Geology of New York, A Short Account: New York State Geological Survey Educational Leaflet No. 20, 49 pages., and 1 map.

79. Burke, K. and Dewey, J. F., 1973, Plume Generated Triple Junctions: Key Indicators in Applying Plate Tectonics to Old Rocks: Journal of Geology, V. 81, pp. 406-431.

80. Hutchinson, D. R., Pomeroy, P. W., Wold, R. J., and Halls, H. C., 1979, A geophysical investigation concerning the continuation of the Clarendon-Linden fault across Lake Ontario, Geology, Vol. 7, pp. 206-210.

81. Hinze, William J., Kellogg, Richard L. and Merritt, Donald W., 1971, Gravity and Aeromagnetic Anomaly Maps of the Southern Peninsula of Michigan: Michigan Geological Survey Report Investigation No. 14.

82. Hildenbrand, T. G. and Kucks, R. P., 1984, Residual total intensity magnetic map of Ohio: U.S. Geological Survey Geophysical Investigations Map GP-961, Scale 1:500,000.

83. Beardsley, R. W. and Cable, M. S., 1983, Overview of the evolution of the Appalachian Basin: Northeastern Geology, Vol. 5, pp. 137-145.

84. Pepper, J., 1974, A Real Extent and Thickness of the Salt Deposits of Ohio: Ohio Journal of Science, V. XLVII, No. 6, pp. 225-237.

85. Ailling, H. L. and Briggs, L. I., 1961, Stratigraphy of Upper Silurian Cayugan Evaporities: American Association Petroleum Geologists Bulletin, No. 45, pp. 515-547.

86. Blatt, Middleton and Murray, 1973, Origin of Sedimentary Rocks: Englewood Cliffs, New Jersey: Prentis Hall, Inc., pp. 409-531.

87. Clifford, M. J., 1973, Silurian Rock Salt of Ohio: Ohio Division of Geological Survey: Report of Investigations, No. 90, 42 pages.

88. Ulteig, J. R., 1964, Upper Niagaran and Cayugan Stratigraphy of Northeastern Ohio and Adjacent Areas: Ohio Division of Geologic Survey, Report of Investigations 51, 48 pages.

89. Dew, J. W., 1962, Lower and Middle Devonian Limestones in Northeastern Ohio and Adjacent States: Ohio Division of Geological Survey, Report of Investigations, No. 42, 67 pages.

90. Pepper, J. F., DeWitt, Wallace, Jr. and Demarest, D. F., 1954, Geology of the Bedford Shale and Berea Sandstone in the Appalachian Basin: U.S. Geological Survey Professional Paper 259, 111 pages.

91. Goldthwaite, R. P., White, G. W. and Forsyth, J. L., 1961: Glacial Map of Ohio: U.S. Geological Survey Miscellaneous Geological Investigations Map I-316.

92. Hough, J., 1958, Geology of the Great Lakes: Urbana, University of Illinois Press, 313 pages.

93. Ohio Department of Natural Resources, Annual Reports on Ohio Mineral Industries Division of Geological Survey, Columbus, Ohio (1981-1989).

94. Pepper, J. F., 1961, Areal Extent and Thickness of Salt Deposits of Ohio: Geological Survey of Ohio, Report of Investigations No. 3.

95. Ulterg, J. R., 1964, Upper Niagaran and Cayugan Startigraphy of Northeastern Ohio and Adjacent Areas: State of Ohio, Division of Geological Survey, Report of Investigation No. 51.

96. Oinonen, R., 1965, A Study of Selected Salina Salt Beds in Northeastern Ohio: Ohio University, Master's Thesis.

97. Owens, G. L., 1970, The Subsurface Silurian-Devonian "Big Lime" of Ohio: State of Ohio, Division of Geological Survey, Report of Investigations No. 75.

98. Lafortune, R., March 1973, Supervisor and Field Engineer, Diamond Shamrock Chemical Corporation, Personal Communication.

99. Richner, D. R., May 1973, Consulting Geologist; Private Communications.

100. Vernman, P., Chief Engineer, Morton Salt Company of Morton Norwick, Private Communication.

101. Bays, C. A., Peters, W. C. and Pullen, M. W., February 17, 1960, Solution Extraction of Salt Using Wells Connected by Hydraulic Fracture: Preprint Paper No. 60-H-100 of presentation made at New York City meeting of Mining, Metallurgical and Petroleum Engineers.

102. Lawhead, A. H., 1949, Preliminary Report on Natural Brines in Northeastern Ohio: Cleveland Electric Illuminating Company, Industrial Development Division.

103. Stout, W., Lamborn, R. E. and Schaaf, D., 1932, Brines of Ohio: Geological Survey of Ohio, Fourth Series, Bulletin 37.

104. Interview on November 8 with technical staff, Diamond Shamrock Chemical Company (a unit of Diamond Shamrock Corporation), Painesville, Ohio.

105. Voight, B. and Pariseau, W., March 1970, State of Predictive Art in Subsidence Engineering: Journal of the Soil Mechanics and Foundation Division, ASCE, V. 96, No. SM-2, pp. 721-750.

106. Terzagi, R. D., 1966, Brinefield Subsidence at Windsor Ontario: The Northern Ohio Geological Society, Inc., Volume III Third Symposium on Salt.

107. Woodruff, S. M., 1966, Methods of Working Coal and Metal Mines, Vol. II: Pergamon Press.

108. Bays, C. A., 1965, Significant Uncertainties in Current Salt Solution Extraction Operations: Second Symposium on Salt, Vol. II, The Northern Ohio Geological Society, Inc.

109. Myers, A. J., 1965, Sonar Measurements of Brine Cavity Shapes: Second Symposium on Salt, Vol. II, The Northern Ohio Geological Society, Inc.

110. Yerkes, R. F. and Castle, R. O., 1969, Surface Deformation Associated with Oil and Gas Field Operations in the United States: International Association of Scientific Hydrology, Tokyo Conference.

111. Thompson, Erik and Ripperger, E. A., 1964, An Experimental Technique for the Investigation of the Flow of Halite and Sylvinite: Proceedings, Sixth Symposium on Rock Mechanics, Rollo, Missouri.

112. Fader, S. W., March 1973, Land Subsidence Caused by Dissolution of Salt near Four Wells in Central Kansas: U.S. Geological Survey Administrative Report.

113. Mereu, R. F., Brunet, J., Morrissey, K., Price, B., and Yapp, A., 1986, A study of the microearthquakes of the Gobles oil field area of Southwestern Ontario: Bulletin of the Seismological Society of America, Vol. 76, pp. 1215-1223.

114. "Ohio Oil and Gas Law," Revised Code, Chapter 1509 with Rules and Regulations, Ohio Department of Natural Resources, Division of Oil and Gas, July 1970.

115. Subsidence Handbook, National Coal Board of Great Britain, 1966.

116. Preliminary Safety Analysis Report, Midland Nuclear Power Plant, Amendment No. 11, p. 2.17-10, May 1970.

117. 1973, Grosse Ile Subsidence Data, Solution Mining Research Institute, Washington, D.C.

118. Nair, K. and Chang, C-Y, 1971, Analytical Methods for Predicting Subsidence: Report to Solution Mining Research Institute, Woodward-Lundgren & Associates.

119. Marr, J. E., 1958-59, A New Approach to the Estimation of Mining Subsidence: Trans. Inst. of Mining Engineers, London, Vol. 118, Part II, pp. 692-707.

120. Winters, John, 1973, Resident, North Perry Village, Ohio, private communication.

121. Orton, E., 1888, The Ohio Shale as a Source of Oil and Gas in Ohio: Ohio Geological Survey, V. VI, pp. 410-442.

122. Calvert, W. L., 1964, Map of Oil and Gas Fields in Ohio: Geological Survey of Ohio.

123. Norling, D. L., DeBrosse, T. A. and Buschman W. J., Jr., 1965, Summary of Oil and Gas Activity in Ohio during 1964: Geological Survey of Ohio, Report of Investigations No. 56.

124. 1970, Ohio Department of Natural Resources, Division of Geological Survey in Cooperation with Division of Oil and Gas, 1976 Oil and Gas Fields Map of Ohio.

125. Healy, J. H., Rubey, W. W., Griggs, D. T., and Raleigh, C. B., 1968, The Denver earthquakes, Science, Vol. 161, pp. 1301-1309.

126. Raleigh, C. B., Healy, J. H. and Bredehoeft, J. D., 1976, An experiment in earthquake control at Rangely, Colorado, Science, Vol. 191, pp. 1230-1237.

127. Talwani, P. and Acree, S., 1986, Deep well injection at the Calhio wells and the Leroy, Ohio, earthquake of January 31, 1986, A report to the Cleveland Electric Illuminating Co., Cleveland, Ohio, 92 pages.

128. Wesson, R. L. and Nicholson, C., 1986, Studies of the January 31, 1986, Northeastern Ohio earthquake: A report to the U.S. Nuclear Regulatory Commission, U.S. Geological Survey Open-File Report 86-331, 131 pages.

129. Forsyth, Jane L., 1959, The Beach Ridges of Northern Ohio: Ohio Division of Geological Survey Information Circular No. 25, 10 pages.

130. Ohio Division of Geological Survey, 1961, Preliminary Estimate of Erosion or Accretion along the Ohio Shore of Lake Erie and Critical Erosion Areas: Technical Report No. 8.

131. U.S. Corps of Engineers, 1953, Report on a Cooperative Beach Erosion Control Study of the Ohio Shoreline of Lake Erie between Fairport and Ashtabula Beach Erosion Control Study: House Document 351.

132. Stone and Webster Engineering Corporation, October 1978, Regional Geology of the Salina Basin, Report of Geologic Project Manager - Salina Basin: Phase I August 1977 - January 1978, V. I, p. 3.3-1.

133. Heimlich, R. A., Manus, R. W. and Jacoby, C. H., 1974, General Geology of the International Salt Mine, Cleveland, Ohio, in Heimlich, R. A., and Feldmann, R. M. (eds.), Selected Field Trip in Northeastern Ohio: Ohio Department of Natural Resources, Division of Geology Survey Guidebook No. 2, p. 5-17, 59 pages.

134. Jacoby, Charles H., 1979, Structural Geology of the Fairport, Ohio, area: unpublished report prepared for Applicant.

135. Richner, Donald R., 1974, Minor Discontinuities reported in the Core Description of Diamond Alkali Core Hole #202 Perry Township, County of Lake, State of Ohio, U.S.A.: unpublished report prepared for Applicant.

136. Prosser, Charles S., 1912, The Devonian and Mississippian Formations of Northeastern Ohio: Ohio Geological Survey Bulletin 15.

137. LaFleur, R. G., 1979, personal communication.

138. Lessig and Rice, 1962, Kansan Drift of the Elkton, Ohio Rift: American Journal of Science, V. 260, pp. 439-454.

139. White, George W., 1960, Classification of Wisconsin Glacial Deposits in Northeastern Ohio: U.S. Geological Survey Bulletin, No. 1121-A.

140. Shane, Linda C. K., 1975, Palynology and Radiocarbon Chronology of Battaglia Bog, Portage County, Ohio: Ohio Journal of Science, V. 75, No. 2, pp. 96-102.

141. White, George W., Totten, Stanley M. and Gross, David L., 1969, Pleistocene Stratigraphy of Northeastern Pennsylvania: Pennsylvania Geological Survey Bulletin G 55.

142. Walcott, R. I., 1972, Late Quaternary Vertical Movements in Eastern North America: Quantitative Evidence of Glasio-Isostatic Rebound: Reviews of Geophysics and Space Physics, V. 10, No. 4, p. 867.

143. Meade, B. K., 1971, Report of the Sub-Commission on Recent Crustal Movements in North America: in Recent Crustal Movements, Symposium International 15, Association of Geodesy.

144. Mather, K. F. and Godfrey, H., assisted by Manpson, K., 1927, The Record of Earthquake Felt by Man in New England: copy of the manuscript of a paper presented to the Eastern Section of the Seismological Society of America.

145. Brigham, William T., 1871, Volcanic Manifestations in New England: Being an Enumeration of the Principal Earthquakes from 1638 to 1869: Memoirs of the Boston Society of Natural History, 28 pages.

146. Brooks, John E., S. J., 1960, A Study in Seismicity and Structural Geology (Parts I and II): Bulletin de Geophysique, Observatoire de Geophysique, College, Jean-de-Brebeuf, Montreal, Quebec, Nos. 6 and 7.

147. Docekal, Jerry, 1970, Earthquakes of the Stable Interior, with Emphasis on the Midcontinent: University of Nebraska Ph.D. Thesis, 332 pages.

148. Nuttli, O. W., 1979, Seismicity of the central United States, Geological Soc. America, Reviews in Engineering Geology, Vol. IV, pp. 67-93.

149. Nuttli, Otto W. and Hermann, Robert, 1978, State of the Art for Assessing Earthquake Hazards in the United States: in Report 12, Credible Earthquakes for the Central United States, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, pp. 1100.

150. Hopper, Margaret G. and Bollinger, G. A., 1971, The Earthquake History of Virginia, 1722 to 1900: Virginia Polytechnic Institute and State University, Department of Geological Sciences publication.

151. Bollinger, G. A. and Hopper, Margaret G., 1972, The Earthquake History of Virginia, 1900-1970: Virginia Polytechnic Institute and State University, Department of Geological Sciences publication, 85 pages.

152. Bollinger, G. A., 1969, Seismicity of the Central Appalachian States of Virginia, West Virginia and Maryland - 1758 through 1968: Bulletin of the Seismological Society of America, V. 59, No. 5, pp. 2103-2111.

153. Bollinger, G. A., 1973, Seismicity of the Southeastern United States: Bulletin of the Seismological Society of America, V. 63, No. 5, pp. 1785-1808.

154. Bollinger, G. A., 1975, A Catalog of Southeastern United States Earthquakes 1754 through 1974 Research Division Bulletin 101, Department of Geological Sciences: Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 68 pages.

155. Barstow, N. L., 1980, Earthquake Catalog: Appendix B1 in An approach to Seismic Zonation for siting Nuclear Electric Power Generating Facilities in the United States, by N. L. Barstow, K. G. Brill, D. W. Nuttli, and P. Pomeroy, <NUREG/CR-1577> prepared for the U.S. N.R.C.

156. Dewey, J. W. and Gordon, D. W., 1984, Map showing recomputed hypocenters of earthquakes in the Eastern and Central United States and adjacent Canada, 1925-1980, MFS MF-1699, U.S. Geological Survey, Department of the Interior.

157. Gordon, D. W., 1985, New determinations of hypocenters and magnitudes of instrumentally-recorded earthquakes, 1931-1980, in Central United States, and an investigation of the association of seismicity with geologic structure in the region - Private Communication.

158. Macelwane, J. B., 1950, Jesuit Seismological Association, 1925-1950, Central Station, St. Louis University, 347 pages.

159. Nicholson, C., Roeloffs, E. and Wesson, R. L., 1987, The Northeastern Ohio earthquake of January 31, 1986: Was it induced?, Bulletin of the Seismological Society of America.

160. Westland, A. J., S. J. and Heinrich, R. R., 1940, A Macroseismic Study of the Ohio Earthquakes of March 1937: Bulletin of the Seismological Society of America, Vol. 30, No. 3, pp. 251-260.

161. Bradley, Edward A., S. J. and Bennett, Theron J., 1965, Earthquake History of Ohio: Bulletin of the Seismological Society of America, V. 55, No. 4, pp. 745-752.

162. Coffman, J. L. and Von Hake, C. A., 1973, Earthquake History of the United States: U.S. Department of Commerce/N.O.A.A. Publication No. 41-1, Boulder, Colorado.

163. Nuttli, O. W., and Brill, K. G., 1980, Earthquake Source zones in the central United States determined from historical seismicity by N. L. Barstow, K. G. Brill, O. W. Nuttli and P. W. Pomeroy, <NUREG/CR-1577>, prepared for the NRC.

164. Dewey, Dr. James and Gordon, 1978, personal communication.

165. Smith, W. E. T., 1966, Earthquakes of eastern Canada and adjacent areas, 1928-1959, Publ. Dominion Observ. Ottawa, Vol. 32, pp. 87-121.

166. Woolland, G. P., 1969, Tectonic activity in North America, in The Earth’s Crust and Upper Mantle, Geophys. Monogr. Sers., Vol. 13, edited by P. J. Hart, pp. 125-131, AGU, Washington, D.C.

167. Oliver, J., Isacks, B. L., and Barazangi, M., 1974, seismicity at continental margins in the Geology of Continental Margins, edited by C. A. Burk and C. L. Drake, pp. 85-92, Springer, New York.

168. (Deleted)

169. Hermann, R. B., 1978, A Seismological Study of Two Attica, New York Earthquakes: Bulletin of the Seismological Society of America, V. 68, No. 3, pp. 641-651.

170. Street, R. L. and Turcotte, F. T., 1977, A Study of Northeastern North American Spectral Moments, Magnitudes, and Intensities: Bulletin of the Seismological Society of America, V. 67, No. 3, pp. 599-614.

171. Wetmiller, R. J., 1980, Investigation of Earthquakes in Burlington, Ontario, Internal Report 80-5, Earth Physics Branch, Ottawa, Ontario, 18 pages.

172. Armbruster, J. G., Seeber, L. and Evans, K., 1987, The July 1987, Ashtabula earthquake (m_b=3.6) sequence in Northeastern Ohio and a deep fluid injection well: Abstracts of the 59th annual meeting of the Eastern Section of the Seismological Society of America, October 7-9, 1987, St. Louis University.

173. Weston Geophysical Corp., 1987-1991, Quarterly Reports, CEI Seismic Monitoring Network, Numbers 1 through 18.

174. Dewey, J. R., 1986, Personal Communication.

175. Borcherdt, R. D., 1986, Preliminary report on aftershock sequence for earthquake of January 31, 1986, near Painesville, Ohio, U.S.G.S Open-File report 86-181.

176. Herrmann, R. B. and Nguyen, B. V., 1986, Focal mechanism studies of the January 31, 1986, Perry, Ohio, earthquake, Abstracts of the 58th annual meeting of the Eastern Section of the Seismological Society of America., p. 32.

177. Zietz, Isidore, King, Elizabeth R., Geddes, Wilbur, and Lidiak, Edward G., 1966, Crustal Study of a Continental Strip from the Atlantic Ocean to the Rocky Mountains: Geological Society of America Bulletin, V. 77, No. 12, pp. 1427-1448.

178. Mauk, F. J., Christensen, D. and Henry, S., 1982, The Sharpsburg, Kentucky, earthquake 27 July, 1980, main shock parameters and isoseismal maps: Bulletin of the Seismological Society of America, Vol. 72, No. 1, pp. 221-236.

179. Herrmann, R. B., Langston, C. A. and Zollweg, J. E., 1982, The Sharpsburg, Kentucky, earthquake of 27 July 1980: Bulletin of the Seismological Society of America, Vol. 72, No. 4, pp. 1219-1239.

180. Keller, G. R., Russell, D. R., Hinze, W. J., Reed, J. E., and Geraci, P. J., 1980, Bouguer Gravity Anomaly Map of the East Central Mid-continent of the United States, Nuclear Regulatory Commission, <NUREG/CR-1663>.

181. Street, R., Zekulin, A., Allsop, M., and Couch, D., 1985, The spatial correlation between a lateral seismic velocity discontinuity in the Precambrian basement rock and the Sharpsburg, Kentucky, earthquake of July 27, 1980: Earthquake Notes, Vol. 56, No. 2, pp. 47-54.

182. Sbar, M. L. and Sykes, L. B. 1977, Seismicity and Lithospheric Stress in New York and Adjacent Areas: Journal Geophysical Research, V. 82, No. 36, pp. 5771-5786.

183. Gupta, Indra and Nuttli, Otto W., 1976, Spatial Attenuation of Intensities for Central U.S. Earthquakes: Bulletin of the Seismological Society of America, V. 66, No. 3, pp. 743-751.

184. Bollinger, G. A., 1977, Reinterpretation of the Intensity Data for the 1886 Charleston, South Carolina, Earthquake, in Studies Related to the Charleston, South Carolina, Earthquake of 1886 - A Preliminary Report: U.S. Geological Survey Professional Paper 1028, pp. 17-32.

185. Joyner, W. B. and Boore, D. M., 1981, Peak Horizontal Acceleration and Velocity from Strong Motion Records from the 1979 Imperial Valley, California, Earthquake, Bulletin of the Seismological Society of America, Vol. 71, No. 6, pp. 2011-2038.

186. Campbell, K. W., 1981, Near-Source Attenuation of Peak Horizontal Acceleration: Bulletin of the Seismological Society of America, Vol. 71, No. 6, pp. 2039-2070.

187. Klimkiewicz, G. C., Leblanc, G., Holt, R. J., and Thiruvengadam, T. R., 1984, Relative Seismic Hazard Assessment for the North-Central United States, Proceedings, Eighth World Conference on Earthquake Engineering, July 21-28, 1984, San Francisco, California, Vol. 1, pp. 149-156.

188. Klimkiewicz, G. C. and Pulli, J. J., 1983, Ground Motion Attenuation Models for New England, abstract, 78th Annual Meeting, Eastern Section of the Seismological Society of America, Earthquake Notes, Vol. 54, No. 1, pp. 10-11.

189. Stover, C. W., 1986, Preliminary Isoseismal Map for the Northeastern Ohio Earthquake of January 31, 1986, U.S. Department of the Interior, Geological Survey, Open-File Report 86-356, 7 pages.

190. Kinemetrics Systems, 1986, Strong Motion Data Report for the 5.0 ML Earthquake of 11:47 EST, January 31, 1986, Perry, Ohio, for Cleveland Electric Illuminating Co., February 3, 1986.

191. U.S. Atomic Energy Commission, 1973, <Regulatory Guide 1.60>, Design Response Spectra for Seismic Design of Nuclear Power Plants, Revision 1, December 1973.

192. Newmark, N. M. Consulting Engineering Services, 1973, A Study of Vertical and Horizontal Earthquake Spectra, USAEC Contract No. AT(49-5)-2667, WASH-1255, Urbana, IL, April 1973.

193. Blume, J. A. and Associates, 1973, Recommendations for Shape of Earthquake Response Spectra, USAEC Contract No. AT(49-5)-3011, WASH-1254, San Francisco, CA, February 1973.

194. O'Brien, L. J., 1980, The Correlation of Response Spectral Amplitudes with Seismic Intensity, <NUREG/CR-1259>, prepared for the U.S. Nuclear Regulatory Commission, Site Safety Research Branch, Contract No. NRC-04-78-737.

195. Zoback, M. D., 1983, Intraplate Earthquakes, Crustal Deformation and In Situ Stress, in W. W. Hays and P. L. Gori (editors), A Workshop on the 1886 Charleston, South Carolina, Earthquake and its Implications for Today, Proceedings of Conference XX, U.S. Geological Survey Open-File Report 83-843, pp. 169-178.

196. Zoback, M. L. and Zoback, M. D., 1980, State of Stress in the Conterminous United States: Journal of Geophysical Research, Vol. 85, pp. 6113-6156.

197. USNRC, 1986, Safety Evaluation Report related to the operation of Perry Nuclear Power Plant Units 1 and 2, <NUREG-0887> Supplement No. 9.

198. Nuttli, O. W., 1983, Average seismic source - parameter relations for mid-plate earthquakes: Bulletin of the Seismological Society of America, Vol. 73, No. 2, pp. 519-535.

199. Anglin, F. M., 1984, Seismicity and Faulting in the Charlevoix Zone of the St. Lawrence Valley, Bulletin of the Seismological Society of America, Vol. 74, pp. 595-603.

200. Leblanc, G. and Buchbinder, G., 1977, Second Microearthquake Survey of the St. Lawrence Valley near La Malbaie, Quebec, Canadian Journal of Earth Sciences, Vol. 14, No. 12, pp. 2778-2789.

201. Russ, D. P., 1981, Model for Assessing Earthquake Potential and Fault Activity in the New Madrid Seismic Zone, in proceedings of EARTHQUAKES and Earthquake Engineering: The Eastern United States, September 14-16, 1981, Knoxville, TN, pp. 309-335.

202. Stauder, W., Herrmann, R. and others (1977-1987), Central Mississippi Valley Earthquake Bulletin, St. Louis University, Dept. of Earth and Atmospheric Sciences, Quarterly Bulletins 1 through 51.

203. Gutenberg, B. and Richter, C. F., 1942, Earthquake Magnitude, Intensity Energy, and Acceleration: Bulletin of the Seismological Society of America, V. 32, pp. 163-191.

204. Housner, G. W. and Jennings, 1964, Generation of Artificial Earthquakes: Proceedings of ASCE, V. 90, EMI, p. 113.

205. Vanmarcke, E. H. and Cornell, C. A., Seismic Risks and Design Response Spectra: Proceedings ASCE Specialty Conference on the Reliability of Metal Structures, Pittsburgh, 1972.

206. Hou, S. W., May 1968, Earthquake Simulation Models and their Applications: M.I.T. Department of Civil Engineering Technical Report R68-17.

207. Rascon, O. A. and Cornell, C. A., 1968, Strong Motion Earthquake Simulation: M.I.T. Department of Civil Engineering Technical Report R68-15.

208. Williams, S. Jeffress, 1978, personal communication.

209. Williams, S. Jeffress, 1979, written communication.

210. O'Leary, D. W., Friedman, J. D. and Pohn, H. A., 1976, Lineament, Linear, Lineation: Some Proposed New Standards for Old Terms: Geological Society of America Bulletin, V. 87, p. 1463-1469.

211. Bownocker, J. A. (compiler), 1965, Geological Map of Ohio: Ohio Division of Geological Survey (Scale 1:500,000).

212. Stone and Webster Eng. Corp., 1978, New York and Ohio: Geology of Bedded Salt and Program Plan, Volume III.

213. Berg, T. M. (complier), 1980, Geologic Map of Pennsylvania: Commonwealth of Pennsylvania, Department of Natural Resources, Pennsylvania Topographic and Geologic Survey.

214. Wagner, W. R. and Lytle, W. S., 1976, Revised Surface Structure Map of Greater Pittsburgh Area and its Relationship to Oil and Gas Fields: Pennsylvania Topographic and Geological Survey, 4th ser., Inf. Circ. 80.

215. Briggs, R. P. and Kohl, W. R., 1976, Map Showing Major Fold Axes, Satellite-Imagery Lineaments, Elongate Aeroradioactivity Anomalies, and Lines of Structural Discontinuity, Southwestern Pennsylvania and Vicinity: U.S.G.S. Miscellaneous Field Studies, Map MF-815.

216. Shepps, V. C., White, G. W., Droste, J. B., and Sitler, R. F., 1959, Glacial Geology of Northwestern Pennsylvania: Pennsylvania Topographic and Geologic Survey, Bulletin G-32.

217. Cummings, J. W., 1959, Buried River Valleys In Ohio: Ohio Department of Natural Resources, Division of Water, Report No. 10, State of Ohio, Department of Natural Resources, Columbus, Ohio.

218. Carney, F., 1909, The Metamorphism of Glacial Deposits: Journal of Geology, V. XVII, p. 473-487.

219. Smith, Ronald E. and Wahls, Harvey F., 1969, Consolidation under Constant Rates of Strain: Journal of the Soil Mechanics and Foundations Division, ASCE, V. 95, SM-2.

220. Menard, L. F., The Application of the Pressuremeter for Investigation of Rock Masses: Colloquium of the International Society of Rock Mechanics, Salzburg, Austria, 1965.

221. Coates, D. F. and Gyenge, M., 1966, Plate-Load Testing on Rock for Deformation and Strength Properties: Testing Techniques for Rock Mechanics, ASTM STP 402, American Society for Testing and Materials.

222. Harr, M. E., 1966, Foundations of Theoretical Soil Mechanics: New York, McGraw-Hill.

223. Scherman, K. A., 1969, In Situ Investigation in Soils and Rocks: Proceedings, British Geotechnical Society Conference, London, pp. 50-51.

224. Hardin, R. O. and Drnevich, V. P., 1970, Shear Modulus and Damping in Soils: I. Measurement and Parameter Effects, II. Design Equations and Curves, Technical Reports UKY 27-70-CE 2 and 3, College of Engineering, University of Kentucky.

225. Sherard, James L., Dunnigan, L. P., Decker, R. S., and Steele, E. F., 1976, Pinhole Test for Identifying Dispersive soils: Journal of the Geotechnical Engineering Division, ASCE, V. 102, No. GT1.

226. Sherard, James L., Decker, R. S. and Ryker, N. L., 1972, Piping in Earth Dams of Dispersive Clay: Proceedings, Specialty Conference on Performance of Earth and Earth-Supported Structures, ASCE, Lafayette, Indiana.

227. Sherard, James L., Dunnigan, L. P. and Decker, R. S., 1976, Identification and Nature of Dispersive Soils: Journal of the Geotechnical Engineering Division, ASCE, V. 102, No. GT4.

228. Skempton, A. W., 1953, The Colloidal ‘Activity’ of Clays: Proceedings, Third International Conference on Soil Mechanics and Foundation Engineering, V. I, p. 57.

229. Franklin, J. A., 1970, Suggested Methods for Determining the Slaking, Swelling, Porosity, Density, and Related Rock Index Properties, Research Report D12 (final draft), Imperial College, London.

230. Deere, D. U. and Miller, R. P., 1966, Engineering Classification and Index Properties for Intact Rock: Technical Report No. AFWL-TR-65-116, Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico.

231. Lambe, T. W., 1964, Methods of Estimating Settlement: Proceedings, Design of Foundations for Control of Settlement, ASCE, Evanston, Illinois.

232. Terzaghi, K. and Peck, R. B., 1967, Soil Mechanics in Engineering Practice, (2nd ed): New York, John Wiley, pp. 310-312.

233. Deere, D. U., Hendron, A. J., Patton, F. D., and Cording, E. J., 1967, Failure and Breakage of Rock: Chapter 11, Proceedings, Eighth Symposium on Rock Mechanics, American Institute of Mining and Metallurgical Engineers.

234. Herdendorf, C. E., 1966, Geology of the Vermillion West and Berlin Heights Quadrangles, Erie and Huron Counties, Ohio: Ohio Division of Geological Survey Report of Investigations No. 60, (1 sheet, Scale 1:24,000).

235. STRAAM Engineers, Inc., 1979 Perry Nuclear Power Plant - Units 1 and 2, Cooling and Emergency Service Water Tunnels; Design of Concrete Final Lining for Gilbert Associates, Inc. - Reading, Pennsylvania.

236. Katz, D. L. and Coats, K. H., 1968, Underground Storage Fluids, Ann Arbor, Michigan, Ulrich's Books.

237. Ibrahim, M. A., Tek, M. R. and Katz, D. L., 1970, Threshold Pressure in Gas Storage: Arlington, Virginia, American Gas Association.

238. Pandey, G. N., Tek, M. R. and Katz, D. L., 1972, Diffusion of Fluids through Porous Media applied to the Earth: NSF Grand GK 2085, Department of Chemical Engineering, University of Michigan, Ann Arbor, Michigan.

239. Seed, H. B. and Idriss, I. M., 1970, Soil Moduli and Damping Factors for Dynamic Response Analysis: Earthquake Engineering Research Center, University of California, Berkeley, Report No. EERC 70-10.

240. U.S. Department of Agriculture, Soil Conservation Service, 1968, Soil Mechanics Note - 1.

241. Report of Pumping and Permeability Tests, Perry Nuclear Power Plant - Units 1 and 2, Docket Nos. 50-440 and 50-441, March 27, 1975.

242. Seed, H. B. and Idriss, I. M., 1967, Analysis of Soil Liquefaction: Niigata Earthquake: Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 93, No. SM3.

243. Schnabel, P. E., Lysmer, J. and Seed, H. B., 1972, SHAKE, a Computer Program for Earthquake Response Analysis of Horizontally Layered Sites: University of California, Earthquake Engineering Research Center, Berkeley, Report No. EERC 72-12.

244. Lee, K. L. and Seed, H. B., 1967, Cyclic Stress Conditions causing Liquefaction of Sand: Journal of the Soil Mechanics and Foundations Division, ASCE, V. 93, No. SM1.

245. Seed. H. B. and Peacock, W. H., 1970, Applicability of Laboratory Test Procedures for Measuring Soil Liquefaction Characteristics under Cyclic Loading: University of California, Earthquake Engineering Research Center, Berkeley, Report No. EERC 70-8.

246. Wong, R. T., 1971, Deformation Characteristics of Gravels and Gravelly Soils under Cyclic Loading Conditions: University of California, Berkeley, Ph.D. dissertation.

247. Seed, H. B. and Idriss, I. M., 1970, A Simplified Procedure for Evaluating Soil Liquefaction Potential: University of California, Earthquake Engineering Research Center, Berkeley, Report No. EERC 70-9.

248. Seed, H. B. and Idriss, I. M., 1971, Simplified Procedure for Evaluating Soil Liquefaction Potential, Journal of the Soil Mechanics and Foundations Division, ASCE, Volume 97, No. SM9, Proc. Paper 8371, pp. 1249-1273.

249. Nuttli, O. W., 1979, State-of-the Art for Assessing Earthquake Hazards in the United States, Misc. Paper S-73-1, Report 16, The Relation of Sustained Maximum Ground Acceleration and Velocity to Earthquake Intensity and Magnitude, U.S. Army Waterways Experiment Station, Vicksburg, Mississippi.

250. Seed, H. B., et al., Representation of Irregular Stress Time Histories by Equivalent Uniform Stress Series in Liquefaction Analyses, Report No. EERC75-29, Earthquake Engineering Research Center, Berkeley, California.

251. Gibbs, H. J. and Holtz, W. G., 1957, Research on Determining the Density of Sands by Spoon Penetration Sampling, Proceedings, Fourth International Conference on Soil Mechanics and Foundation Engineering, London, England.

252. Clough, R. W. and Duncan, J. M., 1969, Finite-Element Analysis of Port Allen and Old River Locks: University of California, Berkeley, Report No. TE-69-3.

253. Moorhouse, D. C., 1972, Shallow Foundations: Proceedings, Specialty Conference on Performance of Earth and Earth-Supported Structures, ASCE, Purdue University.

254. Seed, H. B. and Whitman, R. V., 1970, Design of Earth Retaining Structures for Dynamic Loads: Proceedings, Specialty Conference on Lateral Stresses and Earth Retaining Structures, ASCE, Cornell University.

255. Scott, R. F., 1973, Earthquake Induced Earth Pressures on Retaining Walls: Proceedings, Fifth World Conference on Earthquake Engineering, Session 4D: Dynamics of Soils and Soil Structures, Rome.

256. Seed, H. B., 1969, Dynamic Lateral Pressures on Retaining Structures: Lecture presented at University of California, Berkeley.

257. Bowles, E., 1968, Foundation Analysis and Design: New York, McGraw-Hill.

258. Winterkorn, H. F. and Fang, H-Y; Foundation Engineering Handbook: VanNostrand Reinhold Company, New York, p. 517.

259. Baily, W. A. and Christian, J. T., 1969, ICES-LEASE-I, a Problem Oriented Language for Slope Stability Analysis: Soil Mechanics Publication No. 235, Massachusetts Institute of Technology.

260. Terzaghi, K. and Peck, R. B., 1967, Soil Mechanics in Engineering Practice: New York, John Wiley.

261. Dawson, A. W., 1972, LEASE II, A Computerized System for the Analysis of Slope Stability, Thesis, Department of Civil Engineering, Massachusetts Institute of Technology.

262. Morgerstern, N. and Price, V. E., 1965, The Analysis of the Stability of General Slip Surface, Geotechnique, Vol. 15, pp. 79-93.

263. Institute of Science and Technology, University of Michigan Handbook: World-wide Seismograph Network: Washington, D.C., prepared for U.S. Coast and Geodetic Survey.

264. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, 1972, Seismograph Station Abbreviations and Coordinates: Washington, D.C.

265. Wetmiller, R. J. and Horner, R. B., 1978, Canadian Earthquakes - 1976: Ottawa, Earth Physics Branch, E.M.R.

266. Bishop, A. W. and Henkel, D. J., 1962, The Measurement of Soil Properties in the Triaxial Test: 2nd Edition, London, Edward Arnold.

267. Kenny, T. C. and Watson, G. H., 1961, Multiple-Stage Triaxial Test for Determining c′ and ∅′ of Saturated Soils: Proceedings, Fifth International Conference of Soil Mechanics, V. I, pp. 191-195.

268. Chayes, F., 1965, Petrographic Model Analysis: New York, John Wiley, p. 113.

269. Ohio Geologic Survey, 1956, Physiographic Section Map of Ohio.

270. Berggren, H. and Couvering, V., 1977, Nature, 269, pp. 483-488.

271. Bayer, K. C., 1983, Generalized structural lithologic and physiographic pronnces in the fold and thrust belts of the United States, Scale 1:2,500,000.

272. Lapedes, 1978, McGraw-Hill Encyclopedia of Geologic Sciences.

273. Friis, Herman R., 1968, A Series of Population Maps of the Colonies and the United States: 1625-1790: American Geographical Society, Mimeographed and Offset Publication No. 3, Revised, New York, N.Y.

274. Geological Survey, United States Dept. of the Interior, 1970, National Atlas of the United States of America: Dept. of Interior, Washington, D.C., pp. 134-139.

275. The Maine Historical Society, 1976, Maine Bicentennial Atlas: A Historical Survey: Maine Historical Society, Portland, Maine.

276. Stover, C. W. and von Hake, C. A., 1982, United States Earthquakes, U. S. Dept. of the Interior, Golden, CO.

277. Howell, B. F. and Schultz, T. R., 1975, Attenuation of Modified Mercalli Intensity with Distance from the Epicenter: Bulletin Seismological Association of America, V. 65 No. 3, pp. 651-665.

278. Cornell, C. A. and Merz, H. A., 1975, Seismic Risk Analysis of Boston: Journal of the Structural Division ASCE V. 101, No. ST10, Proc. Paper 11617, pp. 2027-2043.

279. Brazee, R. J., 1976, Final report; An Analysis of Earthquake Intensities with Respect to Attenuation, Magnitude and Rate of Recurrence, Revised Edition NOAA Technical Memorandum EDS NGEDC-2, National Geophysical and Solar Terrestrial Data Center, Boulder, Colorado.

280. Nuttli, Otto W., 1973, The Mississippi Valley Earthquakes of 1811 and 1812: Intensities, Ground Motion and Magnitudes: Bulletin of the Seismological Society of America, V. 63, No. 1, pp. 227-248.

281. Bollinger, G. A., 1977, “Reinterpretation of the Intensity Data for the 1886 Charleston, South Carolina, Earthquake of 1886” Studies Related to the Charleston, South Carolina, Earthquake of 1886 - A Preliminary Report: United States Geological Survey Professional Paper 1028, United States Dept. of the Interior, Washington, D.C., p. 25.

282. Smith, W. E. T., 1966, Earthquakes of Eastern Canada and Adjacent Areas, 1928 - 1959: Publications of the Dominion Observatory, V. 32, No. 3, Department of Mines and Technical Surveys, Ottawa, Canada, p. 119.

283. Heck, N. H. and Bodle, R. R., 1931, United States Earthquakes, 1929: United States Department of Commerce, Coast and Geodetic Survey, Washington, D.C., p. 7.

284. Neumann, F., 1932, United States Earthquakes, 1931: United States Department of Commerce, Coast and Geodetic Survey, Washington, D.C., p. 8.

285. Bodle, R. R., 1945, United States Earthquakes, 1943: United States Department of Commerce, Coast and Geodetic Survey, Washington, D.C., p. 7.

286. Smith, W. E. T., 1966, Earthquakes of Eastern Canada and Adjacent Areas, 1928 - 1959: Publications of the Dominion Observatory, V. 32, No. 3, Department of Mines and Technical Surveys, Ottawa, Canada, p. 115.

287. Newman, F., 1954, Earthquake Intensity and Related Ground - Ground Motion, University of Washington Press, Seattle, Washington.

288. Hardin, R. O. and Drnevich, D. P., 1970 Shear Modulus and Damping in Soils: I Measurement and Parameter Effects, II Design Equations and Curves: Technical Reports UKY 27-70-CE 2 and 3, College of Engineering, University of Kentucky, Lexington, Kentucky.

289. Van Horn, Frank R., 1910, Landslide Accompanied by Buckling and its Relation to Local Anticlinal Folds: Geological Society of America Bulletin, V. 20, pp. 625-632.

290. Van Horn, Frank, R., 1910, Local Anticlines in the Chagrin Shales at Cleveland, Ohio (with discussion): Geological Society of America Bulletin, V. 21, pp. 771-773.

291. Cornell, C. A., 1968, Engineering seismic risk analysis, B.S.S.A. Vol. 58, No. 5, pp. 1583-1606.

292. Mcguire, R. K., 1976, EQRISK, Evaluation of earthquake risk to site, U.S.G.S. Open-File Report 76,67, 90 p.

293. Easton, R. M., Carter, T. R., and DiPrisco, G., 1990, Bedrock geology and the Precambrian-Paleozoic unconformity in southeastern Ontario, Field Trip No. 1 Guidebook, AAPG Easter Section 1990 Annual Meeting, New London, Ontario, 64p.

294. Green, A. G., Milkereit, B., Davidson, A., Spencer, C., Hutchinson, D. R., Cannon, W. F., Lee, M. W., Agena, W. F., Behrendt, J. C., and Hinze, W. J., 1988, Crustal structure of the Grenville Front and adjacent terranes, Geology, v. 16, p. 788-792.

295. Pratt, T., Culotta, R., Hauser, E., Nelson, D., Brown, L., Kaufman, S., Oliver, J., and Hinze, W., 1989, Major Proterozoic basement features of the eastern midcontinent of North America revealed by recent COCORP profiling, Geology, v. 17, p. 505-509.

296. Forsyth, D. A., Milkereit, B., Hinze, W. J., Mereu, R. F., and Asmis H., 1991, Crustal structures from the southwestern Grenville Province: a progress report on the processing and interpretation of reflection data in lakes Ontario, Erie and Huron; in Current Research, part C, Geological Survey of Canada, Paper 91-96, p. 71-76.

297. Dickas, A. B., 1986, Comparative Precambrian stratigraphy and structure along the midcontinent rift, American Association of Petroleum Geologists Bulletin, v. 70, p. 225-238.

298. Brown, L., Jensen, L., Oliver, J., Kaufman, S., and Steiner, D., 1982, Rift Structure Beneath the Michigan Basin from COCORP Profiling, Geology, v. 10, p. 645-649.

299. Carter, T. R., and Easton, R. M., 1990, Extension of Grenville basement beneath southwestern Ontario: Lithology and Tectonic Boundaries; in Subsurface Geology of Southwestern Ontario: A Core Workshop, edited by T. T. Carter; American Association of Petroleum Geologists, Core Workshop Volume, London, Ontario, p. 6-26.

300. Coogan, A. H. and Maki, M. U., 1988, Knox unconformity in the subsurface of Northern Ohio, Northeastern Geology, Vol. 10, No. 4, p. 271-180.

301. Wickstrom, L. H., and Gray, J. D., 1988, Geology of the Trenton Limestone in northwestern Ohio, Brian D. Keith ed., The Trenton Group (Upper Ordovician Series) of Eastern North America, AAPG Studies in Geology 29, p. 159-172.

302. ICI Americas, 1989, Geological Report-Subsurface studies ICI Americas Inc., Perry Plant Perry TWP., Lake County, Ohio, Report to the Ohio Environmental Protection Agency, 29p.

303. Calvert, W. L., 1974, SubTrenton structure of Ohio with views on isopach maps and stratigraphic sections as basis for structural myths in Ohio, Illinois, New York, Pennsylvania, West Virginia, and Michigan, American Association of Petroleum Geologists Bulletin, v. 58, p. 957-972.

304. Schwartz, S. Y. and Christensen, D. H., 1988, The 12 July 1986 St. Marys, Ohio Earthquake and Recent Seismicity in the Anna, Ohio Seismogenic Zone: Seismological Research Letters, Vol. 59, No. 2, pp. 57-62.

305. Taylor, K. B. and Herrman, R. B., 1989, Source Parameters of the Central Kentucky Earthquake of 07 September 1988: Abstracts, Seismological Research Letters, Vol. 60, No. 4, p. 145.

306. Schieman, D., Geological Survey of Canada, October 23, 1991, personal facsimile to Weston Geophysical Corp.

307. EPRI NP-6395-D, Project P101-53, Special Report, April 1989, Probabilistic Seismic Hazard Evaluations at Nuclear Plant Sites in the Central and Eastern United States: Resolution of the Charleston Earthquake Issue.

308. EPRI Project RP 101-53, April 1989, Probabilistic Seismic Hazard Evaluation for Perry Nuclear Power Plant.

TABLE 2.5-1

STRATIGRAPHY OF SALINA GROUP IN PERRY TOWNSHIP

Unit	Depth To Top of Unit (feet)		Thickness (feet)		Salt Thickness (feet)	
	Well L-106	Well 142	Well L-106	Well 142	Well L-106	Well 142
A	2,331	2,740	79	89	-	-
B	2,130	2,281	201	189	101	99
C	2,084	2,235	46	45	-	-
D	2,047	2,194	37	41	30	33
E	1,957	2,102	90	92	-	-
F	1,899	2,030	58	72	55	66
G	1,731	1,864	168	166	-	-
Total					186	198

TABLE 2.5-2

SUMMARY OF WATER ANALYSES

Chemical Constinents	Oriskany[1]		Newburg[1]		Sea Water[2]
	gms/liter	% Saline	gms/liter	% Saline	% Saline
Chloride	156.12	62.65	173.69	61.24	55.29
Bromide	1.61	0.64	1.69	0.57	0.19
Calcium	41.78	16.46	33.64	11.37	1.20
Magnesium	8.94	3.61	5.67	1.90	3.73
Strontium	1.46	0.62	0.77	0.25	-
Ammonium	0.31	0.12	0.19	0.06	-
Sodium	35.72	14.66	64.94	23.63	30.59
Potassium	2.32	0.88	1.26	0.47	1.11
Silica	0.03	0.01	0.02	0.01	-
Iron and Aluminum Oxides	0.62	0.27	0.60	0.21	-
Sulfate	0.20	0.09	0.49	0.29	7.69
Carbonate	-	-	-	-	0.21

NOTES:

(1) Average of 7 samples from lake and surrounding counties.
(2) Average of 77 samples from USGS.

TABLE 2.5-3

SIMULATED ORISKANY BRINE SOLUTION

Chemical Compound	Proportion in gms/liter
NaC1	88.6
$CaC1_2 \cdot 2H_20$	154.0
$MgC1_2 \cdot 6H_20$	74.6
KC1	3.11
$SrC1_2 \cdot 6H_20$	4.45
NH_4C1	0.97
$A1C1_3 \cdot 6H_20$	1.43
$FeC1_3 \cdot 6H_20$	1.06
NaBr	2.08

TABLE 2.5-4

BRINE ANALYSIS OF TYPICAL SOLUTION WELL

Element	Grams per Liter[1]
C1 and NaC1	308.29
SO_4 as $CaSO_4$	5.24
Ca as $CaSO_4$	5.54
Mg as $MgCl_2$	0.35

NOTE:

[1] Average of 7 tests

TABLE 2.5-5

FIELD INVENTORY OF WELLS
(permitted prior to May 1973)

Well No.[1]	Approximate Depth (ft.)	Use Status	Type	Owner
L-213	812	Plugged	Gas	CEI
L-106[2]	2,474	Exploratory core hole; plugged.	Salt	Diamond Shamrock
L-207	800	Presumed abandoned; could not locate.	Gas	CEI
L-207A	800	Household use	Gas	John Winter
L-207B	800	Capped and abandoned	Gas	John Winter
L-207C	800	Household use	Gas	John Winter
L-203	1,000	Capped and abandoned	Gas	F. E. Welch
L-201	800		Gas	Could not be located
L-202	800	Capped and abandoned	Gas	George & Rosie Klco
L-214	1,100	Household use	Gas	N. H. Droese
L-217	900	Capped and abandoned	Gas	Chicago Merchandizing & Wholesale Auction (Sand pit)
L-215	800	Capped and abandoned	Gas	Brewster - Sand pit
L-208	800	Capped and abandoned	Gas	Bliss
L-206	800	Capped and abandoned	Gas	Herman Losely & Son Nursery
L-204	800	Capped and abandoned	Gas	Daniel
L-205	800	Recently plugged	Gas	Corrigan
L-218	1,100	Household use	Gas	H. Noss
L-212	800	Capped and abandoned	Gas	William D. Hill

TABLE 2.5-5 (Continued)

Well No.[1]	Approximate Depth (ft.)	Use Status	Type	Owner
L-210	800	Capped and abandoned	Gas	Lake Co. Park Board
L-211	800	Capped and abandoned	Gas	Walter & Ruth Rust
L-209	800	Capped and abandoned	Gas	Walter & Ruth Rust
179	3,058	Exloratory well; capped, but not plugged.	Gas	F. & V. Daykin

NOTES:

(1) The above wells were field located May 1973.
(2) Diamond Shamrock Well No. 202.

TABLE 2.5-6

SUPPLEMENTAL WELL DATA
(permitted subsequent to May 1973)

Permit No.	Approximate Depth (ft)	Initial Production[1]	Type	Land Owner (Operator)
203	2,959	Fractured, tested, no further comment.	Gas	Diamond Shamrock Corp.
229	2,985	1.4 MMCFG after fracturing.	Gas	Bobby & Faye Compton
230	2,980	400 MCFG & 1 B.O. after fracturing.	Gas	Roy & Alice Ronke
233	3,000	1.9 MMCFG after fracturing.	Gas	Carol & Ronald Mosher
234	2,990	800 MCFG after fracturing.	Gas	P. E. & V. Golding
270	Incomplete as of March 1979	N/A	Gas	
20	2,476	Core hole	Salt?	Diamond Alkali Co. (Diamond Alkali Co.)
168	660	Unknown	Shale/Gas	Mr. M. Daniels (Harry Nerode)
207	630	Unknown	Shale/Gas	Charles S. Beardslee
213				
232		Permit expired		
282	664	-------	Gas	Camp Roosevelt Unit (James V. Shankars)
289	2,997	A.F. 300 MCFG	Gas	Camp Roosevelt Unit (Petro Evaluation Corp.)
290		Permit expired		

TABLE 2.5-6 (Continued)

Permit No.	Approximate Depth (ft)	Initial Production[1]	Type	Land Owner (Operator)
291		Permit expired		
327	2,990	A.F. 1 MMCFG	Gas	F&G Losely (Viking Resources Corp.)
346		Permit expired		
347	2,990	A.F. 250 MCFG	Gas	Orosz/Cinco Unit (Viking Resources Corp.)
348	2,965	A.F. 200 MCFG	Gas	Orosz/Cinco Unit (Viking Resources Corp.)
349	2,984	A.F. 200 MCFG	Gas	Haskins-Kroggel Unit (Viking Resources Corp.)
350	2,990	A.F. 220 MCFG	Gas	Haskins-Kroggel Unit (Viking Resources Corp.)
357	2,975	A.F. 300 MCFG	Gas	Richard P. West (Petro Evaluation Service, Inc.)
358	2,978	A.F. 80 MCFG	Gas	Losely (Viking Resources Corp.)
359	2,965	A.F. 130 MCFG	Gas	Losely (Viking Resources Corp.)
397	2,960	A.F. 500 MCFG	Gas	Roosevelt Unit (Petro Evaluation Services, Inc.)
407	2,970	A.F. 500 MCFG	Gas	Rosenberg Unit (A.E.D.)
421	2,935	A.F. 30 MCFG	Gas	Long Unit (Viking Resources Corp.)

TABLE 2.5-6 (Continued)

Permit No.	Approximate Depth (ft)	Initial Production[1]	Type	Land Owner (Operator)
421	2,964	A.F. 250 MCFG	Gas	Hopp-Shreve Unit (Petro Evaluation Services, Inc.)
426	2,991	A.F. 750 MCFG	Gas	Secor Unit (Petro Evaluation Services, Inc.)
428	3,021	A.F. 750 MCFG	Gas	Secor Unit (Petro Evaluation Services, Inc.)
450	2,974	A.F. 250 MCFG	Gas	J&L Gerlica (Petro Evaluation Services, Inc.)
451		Permit expired		
470	3,055	A.F. 250 MCFG	Gas	Branisor-Kenney (Petro Evaluation Services, Inc.)
471	2,971	A.F. 200 MCFG	Gas	Anderson-Brainard (Petro Evaluation Services, Inc.)
475	2,982	A.F. 250 MCFG	Gas	Hein Unit (Petro Evaluation Services, Inc.)
525	2,957	A.F. 350 MCFG	Gas	Metro Parks (Petro Evaluation Services, Inc.)
583	2,989	A.F. 200 MCFG	Gas	Royal Crest Acres (Petro Evaluation Services, Inc.)
594		Permitted, not drilled		

NOTE:

[1] Well owners unavailable for comment on present well status.

TABLE 2.5-7

EARTHQUAKES WITHIN 200 MILES OF THE PERRY NUCLEAR POWER PLANT

M AND I GREATER THAN 3.0

ORIGIN TIME						HYPOCENTRAL LOCATION				MAGNITUDE				REF	DISTANCE	REMARKS
YEAR	MO	DA	HR	MN	SEC	LAT.	LONG.	Z(KM.)	I(MM)	MB	MN	ML	MC		(KM.)	
1796	12	26	11	0		43.1000N	79.0300W		- IV					DO	225.94	
1817	12	11	0	0	0.0	38.5000N	84.5000W		IV					NU	464.84	APP. 2D D
1827	7	6	10	0		39.1300N	84.5000W		IV					DO	411.05	
1828	3	9	15	30		38.5800N	83.7500W		- V					DO	420.89	
1828	3	10	5	0		38.5800N	83.7500W		- V					DO	420.89	
1836	7	8	21	15	0.0	41.5000N	81.7000W		IV					WG	57.16	APP. 2D D
1839	9	5	0	0	0.0	38.6000N	83.8000W		IV					NU	421.26	
1840	9	10	0	0		43.2000N	79.8500W		- V			4.0		EP	188.30	BASHAM ET AL 1982
1850	10	1	10	25	0.0	41.5000N	81.7000W		IV					WG	57.16	APP. 2D D
1853	3	13	10	0		43.1000N	79.4000W		V			4.0		EP	203.45	BASHAM ET AL 1982
1854	2	28	0	0	0.0	38.0000N	84.5000W		- V					NU	510.31	FELT AREA = 20000
1856	1	16	8	0		39.3000N	78.2000W		IV					BO	373.19	
1857	2	28	1	40	0.0	41.8000N	80.6000W		- V					WG	45.17	APP. 2D D
1857	10	23	20	15		43.2000N	78.6000W		VI					EP	260.49	
1858	1	1	16	0		42.9000N	78.5500W		IV					DO	246.10	
1858	4	10	11	30	0.0	41.6700N	81.2500W		IV					WG	17.18	APP. 2D D
1869	2	20	0	0	0.0	38.1000N	84.5000W		V					NU	501.06	
1873	4	23	4	14	0.0	39.7000N	84.2000W		- IV					NU	347.91	
1873	4	30	0	0		43.3000N	79.9000W		IV					EP	195.34	
1873	7	6	14	30		43.0000N	79.5000W		- VI			4.5		EP	189.86	BASHAM ET AL 1982
1875	6	18	13	43	0.0	40.2000N	84.0000W		VII					NU	298.93	FELT AREA = 100000
1876	6	0	0	0	0.0	40.4000N	84.2000W		V					NU	300.21	
1877	1	23	21	0	0.0	38.8000N	83.5000W		III		3.6			NU	388.79	FELT AREA = 2500
1877	8	17	16	50	0.0	42.3000N	83.3000W		- V		3.2			NU	186.93	FELT AREA = 500
1879	8	21	8	0		43.2000N	79.2000W		IV					EP	222.87	
1882	2	9	20	0	0.0	40.4000N	84.2000W		V		3.2			NU	300.21	FELT AREA = 250
1882	11	27	23	30		43.0000N	79.2500W		IV					EP	205.04	
1883	5	23	4	30	0.0	38.4000N	82.6000W		IV					NU	397.53	
1884	9	19	20	14	0.0	40.7000N	84.1000W		VI		4.8			NU	276.32	FELT AREA = 320000
1885	1	3	2	16		39.2000N	77.5000W		V					EH	422.80	
1885	1	18	10	30	0.0	41.1000N	81.4500W		IV					WG	80.75	APP. 2D D
1885	9	26	20	30		40.1700N	80.2300W		- IV					DO	196.78	
1886	5	3	3	0	0.0	39.5000N	82.1000W		- IV		3.4			NU	268.02	
1896	3	15	7	0	0.0	40.3000N	84.2000W		IV					NU	306.28	
1897	3	7	0	0		43.1000N	79.2000W		IV					EP	215.36	
1899	11	12	14	0	0.0	39.3000N	83.0000W		IV					NU	319.14	
1901	5	17	7	0	0.0	39.3000N	82.5000W		V		4.2			NU	300.55	FELT AREA = 25000
1902	3	10	5	0		39.6000N	77.2000W		- IV					BO	413.24	
1902	6	14	7	0	0.0	40.3000N	81.4000W		- V					NU	168.09	
1906	4	23	7	12	0.0	40.7000N	83.6000W		V					NU	239.46	

TABLE 2.5-7 (Continued)

M AND I GREATER THAN 3.0

ORIGIN TIME						HYPOCENTRAL LOCATION				MAGNITUDE				REF	DISTANCE	REMARKS
YEAR	MO	DA	HR	MN	SEC	LAT.	LONG.	Z(KM.)	I(MM)	MB	MN	ML	MC		(KM.)	
1907	1	10	0	0		41.2500N	77.1000W		IV					EP	342.97	
1909	4	2	7	25		39.4000N	78.0000W		V					BO	376.63	
1910	2	8	14	0		38.8000N	78.7000W		IV					BO	392.65	
1910	2	25	0	0		43.2000N	79.8000W		IV					EP	190.65	
1912	5	27	12	52		43.2000N	79.7000W		V					SM	195.52	
1918	2	22	0	0	0.0	42.8000N	84.2000W		IV					NU	275.38	
1918	4	10	2	9		38.7000N	78.4000W		VI					EH	415.95	
1918	4	16	13	40		38.7000N	78.4000W		IV					BO	415.95	STREET
1919	9	6	2	46		38.8000N	78.2000W		VI					EH	416.69	
1920	7	24	0	0		38.7000N	78.4000W		IV					BO	415.95	
1923	12	31	16	40		39.2000N	78.0000W		V					BO	392.92	
1924	1	1	0	0		39.2000N	78.0000W		- V					BO	392.92	
1924	1	5	0	0		39.1000N	78.1000W		IV					EP	395.70	
1925	3	27	4	6	0.0	39.5000N	83.9000W		V					NU	345.87	
1926	10	28	11	0	0.0	41.7000N	83.6000W		IV					NU	204.63	
1926	11	5	15	53	0.0	39.1000N	82.1000W		- VII		3.4			NU	310.71	FELT AREA = 900
1927	2	17	5	30	0.0	40.7000N	82.5000W		IV					NU	166.97	
1927	6	10	7	16		38.0000N	79.0000W		V					EH	460.10	
1927	11	12	19	50		43.1000N	79.0600W		IV					EP	224.04	
1928	10	27	0	0	0.0	40.4000N	84.1000W		III		3.2			NU	293.06	FELT AREA = 250
1929	3	8	9	6	0.0	40.4000N	84.2000W		V		4.0			NU	300.21	FELT AREA = 13000
1929	8	12	11	24	48.7	42.9100N	78.4020W		VIII		5.2	5.8		DW	257.27	STREET+TURCOTTE 1977
1929	12	2	22	14		42.8000N	78.3000W		V					EP	259.40	
1929	12	3	12	50		42.8000N	78.3000W		IV					EP	259.40	
1929	12	26	2	56		38.1000N	78.5000W		VI					BH	468.89	
1930	6	26	21	45	0.0	40.5000N	84.0000W		IV					NU	279.94	
1930	6	27	7	23	0.0	40.5000N	84.0000W		IV					NU	279.94	
1930	7	11	0	15	0.0	40.6000N	83.2000W		IV					NU	218.05	
1930	9	30	20	40	0.0	40.3000N	84.3000W		VII		4.2			NU	313.36	
1930	10	0	0	0	0.0	40.4000N	84.2000W		- IV					NU	300.21	
1931	4	22	0	0		42.9000N	78.9000W		IV					EP	221.52	
1931	6	10	8	30	0.0	41.3000N	84.0000W		V		3.7			NU	244.73	FELT AREA = 4000
1931	9	20	23	5	03.4	40.4290N	84.2700W	5	VII		4.6			DW	303.57	
1932	1	21	0	0	0.0	41.0800N	81.5000W		IV					NU	83.36	APP. 2D D
1933	2	23	3	20	0.0	40.3000N	84.2000W		IV		3.8			NU	306.28	FELT AREA = 5000
1933	5	28	15	10	0.0	38.6000N	83.7000W		V		3.6			NU	416.75	FELT AREA = 1800
1934	10	29	20	7		42.0000N	80.2000W		V		4.0			WG	81.35	BASHAM ET AL 1982 APP. 2D D
1935	11	1	8	30		38.9200N	79.8500W		V					US	338.26	
1936	1	31	19	30	0.0	41.2000N	83.2000W		IV					NU	184.23	

TABLE 2.5-7 (Continued)

M AND I GREATER THAN 3.0

ORIGIN TIME						HYPOCENTRAL LOCATION				MAGNITUDE				REF	DISTANCE	REMARKS
YEAR	MO	DA	HR	MN	SEC	LAT.	LONG.	Z(KM.)	I(MM)	MB	MN	ML	MC		(KM.)	
1936	10	8	16	30	0.0	39.3000N	84.4000W		III		3.5			NU	391.38	FELT AREA = 1800
1937	3	2	14	47	33.3	40.4880N	84.2730W	2	VII		4.7			DW	300.46	NUTTLI+ZOLLWEG 1974
1937	3	3	9	50	0.0	40.7000N	84.0000W		V		3.4			NU	268.83	FELT AREA = 500
1937	3	9	5	44	35.5	40.4700N	84.2800W	3	-VIII		4.9			DW	301.98	NUTTLI+ZOLLWEG 1974
1937	4	23	17	15	0.0	40.7000N	84.0000W		III		3.4			NU	268.83	FELT AREA = 650
1937	4	27	17	0	0.0	40.7000N	84.0000W		III		3.4			NU	268.83	FELT AREA = 650
1937	5	2	17	5	0.0	40.7000N	84.0000W		IV					NU	268.83	
1938	3	13	16	10	0.0	42.4000N	83.2000W		IV					NU	182.66	
1938	7	15	22	46	12.0	40.6800N	78.4300W	1	VI		3.3			DW	259.30	NUTTLI+ZOLLWEG 1974
1939	1	14	8	10	16.	43.2500N	79.8500W					3.3		EP	192.88	
1939	3	18	14	3	0.0	40.4000N	84.0000W		- IV		3.6			NU	285.98	FELT AREA = 1400
1939	6	18	3	20	0.0	40.3000N	84.0000W		IV		3.4			NU	292.32	FELT AREA = 1000
1940	3	26	3	28		38.8000N	78.5000W		V					BO	401.90	
1940	6	16	4	30	0.0	40.9000N	82.3000W		IV					NU	139.22	
1943	3	9	3	25	24.9	41.6280N	81.3090W	7	V		4.5			DW	23.65	APP. 2D D
1944	11	13	11	52	0.0	40.4000N	84.4000W		III		4.3			NU	314.70	FELT AREA = 45000
1946	11	10	11	41	23.1	42.8700N	77.4500W					3.1		EP	326.72	
1947	8	10	2	46	41.3	41.9280N	85.0000W	2	VI			4.6		DW	320.49	FA = 180000 SQKM. BASHAM ET AL 1982
1950	4	20	0	0	0.0	39.8000N	84.2000W		IV					NU	340.42	
1951	12	3	7	2	0.0	41.6400N	81.4100W		IV				2.6	WG	30.89	APP. 2D D, CEI RPT JUNE 1988
1952	6	20	9	38	6.0	39.6400N	82.0200W		VI		4.1			GO	251.14	FELT AREA = 13000
1952	9	11	3	15		38.1000N	78.5000W		IV					BO	468.89	
1952	12	25	0	0	0.0	43.8000N	81.0000W		IV					NU	222.38	
1953	5	7	23	32	0.0	39.7000N	82.1000W		IV					NU	246.90	
1953	6	12	0	0	0.0	41.7000N	83.6000W		IV					NU	204.63	
1954	1	31	12	30		42.8900N	77.2800W		IV					US	340.54	
1954	4	27	2	14	08.	43.1000N	79.2000W					4.1		EP	215.36	
1955	5	26	18	9	23.0	41.3300N	81.4000W		+ IV		3.4			WG	56.52	APP. 2D D, CEI RPT JUNE 1988
1955	6	29	1	15	33.0	41.3300N	81.4000W		- V		3.6			WG	56.52	APP. 2D D, CEI RPT JUNE 1988
1955	8	16	7	35		42.8900N	78.2800W		V			4.0		EP	265.15	BASHAM ET AL 1982
1956	1	27	12	3	0.0	40.4000N	84.2000W		V		3.8			NU	300.21	FELT AREA = 5000
1957	6	29	11	25	9.0	42.9200N	81.3200W				3.8			WG	125.14	APP. 2D D
1958	1	24	0	0		44.9800N	81.2500W					3.5		EP	353.30	
1958	7	22	1	46	44.1	43.5830N	79.8270W	14				4.3		DW	225.45	EPB ML
1958	8	4	0	0	0.0	43.1000N	80.0000W		IV					NU	172.25	
1958	8	22	14	25	05.	43.0000N	79.0000W					3.6		EP	221.09	
1961	2	22	9	45	3.0	41.2000N	83.3000W		V		4.0			NU	192.03	FELT AREA = 13000
1962	3	27	6	35	05.	43.0000N	79.3300W		V			3.0		EP	200.07	
1964	2	13	19	46	40.8	40.3770N	77.9570W	1			3.3			DW	310.93	

TABLE 2.5-7 (Continued)

M AND I GREATER THAN 3.0

ORIGIN TIME						HYPOCENTRAL LOCATION				MAGNITUDE				REF	DISTANCE	REMARKS
YEAR	MO	DA	HR	MN	SEC	LAT.	LONG.	Z(KM.)	I(MM)	MB	MN	ML	MC		(KM.)	
1965	7	16	11	6	55.	43.0400N	78.0800W		IV			3.5		PM	287.24	FROM EPRI
1965	8	27	20	57	00.	43.0000N	78.0700W		IV		3.1			PM	285.94	
1965	10	8	2	17	27.	40.0800N	79.7500W					3.3		EP	224.27	
1966	1	1	13	23	39.0	42.8420N	78.2490W	2	VI		4.6			DW	265.13	HERRMANN 1979 STREET & TURCOTTE 1979
1967	2	2	6	30	0.0	42.7000N	84.6000W		IV					NU	302.21	
1967	4	8	5	40	32.0	39.6000N	82.5000W		V		4.0			NU	269.97	FELT AREA = 10000
1967	6	13	19	8	55.5	42.8370N	78.2340W	1	VI	3.9	4.4			DW	266.02	HERRMANN 1979 STREET 1976
1969	5	22	14	59	51.6	39.6100N	78.2450W				3.1			DW	345.22	
1969	8	13	2	42	24.	43.3000N	78.2200W	18	IV		2.5			EP	292.19	
1970	5	27	17	59	41.4	39.6190N	78.2750W				3.2			DW	342.71	
1970	8	11	6	14	25.0	38.2400N	82.0500W		IV					NU	402.90	
1971	9	12	0	6	27.6	38.1500N	77.5920W	5	V		3.6			DW	506.25	
1971	9	12	0	9	22.6	38.1000N	77.4000W	4			3.2			EP	520.67	BOLLINGER 101
1974	6	5	0	16	40.0	38.4800N	84.7500W		VI		3.2			DW	479.96	
1974	10	20	15	13	55.0	39.0600N	81.6100W		V		3.8			DW	306.94	
1974	11	27	10	28	52.	43.3300N	79.1000W				3.3			LD	238.75	
1975	2	3	10	31	0.0	41.3000N	83.2000W		IV					NU	180.38	
1975	2	16	23	21	31.0	38.8700N	82.3500W		IV		3.0			DW	341.23	
1976	2	2	21	14	2.0	41.8800N	82.7300W		III		3.4			GO	132.07	APP. 2D D
1976	5	6	18	46	08.0	39.6000N	79.9000W		IV					EP	266.05	
1977	6	17	15	39	47.0	40.7050N	84.7070W		VI		3.2			NU	322.50	FELT AREA = 550
1978	4	26	19	30	22.6	39.6500N	78.2200W				3.1			PD	343.57	
1979	11	9	21	29	59.1	38.4200W	82.8800W	10	V			3.5		US	403.55	
1980	7	27	18	52	21.8	38.1900N	83.8900W	8	VII	5.1	5.0			DW	464.46	MS = 4.7, KENTUCKY
1980	7	31	9	35	53.0	38.1900N	83.9300W		IV		2.5			NU	466.19	
1980	8	20	9	34	53.4	41.8700N	82.9900W	5	V		3.2			CH	153.57	CHRISTENSEN
1980	8	25	11	41	38.0	38.1900N	83.7900W		IV		2.5			EP	460.21	EPRI (NUTTLI)
1980	10	14	0	58	57.0	43.1700N	80.5600W	5	FELT		3.4			CE	159.45	
1981	8	28	10	51	33.0	43.1500N	80.5900W	1	III		3.3			CE	156.62	
1981	9	5	5	49	21.0	42.8000N	81.4100W	9			3.1			CE	113.13	
1981	11	23	13	14	51.0	38.2400N	79.0900W	10	IV		2.1			US	432.49	VIRGINIA
1982	2	3	4	28	20.6	40.2100N	79.0500W	2	IV		2.6			US	249.47	PENN
1983	8	17	14	3	15.0	38.4720N	82.7720W	12	V		3.5			PD	394.83	WEST VIRGINIA
1983	10	4	17	18	40.0	43.4500N	79.8000W	2			3.1			EP	213.78	
1986	1	31	16	46	42.3	41.6500N	81.1620W	5		4.9	5.0			WG	16.84	LEROY, OH
1986	7	12	8	19	39.5	40.5500N	84.3900W	5			4.5			CH	303.77	ST. MARYS, OH; SCHWARTZ 1988
1987	7	13	5	49	25.	41.9030N	80.7380W				3.6			WG	36.54	ASHTABULA, OH PROBABLY INDUCED
1987	7	13	7	52	20.	41.9030N	80.7380W						3.2	WG	35.53	
1987	7	13	13	5	30.	41.9030N	80.7380W						3.1	WG	35.53	
1987	7	16	4	49	40.2	41.9020N	80.7413W						3.1	JA	35.24	LAMONT FIELD SURVEY STARTS
1987	7	23	9	32	28.0	43.4910N	79.4720W	6			3.4			EP	232.45	

TABLE 2.5-7 (Continued)

M AND I GREATER THAN 3.0

ORIGIN TIME					HYPOCENTRAL LOCATION				MAGNITUDE				REF	DISTANCE	REMARKS
YEAR MO	DA	HR	MN	SEC	LAT.	LONG.	Z(KM.)	I(MM)	MB	MN	ML	MC		(KM.)	
1988 9	7	2	28	09.5	38.1430N	83.8780W	10		4.5	4.6			PM	468.50	KENTUCKY: TAYLOR, 1989
1989 7	15	0	8	02.6	38.6070N	83.5690W	10			3.1			PM	410.37	KENTUCKY
1989 8	5	21	7	58.0	43.2870N	79.7610W	5			3.2			EP	200.36	
1990 4	17	10	27	36.0	40.4600N	84.8500W	18			3.3			EP	345.00	
1990 9	8	0	3	57.4	38.0610N	83.7310W				3.3			PM	470.45	KENTUCKY
1991 1	26	3	21	24.4	41.5995N	81.5983W				3.5			WG	43.98	OFFSHORE EUCLID, OH

THIS CATALOG LISTS 165 EARTHQUAKES
EPICENTRAL DISTANCES ARE COMPUTED FOR SITE LOCATED AT 41.8010N 81.1435W SEE FOLLOWING PAGE FOR CATALOG EXPLANATION

TABLE 2.5-7 (Continued)

EARTHQUAKE CATALOG EXPLANATION

MAGNITUDES	INTENSITY I(MM)	REMARKS
MB = BODY WAVE MAGNITUDE	INTENSITIES ARE MAXIMUM EPI-	FA = TOTAL FELT AREA (SQ KM)
MN = MBLG MAGNITUDE (NUTTLI, 1973)	CENTRAL MODIFIED MERCALLI	MO = SEISMIC MOMENT
ML = RICHTER LOCAL MAGNITUDE	INTENSITIES; A LEADING MINUS	MS = SURFACE WAVE MAGNITUDE
MC = CODA LENGTH MAGNITUDE	SIGN INDICATES A RANGE; I.E.	
	- VII IMPLIES VI - VII	

REFERENCES

REF	DATA SOURCE	REF	DATA SOURCE
BB	BRADLEY AND BENNETT (1965)	MM	MCCLAIN AND MYERS (1970)
BH	BOLLINGER AND HOPPER (1971)	NB	NUTTLI AND BRILL (1981) <NUREG/CR-1577>
BK	BROOKS (1960)	NJ	NEW JERSEY GEOLOGICAL SURVEY
BO	BOLLINGER (1969,1973)	NO	N.O.A.A. EARTHQUAKE DATA FILE
CG	U.S. COAST AND GEODETIC SURVEY	NS	BULLETINS, NORTHEAST U.S. SEISMOGRAPH NETWORK
CH	CHRISTENSEN (1987)	NU	NUTTLI (1974)
DO	DOCEKAL (1970)	PD	PRELIM. DETERMINATION OF EPICENTERS, U.S.G.S.
DW	DEWEY (PERSONAL COMMUNICATION)	PM	PRELIMINARY DETERMINATION OF EPICENTERS (MONTHLY)
EH	EARTHQUAKE HISTORY OF THE U.S. (1958,1973)	SL	BULLETINS, ST. LOUIS UNIV. SEISMOGRAPH NETWORK
EP	EARTH PHYSICS BRANCH, OTTAWA, CAN.	SM	SMITH (1962,1964)
IS	INTERNATIONAL SEISMOLOGICAL SUMMARY	US	U.S. EARTHQUAKES SERIES, 1928-1980
LD	BULLETINS, LAMONT-DOHERTY GEOLOGICAL OBS.	WE	WESTON OBSERVATORY
MA	MATHER AND GODFREY (1927)	WG	WESTON GEOPHYSICAL CORPORATION
MI	BULLETINS, M.I.T. SEISMOGRAPH NETWORK	WQ	BULLETINS, WESTON QUARTERLY REPORT

TABLE 2.5-8

EVENTS WITH DOUBTFUL LOCATION OR ORIGIN

Date	Time Hr Mn	Location	Magnitude or Intensity	Comments
1791 Apr	12 00	Northern and Eastern Kentucky	IV-V	Uncertain date, and source coordinates
1824 Jul 15	16 20	West Virginia, Ohio	V	Uncertain coordinates
1834 Nov 20	18 40	Northern Kentucky	V	Uncertain coordinates
1852 Nov 02	23 35	Virginia	VI	Uncertain coordinates
1853 May 02	14 20	Virginia, West Virginia, Ohio	V-VI	Uncertain coordinates
1872 Jul 23	11 00	Near Elyria	III	Probably non-seismic-Fallen rock
1900 Apr 09	13 00	Berea, Ohio	VI	Probably a blast
1906 Jun 22		Near Berea	I-II	Uncertain
1906 Jun 27	21 10	Fairport, Ohio	IV-V	Probably a blast
1907 Apr 12	18 28	Cleveland	I	Not an earthquake
1927 Oct 29		40.90N, 81.18W	V	Seismic origin doubtful
1928 Sep 09	20 00	41.5N, 82.0W	V	Probably related to a bombing exercise
1929 Sep 17	19 16	Euclid	II	Dubious event
1958 May 01	22 46	Lakewood, Ohio	IV	Seismic origin doubtful

TABLE 2.5-8 (Continued)

Date	Time Hr Mn	Location	Magnitude or Intensity	Comments
1976 Feb 04	21 14	Lake Erie	$3.0m_{bLg}$	Uncertain coordinates
1976 Apr 08	07 39	South-Central Indiana	V	Uncertain coordinates

TABLE 2.5-9

EARTHQUAKES WITHIN 50 MILES OF THE PERRY NUCLEAR POWER PLANT

M AND I GREATER THAN 1.0

ORIGIN TIME						HYPOCENTRAL LOCATION					MAGNITUDE			REF	DISTANCE	REMARKS
YEAR	MO	DA	HR	MN	SEC	LAT.	LONG.	Z(KM.)	I(MM)	MB	MN	ML	MC		(KM.)	
1823	5	30	0	0	0.0	42.5000N	81.0000W		- III					WG	78.55	APP. 2D D
1836	7	8	21	15	0.0	41.5000N	81.7000W		IV					WG	57.16	APP. 2D D
1850	10	1	10	25	0.0	41.5000N	81.7000W		IV					WG	57.16	APP. 2D D
1857	2	28	1	40	0.0	41.8000N	80.6000W		- V					WG	45.17	APP. 2D D
1858	4	10	11	30	0.0	41.6700N	81.2500W		IV					WG	17.05	APP. 2D D
1869	4	9	13	0	0.0	42.7000N	80.8000W		III					WG	103.81	APP. 2D D
1873	8	17	14	0		41.2500N	80.5000W		III					WG	81.42	APP. 2D D
1885	1	18	10	30	0.0	41.1000N	81.4500W		IV					WG	81.96	APP. 2D D
1885	8	15	4	5	0.0	41.2700N	81.1000W		- III					WG	59.09	APP. 2D D
1898	10	29	0	0	0.0	41.5000N	81.7000W		III					WG	57.16	APP. 2D D
1906	4	20	17	30		41.5000N	81.7500W		III					WG	60.58	APP. 2D D
1921	9	27	4	32		42.1000N	80.2000W		III					WG	84.99	APP. 2D D
1922	3	16	9	30	0.0	43.0000N	82.5000W		III					NU	173.81	
1929	6	10	0	0	0.0	41.5000N	81.7000W		III					NU	57.16	
1930	2	16	12	17		42.8300N	80.5200W		III					WG	125.33	APP. 2D D
1932	1	21	0	0	0.0	41.0800N	81.5000W		IV					NU	85.44	APP. 2D D
1934	10	29	20	7		42.0000N	80.2000W		V			4.0		WG	81.35	BASHAM ET AL 1982; APP. 2D D
1934	11	5	20	0		41.8800N	80.3700W		III					WG	64.84	APP. 2D D
1936	8	26	8	55		41.4000N	80.4000W		II					EP	76.33	APP. 2D D
1940	5	31	16	0	0.0	41.1000N	81.5200W		II					WG	83.97	APP. 2D D
1943	3	9	3	25	24.9	41.6300N	81.3090W	7	V		4.5			DW	23.65	APP. 2D D
1951	12	3	7	2	0.0	41.6400N	81.4100W		IV				2.6	WG	28.49	APP. 2D D, CEI RPT JUNE 1988
1955	5	26	18	9	23.0	41.3300N	81.4000W		IV		3.4			WG	56.52	APP. 2D D, CEI RPT JUNE 1988
1955	6	29	1	15	33.0	41.3300N	81.4000W		- V		3.6			WG	56.52	APP. 2D D, CEI RPT JUNE 1988
1957	6	29	11	25	9.0	42.9200N	81.3200W				3.8			WG	125.14	APP. 2D D
1959	2	9	0	0	0.0	43.0000N	81.0000W					2.4		WG	133.71	APP. 2D D
1976	2	2	21	14	2.0	41.8800N	82.7300W		III		3.4			GO	132.07	APP. 2D D
1980	8	20	9	34	53.4	41.8700N	82.9900W	5	V		3.2			CH	153.57	
1981	9	5	5	46	42.0	42.7200N	81.4200W	9				1.9		EP	104.60	
1981	9	5	5	49	21.0	42.8000N	81.4100W	9			3.1			CE	113.13	
1982	12	23	7	6	40.0	42.7600N	81.3900W	10			2.8			EP	108.44	
1982	12	23	12	11	45.0	42.7700N	81.4000W	10			2.3			EP	109.70	
1983	1	22	7	46	59.3	41.7650N	81.1100W				3.0			WG	4.87	N.E. OHIO, CEI RPT JUNE 1986
1983	9	3	4	48	45.0	42.7500N	81.4900W	5			2.6			EP	109.22	
1983	11	19	16	22	20.0	41.7650N	81.1100W				2.3			WG	4.87	N.E. OHIO, CEI RPT JUNE 1986
1983	11	19	23	32	12.0	42.9300N	80.5300W	18			2.2			EP	135.21	
1985	4	14	11	39	51.3	41.4000N	80.3700W					2.0		CH	78.37	
1985	7	11	10	13	19.0	42.3000N	80.7900W	18			2.7			EP	62.68	
1986	1	31	16	46	42.3	41.6500N	81.1620W	5	- VI	4.9	5.0			WG	16.84	LEROY, OH

TABLE 2.5-9 (Continued)

M AND I GREATER THAN 1.0

ORIGIN TIME						HYPOCENTRAL LOCATION					MAGNITUDE			REF	DISTANCE	REMARKS
YEAR	MO	DA	HR	MN	SEC	LAT.	LONG.	Z(KM.)	I(MM)	MB	MN	ML	MC		(KM.)	
1986	2	1	18	54	49.3	41.6445N	81.1528W	4					1.5	WG	17.40	LEROY AFTERSHOCK
1986	2	3	19	47	19.8	41.6487N	81.1580W	6					2.0	WG	16.96	LEROY AFTERSHOCK
1986	2	6	18	36	22.4	41.6453N	81.1602W	6					2.5	WG	17.35	LEROY AFTERSHOCK
1986	2	7	15	20	20.4	41.6505N	81.1537W	4					1.1	WG	16.74	LEROY AFTERSHOCK
1986	3	24	13	42	41.3	41.6384N	81.1552W	5					1.4	WG	18.09	LEROY AFTERSHOCK
1987	2	12	1	10	56.7	41.6517N	81.1518W	4					1.8	WG	16.60	LEROY AFTERSHOCK
1987	2	28	11	38	33.8	41.6200	81.4400W				1.4			WG	31.83	WILLOUGHBY, OH.
1987	5	1	21	13	52.2	41.7466N	81.0921W				1.3			WG	7.40	
1987	6	18	10	30	57.3	41.5146N	80.3859W				2.7			WG	70.67	PENNSYLVANIA
1987	7	13	5	49	25.	41.9030N	80.7380W				3.6			WG	36.54	ASHTABULA, OH PROBABLY INDUCED
1987	7	13	5	59	00.	41.9030N	80.7380W						1.8	WG	35.53	LOCATION INFERRED
1987	7	13	7	26	01.	41.9030N	80.7380W						1.8	WG	35.53	
1987	7	13	7	52	20.	41.9030N	80.7380W						3.2	WG	35.53	
1987	7	13	13	5	30.	41.9030N	80.7380W						3.1	WG	35.53	
1987	7	13	15	25	00.	41.9030N	80.7380W						1.4	WG	35.53	
1987	7	13	18	25	18.	41.9030N	80.7380W						2.2	WG	35.53	
1987	7	13	19	0	15.	41.9030N	80.7380W						1.9	WG	35.53	
1987	7	13	19	39	26.	41.9030N	80.7380W						1.7	WG	35.53	
1987	7	13	20	53	11.	41.9030N	80.7380W						1.8	WG	35.53	
1987	7	13	21	46	00.	41.9030N	80.7380W						1.7	WG	35.53	
1987	7	13	23	49	00.	41.9030N	80.7380W						2.0	WG	35.53	
1987	7	14	7	47	33.	41.9030N	80.7380W						2.2	WG	35.53	
1987	7	14	14	51	17.	41.9030N	80.7380W						2.6	WG	35.53	
1987	7	16	4	49	40.2	41.9020N	80.7413W						3.1	JA	35.24	LAMONT FIELD SURVEY STARTS
1987	7	16	5	19	24.	41.9022N	80.7407W						1.7	JA	35.29	
1987	7	16	6	2	32.0	41.9023N	80.7378W						2.4	JA	35.52	
1987	7	16	9	21	17.7	41.9020N	80.7391W						1.6	JA	35.41	
1987	7	16	11	43	07.5	41.9017N	80.7407W						1.2	JA	35.27	
1987	8	13	7	52	13.0	41.9030N	80.7380W	5			3.0			LD	35.53	ASHTABULA: LOCATION INFERRED
1987	12	19	11	56	00.	41.9030N	80.7380W						2.0	WG	35.53	ASHTABULA: LOCATION INFERRED
1987	12	25	8	28	00.	41.9030N	80.7380W						2.2	WG	35.53	ASHTABULA: LOCATION INFERRED
1987	12	29	7	22	26.9	41.7485N	81.2640W				1.2			WG	11.59	FAIRPORT HARBOR, OH
1988	1	16	23	17	04.4	41.7470N	81.0980W				1.8			WG	7.09	
1988	3	31	16	30	00.0	41.3147N	81.0479W					2.8		JC	54.60	NELSON, OH
1988	4	20	16	51	27.9	41.7739N	81.3090W				1.4			WG	14.08	LAKE ERIE
1988	6	27	4	46	31.3	41.8180N	81.2289W				2.7			WG	7.34	LAKE ERIE
1988	6	27	4	48	26.0	41.8180N	81.2289W				1.7			WG	7.34	
1988	6	27	7	29	40.0	41.8180N	81.2289W				1.3			WG	7.34	
1988	12	25	2	11	24.9	41.8310N	81.0300W		III				2.4	WG	10.00	MADISON-ON-THE-LAKE, OH
1988	12	28	23	28	24.5	41.6360N	81.1660W		III				2.8	WG	18.42	LEROY, OH
1989	3	22	20	13	35.9	41.7270N	81.1550W						1.9	WG	8.27	
1989	8	1	16	12	00.	41.9030N	80.7380W						2.8	WG	35.53	ASHTABULA: LOCATION INFERRED

TABLE 2.5-9 (Continued)

M AND I GREATER THAN 1.0

ORIGIN TIME						HYPOCENTRAL LOCATION				MAGNITUDE				REF	DISTANCE	REMARKS
YEAR	MO	DA	HR	MN	SEC	LAT.	LONG.	Z(KM.)	I(MM)	MB	MN	ML	MC		(KM.)	
1989	8	1	16	15	00.	41.9030N	80.7380W						1.2	WG	35.53	
1989	8	1	16	44	00.	41.9030N	80.7380W						1.2	WG	35.53	
1989	8	1	16	50	00.	41.9030N	80.7380W						2.9	WG	35.53	
1989	8	1	18	4	00.	41.9030N	80.7380W						1.9	WG	35.53	
1989	8	2	0	44	00.	41.9030N	80.7380W						2.2	WG	35.53	
1989	8	2	0	58	00.	41.9030N	80.7380W						1.7	WG	35.53	
1989	8	2	2	52	00.	41.9030N	80.7380W						2.2	WG	35.53	
1989	8	2	6	49	00.	41.9030N	80.7380W						1.7	WG	35.53	
1989	8	3	4	7	00.	41.9030N	80.7380W						2.2	WG	35.53	
1989	8	4	0	5	00.	41.9030N	80.7380W						1.8	WG	35.53	
1989	8	11	11	53	54.3	41.8380N	81.0190W						1.2	WG	11.13	MADISON-ON-THE-LAKE
1990	1	1	23	3	00.	41.9030N	80.7380W						2.2	WG	35.53	ASHTABULA: LOCATION INFERRED
1990	5	26	9	51	18.9	41.7500N	81.2620W						1.3	WG	11.37	FAIRPORT HARBOR
1990	7	13	19	14	00.	41.9030N	80.7380W						1.5	WG	35.53	ASHTABULA: LOCATION INFERRED
1990	7	24	23	4	00.	41.9030N	80.7380W						2.1	WG	35.53	ASHTABULA: LOCATION INFERRED
1990	9	1	13	50	54.5	41.6470N	81.1520W						1.5	WG	17.12	LEROY, OH
1990	9	25	12	24	00.	41.9030N	80.7380W						1.4	WG	35.53	ASHTABULA SEQ.: LOCATION INFERRED
1990	9	26	6	13	00.	41.9030N	80.7380W						2.3	WG	35.53	
1990	9	26	12	46	00.	41.9030N	80.7380W						1.6	WG	35.53	
1990	9	26	18	16	00.	41.9030N	80.7380W						1.6	WG	35.53	
1990	9	26	22	44	00.	41.9030N	80.7380W						1.3	WG	35.53	
1990	11	9	22	48	33.2	41.7470N	81.2490W						1.7	WG	10.63	FAIRPORT HARBOR
1990	11	18	9	21	00.	41.9030N	80.7380W						2.3	WG	35.53	ASHTABULA: LOCATION INFERRED
1990	12	7	4	43	18.6	41.9640N	81.0160W						1.3	WG	20.97	LAKE ERIE
1990	12	17	7	22	48.5	41.9530N	80.1220W				2.5			PM	86.46	ERIE, PA: PROB. INDUCED
1991	1	26	3	21	24.4	41.5995N	81.5983W				3.5			WG	43.98	OFFSHORE EUCLID, OH
1991	3	12	8	50	48.9	41.3468N	81.4055W						2.3	WG	54.98	SOLON, OH
1991	5	2	11	9	43.0	41.9030N	80.7380W						1.7	WG	35.53	ASHTABULA, LOCATION INFERRED
1991	5	31	21	1	45.3	41.7550N	81.0591W						1.6	WG	8.68	
1991	5	31	21	28	08.8	41.7562N	81.0580W						1.3	WG	8.68	
1991	7	2	2	44	50.9	41.9640N	80.5755W						1.9	WG	50.50	EAST OF ASHTABULA
1991	7	20	12	53	16.8	41.7732N	81.3133W						1.6	WG	14.45	
1991	7	31	9	39	48.3	41.7256N	81.1227W						1.2	WG	8.55	

THIS CATALOG LISTS 114 EARTHQUAKES
EPICENTRAL DISTANCES ARE COMPUTED FOR SITE LOCATED AT 41.8010N 81.1435W
SEE FOLLOWING PAGE FOR CATALOG EXPLANATION

TABLE 2.5-9 (Continued)

EARTHQUAKE CATALOG EXPLANATION

MAGNITUDES	INTENSITY I(MM)	REMARKS
MB = BODY WAVE MAGNITUDE MN = MBLG MAGNITUDE (NUTTLI,1973) ML = RICHTER LOCAL MAGNITUDE MC = CODA LENGTH MAGNITUDE	INTENSITIES ARE MAXIMUM EPI-CENTRAL MODIFIED MERCALLI INTENSITIES; A LEADING MINUS SIGN INDICATES A RANGE; I.E. - VII IMPLIES VI - VII	FA = TOTAL FELT AREA (SQ KM) MO = SEISMIC MOMENT MS = SURFACE WAVE MAGNITUDE

REFERENCES

REF	DATA SOURCE	REF	DATA SOURCE
BB	BRADLEY AND BENNETT (1965)	MM	MCCLAIN AND MYERS (1970)
BH	BOLLINGER AND HOPPER (1971)	NB	NUTTLI AND BRILL (1981) <NUREG/CR-1577>
BK	BROOKS (1960)	NJ	NEW JERSEY GEOLOGICAL SURVEY
BO	BOLLINGER (1969,1973)	NO	N.O.A.A. EARTHQUAKE DATA FILE
CG	U.S. COAST AND GEODETIC SURVEY	NS	BULLETINS, NORTHEAST U.S. SEISMOGRAPH NETWORK
DO	DOCEKAL (1970)	NU	NUTTLI (1974)
DW	DEWEY(PERSONAL COMMUNICATION)	PD	PRELIM. DETERMINATION OF EPICENTERS, U.S.G.S.
EH	EARTHQUAKE HISTORY OF THE U.S. (1958,1973)	PM	POMEROY (PERSONAL COMMUNICATION)
EP	EARTH PHYSICS BRANCH, OTTAWA, CAN.	SL	BULLETINS, ST. LOUIS UNIV. SEISMOGRAPH NETWORK
IS	INTERNATIONAL SEISMOLOGICAL SUMMARY	SM	SMITH (1962,1964)
LD	BULLETINS, LAMONT-DOHERTY GEOLOGICAL OBS.	US	U.S. EARTHQUAKES SERIES, 1928-1980
MA	MATHER AND GODFREY (1927)	WE	WESTON OBSERVATORY
MI	BULLETINS, M.I.T. SEISMOGRAPH NETWORK	WG	WESTON GEOPHYSICAL CORPORATION

TABLE 2.5-10

JESUIT SEISMOLOGICAL ASSOCIATION STATIONS(1)

Station	Latitude	Longitude	Elevation Meters	Date Opened Day	Date Opened Mo.	Date Opened Year	Date Closed Day	Date Closed Mo.	Date Closed Year	Location
BUF	42.9333N	78.8500W	195	01	01	1912		--		Buffalo, NY
CHI	41.9000N	87.6333W	183	01	09	1912		--	1990	Chicago, IL
CNN	39.1450N	84.4967W	203	01	01	1927	01	01	1963	Cincinnati, OH
CLE	41.4888N	81.5321W	328	01	01	1904		--		Cleveland, OH
FOR	40.8631N	73.8856W	24	01	01	1910		08	1976	Fordham, NY
GEO	38.9000N	77.0667W	29	01	01	1911		--	1973	Georgetown, D.C.
MLW	43.0333N	87.9167W	194	01	01	1909		--	1957	Milwaukee, WI
NOL	29.9483N	90.1200W	2	01	01	1910		--		New Orleans, LA
SHA	30.6944N	88.1428W	61	01	12	1910		--	1989	Spring Hill, AL
WES	42.3847N	71.3221W	60	01	01	1929		--		Weston, MA
FLO	38.8017N	90.3700W	160	09	07	1961	08	31	1971	Florisant, MO
SLM	38.6364N	90.2333W	-	01	01	1910	early 60's			St. Louis, MO
SLM	38.6361N	90.2361W	-			1927		--		St. Louis, MO

TABLE 2.5-10 (Continued)

Station	Latitude	Longitude	Elevation Meters	Date Opened Day	Date Opened Mo.	Date Opened Year	Date Closed Day	Date Closed Mo.	Date Closed Year	Location
CGM	37.3167N	89.5333W	-			1938		--		Cape Girardeau, MO
LRA	34.7783N	92.3517W	-		2	1931		7	1967	Little Rock, AR

NOTE:

(1) (Reference 263).

TABLE 2.5-11

WORLD WIDE STATIONS EASTERN UNITED STATES[1]

Station	Latitude	Longitude	Elevation Meters	Date Opened Day	Date Opened Mo.	Date Opened Year	Date Closed Day	Date Closed Mo.	Date Closed Year	Location
AAM	42.2997N	83.6561W	249	01	01	1940		--		Ann Arbor, MI
ATL	33.4333N	84.3375W	273	21	06	1963		--		Atlanta, GA
BLA	37.2112N	80.4205W	634	04	09	1962		--		Blacksburg, VA
FLO	38.8017N	90.3700W	160	09	07	1961	08	31	1971	Florisant, MO
FVM	37.9840N	90.4260W	-	10	05	1974		--		French Village, MO
GEO	38.9000N	77.0667W	43	07	12	1961		--	1973	Georgetown, D.C.
MDS	43.3722N	89.7600W	278	16	01	1962	10	06	1968	Madison, WI
MNN	44.9145N	93.1900W	-	07	05	1962	04	11	1965	Minneapolis, MN
OGD	41.0875N	74.5958W	367	01	01	1960		--	1981	Ogdensburg, NJ
OXF	34.5118N	89.4092W	101	01	08	1963	01	05	1976	Oxford, MS
SCP	40.8098N	77.8694W	353	26	01	1962		--		State College, PA
SHA	30.6944N	88.1428W	61	01	12	1910		--	1989	Spring Hill, AL
WES	42.3847N	71.3221W	60	01	01	1929		--		Weston, MA

NOTE:

[1] (Reference 264).

TABLE 2.5-12

SEISMOGRAPH STATIONS IN EASTERN CANADA[1]

Station	Latitude	Longitude	Elevation Meters	Date Opened Day	Mo.	Year	Date Closed Day	Mo.	Year	Location
TNT	43.6670N	79.3990W		01	09	1897	01	01	1942	Toronto, Ont.
SHF	46.3300N	72.4500W				1928	08	12	1965	Shawinigan Falls, Que.
SFA	47.1200N	70.8200W	232			1928	31	07	1975	Seven Falls, Que.
HAL	44.6300N	63.6000W	56			1915				Halifax, N.S.
KLC	48.0900N	80.0200W		19	12	1939	30	06	1957	Kirkland Lake, Ont.
MNT	45.5000N	73.6200W	112	01	04	1956				Montreal, Que.
OTT	45.3900N	75.7200W	83	01	01	1906				Ottawa, Ont.
LND	42.5900N	81.1400W		01	01	1961	31	05	1967	London, Ont.
CHQ	46.8900N	71.3000W	145	11	11	1971		07	1982	Charlesbourg, Que.
LHC	48.4200N	89.2700W	196	28	02	1969				Thunder Bay, Ont.
PBQ	55.2800N	77.7400W	20	14	09	1972		03	1984	Post-De-La-Baleine, Que.
POC	47.3600N	70.0400W	61	20	01	1972		10	1980	La Pocatiere, Que.
QCQ	46.7800N	71.2800W	91	24	09	1971				Quebec, Que.
SCB	43.7200N	79.2300W	153	01	01	1962		01	1974	Scarborough, Ont.
SCH	54.8200N	66.7800W	540	22	07	1962		09	1991	Schefferville, Que.
SIC	50.1900N	66.7400W	283	01	01	1962				Seven Islands, Que.
STJ	47.5700N	52.7300W	62	01	06	1964		03	1991	St. John's, Nfld.
SUD	46.4700N	80.9700W	267	22	11	1967		09	1986	Sudbury, Ont.
UNB	45.9500N	66.6300W	56	01	09	1971				Fredericton, N.B.
GWC	55.2910N	77.7520W	8	29	09	1965	01	07	1972	Great Whale R., Que.
MNQ	50.5333N	68.7744W	487	01	01	1974				Manicouagan, Que.
MIQ	46.2300N	75.5800W		01	01	1974		04	1981	Maniwaki, Que.
HV	49.1100N	68.1600W		01	04	1974	01	12	1974	Hauterive, Que.
LGQ	53.6900N	77.7300W	190	04	08	1976		04	1980	La Grande, Que.

TABLE 2.5-12 (Continued)

Station	Latitude	Longitude	Elevation Meters	Date Opened Day	Mo.	Year	Date Closed Day	Mo.	Year	Location
LMQ	47.5500N	70.3300W	419	03	11	1976				La Malbaie, Que.
GNT	46.3630N	72.3720W	10	04	24	1978				Gentilly, Que.

NOTE:

(1) (Reference 265) and (Reference 306).

TABLE 2.5-13

JOHN CARROLL UNIVERSITY SEISMIC NETWORK
STATION COORDINATES

	Latitude		Longitude		Elev. [M]	Opened	Closed
Leroy	41°N	39.96′	81°W	9.66′	311	09-26-86	06-15-90
Thompson	41°N	41.51′	81°W	02.84′	387	09-26-86	
E. Claridon	41°N	32.82′	81°W	06.12′	362	10-24-86	02-21-91
Chesterland	41°N	33.67′	81°W	21.72′	365	09-26-86	
Mentor on the Lake	41°N	41.04′	81°W	24.24′	188	02-03-87	
Girdled Road Reservation	41°N	38.52′	81°W	10.72′	332	11-04-90	
Thorn Acres	41°N	32.53′	81°W	06.65′	362	02-26-91	

TABLE 2.5-14

STATION LOCATIONS OF CEI NETWORK

CODE	LATITUDE	LONGITUDE	ELEVATION	LOCATION	OPENED	CLOSED
ANT	41.8000N	81.1295W	192 M.	ANTIOCH RD	4/87	
SCH	41.7473N	81.1435W	220 M.	ROUTE 84	4/87	
FORD	41.7258N	81.0890W	272 M.	FORD RD	4/87	
RAD	41.6388N	81.1408W	368 M.	RADCLIFFE RD	4/87	
WIL	41.6866N	81.1973W	260 M.	WILLIAMS RD	4/87	
GEN	41.8463N	80.9902W	181 M.	WHEELER CREEK RD.	7/89	

TABLE 2.5-15

RELOCATED ANNA, OHIO EARTHQUAKES WITH 95%

CONFIDENCE ELLIPSE LOCATION STATISTICS[1]

Earthquake Date	Latitude	Longitude	Depth (km)	Error Ellipse Statistics		
				A-Axis Azimuth	A-Axis Length	B-Axis Length
September 20, 1931	40.53°N	84.26°W	16.5	N 4° E	36 km	23 km
March 2, 1937	40.50°N	84.34°W	4.8	N 107° E	15 km	12 km
March 9, 1937	40.47°N	84.28°W	13.0	N 115° E	13 km	10 km

NOTE:

(1) Data provided by Dr. James Dewey, U.S. Geological Survey as cited in (Reference 1).

TABLE 2.5-16

LOCAL SEISMICITY DATA

DATE	PRESENT LOCATION N	PRESENT LOCATION W	UNCERTAINTY	PREVIOUS LOCATION N	PREVIOUS LOCATION W	PRESENT INTENSITY OR MAGNITUDE	PREVIOUS INTENSITY OR MAGNITUDE	REMARKS
1823 May 30	42.5	81.0	±1/2°	(41.5	81.0)	II-III	(IV)	Dawson refers to Canada. Probable typographic error of Smith.
1836 July 08	41.5	81.7	±15 mi	--	--	IV	--	Poorly located: either Cleveland or Elyria.
1850 Oct. 01	41.5	81.7	±12 mi	(41.4	82.3)	IV	--	Previously mislocated. Relocated near Cleveland.
1857 Feb. 28	41.8	80.6	±20 mi	(41.67	81.25)	IV-V	(IV)	Former location in Painesville; New data as far as Pennsylvania suggests a more Easterly location. Previously carried on March 1.
1858 Apr. 10	41.67	81.25	±15 mi	--	--	IV	--	Previously carried on April 16. Probable typographic error.

TABLE 2.5-16 (Continued)

DATE	PRESENT LOCATION N	PRESENT LOCATION W	UNCERTAINTY	PREVIOUS LOCATION N	PREVIOUS LOCATION W	PRESENT INTENSITY OR MAGNITUDE	PREVIOUS INTENSITY OR MAGNITUDE	REMARKS
1867 Jan. 13	42.97	77.85	±15 mi	(41.5	81.7)	III	--	Previously mislocated in Cleveland, moved to Caledonia, New York, where it was felt.
1869 Apr. 09	42.7	80.8	±10 mi	--	--	III	--	Very local.
1873 Aug. 17	41.25	80.50	±10 mi	(41.5	81.7)	III	(III-IV)	Felt in one place only. Previously carried on August 18.
1885 Jan. 18	41.10	81.45	±10 mi	(41.3	81.5)	IV	(II-III)	Moved from Garrettsville to Akron/Kent to account for new data.
1885 Aug. 15	41.27	81.10	±20 mi	(41.3	81.15)	II-III	(II)	Poorly documented location.
1898 Oct. 29	41.5	81.7	±15 mi	--	--	III	--	Previously listed on wrong day.
1906 Apr. 20	41.50	81.75	±10 mi	(41.5	81.7)	III	(III-IV)	From Cleveland to W. Cleveland.
1921 Sep. 27	42.1	80.2		--	--	III	--	Felt by two persons only at Erie, PA.

TABLE 2.5-16 (Continued)

DATE	PRESENT LOCATION N	PRESENT LOCATION W	UNCERTAINTY	PREVIOUS LOCATION N	PREVIOUS LOCATION W	PRESENT INTENSITY OR MAGNITUDE	PREVIOUS INTENSITY OR MAGNITUDE	REMARKS
1930 Feb. 16	42.83	80.52		--	--	III	--	Felt locally only in Ontario.
1932 Jan. 21	41.08	81.50		--	--	IV	--	Felt locally only at Summit Lake, (Akron, Ohio).
1934 Oct. 29	42.0	80.2		--	--	V	--	Felt over 700 sq mi, around Erie, PA.
1934 Nov. 05	41.88	80.37		--	--	III	--	Felt locally only at Albion, PA.
1936 Aug. 26	41.4	80.4		--	--	II	(III)	Felt locally only at Greensville, PA.
1940 May 31	41.10	81.52		(41.5	81.7)	II	(III)	Felt by a few at Akron, Ohio.
1943 Mar. 09	41.63	81.31	±10 mi	(41.6	81.3)	V	--	Originally mislocated in Lake Erie. Relocated on land by Coffman & Von Hake. Relocated again by Dewey & Gordon (Reference 156).

TABLE 2.5-16 (Continued)

DATE	PRESENT LOCATION N	PRESENT LOCATION W	UNCERTAINTY	PREVIOUS LOCATION N	PREVIOUS LOCATION W	PRESENT INTENSITY OR MAGNITUDE	PREVIOUS INTENSITY OR MAGNITUDE	REMARKS
1951 Dec. 03	41.65	81.41	±10 mi	--	--	IV	--	Poorly recorded at Cleveland. Vague location.
1955 May 26	41.33	81.40	±10 mi	(41.5	81.7)	IV-V	(V)	Relocated from Cleveland to northwest of Aurora, Ohio. Poor seismograms at Cleveland.
1955 June 29	41.33	81.40	±10 mi	(41.5	81.7)	IV	(V)	Relocated from Cleveland to northwest of Aurora, Ohio.
1957 June 29	42.92	81.32		--	--	$3.8m_{bLg}$	$4.2M_L$	Nine miles southwest of London, Ontario.
1959 Feb. 09	43.0	81.0		--	--	$2.4M_L$	--	From Smith's Catalog (Reference 282).
1976 Feb. 02	41.88	82.73		(41.96	82.67)	$3.4m_{bLg}$	--	Relocated from Dewey & Gordon(Reference 156).

TABLE 2.5-17

STATION LOCATIONS DEPLOYED TO MONITOR
AFTERSHOCKS THROUGH APRIL 15, 1986

STATION ABBREV.	LATITUDE Deg Min	LONGITUDE Deg Min	AFFILIATION ABBREV.[1]	DATES OF OCCUPATION
CON	41N42.06	81W12.55	LDGO	FEB. 01 - FEB. 28
GAR	41N47.30	81W10.64	LDGO	FEB. 01 - FEB. 02
HLH	41N41.20	81W07.01	LDGO	FEB. 01 - FEB. 28
HPV	41N44.41	81W03.08	LDGO	FEB. 01 - FEB. 02
HSE	41N33.77	81W06.76	LDGO	FEB. 02 - FEB. 28
POP	41N37.23	81W07.05	LDGO	FEB. 03 - FEB. 28
TTR	41N35.25	81W11.69	LDGO	FEB. 02 - FEB. 28
WKR	41N36.06	81W03.13	LDGO	FEB. 02 - FEB. 02
HSOH	41N35.66	81W07.84	MICHIGAN	FEB. 01 - FEB. 02
MTOH	41N36.68	81W03.07	MICHIGAN	FEB. 01 - FEB. 02
CHOH	41N35.56	81W11.84	SLU	JAN. 31 - FEB. 03
HAOH	41N36.46	81W08.51	SLU	JAN. 31 - FEB. 03
PAOH	41N45.41	81W11.95	SLU	JAN. 31 - FEB. 03
CALM	41N34.1	81W10.3	TEIC	FEB. 02 - FEB. 07
ELFM	41N36.8	81W10.9	TEIC	FEB. 03 - FEB. 07
FARM	41N38.3	81W10.4	TEIC	FEB. 02 - FEB. 07
HOWM	41N35.0	81W07.9	TEIC	FEB. 01 - FEB. 07
MONM	41N36.7	81W02.9	TEIC	FEB. 01 - FEB. 07
BUR	41N39.24	81W04.94	USGS (DENVER)	FEB. 02 - FEB. 11
CAL	41N41.21	81W08.89	USGS (DENVER)	FEB. 02 - FEB. 11
COT	41N34.73	81W05.93	USGS (DENVER)	FEB. 02 - FEB. 11
CUY	41N33.56	81W10.15	USGS (DENVER)	FEB. 03 - FEB. 11
ERJ	41N39.44	81W05.00	USGS (DENVER)	FEB. 06 - FEB. 11
FOT	41N38.90	80W59.69	USGS (DENVER)	FEB. 04 - FEB. 11
HAM	41N36.18	81W08.48	USGS (DENVER)	FEB. 02 - FEB. 11
HAR	41N36.67	80W59.62	USGS (DENVER)	FEB. 02 - FEB. 04
HWK	41N41.83	80W59.03	USGS (DENVER)	FEB. 02 - FEB. 11
LOX	41N44.58	81W02.60	USGS (DENVER)	FEB. 02 - FEB. 11
MON	41N35.52	81W02.39	USGS (DENVER)	FEB. 02 - FEB. 11
WSH	41N37.61	81W13.30	USGS (DENVER)	FEB. 02 - FEB. 11
GS01	41N48.27	81W08.52	USGS (MENLO PARK)	FEB. 01 - APR. 03
GS02	41N43.75	81W09.47	USGS (MENLO PARK)	FEB. 01 - APR. 03
GS03	41N39.45	81W10.07	USGS (MENLO PARK)	FEB. 01 - APR. 03
GS04	41N36.85	81W17.55	USGS (MENLO PARK)	FEB. 01 - FEB. 11
GS05	41N35.64	81W08.19	USGS (MENLO PARK)	FEB. 01 - FEB. 04
GS06	41N37.75	81W03.77	USGS (MENLO PARK)	FEB. 01 - APR. 03

TABLE 2.5-17 (Continued)

STATION ABBREV.	LATITUDE Deg Min	LONGITUDE Deg Min	AFFILIATION ABBREV.[1]	DATES OF OCCUPATION
GS07	41N32.40	81W04.26	USGS (MENLO PARK)	FEB. 01 - FEB. 11
GS08	41N32.38	81W12.93	USGS (MENLO PARK)	FEB. 02 - FEB. 10
GS09	41N24.81	81W11.91	USGS (MENLO PARK)	FEB. 02 - FEB. 10
GS11	41N09.20	81W04.42	USGS (MENLO PARK)	FEB. 02 - FEB. 10
GS55	41N37.10	81W07.18	USGS (MENLO PARK)	FEB. 04 - FEB. 10
CFD	41N40.45	81W13.41	WESTON GEOPHYSICAL	FEB. 04 - APR. 15
CLD	41N31.44	81W20.19	WESTON GEOPHYSICAL	FEB. 01 - FEB. 20
HTG	41N37.17	80W57.27	WESTON GEOPHYSICAL	FEB. 01 - APR. 08
KEL	41N32.82	81W06.12	WESTON GEOPHYSICAL	FEB. 20 - APR. 15
MFD	41N27.77	81W04.41	WESTON GEOPHYSICAL	FEB. 01 - FEB. 14
MIN	41N33.56	81W15.41	WESTON GEOPHYSICAL	FEB. 01 - MAR. 01
PAT	41N33.63	81W21.91	WESTON GEOPHYSICAL	MAR. 01 - APR. 15
PER	41N48.06	81W08.61	WESTON GEOPHYSICAL	FEB. 01 - APR. 15
TOM	41N41.29	81W03.09	WESTON GEOPHYSICAL	FEB. 02 - APR. 15
WEL	41N45.00	81W09.31	WESTON GEOPHYSICAL	FEB. 24 - APR. 15
WC01	41N36.90	81W18.08	WOODWARD-CLYDE	JAN. 31 - APR. 15
WC02	41N40.05	81W09.53	WOODWARD-CLYDE	FEB. 01 - APR. 15
WC03	41N43.87	81W04.46	WOODWARD-CLYDE	FEB. 01 - APR. 14
WC04	41N35.10	81W09.36	WOODWARD-CLYDE	FEB. 01 - FEB. 22
WC06	41N32.40	81W01.75	WOODWARD-CLYDE	FEB. 01 - APR. 14
WC07	41N48.00	81W08.58	WOODWARD-CLYDE	FEB. 03 - FEB. 24
WC08	41N40.24	81W14.48	WOODWARD-CLYDE	FEB. 06 - MAR. 25
WC09	41N35.45	81W09.36	WOODWARD-CLYDE	FEB. 23 - APR. 14
WC10	41N40.04	81W14.45	WOODWARD-CLYDE	MAR. 27 - APR. 14

NOTE:

[1] Abbreviations:

LDGO - Lamont-Doherty Geological Observatory, Columbia University
MICHIGAN - University of Michigan
SLU - St. Louis University
TEIC - Tennessee Earthquake Information Center
USGS - U.S. Geological Survey
WESTON GOPHYSICAL - Weston Geophysical Corporation
WOODWARD-CLYDE - Woodward-Clyde Consultants

TABLE 2.5-18

AFTERSHOCK PARAMETERS OF JANUARY 31, 1986 EARTHQUAKE[1]

	YEARMCOY	HRMISEC	LATITUDE	LONGITUDE	DEPTH	NP	GAP	RMS	ERH	ERZ	Mc
1.	19860201	185449.35	41N38.67	81W 9.17	4.35	20	94	.09	.3	.5	1.5
2.	19860202	32248.67	41 38.72	81 9.55	4.86	37	72	.07	.1	.2	.9
3.	19860203	194719.77	41 38.92	81 9.48	5.83	52	75	.08	.2	.2	2.0
4.	19860205	6342.47	41 38.90	81 9.27	3.73	31	52	.08	.2	.3	.1
5.	19860206	183622.44	41 38.72	81 9.61	5.50	50	47	.07	.1	.2	2.5
6.	19860207	152020.38	41 39.03	81 9.22	3.76	44	42	.07	.1	.3	1.1
7.	19860210	200613.61	41 39.10	81 9.39	4.73	29	70	.06	.1	.4	.8
8.	19860223	32948.50	41 39.18	81 9.09	5.48	22	76	.06	.2	.4	-.1
9.	19860224	16556.48	41 38.85	81 9.60	3.25	10	91	.09	.5	2.7	.1
10.	19860228	13934.21	41 39.23	81 9.61	3.91	12	91	.06	.3	.5	-.1
11.	19860308	204249.68	41 38.67	81 9.20	3.12	20	65	.10	.3	.7	-.1
12.	19860324	134241.31	41 38.31	81 9.31	3.84	12	79	.12	.5	1.8	1.4
13.	19860410	65805.71	41 38.91	81 9.55	5.11	22	63	.08	.2	.3	-.1
14.	19860617	221633.20	41 38.91	81 9.55	3.40	16	93	.09	.3	.8	.8
15.	19860714	075423.12	41 38.68	81 9.13	4.93	12	99	.08	.3	.8	.3
16.	19870212	011056.67	41 39.10	81 9.11	3.87	13	186	.09	.8	1.0	1.8
17.	19880805	222632.99	41 39.07	81 9.11	4.60	12	170	.04	.2	.3	0.1
18.	19881011	063132.33	41 39.20	81 8.78	5.33	13	147	.04	.2	.3	-.2
19.	19881228	232824.52	41 38.17	81 9.97	5.87	18	90	.05	.1	.2	2.8
20.	19900901	135054.46	41 38.87	81 9.09	4.56	17	82	.05	.2	.3	1.5
21.	19910117	071153.29	41 39.33	81 8.91	6.13	8	159	.02	.1	.2	-.2

Vp1 = 4.25 km/s Thickness = 2 km
Vp2 = 6.5 km/s Thickness = 33 km
Vp/Vs = 1.78

NOTE:

[1] The more recent events may not be true aftershocks.

TABLE 2.5-19

ESTIMATED SITE INTENSITIES

Year	Date Mo.	Day	Hr	Mn	Sec (UT)	Lat. (N)	Long. (W)	Epicentral Intensity	Magnitude m_{bLg}	M_L	Dist. to Site (M)	Site Intensity A[1]	B[2]	C[3]
1663	02	05	17	30		47.60	70.10	IX			672.6	3.3	2.8	
1732	09	16	16	00		45.50	73.60	VIII			454.3	3.2	2.4	
1776			14			40.00	82.00	VI			132.1	3.2	1.9	
1811	12	16	08	00		36.00	90.00	XI			621.0	5.5	4.2	
1812	01	23	15			36.30	89.60	X-XI			590.5	5.1	4.1	
1812	02	07	09	45		36.50	89.60	XI-XII			581.2	6.1	4.7	V
1857	02	28	01	40		41.80	80.60	IV-V			28.3	4.2	2.2	
1858	04	10	11	00		41.70	81.30	IV			10.4	4.0	1.9	
1870	10	20	16	30		47.40	70.50	VIII-IX			650.0	3.4	1.9	
1873	07	06	14	30		43.00	79.50	VI			117.3	3.3	1.1	
1875	06	18	13	43		40.20	84.00	VII			185.6	3.7	2.7	
1886	09	01	02	51		32.90	80.00	X			617.0	4.5	4.1	II-III
1895	10	31	11	08		37.00	89.40	IX	6.2		550.3	3.8	2.7	
1897	05	31	18	58		37.30	80.70	VIII			311.2	3.9	3.1	III
1925	03	01	02	19	20.0	47.60	70.10	IX	6.6		672.6	3.3	2.9	III
1926	11	05	14	53		39.10	82.10	VI-VII	3.4		193.0	3.1	1.0	
1928	09	09	20	00		41.50	82.00	V	3.7		49.2	3.5	1.6	
1929	08	12	11	24	48.0	42.91	78.40	VIII	5.2	5.8	159.9	4.9	3.0	I-IV
1930	09	30	20	40		40.3	84.3	VII	4.2		194.5	3.6	1.0	
1931	09	20	23	05		40.43	84.27	VII	4.6		187.7	3.7	1.7	NF
1934	10	29	20	07		42.00	80.20	V		4.0	49.8	3.4	1.1	
1937	03	02	14	47	33.3	40.49	84.27	VII	4.7		185.7	3.7	1.9	II
1937	03	09	05	44	35.5	40.47	84.28	VII-VIII	4.9		187.4	4.7	2.3	III
1943	03	09	03	25	24.9	41.63	81.31	V	4.5		14.4	5.0	4.1	I-IV

TABLE 2.5-19 (Continued)

Date Year	Mo.	Day	Hr	Mn	Sec (UT)	Lat. (N)	Long. (W)	Epicentral Intensity	Magnitude m_{bLg}	M_L	Dist. to Site (M)	Site Intensity A[1]	B[2]	C[3]
1944	09	05	04	38	45.7	44.96	74.72	VIII	5.8		388.8	3.5	2.7	III
1951	12	03	07	02		41.60	81.40	IV			19.5	3.6	1.5	
1954	04	27	02	14	08.0	43.10	79.20			4.1	133.1	3.1	0.3	
1955	05	26	18	09	23.0	41.33	81.40	IV-V			35.2	3.9	1.7	
1955	06	29	01	16	33.0	41.33	81.40	IV			35.2	2.9	1.4	
1957	06	29	11	25	09.0	42.92	81.32	IV	3.8		77.8	1.9	1.3	
1958	07	22	01	46	44.1	43.58	79.83			4.3	140.1	2.0	0.6	
1980	07	27	18	52	21.8	38.17	83.91	VI-VII	5.2		289.8	3.0	2.2	II-IV
1986	01	31	16	46	42.3	41.65	81.16	VI	5.0		10.4	6.4	5.2	V
1987	07	12	08	19	39.9	40.56	84.37		4.5		187.7		1.5	
1988	11	25	23	46	04.5	48.12	71.18	VII-VIII	6.6		1052.0	1.9	2.9	

NOTES:

(1) Site intensity derived using: $I_{site} = I_o + 3.7 - .0011(\Delta km) - 2.7 \, Log_{10}(\Delta km)$ (Reference 183).
(2) Site intensity derived using: $I_{site} = -1.43 + 1.79 m_b - 1.83 \, Log_{10}(\Delta km) - .0018 \, (\Delta km)$.
(3) Site intensity observed from isoseismal maps.

TABLE 2.5-20

RESOURCES INVESTIGATED
FOR LOCAL SEISMICITY

In documenting the seismic history of the site area, books, periodicals, and newspapers in the following libraries and offices were investigated:

Ashtabula Public Library: Ashtabula
Cleveland Public Library: Cleveland
Madison Press (Office of): Madison
Madison Public Library: Madison
Morley Public Library: Painesville
Western Reserve Historical Society Library: Cleveland
Willoughby Public Library: Willoughby

The following newspapers were researched for accounts of earthquakes which were felt or occurred near the site area:

City	Paper
Ashtabula	Beacon; Star-Beacon; Beacon-Record; Weekly Telegraph; Sentinel.
Cleveland	Daily Plain Dealer, Plain Dealer; Press; Daily Herald; Leader; Daily True Democrat; Register; Herald, Herald-Week, Herald and Gazette.
Madison	Press; Lake County Weekly Herald, Lake County Republican Herald, Lake County News Herald.
Painesville	Evening Telegraph, Telegraph Republican, Telegram.
Willoughby	News Herald.

Other sources included city and county histories, archival collections of letters, diaries, and journals, periodicals, and books. Those works containing information on earthquakes are as follows:

(Authors unknown) Work Project Administration, Index to the Cleveland Plain Dealer, 1931, 1933-1934, 1936-1938.

(Authors unknown) Annals of Cleveland: Index to Cleveland Newspapers for the period 1818-1875.

Rose, Williams G., 1950, "Cleveland, The Making of A City."

Whittlesey, Charles, 1872, Fugitive Papers, "The Earthquake of October 1870, Its Date of Progress." (Fugitive is misspelled in original title.)

TABLE 2.5-21

COMPRESSIONAL AND SHEAR WAVE RESULTS, ELASTIC MODULI CALCULATIONS

AND GENERALIZED GEOLOGIC CORRELATION[1]

Elevation (ft)	Generalized Geologic Correlation (Based on Boring 1-33)	Compressional Wave Velocity (ft/sec)	Shear Wave Velocity (ft/sec)	Unit Weight[2] (wet) Ratio	Poisson's (lbs/in^2)	Young's Modulus (lbs/in^2)	Shear Modulus (lbs/in^2)	Bulk Modulus
Cross-hole								
620 to 612±	Lacustrine sediments (unsaturated)	1,200	600	122	0.33	0.25×10^5	0.09×10^5	0.25×10^5
612± to 605±	Lacustrine sediments (saturated)	5,000	700	122	0.49	0.38×10^5	0.13×10^5	6.41×10^5
605± to 595±	Lacustrine sediments (saturated)	5,000	1,200	129	0.47	1.18×10^5	0.40×10^5	6.43×10^5
595± to 583±	Upper Till	5,900	1,900	132	0.44	2.97×10^5	1.03×10^5	8.55×10^5
583± to 560±	Lower Till	7,800	2,600	141	0.44	5.92×10^5	2.06×10^5	15.77×10^5
560± to 510	Chagrin Shale	10,400	4,900	152	0.36	21.38×10^5	7.88×10^5	24.98×10^5
Down-hole								
560 to 410	Chagrin Shale	9,000	4,000	152	0.38	14.46×10^5	5.25×10^5	19.58×10^5

NOTES:

(1) Tabulated data and results based on Borings 1-2, 1-22, 1-30, 1-31, 1-32, 1-33, and 1-34.
(2) See <Section 2.5.4.2> for site material physical properties.

TABLE 2.5-22

PROBABILISTIC ASSESSMENT OF PNPP-1 OBE EXCEEDANCE
SEISMICITY AND ATTENUATION INPUT PARAMETERS

Source Zone	Coordinates	-----Magnitude-Frequency Model------- a-value	b-value	rate > 4mb
Alternative 1				
200 mile radius site region	38 - 45 N 77 - 86 W	2.967	0.864	0.3243
Alternative 2				
50 mile radius local site region	41 - 42 N 80.8 - 81.8 W	1.598	0.777	0.0309

Attenuation Model (Reference 187)

$$I_s = -1.43 + 1.79\ mb - 0.80\ \ln R - 0.0018\ R \pm \sigma I_s$$

where
- I_s = Modified Mercalli Site Intensity (median estimate)
- mb = magnitude
- R = epicentral distance in kilometers
- σI_s = 1.0 MMI units

TABLE 2.5-23

PROBABILISTIC ASSESSMENT OF PNPP OBE EXCEEDANCE
ANNUAL FREQUENCIES OF EXCEEDING OBE INTENSITY

Source Zone	Modified Mercalli Intensity V	VI	VII
Alternative 1			
200 mile radius site region	3.87E-03	7.19E-04	1.00E-04
Alternative 2			
50 mile radius local site region	8.07E-03	2.03E-03	3.96E-04

NOTE:

(1) Annual frequency of OBE exceedance is equated to the annual frequency of exceeding a Modified Mercalli Intensity VI at the PNPP site.

TABLE 2.5-24

SUMMARY OF TEST METHODS

Test Description	Test Procedure
Natural Water Content	ASTM D 2216
Specific Gravity of Solids	ASTM D 854
Liquid Limit	ASTM D 423
Plastic Limit	ASTM D 424
Grain Size Distribution	ASTM D 422
Unconfined Compression	ASTM D 2166
Unconsolidated-Undrained Triaxial Compression	ASTM D 2850
One Dimensional Consolidation	ASTM D 2435
One Dimensional Consolidation with Constant Rate of Strain	(Reference 219)
Consolidated-Undrained Triaxial Compression with Pore Pressure Measurements	(Reference 266)
Multiple Stage Triaxial Compression with Pore Pressure Measurements	(Reference 267)
Triaxial Compression Following Predetermined Stress Paths	(Reference 231)
Cyclic Stress-Controlled Triaxial Compression	ASTM STP 477
Slaking Durability	(Reference 229)
Petrographic Analysis	(Reference 268)
X-ray Diffraction	ASTM STP 479
Cyclic Torsion (Resonant Column)	ASTM STP 479
Sonic Velocity	ASTM D 2845

TABLE 2.5-25

SUMMARY OF LABORATORY TEST RESULTS

Lacustrine Sediments

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits		Uncon Compress		Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size		Opt Moist	Consolid.	Triaxial			
					Liquid Limit	Plastic Limit	Stress (tsf)	Strain (%)			Sieve	Hydr.			U.U.	CIU	Cell Press (psi)	Back Press (psi)
1-1																		
S-1	2.5-4.0	LAC		21.6	33	21					See Note[3]	See Note[3]						
S-3	10.0-11.5	LAC		22.4	21	NP												
S-5	17.0-18.5	LAC		23.7	25	19					See Note[3]	See Note[3]						
S-6	18.5-20.0	LAC		21.8														
1-2																		
S-1	2.5-4.0	LAC		22.2	31	21					See Note[3]	See Note[3]						
S-3	10.5-12.0	LAC		22.6	21	19					See Note[3]	See Note[3]						
1-14				27.4					99.0	2.68	See Note[3]	See Note[3]		See Note[3]				
ST-1	16.0-18.0	LAC		28.3					@25.6%									
				21.0	27	21			97.9									
									@28.7%							See Note[3]		
1-17																		
S-1	2.5-4.0	LAC		21.5							See Note[3]							
S-2	7.0-3.5	LAC		20.1	19	18					See Note[3]	See Note[3]						
S-3	8.5-10.0	LAC		29.1	19	17					See Note[3]							
S-4	10.5-12.0	LAC		27.6	17	NP					See Note[3]	See Note[3]						
S-5	13.5-15.0	LAC		27.7	21	18					See Note[3]							
S-6	18.5-20.0	LAC		19.3	22	17					See Note[3]	See Note[3]						
S-7	23.5-25.0	LAC		28.4	29	18					See Note[3]							
1-20									105.6									
ST-2	9.0-11.0	LAC							@20.5%									

TABLE 2.5-25 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits		Uncon Compress		Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size		Opt Moist	Consolid.	Triaxial			
					Liquid Limit	Plastic Limit	Stress (tsf)	Strain (%)			Sieve	Hydr.			U.U.	CIU	Cell Press (psi)	Back Press (psi)
1-24																		
S-1	2.5-4.0	LAC		20.2	32	23												
S-2	7.0-8.5	LAC		27.5	21	17					See Note[3]	See Note[3]						
S-3	10.5-12.0	LAC		23.3	20	NP												
S-4	17.0-18.5	LAC		23.6	20	NP					See Note[3]	See Note[3]						
S-5	20.0-21.5	LAC		23.3														
S-6	27.0-28.5	LAC		21.3	29	20												
1-30																		
S-1	2.5-4.0	LAC		26.5	30	20												
S-2	5.5-7.0	LAC		28.3	20	NP					See Note[3]	See Note[3]						
S-3	8.5-10.0	LAC		22.1	28	18												
S-4	10.5-12.0	LAC		21.8	28	NP												
S-5	13.5-15.0	LAC		18.4	20	16					See Note[3]	See Note[3]						
S-6	18.5-20.0	LAC		23.5	NP	NP												
1-35																		
S-1	2.5-4.0	LAC		28.0														
S-3	10.0-11.5	LAC		28.9	23	20					See Note[3]	See Note[3]						
S-4	17.0-18.5	LAC		26.4														
1-36																		
S-1	2.5-4.0	LAC		20.0														
S-2	7.0-8.5	LAC		24.6	22	18					See Note[3]	See Note[3]						
S-3	10.5-12.0	LAC		37.1														

TABLE 2.5-25 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Plastic Limit	Uncon Compress Stress (tsf)	Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	CIU	Cell Press (psi)	Back Press (psi)
ST-2	15.0-17.0	LAC		25.7	20	18	105.9 @21.5%				See Note[3]	See Note[3]		See Note[3]				
S-4	17.0-18.5	LAC		21.2	22	21					See Note[3]	See Note[3]						
S-5	20.0-21.5	LAC		26.0	26	NP												
1-54A				22.1					107.2									
ST-3-5	16.0-18.0	LAC		21.4	27	15			@21.3%							See Note[3]		
ST-3-3	20.0-22.0	LAC		25.4	32	21			105.6 @22.9%							See Note[3]		
1-1	4.5-5.0	LAC (tested by Herron Testing Labs)		23.5	27	17			99.8		See Note[3]	See Note[3]				See Note[2][3]		
ST-1	5.0-5.5			30.8	25	19			87.6		See Note[3]	See Note[3]						
ST-1	5.5	LAC (tested by Herron Testing Labs)		31.2	NP	NP			86.2	2.70				See Note[3]				
ST-3	15.5-16.0			17.5	22	17			110.8		See Note[3]	See Note[3]				See Note[2][3]		
	16.0-16.5	LAC (tested by Herron Testing Labs)		18.6	18	15			109.1		See Note[3]	See Note[3]						
ST-3	16.7	LAC (tested by Herron Testing Labs)			30	20				2.75				See Note[3]				
1-2																		
ST-1	5.5-6.0	LAC (tested by Herron Testing Labs)[1]		27.9	NP	NP			90.3	2.70	See Note[3]	See Note[3]						
ST-2	9.5-10.0	LAC (tested by Herron Testing Labs)[1]		24.7	NP	NP			100.4	2.76	See Note[3]	See Note[3]						
ST-3	16.5-17.0	LAC (tested by Herron Testing Labs)[1]		26.8	NP	NP			96.4	2.72	See Note[3]	See Note[3]						

TABLE 2.5-25 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plastic Limit	Uncon Compress: Stress (tsf)	Uncon Compress: Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size: Sieve	Hydr.	Opt Moist	Consolid.	Triaxial: U.U.	Triaxial: CIU	Triaxial: Cell Press (psi)	Triaxial: Back Press (psi)
1-3																		
ST-1	8.0-8.5	LAC (tested by Herron Testing Labs)		29.2	28	23												
	8.5-9.0				18.3	20	13	1.38	11.2	111.5		See Note(3)	See Note(3)					
ST-1	9.0-9.5	LAC (tested by Herron Testing Labs)		18.0	20	17												
	9.0	LAC (tested by Herron Testing Labs)		18.0	19	17			115.4	2.71	See Note(3)							
1-5																		
ST-1	24.5-25.0	LAC (tested by Herron Testing Labs)		21.8	NP	NP			103.7		See Note(3)	See Note(3)						
1-7																		
S-1	2.5-4.0	LAC (tested by Herron Testing Labs)		24.1	26	18					See Note(3)							
S-2	5.5-7.0	LAC (tested by Herron Testing Labs)		21.1	24	17					See Note(3)							
S-4	10.5-12.0	LAC (tested by Herron Testing Labs)		27.2	18	13					See Note(3)							
1-17																		
S-1	2.5-4.0	LAC (tested by Herron Testing Labs)		21.6							See Note(3)							
S-2	7.0-8.5	LAC (tested by Herron Testing Labs)		21.9	24	16					See Note(3)	See Note(3)						

TABLE 2.5-25 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Grain Size Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
S-3	8.5-10.0	LAC (tested by Herron Testing Labs)		25.7	18	15					See Note[3]							
S-4	10.5-12.0	LAC (tested by Herron Testing Labs)		26.6	21	16					See Note[3]	See Note[3]						
S-5	13.5-15.0	LAC (tested by Herron Testing Labs)		29.4	21	17					See Note[3]							
S-6	18.5-20.0	LAC (tested by Herron Testing Labs)		20.0	21	15					See Note[3]	See Note[3]						
S-7	23.5-25.0	LAC (tested by Herron Testing Labs)		24.9	24	14					See Note[3]							
S-9	35.5-37.0	LAC (tested by Herron Testing Labs)		25.1	23	14					See Note[3]	See Note[3]						
1-30																		
S-1	2.5-4.0	LAC (tested by Herron Testing Labs)		25.9	23	15												
S-2	5.5-7.0	LAC (tested by Herron Testing Labs)		27.7	NP	NP					See Note[3]	See Note[3]						
S-3	8.5-10.0	LAC (tested by Herron Testing Labs)		23.5	27	17												
S-4	10.5-12.0	LAC (tested by Herron Testing Labs)		22.9	NP	NP					See Note[3]	See Note[3]						

TABLE 2.5-25 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
S-5	13.5-15.0	LAC (tested by Herron Testing Labs)		21.4	NP	NP												
S-6	18.5-20.0	LAC (tested by Herron Testing Labs)		20.9	NP	NP												
1-35																		
S-1	2.5-4.0	LAC (tested by Herron Testing Labs)		21.5														
S-3	10.0-11.5	LAC (tested by Herron Testing Labs)		28.8	23	16					See Note(3)	See Note(3)						
S-4	17.0-18.5	LAC (tested by Herron Testing Labs)		25.3														
S-5	20.0-21.5	LAC (tested by Herron Testing Labs)		23.1	26	15					See Note(3)	See Note(3)						
1-37																		
S-8	23.5-25.0	LAC (tested by Herron Testing Labs)		22.3	27	16					See Note(3)	See Note(3)						
1-38																		
S-2	5.5-7.0	LAC (tested by Herron Testing Labs)		25.6	NP	NP					See Note(3)	See Note(3)						
S-9	26.5-28.0	LAC (tested by Herron Testing Labs)		19.1	26	17					See Note(3)	See Note(3)						

TABLE 2.5-25 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
1-39																		
S-7	23.5-25.0	LAC (clay ptn)		24.3	31	18					See Note(3)	See Note(3)						
S-7	23.5-25.0	LAC (silt ptn)		18.7	NP	NP					See Note(3)	See Note(3)						
1-40																		
S-9	26.5-28.0	LAC		23.6	27	18					See Note(3)	See Note(3)						
1-41																		
S-9	26.5-28.0	LAC (tested by Herron Testing Labs)		23.9	29	18					See Note(3)	See Note(3)						
1-44																		
S-9	26.5-28.0	LAC (tested by Herron Testing Labs)		25.6	28	18					See Note(3)	See Note(3)						
1-46																		
S-9	26.5-28.0	LAC (tested by Herron Testing Labs)		23.0	29	18					See Note(3)	See Note(3)						
1-48																		
S-8	23.5-25.0	LAC (tested by Herron Testing Labs)		16.1	22	15					See Note(3)	See Note(3)						
S-9	26.5-28.0	LAC (tested by Herron Testing Labs)		16.9	24	16					See Note(3)	See Note(3)						
1-49																		
S-8	23.5-25.0	LAC (tested by Herron Testing Labs)		20.5	26	16					See Note(3)	See Note(3)						
1-50																		
S-7	20.5-22.0	LAC (tested by Herron Testing Labs)		23.1	NP	NP					See Note(3)	See Note(3)						

TABLE 2.5-25 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Grain Size Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
S-8	23.5-25.0	LAC (tested by Herron Testing Labs)		23.5	30	19					See Note(3)	See Note(3)						
1-51																		
S-9	26.5-28.0	LAC (tested by Herron Testing Labs)		26.1	28	16					See Note(3)	See Note(3)						
1-52																		
S-8	23.5-25.0	LAC (tested by Herron Testing Labs)		20.8	30	18					See Note(3)	See Note(3)						
S-9	26.5-28.0	LAC (tested by Herron Testing Labs)		18.0	25	16					See Note(3)	See Note(3)						

NOTES:

(1) Permeability test.
(2) No pore pressure measurement in CIU tests.
(3) See test curves.

TABLE 2.5-26

SUMMARY OF LABORATORY TEST RESULTS

Upper Till

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
1-1																		
S-8	28.5-30.0	UT		14.2	21	16												
S-9	33.5-35.0	UT		15.6	21	16					See Note[1]	See Note[1]						
1-2																		
S-5	18.5-20.0	UT		23.3														
S-6	23.5-25.0	UT		19.3	30	19					See Note[1]	See Note[1]						
S-8	33.5-35.0	UT		16.8														
1-17																		
S-8	35.5-37.0	UT		22.5	29	17					See Note[1]	See Note[1]						
S-9	38.5-40.0	UT		16.3	24	16					See Note[1]							
1-20				20.6					110.2									
ST-4	28.0-30.0	UT		18.4	25	17			@19.5%	2.67	See Note[1]	See Note[1]		See Note[1]	See Note[1]			
1-24				17.8					111.5									
ST-4	30.0-32.0	UT		16.1	23	16			@19.3%	2.73	See Note[1]	See Note[1]		See Note[1]	See Note[1]			
				13.8														
S-7	32.0-33.5	UT		16.9														
1-30																		
S-7	23.5-25.0	UT		15.1	21	17												
1-35																		
S-5	20.0-21.5	UT		21.5	22	19					See Note[1]	See Note[1]						
S-6	27.0-28.5	UT		19.7														

TABLE 2.5-26 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
ST-4	30.0-32.0	UT		17.8 17.2 18.2	28	19			111.8 @18.2% 115.2 @17.5%		See Note[1]	See Note[1]		See Note[1]	See Note[1]			
1-36 S-6	27.0-28.5	UT		17.4	29	19					See Note[1]	See Note[1]						
1-36 ST-4	30.0-32.0	UT		18.8	28	17			107.9 @19.9		See Note[1] See Note[1]	See Note[1]				See Note[1]		
S-7	32.0-33.5	UT		17.4	23	17												
ST-5	35.0-36.7	UT		16.4 12.9 18.3	25	18			97.6 @13.7		See Note[1]	See Note[1]			See Note[1]			
1-23 ST-3	20.0-22.0	UT													See Note[1]			
ST-4	25.0-27.0	UT							101.4 @21.5						See Note[1] See Note[1]			
1-36 ST-4	30.0-32.0	UT							107.9 @20.8									
1-54A	ST-3-5 28.0-30.0	UT		13.8	27	19			@13.8	120.0					See Note[1]			
1-3 ST-2	29.0-29.5 29.5-30.0	UT (tested by Herron Testing Labs)		12.6 15.7	22 24	13 17	3.69	15.2	121.4		See Note[1]	See Note[1]						
1-7 S-7	23.5-25.0	UT (tested by Herron Testing Labs)		15.7	22	14					See Note[1]							

TABLE 2.5-26 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
1-17																		
S-10	38.5-40.0		UT (tested by Herron Testing Labs)	17.3	24	15					See Note(1)							
S-11	43.5-45.0		UT (tested by Herron Testing Labs)	13.8	24	16					See Note(1)	See Note(1)						
1-30																		
S-7	23.5-25.0		UT (tested by Herron Testing Labs)	14.3	22	15												
1-35																		
S-6	27.0-28.5		UT (tested by Herron Testing Labs)	20.2														
S-7	32.0-33.5		UT (tested by Herron Testing Labs)	16.3	26	15					See Note(1)	See Note(1)						
1-37																		
S-10	29.5-31.0		UT (tested by Herron Testing Labs)	19.9	26	17					See Note(1)	See Note(1)						
1-38																		
S-10	29.5-31.0		UT (tested by Herron Testing Labs)	19.9	27	17					See Note(1)	See Note(1)						
S-11	32.5-34.0		UT (tested by Herron Testing Labs)	15.2	29	15					See Note(1)	See Note(1)						
S-12	35.5-37.0		UT (tested by Herron Testing Labs)	12.8	22	14					See Note(1)	See Note(1)						

TABLE 2.5-26 (Continued)

Boring and Sample No.	Depth (ft)	Classification	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Specific Gravity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
1-39																		
S-8	28.0-29.5		UT (tested by Herron Testing Labs)	18.2	26	17					See Note[1]	See Note[1]						
S-9	32.5-34.0		UT (tested by Herron Testing Labs)	16.8	23	16					See Note[1]	See Note[1]						
1-40																		
S-11	32.5-34.0		UT (tested by Herron Testing Labs)	18.7	26	14					See Note[1]	See Note[1]						
S-12	35.5-37.0		UT (tested by Herron Testing Labs)	15.5	22	14					See Note[1]	See Note[1]						
1-41																		
S-10	29.5-31.0		UT (tested by Herron Testing Labs)	18.9	26	17					See Note[1]	See Note[1]						
S-11	32.5-34.0		UT (tested by Herron Testing Labs)	19.8	27	17					See Note[1]	See Note[1]						
1-43																		
S-10	29.5-31.0		UT (tested by Herron Testing Labs)	20.5	24	15					See Note[1]	See Note[1]						
S-11	32.5-34.0		UT (tested by Herron Testing Labs)	15.7	25	16					See Note[1]	See Note[1]						
S-12	35.5-37.0		UT (tested by Herron Testing Labs)	14.5	24	16					See Note[1]	See Note[1]						

TABLE 2.5-26 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
1-44																		
S-10	29.5-31.0	UT (tested by Herron Testing Labs)		19.3	26	17					See Note[1]	See Note[1]						
1-46																		
S-10	29.5-31.0	UT (tested by Herron Testing Labs)		15.0	24	15					See Note[1]	See Note[1]						
S-11	32.5-34.0	UT (tested by Herron Testing Labs)		13.3	22	16					See Note[1]	See Note[1]						
1-46																		
S-12	35.5-37.0	UT (tested by Herron Testing Labs)		10.8	25	15					See Note[1]	See Note[1]						
1-48																		
S-11	32.5-34.0	UT (tested by Herron Testing Labs)		15.9	22	15					See Note[1]	See Note[1]						
S-12	35.5-37.0	UT (tested by Herron Testing Labs)		11.5	19	17					See Note[1]	See Note[1]						
1-49																		
S-10	29.5-31.0	UT (tested by Herron Testing Labs)		15.2	24	16					See Note[1]	See Note[1]						
S-11	32.5-34.0	UT (tested by Herron Testing Labs)		14.5	23	16					See Note[1]	See Note[1]						
S-12	35.5-37.0	UT (tested by Herron Testing Labs)		11.9	22	14					See Note[1]	See Note[1]						

TABLE 2.5-26 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
1-50																		
S-11	32.5-34.0		UT (tested by Herron Testing Labs)	14.9	22	14					See Note[1]	See Note[1]						
1-51																		
S-10	29.5-31.0		UT (tested by Herron Testing Labs)	19.4	24	16					See Note[1]	See Note[1]						
S-12	35.5-37.0		UT (tested by Herron Testing Labs)	12.5	23	14					See Note[1]	See Note[1]						
1-52																		
S-10	29.5-31.0		UT (tested by Herron Testing Labs)	19.7	27	16					See Note[1]	See Note[1]						
S-11	32.5-34.0		UT (tested by Herron Testing Labs)	18.2	25	17					See Note[1]	See Note[1]						
S-12	35.5-37.0		UT (tested by Herron Testing Labs)	14.5	23	16					See Note[1]	See Note[1]						

NOTE:

[1] See test curves

TABLE 2.5-27

SUMMARY OF LABORATORY TEST RESULTS

Lower Till

Boring and Sample No.	Depth (ft)	Classification	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Specific Gravity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
1-1																		
S-10	38.5-40.0	LT		9.3	18	15												
S-11	43.5-45.0	LT		9.3														
S-12	48.5-50.0	LT		11.2	23	17					See Note(2)	See Note(2)						
S-13	54.5-56.0	LT		5.2														
1-2																		
S-9	38.5-40.0	LT		10.1	23	18					See Note(2)	See Note(2)						
S-10	43.5-45.0	LT		8.9														
S-11	48.5-50.0	LT		13.9	22	16					See Note(2)	See Note(2)						
S-12	53.5-54.5	LT		3.3														
1-17																		
S-10	43.5-45.0	LT		11.5	24	17					See Note(2)	See Note(2)						
S-11	49.0-50.5	LT		13.6	24	17					See Note(2)							
1-20																		
ST-5	38.0-39.2	LT		10.9	24	19			120.8 @13.0%	2.69	See Note(2)	See Note(2)		See Note(2)				
PS-1	41.0-41.9	LT		14.5	24	17			127.9 @13.8%	2.67	See Note(2)	See Note(2)		See Note(2)				
1-23																		
PS-2	40.0-42.5	LT		10.6	24	18												
1-24																		
S-8	36.8-38.1	LT		11.6	23	17												

TABLE 2.5-27 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits		Uncon Compress		Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size		Opt Moist	Consolid.	Triaxial			
					Liquid Limit	Plastic Limit	Stress (tsf)	Strain (%)			Sieve	Hydr.			U.U.	CIU	Cell Press (psi)	Back Press (psi)
				11.5	26	19			130.4									
PS-1	40.0-42.5	LT	(SP)[1]	11.8	24	17			@11.1%	2.69	See Note[2]	See Note[2]		See Note[2]		See Note[2]		
				13.1														
				11.2														
1-24																		
S-9	42.5-44.0	LT		11.0														
				11.1					130.8									
PS-2	45.0-47.5	LT		10.8	23	17			@10.7%	2.74	See Note[2]	See Note[2]		See Note[2]		See Note[2]		
				10.8					130.3									
				11.2					@10.8%					See Note[2]		See Note[2]		
				10.9														
S-10	47.5-49.0	LT		9.3														
1-30																		
S-8	28.5-30.0	LT		10.0	23	16												
S-9	33.5-35.0	LT		11.3	22	17					See Note[2]	See Note[2]						
S-10	38.5-40.0	LT		12.1	25	18												
S-11	43.5-45.0	LT		10.8	25	17												
S-12	48.5-49.6	LT		10.0	25	18												
1-35																		
S-7	32.0-33.5	LT		17.6	22	16					See Note[2]	See Note[2]						
S-8	36.8-38.3	LT		11.4														
									132.3									
PS-1	40.0-42.5	LT		10.6	23	18			@9.8%	2.73	See Note[2]	See Note[2]		See Note[2]		See Note[2]		
S-9	42.5-44.0	LT		11.1	23	17					See Note[2]	See Note[2]						
									129.3							See Note[2]		
PS-2	45.0-47.5	LT		11.1	24	17			@11.3%	2.74	See Note[2]	See Note[2]		See Note[2]		See Note[2]		
S-10	47.5-49.0	LT		11.8														

TABLE 2.5-27 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plastic Limit	Uncon Compress: Stress (tsf)	Uncon Compress: Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size: Sieve	Hydr.	Opt Moist	Consolid.	Triaxial: U.U.	Triaxial: CIU	Triaxial: Cell Press (psi)	Triaxial: Back Press (psi)
1-35				9.4	22	16			136.6						See Note(2)			
PS-3	50.0-52.5	LT		8.9	21	16			@9.0%		See Note(2)	See Note(2)			See Note(2)			
S-11	53.5-55.0	LT		9.9	19	14					See Note(2)	See Note(2)						
1-36																		
S-8	36.8-38.1	LT		10.3														
I-36									137.7									
PS-1	40.0-42.5	LT		9.5	24	18			@9.7%		See Note(2)	See Note(2)				See Note(2)		
S-9	42.5-44.0	LT		10.4	23	16					See Note(2)	See Note(2)						
									129.0							See Note(2)		
PS-2	44.0-46.5	LT		11.9	27	18			@11.4%		See Note(2)	See Note(2)		See Note(2)		See Note(2)		
S-10	46.5-48.0	LT		11.7														
				12.3					134.3									
PS-3	48.0-50.5	LT		7.3	21	16			@9.9%		See Note(2)	See Note(2)			See Note(2)			
S-11	50.5-52.0	LT		8.4	21	15					See Note(2)	See Note(2)						
S-12	54.5-56.0	LT		9.0														
S-13	57.3-57.8	LT		4.9	15	11					See Note(2)	See Note(2)						
S-14	61.5-61.8	LT		10.8														
TC-1									132.3									
BLK-1	44.5	LT		8.8	18	16			@10.2%	2.70				See Note(2)		See Note(2)		
				8.2					135.0									
BLK-2	44.5	LT		8.7					@8.2%		See Note(2)	See Note(2)						

TABLE 2.5-27 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plastic Limit	Uncon Compress: Stress (tsf)	Uncon Compress: Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size: Sieve	Grain Size: Hydr.	Opt Moist	Consolid.	Triaxial: U.U.	Triaxial: CIU	Triaxial: Cell Press (psi)	Triaxial: Back Press (psi)
BLK-3	50.5	LT		8.4	22	16			144.1 @8.4%	2.71	See Note(2)	See Note(2)						
BLK-4	50.5	LT		8.3					135.0 @8.3%					See Note(2)				
TC-1 HB-1-N	44.5	LT		7.3														
HB-1-S	44.5	LT		9.6														
HB-2-S	48.5	LT		11.2														
HB-2-N	50.5	LT		5.5														
HB-2-S	50.5	LT		7.1														
HB-3-N	55.4	LT		7.5														
HB-3-S	55.4	LT		6.9														
HB-3-N	56.5	LT		3.6 6.5														
HB-3-S	56.5	LT		3.8														
HB-4-A	62.0-62.5	LT		3.2														
HB-4-B	63.0-63.5	LT		4.6														
HB-4-C	64.3-64.7	LT		4.6														
HB-4-D	65.3-65.7	LT		3.4														
TC-2 BLK-3	44.0	LT		10.0	23	20			129.7 @9.7%					See Note(2)				
BLK-5	56.0	LT		15.1	31	22			109.2 @14.9%				See Note(2)	See Note(2)				

TABLE 2.5-27 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
HB-1-N	40.3	LT		9.9														
HB-1-S	40.3	LT		9.6														
HB-1-E	43.5	LT		9.7														
HB-1-W	43.5	LT		8.9														
HB-2-N	49.0	LT		7.8														
HB-3-N	55.7-56.5	LT		17.7 17.6 16.4														
HB-3-S	55.9-56.5	LT		15.7 16.1 16.3														
HB-3	55.9-56.5	LT			29	21												
	55.9-56.5	LT			28	21												
	55.9-56.5	LT			28	21												
1-35 PS-3	50.0-52.5	LT							138.8 @8.8%									
1-36 PS-4	52.0-54.5	LT							135.3 @9.8%						See Note(2)			
TC-2 BLK-3	44.0	LT							137.5 @9.3%									
1-7 S-11	43.5-45.0	LT (tested by Herron Testing Labs)		10.2	23	15					See Note(2)							

TABLE 2.5-27 (Continued)

Boring and Sample No.	Depth (ft)	Classification	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Specific Gravity	Grain Size Sieve	Grain Size Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
1-7																		
S-14	59.5-59.8	LT (tested by Herron Testing Labs)		10.8	26	17					See Note(2)							
1-17																		
S-12	49.0-50.5	LT (tested by Herron Testing Labs)		11.2	26	15					See Note(2)							
1-30																		
S-8	28.5-30.0	LT (tested by Herron Testing Labs)		10.8	25	15												
S-9	33.5-35.0	LT (tested by Herron Testing Labs)		13.0	24	16					See Note(2)	See Note(2)						
S-10	38.5-40.0	LT (tested by Herron Testing Labs)		10.3	24	13												
S-11	43.5-45.0	LT (tested by Herron Testing Labs)		12.2	24	16												
S-12	48.5-49.6	LT (tested by Herron Testing Labs)		11.8	20	15												
1-35																		
S-8	36.8-38.3	LT (tested by Herron Testing Labs)		10.4														
S-9	42.5-44.0	LT (tested by Herron Testing Labs)		11.1	24	15					See Note(2)	See Note(2)						

TABLE 2.5-27 (Continued)

Boring and Sample No.	Depth (ft)	Classification	Special Tests	Natural Water Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plastic Limit	Uncon Compress: Stress (tsf)	Uncon Compress: Strain (%)	Unit Dry Wt. (pcf)	Specific Gravity	Grain Size: Sieve	Grain Size: Hydr.	Opt Moist	Consolid.	Triaxial: U.U.	Triaxial: CIU	Triaxial: Cell Press (psi)	Triaxial: Back Press (psi)
S-10	47.5-49.0	LT (tested by Herron Testing Labs)		11.8														
S-11	53.5-55.0	LT (tested by Herron Testing Labs)		5.4	25	20					See Note[2]	See Note[2]						
1-37 S-13	37.5-39.0	LT (tested by Herron Testing Labs)		9.9	23	13					See Note[2]	See Note[2]						
S-16	46.5-48.0	LT (tested by Herron Testing Labs)		10.6	22	14					See Note[2]	See Note[2]						
S-18	52.5-54.0	LT (tested by Herron Testing Labs)		9.2	23	14					See Note[2]	See Note[2]						
1-38 S-17	50.5-52.0	LT (tested by Herron Testing Labs)		8.3	25	16					See Note[2]	See Note[2]						
1-39 S-10	37.0-38.5	LT (tested by Herron Testing Labs)		10.3	24	16					See Note[2]	See Note[2]						
S-12	44.5-46.0	LT (tested by Herron Testing Labs)		9.9	24	16					See Note[2]	See Note[2]						
	Approx. 50.0-52.0	LT (tested by Herron Testing Labs)		12.3	22	16					See Note[2]	See Note[2]						

TABLE 2.5-27 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Grain Size Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
1-40 S-17	50.5-51.5	LT (tested by Herron Testing Labs)		8.1	22	13					See Note(2)	See Note(2)						
1-41 S-13	38.5-40.0	LT (tested by Herron Testing Labs)		11.6	24	17					See Note(2)	See Note(2)						
1-43 S-13	38.5-40.0	LT (tested by Herron Testing Labs)		10.3	22	16					See Note(2)	See Note(2)						
S-17	50.5-52.0	LT (tested by Herron Testing Labs)		9.7	25	14					See Note(2)	See Note(2)						
1-44 S-12	38.5-40.0	LT (tested by Herron Testing Labs)		14.5	24	17					See Note(2)	See Note(2)						
S-17	50.5-52.0	LT (tested by Herron Testing Labs)		8.7	22	15					See Note(2)	See Note(2)						
	Approx. 53.0	LT (tested by Herron Testing Labs)		11.6	25	15					See Note(2)	See Note(2)						
1-46 S-17	50.5-52.0	LT (tested by Herron Testing Labs)		12.8	23	15					See Note(2)	See Note(2)						

TABLE 2.5-27 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
1-48																		
S-13	38.5-40.0		LT (testing by Herron Testing Labs)	9.6	NP	NP					See Note(2)	See Note(2)						
S-17	50.5-52.0		LT (tested by Herron Testing Labs)	6.1	20	17					See Note(2)	See Note(2)						
	Approx. 53.0		LT (tested by Herron Testing Labs)	9.0	20	15					See Note(2)	See Note(2)						
1-49																		
S-13	38.5-40.0		LT (tested by Herron Testing Labs)	12.8	23	15					See Note(2)	See Note(2)						
S-15	44.5-46.0		LT (tested by Herron Testing Labs)	13.0	23	16					See Note(2)	See Note(2)						
1-50																		
S-13	38.5-40.0		LT (tested by Herron Testing Labs)	11.3	22	18					See Note(2)	See Note(2)						
S-16	47.5-49.0		LT (tested by Herron Testing Labs)	6.8	18	13					See Note(2)	See Note(2)						
S-17	50.5-51.5		LT (tested by Herron Testing Labs)	8.9	24	16					See Note(2)	See Note(2)						
1-51																		
S-13	38.5-40.0		LT (tested by Herron Testing Labs)	10.9	23	13					See Note(2)	See Note(2)						

TABLE 2.5-27 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
S-17	50.5-52.0		LT (tested by Herron Testing Labs)	8.3	22	13					See Note[2]	See Note[2]						
1-52																		
S-13	38.5-40.0		LT (tested by Herron Testing Labs)	11.5	23	14					See Note[2]	See Note[2]						
S-14	41.5-43.0		LT (tested by Herron Testing Labs)	11.9	21	15					See Note[2]	See Note[2]						
S-15	44.5-46.0		LT (tested by Herron Testing Labs)	10.9	24	16					See Note[2]	See Note[2]						
S-16	47.5-49.0		LT (tested by Herron Testing Labs)	8.0	20	12					See Note[2]	See Note[2]						
S-17	50.5-51.0		LT (tested by Herron Testing Labs)	8.3	22	13					See Note[2]	See Note[2]						

NOTES:

(1) Stress path.
(2) See test curves

TABLE 2.5-28

PHYSICAL PROPERTIES OF SOIL MATERIALS

Material	Natural Water Content W_n (%)	Dry Unit Weight γ_d (pcf)	Specific Gravity G_s	Liquid Limit LL (%)	Plastic Limit PL (%)	Plasticity Index PI (%)	Grain Size Classification Gravel (%)	Sand (%)	Silt-Clay (%)
Lacustrine:									
Minimum	18.4	92.8	2.67	17	16	0	0	2	15
Maximum	37.1	105.9	2.73	33	23	12	4	85	98
Average	24.3	99.8	2.68	24	19	5	1	20	79
No. of Tests	47	10	3	30	30	23	23	23	23
Upper Till:									
Minimum	12.9	97.6	2.67	21	16	4	0	4	67
Maximum	23.3	118.2	2.73	30	19	12	4	30	96
Average	18.0	109.1	2.70	25	17	8	1	18	81
No. of Tests	36	11	2	14	14	14	11	11	11
Lower Till:									
Minimum	3.2	97.6	2.63	15	11	2	0	16	32
Maximum	18.3	144.1	2.74	31	20	11	32	44	83
Average	10.3	128.8	2.71	23	17	6	5	27	68
No. of Tests	87	20	8	35	35	35	24	24	24

TABLE 2.5-29

SUMMARY OF ONE-DIMENSIONAL CONSOLIDATION TEST RESULTS ON SOIL MATERIALS

Boring No.	Sample Depth (ft)	Stratum	Dry Unit Weight γ_d (pcf)	Natural Water Content W_n (%)	Plasticity Index PI (%)	Effective Overburden Pressure P_o (tsf)	Preconsolidation Pressure P_c (tsf)	Overconsolidation Ratio P_c/P_o	Initial Void Ratio e_o	Recompression Index[(1)(2)] C'_r	Compression Index[(1)] C'_c
1-14	16-18.0	LAC	97.9	27.7	6	0.65	1.7	2.6	0.710	0.008	0.095
1-36	15-17.0	LAC	105.9	25.7	2	0.60	2.0	3.3	0.580	0.005	0.051
1-20	28-30.0	UT	108.5	21.9	8	1.04	4.0	3.8	0.537	0.011	0.093
1-24	30-32.0	UT	111.5	19.3	7	1.10	5.0	4.5	0.529	0.008	0.084
1-35	30-32.0	UT	111.8	18.2	9	1.10	4.0	3.6	0.524	0.014	0.090
1-20	38-39.2	LT	123.5	10.5	5	1.43	5.0	3.5	0.315	0.008	0.054
1-20	41-41.9	LT	123.8	13.0	7	1.50	5.0	3.3	0.347	0.009	0.054
1-24	45-47.5	LT	130.8	10.7	6	1.60	6.0	3.8	0.307	0.006	0.051
1-24	45-47.5	LT	130.3	10.8	6	1.60	4.5	2.8	0.288	0.005	0.035
1-24[(3)]	40-42.5	LT	130.4	11.1	7	1.50	7.0	4.7	0.288	0.006	0.038
1-35[(3)]	40-42.5	LT	132.3	9.8	5	1.50	7.0	4.7	0.280	0.006	0.035
1-35[(3)]	45-47.5	LT	129.3	11.3	7	1.60	4.5	2.8	0.294	0.005	0.037
1-36	44-46.5	LT	129.0	11.4	9	1.59	4.0	2.5	0.297	0.011	0.046
TC-1[(4)]	44.5	LT	132.3	10.2	2	1.58	6.0	3.8	0.278	0.005	0.036
TC-1[(3)(4)]	50.5	LT	135.0	8.3	6	1.88	9.0	5.3	0.248	0.004	0.042

NOTES:

(1) Unit strain basis.
(2) Swell index, C'_s, approximately equal to C'_r.
(3) Constant rate of loading test.
(4) Block sample.

TABLE 2.5-30

DRAINED DEFORMATION MODULI OF LOWER TILL[1]

Boring No.	Sample Depth (ft)	Recompression Index Ratio	Constrained Modulus, E_d (ksi)	Deformation Modulus, E_s (ksi)
1-20	38.5	0.008	13.7	6.4
1-20	41.5	0.008	13.7	6.4
1-24	41.0	0.006	18.2	8.5
1-24	46.0	0.006	18.2	8.5
1-24[2]	46.0	0.005	21.9	10.2
1-35[2]	41.0	0.006	18.2	8.5
1-35[2]	46.0	0.005	21.9	10.2
1-36	45.0	0.011	10.1	4.7
TC-1[3]	44.0	0.0055	19.9	9.3
TC-1[2][3]	50.0	0.004	27.4	12.8

NOTES:

[1] Poisson's ratio assumed to be 0.40; Compression Index Ratio = $C'_r/(1 - \varepsilon_o)$ (unit strain basis)
[2] Constant rate of loading consolidation test
[3] Block sample

TABLE 2.5-31

PRESSUREMETER TEST RESULTS IN LOWER TILL

Hole No.	Test Elevation (ft)	Dry Unit Weight γ_d (pcf)	Natural Water Content W_n (%)	Plasticity Index PI (%)	Plastic Yield Pressure P_l (ksf)	Compressibility Moduli E_1[(1)] (ksi)	E_2[(2)] (ksi)	E_c[(3)] (ksi)	Undrained Shear Strength S_o (tsf)
1-22P2	575.3	136.0	10.0	6	44.0	2.56	1.74	20.2	11.5
	572.2	130.0	9.5	6	37.6	1.35	1.34	25.7	12.0
	567.2	135.0	8.5	5	34.8	1.74	1.42	20.8	10.0
1-35P	585.1	132.3	10.0	5	29.4	1.86	1.07	--	6.5
	584.1	132.3	9.5 to 11.4	5	30.0	1.15	0.93	94.7 to 75.6	10.0
	578.1	129.3 to 137.7	10.6 to 11.1	6,7	44.4	2.61	2.2	15.9	12.0
	573.1	136.6	8.9 to 11.8	5,6	35.2	1.10	--	18.6	11.0
1-36P	583.8	126.0	9.5 to 10.3	6	36.8	2.92	2.29	6.9	8.3
	578.8	129.0	10.4	7,9	20.8	1.94	1.39	4.7	4.6
	573.8	134.3	7.3 to 12.3	5	38.4	7.22	3.47	7.2	8.1

NOTES:

(1) E_1 = Modulus at pressures less than preconsolidation pressure

(2) W_2 = Modulus at pressures greater than preconsolidation pressure

(3) E_c = Unload-reload modulus

TABLE 2.5-32

VERTICAL PLATE LOADING TEST RESULTS IN LOWER TILL[1]

Inspection Shaft No.	Test No.	Test Elev. (ft)	Dry Unit Weight γ_d (pcf)	Natural Moisture Content W_n (%)	Plasticity Index PI (%)	Effective Overburden Pressure P_o (tsf)	Preconsolidation Pressure P_c (tsf)	Over-Consolidation Ratio P_c/P_o	Compressibility Moduli E_1[2] (ksi)	E_2[3] (ksi)	E_c[4] (ksi)
TC-1	VB-1	582.8	132.3	10.2	2	1.48	6.5	4.4	37.9	6.04	227.0
	VB-2	574.3	144.1	7.8	6	1.77	9.3	5.3	68.8	9.36	210.0
	VB-3	567.4	136.0	6.9 to 7.5	7	2.05	5.5	2.7	54.5	16.80	236.0
TC-2	VB-1	582.5	129.7	9.6 to 10.0	3	1.49	5.9	4.0	25.0	5.28	122.0
	VB-2	573.8	136.6	7.8	5	1.80	10.0	5.6	47.2	13.00	140.5
	VB-3	566.9	109.2	14.9 to 17.7	7 to 9	2.08	8.8	4.2	90.8	6.90	91.0

NOTES:

[1] Plate diameter = 22 inches; shape and depth correction factor = 0.59
[2] E_1 = Modulus at pressures $<P_c$
[3] E_2 = Modulus at pressures $>P_c$
[4] E_c = Unload-reload modulus

TABLE 2.5-33

HORIZONTAL PLATE LOADING TEST RESULTS IN LOWER TILL[1]

Inspection Shaft No.	Test No.	Test Elevation (ft)	Dry Unit Weight γ^d (pcf)	Natural Moisture Content W_n (%)	Plasticity Index PI (%)	Compressibility Moduli E_1[2] (ksi)	E_2[3] (ksi)	E_c[4] (ksi)
TC-1	HB-1, N	578.3	132.3	10.2	2	155.0	7.0	-
	HB-1, S	578.3	132.3	10.2	2	373.0	8.7	694.0
	HB-2, N	572.3	144.1	7.8	6	435.0	7.7	496.0
	HB-2, S	572.3	144.1	7.8	6	410.0	8.9	800.0
	HB-3, N	566.3	136.0	6.9	7	856.0	117.0	-
	HB-3, S	566.3	136.0	7.5	7	710.0	692.0	-
TC-2	HB-1, E	479.3	129.7	9.9	3	186.0	12.4	-
	HB-1, W	479.3	129.7	9.9	3	249.0	5.8	-
	HB-2, N	569.8	109.2	16.1	8	335.0	12.9	404.0
	HB-2, S	569.8	109.2	16.1	8	620.0	11.0	670.0

NOTES:

(1) Plate diameter = 13.55 inches; shape and depth correction factor = 0.66
(2) E_1 = Modulus at pressures $<P_c$
(3) E_2 = Modulus at pressures $>P_c$
(4) E_c = Unload-reload modulus

TABLE 2.5-34

SUMMARY OF LABORATORY COMPRESSION TEST RESULTS - LACUSTRINE SEDIMENTS

Boring No.	Sample Depth (ft)	Type of Test[(1)(2)]	Dry Unit Weight γ_d (pcf)	Natural Moisture Content W_n (%)	Liquid Limit LL (%)	Plasticity Index PI (%)	Shear Strength (tsf)	Strain at Failure e_f (%)	Deformation Moduli (ksi) E_i[(3)]	Deformation Moduli (ksi) E_{sec}[(4)]	Consolidation or Confining Pressure (tsf) σ_c or σ_c	Remarks
1-22A	5.0- 7.0	$\overline{CIU}$	92.8	27.2			1.07	9.4	7.40	0.78	0.29	Test No. 14
	5.0- 7.0	$\overline{CIU}$	93.4	30.4			2.05	10.0	5.28	1.25	0.86	Test No. 15
	5.0- 7.0	$\overline{CIU}$	94.9	26.3			7.00	8.4	9.63	2.75	2.59	Test No. 16
1-23	15.0-17.0	$\overline{CIU}$	105.0	20.0			3.47	6.0	9.04	2.50	1.42	Test No. 17
1-22A	15.0-17.0	$\overline{CIU}$	99.7	22.0			1.06	13.5	8.00	0.76	0.86	Test No. 18
	15.0-17.0	$\overline{CIU}$	104.3	19.7			1.94	17.8	13.90	2.32	2.59	Test No. 19
1-14	16.0-18.0	UU	96.4	26.5	27	6	0.64	21.2	1.11	0.18	0.63	
1-23	15.0-17.0	UU	101.4	21.5			0.39	7.5	0.94	0.21	0.65	
1-54A	16.0-18.0	$\overline{CIU}$	102.1	25.7	27	12	1.00	2.0	4.47	0.52	0.30	Test No. 23
	16.0-18.0	$\overline{CIU}$	107.2	21.3	27	12	1.23	2.5	7.78	1.13	0.90	Test No. 24
	20.0-22.0	$\overline{CIU}$	105.6	22.9			1.51	3.2	7.78	1.28	1.50	Test No. 25

NOTES:

(1) $\overline{CIU}$ = Isotropically consolidated-undrained triaxial compression test with pore pressure measurements.

(2) UU = Unconsolidated-undrained triaxial compression test.

(3) E_i = Initial deformation modulus.

(4) E_{sec} = Deformation modulus at 1/2 of ultimate stress.

TABLE 2.5-35

SUMMARY OF LABORATORY COMPRESSION TEST RESULTS - UPPER TILL

Boring No.	Sample Depth (ft)	Type of Test[1][2]	Dry Unit Weight γ_d (pcf)	Natural Moisture Content W_n (%)	Liquid Limit LL (%)	Plasticity Index PI (%)	Shear Strength (tsf)	Strain at Failure e_f (%)	Deformation Moduli (ksi) E_i[3]	Deformation Moduli (ksi) E_{sec}[4]	Consolidation or Confining Pressure (tsf) σ_c or σ_c	Remarks
1-20	28.0-30.0	UU	105.7	21.6	25	8	0.67	17.3	1.04	0.27	1.01	
1-24	30.0-32.0	UU	114.1	17.6	23	7	0.87	18.0	1.08	0.67	1.00	
1-35	30.0-32.0	$\overline{CIU}$	111.8	18.2	28	9	1.70	11.8	6.95	2.36	1.80	Test No. 7
1-36	30.0-32.0	$\overline{CIU}$	107.9	19.9	28	9	2.44	9.3	11.10	3.77	3.60	Test No. 8
1-36	30.0-32.0	$\overline{CIU}$	107.9	19.9	28	9	3.60	13.7	23.20	8.33	7.20	Test No. 9
1-36	35.0-36.5	UU	97.6	13.7	25	7	2.23	32.5	1.60	0.61	1.30	
1-23	20.0-22.0	UU	99.5	25.2			0.68	11.0	1.46	0.29	0.83	
1-23	25.0-27.0	UU	117.9	16.4			1.30	9.2	1.58	0.78	0.65	
1-22A	20.0-22.0	$\overline{CIU}$	111.9	15.6			1.31	14.0	6.45	0.70	0.86	Test No. 20
1-35	25.0-27.0	$\overline{CIU}$	118.2	21.5			0.83	13.2	8.22	1.32	1.73	Test No. 21
1-36	25.0-27.0	$\overline{CIU}$	106.9	19.4			2.85	18.4	11.60	3.85	3.46	Test No. 22
1-54A	28.0-30.0	$\overline{CIU}$	120.0	13.8	27	8	1.20	15.8	0.81	0.11	0.90	Test No. 26

NOTES:

(1) $\overline{CIU}$ = Isotropically consolidated-undrained triaxial compression test with pore pressure measurements.
(2) UU = Unconsolidated-undrained triaxial compression test.
(3) E_i = Initial deformation modulus.
(4) E_{sec} = Deformation modulus at 1/2 of ultimate stress.

TABLE 2.5-36

SUMMARY OF LABORATORY COMPRESSION TEST RESULTS - LOWER TILL

Boring No.	Sample Depth (ft)	Type of Test [1][2][3]	Dry Unit Weight γ_d (pcf)	Natural Moisture Content W_n (%)	Liquid Limit LL (%)	Plasticity Index PI (%)	Shear Strength (tsf)	Strain at Failure e_f (%)	Deformation Moduli (ksi) E_i [4]	E_{sec} [5]	E_c [6]	Consolidation or Confining Pressure (tsf) σ_c or σ_c	Remarks
1-24	40.0-42.5	$\overline{CIU}$	130.4	11.1	26	7	2.13	6.0	9.26	1.97		1.80	Test No. 1
1-24	45.0-47.5	$\overline{CIU}$	130.3	10.8	23	6	5.88	9.1	18.6	3.97		3.60	Test No. 2
1-24	45.0-47.5	$\overline{CIU}$	130.8	10.7	23	6	9.60	9.5	34.8	5.41		7.20	Test No. 3
1-35	40.0-42.5	$\overline{CIU}$	132.3	9.8	23	5	6.22	11.7	8.69	4.24		1.80	Test No. 4
1-35	45.0-47.5	$\overline{CIU}$	129.3	11.3	24	7	7.64	10.8	13.9	4.32		3.60	Test No. 5
1-35	45.0-47.5	$\overline{CIU}$	129.3	11.3	24	7	6.42	8.1	23.2	8.50		7.20	Test No. 6
1-35	50.0-52.5	UU	138.8	8.8	22	6	7.26	6.5	4.30	4.30		1.92	Stress Path Test
1-36	40.0-42.5	$\overline{CIU}_s$	137.7	9.7	24	6	10.56	6.6	27.8	7.78	41.7	7.20	Test No. 12
1-36	44.0-46.5	$\overline{CIU}$	129.0	11.4	27	9	3.70	11.4	6.95	2.44		1.80	Test No. 10
1-36	44.0-46.5	$\overline{CIU}_s$	129.0	11.4	27	9	5.66	8.0	17.4	5.18	23.2	3.60	Test No. 11
1-36	48.0-50.0	UU	134.3	9.9	21	5	2.59	16.0	2.78	0.89		1.75	
TC-1	44.5	$\overline{CIU}$	132.3	10.2	18	2	6.06	9.8	8.54	3.05		1.80	Test No. 13
TC-2	44.0	UU	137.2	9.3	23	3	6.60	4.8	7.50	5.91		1.66	

TABLE 2.5-36 (Continued)

Boring No.	Sample Depth (ft)	Type of Test (1)(2)(3)	Dry Unit Weight γ_d (pcf)	Natural Moisture Content W_n (%)	Liquid Limit LL (%)	Plasticity Index PI (%)	Shear Strength (tsf)	Strain at Failure e_f (%)	Deformation Moduli (ksi) E_i (4)	E_{sec} (5)	E_c (6)	Consolidation or Confining Pressure (tsf) σ_c or $\bar{\sigma}_c$	Remarks
TC-2	56.0	UU	135.3	14.9	31	9	6.96	8.3	2.78	2.78		2.09	
1-36	52.0-54.5	UU	135.3	9.8	-	-	6.78	10.0	2.48	2.44		1.89	
1-35	50.0-52.5	UU	136.6	9.0	22	16	3.00	15.7	4.14	4.10		1.80	

NOTES:

(1) $\overline{CIU}$ = Isotropically consolidated-undrained triaxial compression test with pore pressure measurements.

(2) UU = Unconsolidated-undrained triaxial compression test.

(3) $\overline{CIU}_s$ = Multiple-stage $\overline{CIU}$ test.

(4) E_i = Initial deformation modulus.

(5) E_{sec} = Deformation modulus at 1/2 of ultimate stress.

(6) E_c = Cyclic deformation modulus.

TABLE 2.5-37

SUMMARY OF EFFECTIVE STRESS PARAMETERS

Stratum	Test Nos.	Dry Unit Weight γ_d (pcf)	Natural Moisture Content W_n (%)	Effective Cohesion $\bar{C}$ (tsf)	Effective Friction Angle $\bar{\phi}$ (degrees)	Pore Pressure Parameter at Failure A_f
Lacustrine	14, 15, 16	92.8 to 94.9	26.3 to 30.4	0	35.0	-0.74 to -0.279
	17, 18, 19	99.7 to 105.0	19.7 to 22.0	0.12	33.5	0.222 to -0.212
	23, 24, 25	102.1 to 107.2	21.3 to 25.7	0	35.0	0.28 to -0.27
Upper Till	7, 8, 9	107.9 to 111.8	18.2 to 19.9	0.33	24.0	0 to 0.33
	20, 21, 22	106.9 to 118.2	15.6 to 21.5	0	35.0	0.2 to -0.13
Lower Till	1, 2, 3	130.3 to 130.8	10.7 to 11.1	0.46	35.0	0.01 to -0.03
	4, 5, 6	129.3 to 132.3	9.8 to 11.3	0.91	35.0	0.06 to -0.03
	10, 11, 12	129.0 to 137.7	9.7 to 11.4	0.44	35.0	-0.02 to -0.12

TABLE 2.5-38

CYCLIC TORSION TEST RESULTS FOR LACUSTRINE SEDIMENTS

Boring No.	Sample Depth (ft)	Test Series No.	Dry Unit Weight γ_d (pcf)	Natural Moisture Content W^n (%)	Consolidation Pressure $\overline{\sigma}_c$ (tsf)	Resonant Frequency f (cps)	Shear Modulus G (ksi)	Damping Ratio D (%)	Shear Strain γ (10^{-2}%)	K_2[(1)]
1-36	5.0- 7.0	1a	93.3	27.6	0.288	186	5.7	7.1	0.9	34
					0.288	174	2.3	15.5	10.2	14
		1b			0.864	207	11.5	4.8	0.7	40
					0.864	187	6.0	7.1	7.0	21
		1c			2.59	235	20.6	3.2	0.44	41
					2.59	222	16.1	3.7	5.17	32
1-23	15.0-17.0	2a	118.9	20.1	0.288	193	7.5	5.9	1.22	45
					0.288	177	3.5	3.8	0.87	21
		2b			0.864	216	14.3	3.8	1.37	50
					0.864	202	10.0	4.9	0.62	35
		2c			2.59	249	26.3	2.8	1.06	53
					2.59	236	20.5	3.2	0.46	41

NOTE:

(1) $G = 1{,}000\ K_2\ (\sigma'_m)^{1/2}$, (Reference 239)

TABLE 2.5-39

CYCLIC TORSION TEST RESULTS FOR UPPER TILL

Boring No.	Sample Depth (ft)	Test Series No.	Dry Unit Weight γ_d (pcf)	Natural Moisture Content W^n (%)	Consolidation Pressure $\overline{\sigma}_c$ (tsf)	Resonant Frequency f (cps)	Shear Modulus G (ksi)	Damping Ratio D (%)	Shear Strain γ (10^{-2}%)	K_2 (1)
1-22A	20.0-22.0	3a	117.9	16.4	0.864	227	18.2	4.5	0.60	63
					0.864	191	7.3	6.1	7.00	25
		3b			1.73	228	17.9	3.4	0.60	44
					1.73	217	14.5	3.9	4.80	35
		3c			3.46	234	20.1	3.2	1.04	35
					3.46	222	16.4	3.7	4.80	28
1-35	25.0-27.0	4a	101.4	21.5	0.864	186	5.7	7.1	1.0	20
					0.864	173	2.6	13.8	8.8	9
		4b			1.73	218	14.7	3.8	1.0	36
					1.73	204	10.5	5.2	5.1	26
		4c			3.46	245	23.8	3.0	0.74	41
					3.46	233	19.6	3.5	4.10	34

NOTE:

(1) $G = 1,000\ K_2\ (\sigma'_m)^{1/2}$, (Reference 239)

TABLE 2.5-40

CYCLIC TORSION TEST RESULTS FOR LOWER TILL

Boring No.	Sample Depth (ft)	Test Series No.	Dry Unit Weight γ_d (pcf)	Natural Moisture Content W^n (%)	Consolidation Pressure $\overline{\sigma}_c$ (tsf)	Resonant Frequency f (cps)	Shear Modulus G (ksi)	Damping Ratio D (%)	Shear Strain γ (10^{-2}%)	K_2 (1)
TC-1	44.5	5a	132.3	10.2	1.66	277	34.4	4.0	1.22	86
		5b			3.31	292	40.2	3.7	1.15	71
		5c			6.62	322	52.5	3.4	0.92	69
TC-1	50.5	6a	144.1	8.4	1.87	284	36.6	3.8	1.22	87
		6b			3.74	300	44.0	3.6	1.19	73
		6c			7.49	388	84.5	3.3	0.72	100
TC-2	45.0	7a	138.8	9.9	1.66	296	38.5	4.2	0.009	96
					1.66	288	35.4	4.5	0.55	89
					1.66	273	30.8	3.5	1.40	77
		7b			3.31	330	51.5	3.4	0.14	91
					3.31	332	52.3	3.0	0.37	92
					3.31	320	48.4	3.1	1.16	86
		7c			6.62	371	70.3	4.6	0.20	92
					6.62	369	69.8	4.6	0.39	91
					6.62	364	67.2	3.6	0.93	88

NOTE:

(1) $G = 1{,}000\ K_2\ (\sigma'_m)^{1/2}$, (Reference 239)

TABLE 2.5-41

DYNAMIC PROPERTIES OF SOIL MATERIALS BY IN SITU SHEAR WAVE VELOCITY MEASUREMENTS

Stratigraphic Unit	Shear Wave Velocity V_s (fps)	Void Ratio e	Mean Principal Effective Stress σ'_m (psf)	Shear Wave Basis: Maximum Shear Modulus G_{max} (ksi)(1)	Shear Wave Basis: K_2(3)	Void Ratio Basis: Maximum Shear Modulus G_{max} (ksi)(2)	Void Ratio Basis: K_2(3)
Lacustrine Soils	700	0.645	1,100	13	56	12.0	52.0
	1,200	0.640	1,600	40	144	14.5	51.9
Upper Till	1,900	0.530	2,360	103	306	22.2	65.9
Lower Till	2,600	0.283	3,680	206	490	40.3	95.5

NOTES:

(1) $G_{max} = V_s^2 \rho$ (shear wave basis); where: ρ = mass density.

(2) $G_{max} = 14{,}760 \left(\frac{2.973-e^2}{1+e}\right) (OCR)^{0.1} (\sigma m')^{0.5}$ (void ratio basis); where: OCR = over-consolidation ratio.

(3) $K_2 = G_{max}/1{,}000\ (\sigma'_m)^{1/2}$

TABLE 2.5-42

PINHOLE TEST RESULTS ON LOWER TILL

Sample No.	Head (in.)	Flow (ml/sec)	Color[1]	Dispersion[2] Classification
1	2	3.6	B	D1
2	2	0.17	C	
	6.75	0.5	C	
	15	4.0	A	ND3
3	2	0.15	C	
	6.75	0.4	B	
	15	3.5	B	ND3
4	2	0.16	C	
	6.75	0.4	C	
	15	0.9	C	
	40	5.9	B	ND2
5	2	0.12	C	
	6.75	0.8	C	
	15	3.0	C	
	40	5.4	B	ND3

NOTES:

(1) Color Code:
A = Dark
B = Slight to medium
C = Barely visible
D = Completely clear

(2) Dispersion Code:
D1, D2 = Dispersive and erodible
ND1, ND2 = Nondispersive and highly erosion-resistant
ND3, ND4 = Nondispersive and intermediate erosion-resistant

TABLE 2.5-43

DISSOLVED CATIONS IN SATURATION EXTRACT - LOWER TILL

Sample No.	Concentration (meq/liter)				Percent Sodium
	Sodium	Calcium	Magnesium	Potassium	
1	9.14	10.78	4.28	0.89	36.4
2	7.61	9.98	3.29	0.89	35.0
3	6.09	7.98	3.78	0.69	32.8
4	8.27	11.58	5.43	0.97	31.5
5	7.48	12.77	6.00	0.84	27.6

TABLE 2.5-44

APPROXIMATE PERCENTAGES OF PRINCIPAL MINERALS AND ROCK FRAGMENTS IN LOWER TILL

Sample	PT-4 (47.5 ft)	PT-4A (41.5 ft)	PT-1A (41.0 ft)	PT-1A (48.5 ft)
Silt/Clay Matrix	70%	70%	40%	40%
Quartz	7	10	10	7
Feldspar	2	3	3	2
Opaques	2	2	3	7
Pyroxene & Amphibole	P[1]	P[1]	P[1]	P[1]
Silty Shale	10	10	30	25
Sandy Shale	5	3	15	10
Quartzite	P[1]	P[1]	-	P[1]
Carbonate	2	P	2	5

NOTE:

[1] P = Present

TABLE 2.5-45

SUMMARY OF LABORATORY TEST RESULTS

Shale

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests Notes (1.2)	Natural Water Content (%)	Atterberg Limits		Uncon Compress		Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size		Opt Moist	Consolid.	Triaxial			
					Liquid Limit	Plastic Limit	Stress (tsf)	Strain (%)			Sieve	Hydr.			U.U.	CIU	Cell Press (psi)	Back Press (psi)
1-1	124.5	SH					541.0	.91										
1-2																		
S-13	59.5-59.8	SH		1.6														
	135.0	SH		1.3	19	18				2.75	See Note[4]	See Note[4]						
1-8										160.3								
	71.0				20	17			@2.9%									
1-9										164.0								
	67.0	SH																
1-10	57.0	SH	(S)[1]		20	18				2.69	See Note[4]	See Note[4]						
	60.0	SH	(S)[1]		20	19					See Note[4]	See Note[4]						
1-13	61.0	SH	(S)[1]								See Note[4]	See Note[4]						
	67.0	SH	(S)[1]		2	20				2.72	See Note[4]	See Note[4]						
1-22									129.5									
	94.0	SH	(SV)[2]		18	15	194.9	.60	@7.0%	2.79	See Note[4]	See Note[4]						
	146.0	SH								2.73	See Note[4]	See Note[4]						
1-22																		
P2	63.5	SH			20	15												
										130.1								
	78.0	SH		8.7														
										158.1								
	97.5	SH		3.4														

TABLE 2.5-45 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests Notes (1.2)	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
1-22 P2	114.0	SH		2.9					160.4									
	136.5	SH		3.2					159.1									
	146-146.5	SH	(X-D)[3]	2.2	20	15				2.73								
1-23	59.0	SH			20	16	356.0	0.90	102.1 @9.7%	2.74	See Note[4]	See Note[4]						
1-30	59.0	SH		0.9	20	17				2.75	See Note[4]	See Note[4]						
1-31	66.5	SH	(SV)[2]		18	16	223.3	.90	139.0 @11.0	2.73	See Note[4]	See Note[4]						
	97.0-98.0	SH			19	14			170.0 @5.8%	2.75	See Note[4]	See Note[4]						
	100-101.0	SH			19	14			152.4 @4.7%	2.80	See Note[4]	See Note[4]						
1-32	111.0	SH	(X-D)[3]		23	17			159.7 @3.6%					See Note[4]				
1-33	59.0	SH	(SV)[2]				356.5	.90										
	152.0	SH	(SV)[2]		18	16	302.6	.50	118.5 @4.5%	2.73								
	161.5	SH	(SV)[2]				441.0	.50	86.3 @4.7%									
	165.5	SH	(SV)[2]				168.5	.98	142.3 @2.7%									

TABLE 2.5-45 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests Notes (1.2)	Natural Water Content (%)	Atterberg Limits		Uncon Compress		Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size		Opt Moist	Consolid.	Triaxial			
					Liquid Limit	Plastic Limit	Stress (tsf)	Strain (%)			Sieve	Hydr.			U.U.	CIU	Cell Press (psi)	Back Press (psi)
1-33	177.0	SH	(SV)[2]		20	17	55.9	1.20	96.4 @3.0%	2.69	See Note[4]	See Note[4]						
	203.7-204	SH	(SV)[2]		19	14	97.0	1.40	110.9 @2.6%									
1-36 P2	63.5-63.7	SH		3.4														
1-36 P2	64.4-64.5	SH		4.8														
	64.5-64.7	SH		3.7														
	64.7-65.3	SH		4.5														
	65.5-66.0	SH		3.7														
	66.0-66.3	SH		4.2														
	66.3-66.35	SH		3.8														
	66.35-66.4	SH		4.0														
	66.4-66.5	SH		4.5														
	68.2-68.5	SH		3.6														
	69.5-70.0	SH		6.3					148.1 @6.3%									
	70.0-70.7	SH		2.2														
	72.0-72.5	SH		1.5														
	74.3-74.9	SH			19	18			160.7 @4.1%	2.70	See Note[4]	See Note[4]		See Note[4]				

TABLE 2.5-45 (Continued)

Boring and Sample No.	Depth (ft)	Classi- fication	Special Tests Notes (1.2)	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe- cific Grav- ity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
1-36 P2									154.2 @4.1%									
	75.9-76.5	SH	(X-D)[3]	2.2	19	15				2.72	See Note[4]	See Note[4]						
	80.7-81.2	SH		4.1														
1-36 P2	82.0-82.5	SH		7.0					124.8 @7.0%									
	83.5-84.0	SH		3.5														
	85.9-86.5	SH		3.8														
	87.5-88.0	SH		3.8														
1-36	90.0-90.7	SH		1.4														
	95.1-95.7	SH			19	13			166.3 @3.9%		See Note[4]	See Note[4]		See Note[4]				
									156.5 @3.9%	2.83								
	111-111.5	SH		3.2	20	15				2.80								
		153.0							158.0 @3.1%					See Note[4]				
Combined	57-147	SH									See Note[4]	See Note[4]						
1-1	62	SH (tested by Herron Testing Labs)					102.4											
	66	SH (tested by Herron Testing Labs)					118.3											

TABLE 2.5-45 (Continued)

Boring and Sample No.	Depth (ft)	Classi-fication	Special Tests Notes (1.2)	Natural Water Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Uncon Compress Stress (tsf)	Uncon Compress Strain (%)	Unit Dry Wt. (pcf)	Spe-cific Grav-ity	Grain Size Sieve	Hydr.	Opt Moist	Consolid.	Triaxial U.U.	Triaxial CIU	Triaxial Cell Press (psi)	Triaxial Back Press (psi)
1-1	73	SH (tested by Herron Testing Labs)					135.4											
	105	SH (tested by Herron Testing Labs)					178.3											
1-3																		
	67	SH (tested by Herron Testing Labs)					206.0											
1-5																		
	68.5	SH (tested by Herron Testing Labs)					123.9											

NOTES:

(1) (S) = Slake Test
(2) (SV) = Sonic Velocity
(3) (X-D) = X- ray Diffraction
(4) See test curves

TABLE 2.5-46

PHYSICAL PROPERTIES OF CHAGRIN SHALE

Range	Natural Water Content W_n (%)	Dry Unit Weight γ_d (pcf)	Specific Gravity G_s	Liquid Limit LL (%)[1]	Plasticity Index PI (%)[1]	Silt-Clay[1] (%)
Minimum	0.9	86.3	2.69	18	1	46
Maximum	11.0	170.0	2.83	23	6	62
Average	4.1	142.0	2.74	20	3	55
No. of Tests	48	24	17	21	21	17

NOTE:

(1) Liquid limit, plasticity index and silt-clay determined on sample reduced by grinding.

TABLE 2.5-47

MINERAL COMPOSITION OF CHAGRIN SHALE[1]

Component	Maximum (%)	Minimum (%)	Average (%)
Quartz	54	5	21
Muscovite	12	6	8
Chlorite	8	4	6.5
Illite-Chlorite Matrix	76	18	53.5
Opaques	15	2	7
Feldspar	1	Trace	Trace
Carbonate	1	Trace	Trace
Unidentified	9	0	2.5
Illite/Chlorite Ratio	9/1	1.3/1	3/1

NOTE:

(1) Based on six tests.

TABLE 2.5-48

JAR SLAKING TEST RESULTS - CHAGRIN SHALE

	Specimen No.			
	1	2	3	4
Initial Wet Weight, g	229.9	337.8	248.9	328.5
Initial Dry Weight, g	N/A	329.8	N/A	310.9
Maximum Wet Weight, g	234.9	340.3	252.2	336.8
Final Wet Weight, g	234.3	340.3	25.2	313.5
Final Dry Weight, g	N/A	329.7	N/A	282.7
Wet Slaking Loss, %	0.3	0.0	0.0	6.9
Dry Slaking Loss, %	N/A	0.0	N/A	9.1

TABLE 2.5-49

SUMMARY OF UNCONFINED COMPRESSION TESTS ON CHAGRIN SHALE

Boring No.	Sample Depth (ft)	Dry Unit Weight γ_d (pcf)	Natural Moisture Content W_n (%)	Liquid Limit LL (%)	Plasticity Index PI (%)	Shear Strength (tsf)	Strain at Failure ε_f (%)	Deformation Moduli (ksi) E_i [1]	E_{sec} [2]
1-1	124.5	164.7	2.1			271.0	0.91	920	740
1-31	66.5	139.0	11.0	18	2	112.0	0.90	458	278
1-22	94.0	129.5	7.0	18	3	97.0	0.60	630	431
1-33	165.5	142.3	2.7			84.0	0.98	340	222
1-33	204.0	110.9	2.6	19	5	48.0	1.40	135	87
1-33	161.5	150.0	4.7			220.0	0.50	1,650	1,420
1-23	59.0	112.0	9.7	20	4	178.0	0.90	785	514
1-33	152.0	154.0	4.5	18	2	151.0	0.50	934	934
1-33	177.0	96.4	3.0	20	3	28.0	1.20	68	60
5-3	78.4	159.7	3.1			91.0	1.62	112	163
5-1	113.1	158.9	2.6			100.0	2.07	125	93
5-5	92.3	161.1	2.5			126.0	0.45	800	625

TABLE 2.5-49 (Continued)

Boring No.	Sample Depth (ft)	Dry Unit Weight γ_d (pcf)	Natural Moisture Content W_n (%)	Liquid Limit LL (%)	Plasticity Index PI (%)	Shear Strength (tsf)	Strain at Failure ε_f (%)	Deformation Moduli (ksi) E_i [1]	E_{sec} [2]
5-3	89.8	155.1	1.0			123.0	0.94	828	550
5-8	119.0	135.7	2.4			168.0	0.74	987	837
1-1	62.0					102.4			
1-1	66.0					118.3			
1-1	73.0					135.4			
1-1	105.0					178.3			
1-3	67.0					206.0			
1-5	68.5					123.9			

NOTES:

(1) E_i = Initial deformation modulus.

(2) E_{sec} = Deformation modulus at 1/2 of ultimate stress.

TABLE 2.5-50

SUMMARY OF OEDOMETER TESTS ON CHAGRIN SHALE

Boring No.	Sample Depth (ft)	Dry Unit Weight γ_d (pcf)	Natural Moisture Content W_n (%)	Plasticity Index PI (%)	Preconsolidation Pressure P_c (tsf)	Overconsolidation Ratio P_c/P_o	Initial Void Ratio e_o	Swell Pressure (tsf)	Recompression Index C'_r (1)(2)	Swelling Index C'_s (1)(2)	Compression Index C'_c (2)	Test Condition
1-32	111.0	159.7	3.6	6	30	6.3	0.066	0.75	0.0019 to 0.0052 (0.0037)	0.0036 to 0.0058 (0.0047)	0.025	Dry
1-36P2	152.0	158.0	3.1	2	20	2.9	0.079	0.75	0.002	0.002	0.0053	Dry
1-8	71.0	158.0	3.8	3	-	-	0.068	2.60	0.0015 to 0.0086	0.0055	-	Added Water
1-36P2	74.6	154.2	4.1	1	9	3.0	0.100	9.00	0.0021	0.005 to 0.007 (0.006)	0.034	Added Water
1-36P2	95.4	156.5	3.9	6	20	5.0	0.088	0.75	0.0033	0.0036	0.025	Added Water
1-36P2	111.3	172.4	3.8	5	25	5.5	0.125	-	0.0069	0.0060	0.035	Added Water

NOTES:

(1) ( ) = Average.
(2) C'_r, C'_s and C'_c are derived from slope of log pressure vs. unit strain curve.

TABLE 2.5-51

DRAINED DEFORMATION MODULI OF CHAGRIN SHALE[1]

Boring No.	Sample Depth (ft)	Average Effective Stress $\bar{\sigma}_{avg}$ (tsf)	Recompression Index Ratio[2]	Constrained Modulus E_d (ksi)	Deformation Modulus E_s (ksi)
1-8	71.0	6.1	0.0045	44.0	26.2
1-32	111.0	4.6	0.0020	74.0	44.0
1-36P2	74.5	6.1	0.0050	40.0	23.8
1-36P2	95.4	4.9	0.0033	47.5	28.3
1-36P2	111.3	7.5	0.0069	35.2	20.9
1-36P2	152.0	6.1	0.0020	97.0	57.8

NOTES:

[1] Poisson's Ratio assumed to be 0.36

[2] Compression Index Ratio = $C'_r/(1 - \varepsilon_o)$ (Unit strain basis)

TABLE 2.5-52

DRAINED DEFORMATION MODULUS OF SHALE FROM STRESS PATH TESTS

Simulated Construction Activities	Stress Conditions (tsf) Initial $p^{(1)}$	Initial $q^{(2)}$	Final $p^{(1)}$	Final $q^{(2)}$	$\Delta\left(\bar{\sigma}_1 - \bar{\sigma}_3\right)^{(3)(4)}$ (tsf)	Test No.	Strain ($\varepsilon \times 10^{-4}$)	Deformation Modulus Es (ksi)
Excavation Unloading	8.85		8.59	-0.396	-0.792	1	2.58	42.7
						2	2.53	43.5
	8.59	-3.96	8.25	-0.800	-0.810	1	2.97	38.1
						2	2.87	39.4
	8.25	-8.00	7.87	-1.260	-0.880	1	5.35	22.8
						2	9.20	13.3
Construction Loading	7.87	-1.260	8.07	-1.100	+0.320	1	2.18	20.5
						2	3.37	13.4
	8.07	-1.100	8.13	-0.935	+0.330	1	1.58	28.4
						2	1.29	35.0
	8.13	-0.935	8.28	-0.778	+0.320	1	1.58	26.8
						2	1.03	43.7
	8.28	-0.778	8.40	-0.612	+0.330	1	0.99	45.5
						2	0.99	45.5
	8.40	-0.612	8.54	-4.53	+0.320	1	0.99	45.5
						2	1.05	42.8
	8.54	-4.53	9.24	+0.390	+1.670	1	3.56	65.0
						2	2.32	100.0

TABLE 2.5-52 (Continued)

NOTES:

(1) $p = \frac{\overline{\sigma}_1 + \overline{\sigma}_3}{2}$

(2) $q = \frac{\overline{\sigma}_1 - \overline{\sigma}_3}{2}$

(3) $\overline{\sigma}_1$ = Effective major principal stress

(4) $\overline{\sigma}_3$ = Effective minor principal stress

TABLE 2.5-53

SUMMARY OF STRESS-CONTROLLED UNDRAINED CYCLIC TRIAXIAL COMPRESSION TESTS ON SHALE

Boring No.	Sample Depth (ft)	Cyclic Stress Difference Range (tsf)	Cyclic Strain (%)	Cyclic Modulus E_c (ksi)
1-1	133.5	0 to 4	0.131	42.4
			0.053	105.0
		0 to 8	0.0098	1,133.3
1-1	145.0	0 to 4	0.053	104.9
			0.019	300.0
			0.018	310.0
			0.014	386.0
			0.012	451.4
		0 to 8	0.0062	895.8

TABLE 2.5-54

PRESSUREMETER TEST RESULTS IN SHALE

Hole No.	Test Depth (ft)	Test Elevation (ft)	Dry Unit Weight γ_d (pcf)	Natural Moisture W_n (%)	Plasticity Index PI (%)	Plastic Yield Pressure P_1 (tsf)	Modulus of Compressibility E_1 (ksi)	Cyclic Modulus of Compressibility E_c (ksi)
1-22P	48.3	557.9	142.5	4.0	4	48.0+	66	151
	53.3	552.9	-	-	-	45.4+	232	-
	55.5	550.7	150.5	3.5	3	98.0	616	-
	58.0	548.2	-	-	-	45.0+	151	287
	60.0	546.2	152.0	4.0	4	55.0+	102	696
	65.0	541.2	158.0	4.5	5	50.0+	128	128
	93.0	513.2	161.0	5.0	3	55.0+	196	328
	98.0	508.2	158.1	3.4	5	105.0	143	-
	146.5	459.7	159.1	3.2	5	60.0+	843	847
1-36P2	60.0	562.8	-	-	-	36.0+	20	41
	65.0	557.8	145.5	3.4	4	21.0	9.7	-
	72.5	550.3	150.0	1.5	1	40.0+	32	259
	80.0	542.8	124.8	7.0	5	45.0+	69	348
	87.5	535.3	159.0	3.8	4	46.0+	191	557
	101.5	521.3	-	-	-	50.0+	250	258
	106.5	516.3	161.0	5.0	5	30.0+	158	396
	141.5	481.3	-	-	-	60.0+	209	434
	146.5	476.3	158.0	3.0	2	60.0+	167	650

TABLE 2.5-55

VERTICAL PLATE LOADING TEST RESULTS IN SHALE[1]

Inspection Shaft No.	Test No.	Test Elev. (ft)	Dry Unit Weight γ_d (pcf)	Natural Moisture Content W_n (%)	Plasticity Index PI (%)	Effective Overburden Pressure P_o (tsf)	Preconsolidation Pressure P_c (tsf)	Over-Consolidation Ratio P_c/P_o	Compressibility Moduli E_1[2] (ksi)	E_2[3] (ksi)	E_c[4] (ksi)
TC-1	VB-4	560.8	140.0	3.2 to 4.6	4	2.30	12.8	5.1	618.0	298.0	1,450.0
TC-2	VB-4	560.9	140.0	4.0	5	2.30	6.8	3.0	1,180.0	665.0	>1,450.0

NOTES:

(1) Plate diameter = 22 inches; shape and depth correction factor = 0.59
(2) E_1 = Modulus at pressures $<P_c$
(3) E_2 = Modulus at pressures $>P_c$
(4) E_c = Unload-reload modulus

TABLE 2.5-56

SUMMARY OF SONIC VELOCITY TEST RESULTS ON SHALE

Boring Number	Sample Elevation (ft)	Total Unit Weight γ_t (pcf)	Applied Axial Stress (ksf)	Compressional Wave Velocity V_p (fps)	Shear Wave Velocity V_s (fps)	Poisson's Ratio μ	Shear Modulus G (ksi)	Deformation Modulus E (ksi)
1-23	555.0	166.7	16.3	6,700	4,150	0.188	615	1,642
			26.3	8,430	4,550	0.294	743	1,924
1-31	553.4	172.0	27.2	7,800	4,630	0.227	795	1,953
1-31	522.4	165.9	10.5 (1)	9,260	4,860	0.310	844	2,212
			20.5	10,230	5,110	0.333	934	2,491
			30.5	10,790	5,320	0.339	1,011	2,710
1-31	519.9	163.9	10.8 (1)	8,220	4,460	0.291	703	1,816
			10.8	8,930	4,660	0.312	768	2,016
			30.8	9,330	4,880	0.311	842	2,209
1-22	512.1	165.6	10.2 (1)	7,340	4,300	0.238	665	1,649
			20.2	8,390	4,690	0.273	785	1,998
			30.2	8,960	4,800	0.298	823	2,138
1-33	469.9	160.9	16.6 (1)	8,960	5,570	0.184	1,077	2,552
			26.6	11,280	5,850	0.316	1,185	3,120
			36.6	11,840	5,920	0.333	1,214	3,239
1-33	460.9	164.2	27.7	8,150	4,980	0.202	878	2,111
			37.7	9,070	5,680	0.177	1,143	2,690

TABLE 2.5-56 (Continued)

Boring Number	Sample Elevation (ft)	Total Unit Weight γ_t (pcf)	Applied Axial Stress (ksf)	Compressional Wave Velocity V_p (fps)	Shear Wave Velocity V_s (fps)	Poisson's Ratio μ	Shear Modulus G (ksi)	Deformation Modulus E (ksi)
1-33	456.4	164.0	18.0[1]	7,170	4,600	0.150	1,889	4,343
			28.0	7,650	4,670	0.204	1,941	4,675
			38.0	7,830	4,730	0.213	1,995	4,839
1-33	444.9	165.9	19.4[1]	9,260	5,110	0.281	935	2,395
			29.4	9,970	5,550	0.276	1,100	2,806
			39.4	10,790	5,710	0.306	1,164	3,040
Seismic Cross-Hole	560.0 to 510.0			10,400	4,900	0.36	897	2,434
Seismic Down-Hole	560.0 to 410.0			9,000	4,000	0.38	597	1,645

NOTE:

(1) Equivalent overburden pressure

TABLE 2.5-57

MATERIAL PROPERTIES ADOPTED FOR DESIGN

Stratigraphic Unit	Saturated Unit Weight γ_{sat} (pcf)	Shear Strength[1] τ (tsf)	Undrained Shear Strength S_u (tsf)
Lacustrine	131	$0.12 + \sigma_n \tan 33.5°$ $0.12 + \bar{\sigma}_n \tan 31°$[2]	0.75
Upper Till	130	$0 + \bar{\sigma}_n \tan 35°$ $0.12 + \bar{\sigma}_n \tan 31°$[2]	1.0
Lower Till	142	$0.60 + \bar{\sigma}_n \tan 35°$	5.5
Chagrin Shale	152	-	130

NOTES:

(1) Effective stress basis; $\tau = \bar{c} + \bar{\sigma}_n \tan \bar{\phi}$

where: $\bar{c}$ = Effective cohesion, tsf

$\bar{\sigma}_n$ = Effective normal stress, tsf

$\bar{\phi}$ = Effective friction angle, degrees

(2) Strength parameters used for the Lake Erie Bluff Stability Analysis shown on <Figure 2.5-209> and <Figure 2.5-210>.

TABLE 2.5-58

ONE DIMENSIONAL CONSOLIDATION PROPERTIES ADOPTED FOR DESIGN

Stratigraphic Unit	Compression Index C'_c	Recompression Index C'_r	Swelling Index C'_s	Effective Preconsolidation Pressure (tsf)	Coefficient of Consolidation cm^2/sec	Initial Void Ratio e_o
Lower Till	0.043	0.006	0.006	6	0.086	0.286
Shale, surficial	0.025	0.004	0.0055	24	0.010	0.088
Shale	0.025	0.0028	0.004	24	0.010	0.088

TABLE 2.5-59

DRAINED AND UNDRAINED DEFORMATION PROPERTIES ADOPTED FOR DESIGN

	Undrained			Drained		
Unit	k	n	Poisson's Ratio	k	n	Poisson's Ratio
Lower Till	700	1.0	0.50	530	1.0	0.44
Shale[1]	See Note[2]	0	0.50	11,000[3] 15,000	0	0.48
Shale	See Note[2]	0	0.50	48,000	0	0.35

NOTES:

[1] Surficial zone
[2] Conservatively assumed equal to drained values

$$E_s = k\,P_a \frac{(P_c)^n}{P_a}$$

where:

P_a = Atmospheric pressure

P_c = Preconsolidation pressure

[3] For excavation unload

Revision 12
January, 2003

TABLE 2.5-60

DYNAMIC SOIL PROPERTIES ADOPTED FOR DESIGN

Stratigraphic Unit	Maximum Shear Modulus G_{max} (ksi) (min)	(max)	Damping Ratio D (%) (min)	(max)	Shear Wave Velocity V_s (ft/sec) (min)	(max)
Lacustrine	12	24	3.7	7.1	NA[1]	NA[1]
Upper Till	17	29	3.2	4.5	NA[1]	NA[1]
Lower Till	85	110	3.0	3.4	NA[1]	NA[1]
Shale	597	897	NA[1]	NA[1]	4,000	4,900

NOTE:

[1] NA = Not Applicable

TABLE 2.5-61

PLANT SITE STRATIGRAPHY

Stratum	Elevation at Top of Stratum (ft) Minimum	Maximum	Average	Average Thickness (ft)
Lacustrine	616	624	622	28
Upper Till	591	597	594	8
Lower Till	582	589	586	21
Chagrin Shale	556	572	565	1,000+

TABLE 2.5-62

SUMMARY OF LABORATORY TESTS - OFFSHORE CHAGRIN SHALE SAMPLES

Boring	Depth	Moisture Content, %	Dry Density pcf	Unconfined Compression Test: Strength tsf	Strength psi	Deformation Modulus tsf	Deformation Modulus psi x 10^6	Description
5-1	113.1	2.6	158.9	199.7	2,790	9,000	0.125	Dark gray shale composed of layers of dark gray clay shale; medium gray silt-stone up to 1/8" thick; and light gray, fine-grained sandstone up to 1/16" thick.
5-3	78.4	3.1	159.7	181.96	2,530	11,240	0.156	Dark gray shale composed of layers of clay shale, siltstone and fine-grained sandstone up to 1/16" thick.
5-3	89.8	0.1	170.5	245.27	3,410	59,500	0.829	Dark and light gray shale composed of layers of clay shale up to 1/4" thick; siltstone 1/8" to 1/4" thick; and fine-grained sandstone 1/32" to 1/16" thick.

TABLE 2.5-62 (Continued)

				Unconfined Compression Test				
				Strength		Deformation Modulus		
Boring	Depth	Moisture Content, %	Dry Density pcf	tsf	psi	tsf	psi x 10^6	Description
5-5	92.3	2.5	161.1	252.3	3,500	57,000	0.801	Dark gray shale composed of layers of clay shale up to 1/4″ thick, silt-stone 1/32″ to 3/16″ thick, and fine-grained sandstone 1/32″ to 1/16″ thick.
5-8	119.0	2.4	135.7	315.8	4,390	71,000	0.986	Dark gray shale composed of layers of clay shale up to 1/2″ thick, siltstone up to 1/4″ thick, and fine-grained sandstone up to 1/8″ thick.

TABLE 2.5-63

GAS FLOW MEASUREMENTS IN BORING 1-55

Depth Interval (ft)	Initial Shut-in Pressure P_o (psi)	Pressure During Flow Measurement P_f (psi)	Measured Flow[1] q (cfm)	Flow Rate Per Test Hole Area q/A_s (cfm/ft^2)
106-120	32.0	0.4	1.4	0.127
124-140	39.0	0.6	1.4	0.110
145-160	37.0	0.7	1.6	0.136
158-210	43.8	1.9	4.0	0.098

NOTE:

(1) Uncorrected for gas volume and specific gravity

TABLE 2.5-64

CHROMATOGRAPHY AND PROPERTY ANALYSIS

Gas Constituent and Properties	Volume (%) Boring 1-55	Boring 1-56
Helium	-	0.06
Hydrogen	0.00	0.00
Oxygen	0.02	0.01
Nitrogen	0.57	0.65
Methane	99.00	94.51
Ethane	0.21	3.61
Carbon Dioxide	0.16	0.16
Propane	0.04	0.72
Iso-butane	Trace	0.10
Normal Butane	0.00	0.11
Neo-pentane	0.00	0.00
Iso-pentane	0.00	0.03
Normal Pentane	0.00	0.02
Hexanes +	-	0.02
Sulfur (ppm by weight)	-	1.20
Specific Gravity	0.5601	0.5877
Gross Heating Value (Btu/scf)	1,000.8	1,050.8

Sample @ 1-55: Depth 102 to 120 ft, pressure 30 psig

Sample @ 1-56: Open hole sample

TABLE 2.5-65

PROPERTIES FOR GAS MIGRATION ANALYSES

Material	Coefficient of Permeability k (darcy)	Threshold Pressure P_t (psi)	Diffusion Coefficient De (ft^2/sec)
Shale	1.0×10^{-5}	1,000+	4.52×10^{-8}
Concrete	0.7×10^{-3}	60	3.23×10^{-5}

Viscosity of Methane = 0.010 centipoise

TABLE 2.5-66

CERTIFICATION TEST RESULTS ON CLASS A FILL

	Bestone Quarry	Sidley Quarry	Specified
a. Gradation Sieve Size	Percent Finer by Weight		
2″	100.0	100.0	100
3/4″	97.2 - 99.5	100.0	85 - 100
No. 4	68.5 - 77.2	91.3 - 97.8	60 - 100
No. 10	39.9 - 51.0	64.5 - 75.7	43 - 80
No. 40	27.6 - 35.9	19.0 - 28.0	16 - 45
No. 200	1.0 - 3.2	0.5 - 1.5	0 - 5
Uniformity Coefficient	13.2 - 20.2	4.4 - 5.9	4 - 20
b. Specific Gravity	2.66	2.66	2.65 min
c. Unit Weight at Relative Density of 85% (pcf)	132.5	122.7	120 min(1)
d. Abrasion Loss (%)	35.6	22.5	50 max
e. Sodium Sulfate Loss (%)	6.4	1.8	12.0 max
f. Coefficient of Permeability (cm/sec x 10^{-3})	0.36	8.5	5.0 min
g. Initial Tangent Modulus Coefficient	1,200	756	700 min
h. Effective Friction Angle degrees)	42	40	35 min

TABLE 2.5-66 (Continued)

	Bestone Quarry	Sidley Quarry	Specified
i. Shear Modulus Coefficient	78.0	82.4	76 - 92

NOTE:

(1) After May 1994, the requirement to achieve the specific value of 120 PCF for Unit Weight at 85% Relative Density is deleted. Verification of this value is not significant for controlling compaction.

TABLE 2.5-67

SUMMARY OF PIEZOMETER INSTALLATIONS AND OBSERVATIONS

Piezometer No.	Piezometer Type	Ground Surface Elev. (ft)	Tip Elev. (ft)	Stratum Monitored	Date Installed	Groundwater Observations[1] Elev. (ft)	Date	Elev. (ft)	Date	Elev. (ft)	Date	Elev. (ft)	Date
WP-1	Heavy-Liquid	622.8	573.8	Lower Till	7/11/72	589.1	7/11/72	603.8	7/12/72	616.7	7/17/72	608.3	7/28/72
WP-2	Double-Tube	625.2	577.7	Lower Till	7/07/72	623.2	7/07/72	615.2	7/17/72	620.0	7/24/72	619.2	7/28/72
WP-3a		618.8	585.8	Upper Till	6/29/72	610.3	6/29/72	611.7	6/30/72	615.8	7/10/72	612.1	12/07/72
-3b		619.2	571.7	Lower Till	6/30/72	610.4	6/30/72	609.3	11/10/72	618.8	7/01/72	608.7	12/07/72
-3c		619.4	554.9	Shale	6/29/72	610.4	6/29/72	609.9	7/28/72	611.3	7/30/72	609.9	12/07/72
WP-4a	Pneumatic	620.4	588.9	Upper Till	6/13/72	613.8	6/13/72	613.3	6/14/72	616.6	7/01/72	614.6	12/07/72
-4b		620.0	572.0	Lower Till	6/12/72	608.0	6/12/72	615.9	6/22/72	617.0	6/15/72	616.5	7/28/72
-4c		619.7	556.1	Shale	6/09/72	611.4	6/09/72	611.4	6/09/72	612.9	7/28/72	611.8	12/07/72
WP-5a		623.2	591.2	Upper Till	6/23/72	616.6	6/23/72	618.7	7/26/72	620.5	6/27/72	619.7	12/07/72
-5b		623.3	573.8	Lower Till	6/21/72	620.2	6/21/72	619.9	6/22/72	622.9	7/13/72	620.8	12/07/72
-5c		623.3	560.6	Shale	6/16/72	620.6	6/16/72	615.6	12/07/72	620.6	6/16/72	615.6	12/07/72

NOTE:

[1] Selected readings representing the initial, minimum, maximum, and last piezometric level or record.

TABLE 2.5-68

PERMEABILITY TEST RESULTS IN SHALE - INITIAL INVESTIGATIONS

Boring No.	Test Section Depth (ft)	Test Section Length (cm)	Measured Flow (cm^3/sec)	Corrected Flow[1] (cm^3/sec)	Test Section Diameter (cm)	Excess Head (cm)	Corrected Coefficient of Permeability (cm/sec)
1-68	68.5-78.5	305	0	13.87	7.57	3,654	8.69×10^{-6}
	63.5-78.5	457	6.31	14.19	7.57	3,654	6.33×10^{-6}
	58.5-78.5	607	8.20	14.50	7.57	3,654	4.58×10^{-6}
	58.5-78.5	607	11.98	15.13	7.57	3,654	5.51×10^{-6}
	56.0-78.5	686	8.20	14.50	7.57	3,654	4.58×10^{-6}
	52.0-78.5	808	6.94	14.31	7.57	3,654	4.14×10^{-6}
1-70	68.0-73.0	152	0	13.87	7.57	3,627	1.49×10^{-5}
	63.0-73.0	305	0	13.87	7.57	3,627	8.67×10^{-6}
	58.0-73.0	457	0	13.87	7.57	2,569	9.02×10^{-6}
	52.0-73.0	640	0	13.87	7.57	3,627	4.87×10^{-6}
1-71	68.3-73.5	157	0	13.87	7.57	3,520	1.49×10^{-5}
	63.3-73.5	310	3.15	13.94	7.57	3,414	9.24×10^{-6}
	58.5-63.75	160	0	13.87	7.57	3,627	1.42×10^{-5}
	53.5-58.75	160	0	13.87	7.57	1,509	3.42×10^{-5}
	57.0-62.25	160	0	13.87	7.57	3,627	1.42×10^{-5}
	57.0-73.5	503	0	13.87	7.57	3,627	5.92×10^{-6}
1-74	64.5-74.5	305	0	13.87	7.57	3,658	8.69×10^{-6}
	54.0-74.5	625	5.30	14.12	7.57	3,658	5.02×10^{-6}
	59.0-74.5	472	1.39	13.87	7.57	3,658	6.18×10^{-6}
	54.0-59.25	160	0.63	13.87	7.57	3,658	1.41×10^{-5}
	57.5-62.75	160	0	13.87	7.57	3,658	1.41×10^{-5}
	60.0-65.25	160	1.14	13.87	7.57	3,658	1.41×10^{-5}
	62.0-67.25	160	0	13.87	7.57	3,658	1.41×10^{-5}

NOTE:

[1] Where measured flow is zero, permeability is conservatively based on an assumed flow of 13.87 cm^3/sec, the minimum rate of flow which would activate the water meter.

TABLE 2.5-69

SUMMARY OF FIELD PERMEABILITY TESTS - SUPPLEMENTARY INVESTIGATIONS[1]

Stratum	USAR Design Value (cm/sec)	Range of Reliable Field Test Values (cm/sec)	Estimated Mean of Field Test Data (cm/sec)
Lacustrine	3.0×10^{-4}	1.2×10^{-4} to 4.2×10^{-7}	1.0×10^{-5}
Upper Till	1.0×10^{-5}	3.0×10^{-6} to 5.0×10^{-8}	1.5×10^{-7}
Lower Till	1.6×10^{-6}	3.1×10^{-6} to 3.8×10^{-8}	2.0×10^{-7}
Shale	5.0×10^{-6}	8.4×10^{-7} to 1.3×10^{-8}	8.0×10^{-8}

NOTE:

(1) Horizontal permeability for Lacustrine stratum, isotropic permeability for other strata.

TABLE 2.5-70

RESULTS OF LABORATORY PERMEABILITY TESTS ON NATURAL SOILS

Stratum	Boring No.	Sample Elevation (ft)	Coefficient of Vertical Permeability (cm/sec)
Lacustrine	PT-1	604.4-602.8	1.4×10^{-4}
Lacustrine	PT-3	600.6-598.1	3.0×10^{-7}
Upper Till	PT-1	589.7-587.4	2.4×10^{-6}
Upper Till	PT-3	592.4-590.2	2.0×10^{-8}
Lower Till	PT-1A	580.4-577.9	8.6×10^{-9}
Lower Till	PT-1A	572.9-570.4	6.0×10^{-9}

TABLE 2.5-71

MINIMUM STRESS RATIO IN LOWER TILL
FOR INITIAL LIQUEFACTION IN TEN CYCLES

Case	τ_{hs}[1] (ksf)	τ_{cd}[2] (ksf)	τ_{cd}/τ_{hs}
I	1.04	1.62	1.5+
II	0.10	0.19	1.9
III	0.85	2.87	3.3+

NOTES:

(1) τ_{hs} = Shear stress imposed by 10 cycles of the SSE.
(2) τ_{cd} = Shear stress required to cause liquefaction in 10 cycles of the SSE.

TABLE 2.5-72

BEARING MATERIALS BENEATH PRIMARY SAFETY CLASS STRUCTURES[1]

Structure	Bottom of Foundation Mat Elevation (ft)	Materials Beneath Foundation Mat
Reactor Building Complex, Units 1 and 2	562.23	4″ protective concrete (bottom 561.9′) 12″ porous concrete (bottom 560.9′) on shale
Auxiliary Buildings, Units 1 and 2	562.23	4″ protective concrete (bottom 561.9′) 12″ porous concrete (bottom 560.9′) on shale
Intermediate Building	565.33	4″ protective concrete (bottom 565.0′) 12″ porous concrete (bottom 564.0′) on shale
	616.50	Caissons into shale through 19″ of Class B fill and 27′ of Class A fill
Control Complex	568.83	4″ protective concrete (bottom 568.5′) 3.5′ fill concrete (bottom 565.0′) 12′ porous concrete (bottom 564.0′) on shale
Radwaste Building	570.83	4″ protective concrete (bottom 570.5′) 5.5′ fill concrete (bottom 565.0′) 12′ porous concrete (bottom 564.0′) on shale
Diesel Generator Building	615.97	4″ protective concrete (bottom 615.6′) 4″ fill concrete (bottom 615.3′) 30.3′ Class A fill (bottom 585.0′) on lower till
Offgas Buildings, Units 1 and 2	579.83	4″ protective concrete (bottom 579.5′) 4″ fill concrete (bottom 579.2′) 12″ Class A fill (bottom 578.2′) on lower till
Emergency Service Water Pumphouse	532.00	12″ porous concrete (bottom 531.0′) on shale

NOTE:

[1] 4″ protective concrete is placed over waterproofing membranes; it consists of 1,500 psi concrete except beneath reactor building where it is 3,000 psi concrete.

TABLE 2.5-73

ANNUAL PROBABILITY OF EXCEEDANCE FOR PEAK GROUND ACCELERATION (PGA)[1]

PGA-CM/SEC**2	Mean	Fractiles		
		(0.150)	(0.500)	(0.850)
5.00	0.44E-02	0.10E-02	0.32E-02	0.78E-02
50.00	0.28E-03	0.18E-04	0.18E-03	0.51E-03
100.00	0.87E-04	0.25E-05	0.60E-04	0.17E-03
250.00	0.12E-04	0.12E-06	0.63E-05	0.23E-04
500.00	0.15E-05	0.44E-08	0.50E-06	0.28E-05
700.00	0.45E-06	0.64E-09	0.85E-07	0.73E-06
1000.00	0.11E-06	0.40E-09	0.11E-07	0.15E-06

NOTE:

(1) Results as documented in EPRI Report RP-101-53 “Probabilistic Seismic Hazard Evaluation for Perry Nuclear Power Plant, April 1989” (Reference 308).

TABLE 2.5-74

PERRY
SPECTRAL VELOCITIES (5% DAMPING) ASSOCIATED WITH UNIFORM HAZARD SPECTRA AT 10^{-3}, 10^{-4}, 2 X 10^{-4}, AND 10^{-5} ANNUAL PROBABILITIES OF EXCEEDANCE[3]

Fractile[1][2]	Spectral Velocities (CM/SEC) For 10^{-3} 25 Hz	10 Hz	5 Hz	2.5 Hz	1 Hz
15	0.74E-01	0.13E+00	0.15E+00	0.16E+00	0.12E+00
50	0.18E+00	0.33E+00	0.46E+00	0.46E+00	0.31E+00
85	0.31E+00	0.86E+00	0.12E+01	0.12E+01	0.12E+01

Fractile	Spectral Velocities (CM/SEC) For 2 x 10^{-4} 25 Hz	10 Hz	5 Hz	2.5 Hz	1 Hz
15	0.17E+00	0.33E+00	0.46E+00	0.49E+00	0.33E+00
50	0.61E+00	0.11E+01	0.14E+01	0.14E+01	0.10E+01
85	0.99E+00	0.22E+01	0.29E+01	0.30E+01	0.28E+01

Fractile	Spectral Velocities (CM/SEC) For 1 x 10^{-4} 25 Hz	10 Hz	5 Hz	2.5 Hz	1 Hz
15	0.25E+00	0.50+00	0.74E+00	0.78E+00	0.51E+00
50	0.92E+00	0.17E+01	0.21E+01	0.20E+01	0.14E+01
85	0.15E+01	0.31E+01	0.43E+01	0.45E+01	0.41E+01

Fractile	Spectral Velocities (CM/SEC) For 2 x 10^{-5} 25 Hz	10 Hz	5 Hz	2.5 Hz	1 Hz
15	0.73E+00	0.15E+01	0.19E+01	0.20E+01	0.14E+01
50	0.26E+01	0.48E+01	0.62E+01	0.60E+01	0.39E+01
85	0.42E+01	0.81E+01	0.11E+02	0.12E+02	0.13E-02

NOTES:

(1) The 50th fractile is the median.
(2) The 85th fractile is close to the mean.
(3) From (Reference 308), EPRI Report RP-101-53 “Probabilistic Seismic Hazard Evaluation for Perry Nuclear Power Plant, April 1989.”

<APPENDIX 2A>

ANNUAL JOINT FREQUENCY DISTRIBUTIONS

FOR

CLEVELAND AND ERIE

APPENDIX 2A

ANNUAL JOINT FREQUENCY DISTRIBUTIONS[1]
FOR
CLEVELAND AND ERIE

Contents

NOTE:

[1] Stability Based on Pasquil-Turner Method, specified in "A Diffusion Model for an Urban Area"; J. of Appl. Met., February 3, 1964, pp. 83-91.

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

CLEVELAND, OH (14820) NWS DATA 5/1/72 - 4/30/74, 9/1/77 - 8/31/78
PERIOD OF RECORD: 5/1/72 - 6/30/78

STABILITY CLASS: A

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	1	2	0	0	0	0	3
NNE	0	0	0	0	0	0	0
NE	1	1	0	0	0	0	2
ENE	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0
ESE	0	1	0	0	0	0	1
SE	0	1	0	0	0	0	1
SSE	0	1	0	0	0	0	1
S	1	3	0	0	0	0	4
SSW	0	1	0	0	0	0	1
SW	0	0	0	0	0	0	0
WSW	1	2	0	0	0	0	3
W	0	1	0	0	0	0	1
WNW	0	1	0	0	0	0	1
NW	0	1	0	0	0	0	1
NNW	1	2	0	0	0	0	3
TOTALS	5	17	0	0	0	0	22

PERIODS OF CALMS 17 HOURS

STABILITY CLASS: B

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	2	39	39	0	0	0	80
NNE	0	8	20	0	0	0	28
NE	1	7	6	0	0	0	14
ENE	1	4	3	0	0	0	8
E	2	5	1	0	0	0	8
ESE	0	5	1	0	0	0	6
SE	0	3	0	0	0	0	3
SSE	5	7	11	0	0	0	23
S	8	12	15	0	0	0	35
SSW	5	8	13	0	0	0	26
SW	5	15	20	0	0	0	40
WSW	9	3	9	0	0	0	21
W	4	6	6	0	0	0	16
WNW	3	9	8	0	0	0	20
NW	1	9	18	0	0	0	28
NNW	3	10	17	0	0	0	30
TOTALS	49	150	187	0	0	0	386

PERIODS OF CALMS 27 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

CLEVELAND, OH (14820) NWS DATA 5/1/72 - 4/30/74, 9/1/77 - 8/31/78
PERIOD OF RECORD: 5/1/72 - 6/30/78

STABILITY CLASS: C

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	9	20	105	19	1	0	154
NNE	2	11	70	14	2	0	99
NE	4	6	44	12	0	0	66
ENE	2	6	7	2	0	0	17
E	1	4	13	1	0	0	19
ESE	2	5	12	5	0	0	24
SE	5	5	16	0	0	0	26
SSE	6	13	26	1	0	0	46
S	16	31	75	13	1	0	136
SSW	6	25	68	15	0	0	114
SW	1	33	70	23	1	3	131
WSW	2	18	61	18	1	0	100
W	2	6	37	10	0	0	55
WNW	2	8	32	8	0	0	50
NW	6	6	25	5	0	0	42
NNW	4	9	47	8	0	0	68
TOTALS	70	206	708	154	6	3	1,147

PERIODS OF CALMS 62 HOURS

STABILITY CLASS: D

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	20	154	296	220	11	0	701
NNE	7	98	172	148	17	0	442
NE	6	84	144	145	31	4	414
ENE	3	36	100	37	1	0	177
E	3	34	127	51	3	0	218
ESE	2	35	127	47	4	0	215
SE	5	86	102	48	4	0	245
SSE	15	100	173	124	18	2	432
S	14	142	532	534	70	24	1,316
SSW	15	159	347	325	42	15	903
SW	6	156	292	342	67	21	884
WSW	11	116	274	297	63	24	785
W	6	59	178	178	31	10	462
WNW	3	69	149	179	10	12	422
NW	9	77	163	155	23	3	430
NNW	17	79	145	127	31	2	401
TOTALS	142	1,484	3,321	2,957	426	117	8,447

PERIODS OF CALMS 128 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

CLEVELAND, OH (14820) NWS DATA 5/1/72 - 4/30/74, 9/1/77 - 8/31/78
PERIOD OF RECORD: 5/1/72 - 6/30/78

STABILITY CLASS: E

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	0	23	22	0	0	0	45
NNE	0	28	18	0	0	0	46
NE	0	34	17	0	0	0	51
ENE	0	16	15	0	0	0	31
E	0	13	19	0	0	0	32
ESE	0	26	20	0	0	0	46
SE	0	59	17	0	0	0	76
SSE	0	69	51	0	0	0	120
S	0	107	128	0	0	0	235
SSW	0	103	95	0	0	0	198
SW	0	65	73	0	0	0	138
WSW	0	27	19	0	0	0	46
W	0	11	12	0	0	0	23
WNW	0	13	7	0	0	0	20
NW	0	9	10	0	0	0	19
NNW	0	12	10	0	0	0	22
TOTALS	0	615	533	0	0	0	1,148

PERIODS OF CALMS 0 HOURS

STABILITY CLASS: F

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	5	44	0	0	0	0	49
NNE	2	39	0	0	0	0	41
NE	2	33	0	0	0	0	35
ENE	2	18	0	0	0	0	20
E	3	15	0	0	0	0	18
ESE	1	15	0	0	0	0	16
SE	8	34	0	0	0	0	42
SSE	17	94	0	0	0	0	111
S	12	163	0	0	0	0	175
SSW	10	151	0	0	0	0	161
SW	4	66	0	0	0	0	70
WSW	3	32	0	0	0	0	35
W	1	10	0	0	0	0	11
WNW	0	11	0	0	0	0	11
NW	2	18	0	0	0	0	20
NNW	5	8	0	0	0	0	13
TOTALS	77	751	0	0	0	0	828

PERIODS OF CALMS 115 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

CLEVELAND, OH (14820) NWS DATA 5/1/72 - 4/30/74, 9/1/77 - 8/31/78
PERIOD OF RECORD: 5/1/72 - 6/30/78

STABILITY CLASS: G

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	13	0	0	0	0	0	13
NNE	5	0	0	0	0	0	5
NE	7	0	0	0	0	0	7
ENE	3	0	0	0	0	0	3
E	1	0	0	0	0	0	1
ESE	7	0	0	0	0	0	7
SE	10	0	0	0	0	0	10
SSE	20	0	0	0	0	0	20
S	44	0	0	0	0	0	44
SSW	28	0	0	0	0	0	28
SW	14	0	0	0	0	0	14
WSW	4	0	0	0	0	0	4
W	4	0	0	0	0	0	4
WNW	3	0	0	0	0	0	3
NW	5	0	0	0	0	0	5
NNW	3	0	0	0	0	0	3
TOTALS	171	0	0	0	0	0	171

PERIODS OF CALMS 174 HOURS

STABILITY CLASS: ALL

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	50	282	462	239	12	0	1,045
NNE	16	184	280	162	19	0	661
NE	21	165	211	157	31	4	589
ENE	11	80	125	39	1	0	256
E	10	71	160	52	3	0	296
ESE	12	87	160	52	4	0	315
SE	28	188	135	48	4	0	403
SSE	63	284	261	125	18	2	753
S	95	458	750	547	71	24	1,945
SSW	64	447	523	340	42	15	1,431
SW	30	335	455	365	68	24	1,277
WSW	30	198	363	315	64	24	994
W	17	93	233	188	31	10	572
WNW	11	111	196	187	10	12	527
NW	23	120	216	160	23	3	545
NNW	33	120	219	135	31	2	540
TOTALS	514	3,223	4,749	3,111	432	120	12,149

PERIODS OF CALMS 523 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

CLEVELAND, OH (14820) NWS DATA 5/1/72 - 4/30/74, 9/1/77 - 8/31/78
PERIOD OF RECORD: 5/1/72 - 6/30/78

OBSERVATIONS WITH MISSING DATA 0

TOTAL OBSERVATIONS FOR THE PERIOD ARE 12,672

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
0.31	3.26	9.54	67.67	9.06	7.44	2.72

MEAN WIND SPEED 9.9 MPH

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

ERIE, PA (14820) NWS DATA 5/1/72 - 4/30/74, 9/1/77 - 8/31/78
PERIOD OF RECORD: 5/1/72 - 6/30/78

STABILITY CLASS: A

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	0	1	0	0	0	0	1
NNE	0	0	0	0	0	0	0
NE	0	1	0	0	0	0	1
ENE	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0
ESE	0	0	0	0	0	0	0
SE	0	0	0	0	0	0	0
SSE	0	0	0	0	0	0	0
S	0	0	0	0	0	0	0
SSW	0	0	0	0	0	0	0
SW	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	0
W	0	1	0	0	0	0	1
WNW	0	4	0	0	0	0	4
NW	0	0	0	0	0	0	0
NNW	0	1	0	0	0	0	1
TOTALS	0	8	0	0	0	0	8

PERIODS OF CALMS 0 HOURS

STABILITY CLASS: B

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	2	22	21	0	0	0	45
NNE	0	3	4	0	0	0	7
NE	0	3	5	0	0	0	8
ENE	0	3	1	0	0	0	4
E	2	2	6	0	0	0	10
ESE	1	0	0	0	0	0	1
SE	1	1	0	0	0	0	2
SSE	0	0	2	0	0	0	2
S	8	6	4	0	0	0	18
SSW	3	3	3	0	0	0	9
SW	1	6	4	0	0	0	11
WSW	0	4	5	0	0	0	9
W	0	6	14	0	0	0	20
WNW	1	16	16	0	0	0	33
NW	0	11	15	0	0	0	26
NNW	1	18	35	0	0	0	54
TOTALS	20	104	135	0	0	0	259

PERIODS OF CALMS 10 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

ERIE, PA (14820) NWS DATA 5/1/72 - 4/30/74, 9/1/77 - 8/31/78
PERIOD OF RECORD: 5/1/72 - 6/30/78

STABILITY CLASS: C

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	1	11	50	4	0	0	66
NNE	1	8	25	6	1	0	41
NE	2	0	19	11	3	0	35
ENE	3	5	9	3	0	0	20
E	3	5	3	0	0	0	11
ESE	1	3	4	0	0	0	8
SE	6	4	5	1	0	0	16
SSE	5	4	14	0	0	0	23
S	12	28	64	12	0	0	116
SSW	5	16	26	7	2	1	57
SW	2	7	25	5	0	0	39
WSW	2	3	32	11	0	0	48
W	0	7	81	27	4	1	120
WNW	1	9	50	10	1	0	71
NW	1	6	30	4	0	0	41
NNW	2	14	24	2	0	0	42
TOTALS	47	130	461	103	11	2	754

PERIODS OF CALMS 15 HOURS

STABILITY CLASS: D

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	6	54	110	90	15	2	277
NNE	5	47	59	62	10	1	184
NE	10	60	102	126	40	12	350
ENE	5	64	135	113	36	5	358
E	10	55	60	18	3	1	147
ESE	8	32	32	9	0	0	81
SE	8	37	40	44	6	3	138
SSE	8	35	110	141	91	31	416
S	21	158	351	434	116	21	1,101
SSW	6	72	173	283	78	14	626
SW	6	98	161	252	59	21	597
WSW	6	82	152	196	68	13	517
W	4	69	184	298	88	25	668
WNW	1	57	99	153	62	13	385
NW	2	42	81	90	17	8	240
NNW	3	34	65	78	14	1	195
TOTALS	109	996	1,914	2,387	703	171	6,280

PERIODS OF CALMS 56 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

ERIE, PA (14820) NWS DATA 5/1/72 - 4/30/74, 9/1/77 - 8/31/78
PERIOD OF RECORD: 5/1/72 - 6/30/78

STABILITY CLASS: E

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	0	5	6	0	0	0	11
NNE	0	4	3	0	0	0	7
NE	0	7	9	0	0	0	16
ENE	0	20	12	0	0	0	32
E	0	25	11	0	0	0	36
ESE	0	17	2	0	0	0	19
SE	0	15	3	0	0	0	18
SSE	0	25	21	0	0	0	46
S	0	96	127	0	0	0	223
SSW	0	44	44	0	0	0	88
SW	0	28	28	0	0	0	56
WSW	0	5	13	0	0	0	18
W	0	8	11	0	0	O	19
WNW	0	5	2	0	0	0	7
NW	0	8	8	0	0	O	16
NNW	0	4	7	0	0	0	11
TOTALS	0	316	307	0	0	0	623

PERIODS OF CALMS 0 HOURS

STABILITY CLASS: F

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	2	6	0	0	0	0	8
NNE	1	5	0	0	0	0	6
NE	1	5	0	0	0	0	6
ENE	5	15	0	0	0	0	20
E	5	26	0	0	0	0	31
ESE	10	10	0	0	0	0	20
SE	5	16	0	0	0	0	21
SSE	5	21	0	0	0	0	26
S	19	240	0	0	0	0	259
SSW	4	84	0	0	0	0	88
SW	4	28	0	0	0	0	32
WSW	2	8	0	0	0	0	10
W	2	4	0	0	0	0	6
WNW	0	4	0	0	0	0	4
NW	0	5	0	0	0	0	5
NNW	0	3	0	0	0	0	3
TOTALS	65	480	0	0	0	0	545

PERIODS OF CALMS 42 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

ERIE, PA (14820) NWS DATA 5/1/72 - 4/30/74, 9/1/77 - 8/31/78
PERIOD OF RECORD: 5/1/72 - 6/30/78

STABILITY CLASS: G

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	2	0	0	0	0	0	2
NNE	0	0	0	0	0	0	0
NE	2	0	0	0	0	0	2
ENE	0	0	0	0	0	0	0
E	4	0	0	0	0	0	4
ESE	9	0	0	0	0	0	9
SE	8	0	0	0	0	0	8
SSE	8	0	0	0	0	0	8
S	43	0	0	0	0	0	43
SSW	5	0	0	0	0	0	5
SW	7	0	0	0	0	0	7
WSW	1	0	0	0	0	0	1
W	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0
NW	1	0	0	0	0	0	1
NNW	0	0	0	0	0	0	0
TOTALS	90	0	0	0	0	0	90

PERIODS OF CALMS 70 HOURS

STABILITY CLASS: ALL

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	13	99	187	94	15	2	410
NNE	7	67	91	68	11	1	245
NE	15	76	135	137	43	12	418
ENE	13	107	157	116	36	5	434
E	24	113	80	18	3	1	239
ESE	29	62	38	9	0	0	138
SE	28	73	48	45	6	3	203
SSE	26	85	147	141	91	31	521
S	103	528	546	446	116	21	1,760
SSW	23	219	246	290	80	15	873
SW	20	167	218	257	59	21	742
WSW	11	102	202	207	68	13	603
W	6	95	290	325	92	26	834
WNW	3	95	167	163	63	13	504
NW	4	72	134	94	17	8	329
NNW	6	74	131	80	14	1	306
TOTALS	331	2,034	2,817	2,490	714	173	8,559

PERIODS OF CALMS 193 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

ERIE, PA (14820) NWS DATA 5/1/72 - 4/30/74, 9/1/77 - 8/31/78
PERIOD OF RECORD: 5/1/72 - 6/30/78

OBSERVATIONS WITH MISSING DATA 0

TOTAL OBSERVATIONS FOR THE PERIOD ARE 8,752

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
0.09	3.07	8.79	72.39	7.12	6.71	1.83

MEAN WIND SPEED 11.3 MPH

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

CLEVELAND, OH (14820) NWS DATA 9/1/68 - 8/31/78
PERIOD OF RECORD: 9/1/68 - 8/30/78

STABILITY CLASS: A

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	2	10	0	0	0	0	12
NNE	1	3	0	0	0	0	4
NE	1	3	0	0	0	0	4
ENE	1	1	0	0	0	0	2
E	0	2	0	0	0	0	2
ESE	0	1	0	0	0	0	1
SE	1	2	0	0	0	0	3
SSE	1	3	0	0	0	0	4
S	1	8	0	0	0	0	9
SSW	1	2	0	0	0	0	3
SW	2	5	0	0	0	0	7
WSW	1	2	0	0	0	0	3
W	0	4	0	0	0	0	4
WNW	0	3	0	0	0	0	3
NW	0	6	0	0	0	0	6
NNW	1	7	0	0	0	0	8
TOTALS	13	62	0	0	0	0	75

PERIODS OF CALMS 34 HOURS

STABILITY CLASS: B

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	14	106	148	0	0	0	268
NNE	9	28	68	0	0	0	105
NE	4	17	16	0	0	0	37
ENE	4	12	6	0	0	0	22
E	5	14	4	0	0	0	23
ESE	5	10	5	0	0	0	20
SE	8	23	3	0	0	0	34
SSE	24	33	19	0	0	0	76
S	26	43	28	0	0	0	97
SSW	22	29	38	0	0	0	89
SW	19	49	55	0	0	0	123
WSW	20	37	31	0	0	0	88
W	10	39	42	0	0	0	91
WNW	7	29	28	0	0	0	64
NW	6	44	37	0	0	0	87
NNW	16	49	60	0	0	0	125
TOTALS	199	562	588	0	0	0	1,349

PERIODS OF CALMS 72 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

CLEVELAND, OH (14820) NWS DATA 9/1/68 - 8/31/78
PERIOD OF RECORD: 9/1/68 - 8/30/78

STABILITY CLASS: C

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	24	79	444	70	1	0	618
NNE	9	35	216	54	2	0	316
NE	11	28	85	19	0	0	143
ENE	6	16	21	2	0	0	45
E	5	12	37	2	0	0	56
ESE	5	9	31	7	0	0	52
SE	13	29	47	0	0	0	89
SSE	35	57	68	5	1	0	166
S	49	104	228	44	4	2	431
SSW	28	82	204	46	5	3	368
SW	9	98	226	52	3	4	392
WSW	13	57	174	55	6	1	306
W	11	30	131	42	3	0	217
WNW	10	22	110	23	0	0	165
NW	18	19	91	17	2	0	147
NNW	14	28	180	24	0	0	246
TOTALS	260	705	2,293	462	27	10	3,757

PERIODS OF CALMS 138 HOURS

STABILITY CLASS: D

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	42	521	975	674	52	1	2,265
NNE	11	261	593	403	44	5	1,317
NE	18	212	399	345	69	11	1,054
ENE	6	98	240	95	5	2	446
E	6	90	318	111	13	0	538
ESE	2	92	317	124	14	0	549
SE	24	218	349	145	14	0	750
SSE	34	339	577	335	43	5	1,333
S	30	393	1,550	1,728	303	64	4,068
SSW	37	402	1,093	1,028	208	54	2,822
SW	22	452	1,026	1,149	251	86	2,986
WSW	21	311	879	1,133	318	94	2,756
W	15	206	662	839	175	44	1,941
WNW	11	221	573	666	75	28	1,574
NW	25	224	502	544	102	10	1,407
NNW	32	234	443	427	84	12	1,232
TOTALS	336	4,274	10,496	9,746	1,770	416	27,038

PERIODS OF CALMS 261 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

CLEVELAND, OH (14820) NWS DATA 9/1/68 - 8/31/78
PERIOD OF RECORD: 9/1/68 - 8/30/78

STABILITY CLASS: E

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	0	111	84	0	0	0	195
NNE	0	113	61	0	0	0	174
NE	0	103	63	0	0	0	166
ENE	0	63	43	0	0	0	106
E	0	46	41	0	0	0	87
ESE	0	64	64	0	0	0	128
SE	0	186	42	0	0	0	228
SSE	0	268	164	0	0	0	432
S	0	344	443	0	0	0	787
SSW	0	284	412	0	0	0	696
SW	0	216	280	0	0	0	496
WSW	0	83	101	0	0	0	184
W	0	33	47	0	0	0	80
WNW	0	29	41	0	0	0	70
NW	0	46	30	0	0	0	76
NNW	0	45	35	0	0	0	80
TOTALS	0	2,034	1,951	0	0	0	3,985

PERIODS OF CALMS 0 HOURS

STABILITY CLASS: F

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	33	177	0	0	0	0	210
NNE	14	125	0	0	0	0	139
NE	9	94	0	0	0	0	103
ENE	8	56	0	0	0	0	64
E	6	63	0	0	0	0	69
ESE	4	54	0	0	0	0	58
SE	24	128	0	0	0	0	152
SSE	57	298	0	0	0	0	355
S	53	527	0	0	0	0	580
SSW	35	476	0	0	0	0	511
SW	24	294	0	0	0	0	318
WSW	18	103	0	0	0	0	121
W	8	38	0	0	0	0	46
WNW	5	37	0	0	0	0	42
NW	10	60	0	0	0	0	70
NNW	23	55	0	0	0	0	78
TOTALS	331	2,985	0	0	0	0	2,916

PERIODS OF CALMS 248 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

CLEVELAND, OH (14820) NWS DATA 9/1/68 - 8/31/78
PERIOD OF RECORD: 9/1/68 - 8/30/78

STABILITY CLASS: G

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	42	0	0	0	0	0	42
NNE	19	0	0	0	0	0	19
NE	15	0	0	0	0	0	15
ENE	9	0	0	0	0	0	9
E	7	0	0	0	0	0	7
ESE	12	0	0	0	0	0	12
SE	43	0	0	0	0	0	43
SSE	61	0	0	0	0	0	61
S	140	0	0	0	0	0	140
SSW	91	0	0	0	0	0	91
SW	43	0	0	0	0	0	43
WSW	25	0	0	0	0	0	25
W	10	0	0	0	0	0	10
WNW	10	0	0	0	0	0	10
NW	23	0	0	0	0	0	23
NNW	21	0	0	0	0	0	21
TOTALS	571	0	0	0	0	0	571

PERIODS OF CALMS 460 HOURS

STABILITY CLASS: ALL

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	157	1,004	1,651	744	53	1	3,610
NNE	63	565	938	457	46	5	2,074
NE	58	457	563	364	69	11	1,522
ENE	34	246	310	97	5	2	694
E	29	227	400	113	13	0	782
ESE	28	230	417	131	14	0	820
SE	113	586	441	145	14	0	1,299
SSE	212	998	828	340	44	5	2,427
S	299	1,419	2,249	1,772	307	66	6,112
SSW	214	1,275	1,747	1,074	213	57	4,580
SW	119	1,114	1,587	1,201	254	90	4,365
WSW	98	593	1,185	1,188	324	95	3,483
W	54	350	882	881	178	44	2,389
WNW	43	341	752	689	75	28	1,928
NW	82	399	660	561	104	10	1,816
NNW	107	418	718	451	84	12	1,790
TOTALS	1,710	10,222	15,328	10,208	1,797	426	39,691

PERIODS OF CALMS *** HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

CLEVELAND, OHIO (14820) NWS DATA 9/1/68 - 8/31/78
PERIOD OF RECORD: 9/1/68 - 8/30/78

OBSERVATIONS WITH MISSING DATA 0

TOTAL OBSERVATIONS FOR THE PERIOD ARE 40,904

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
0.27	3.47	9.52	66.74	9.74	7.74	2.52

MEAN WIND SPEED 10.2 MPH

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

ERIE, PA (14820) NWS DATA 9/1/68 - 8/31/78
PERIOD OF RECORD: 9/1/68 - 8/30/78

STABILITY CLASS: A

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	0	5	0	0	0	0	5
NNE	0	0	0	0	0	0	0
NE	0	2	0	0	0	0	2
ENE	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0
ESE	0	0	0	0	0	0	0
SE	0	0	0	0	0	0	0
SSE	0	0	0	0	0	0	0
S	0	0	0	0	0	0	0
SSW	0	0	0	0	0	0	0
SW	0	0	0	0	0	0	0
WSW	0	1	0	0	0	0	1
W	0	2	0	0	0	0	2
WNW	0	7	0	0	0	0	7
NW	0	2	0	0	0	0	2
NNW	0	2	0	0	0	0	2
TOTALS	0	21	0	0	0	0	21

PERIODS OF CALMS 2 HOURS

STABILITY CLASS: B

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	5	71	93	0	0	0	169
NNE	2	22	21	0	0	0	45
NE	4	14	17	0	0	0	35
ENE	3	5	3	0	0	0	11
E	6	6	10	0	0	0	22
ESE	6	3	0	0	0	0	9
SE	2	11	2	0	0	0	15
SSE	2	4	6	0	0	0	12
S	16	18	15	0	0	0	49
SSW	7	5	10	0	0	0	22
SW	1	14	14	0	0	0	29
WSW	2	15	15	0	0	0	32
W	3	17	49	0	0	0	69
WNW	3	58	56	0	0	0	117
NW	1	54	74	0	0	0	129
NNW	2	60	111	0	0	0	173
TOTALS	65	377	496	0	0	0	938

PERIODS OF CALMS 18 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

ERIE, PA (14820) NWS DATA 9/1/68 - 8/31/78
PERIOD OF RECORD: 9/1/68 - 8/30/78

STABILITY CLASS: C

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	5	34	184	29	0	0	252
NNE	3	21	82	20	1	0	127
NE	5	14	73	38	8	0	138
ENE	6	22	38	6	2	0	74
E	8	18	14	1	0	0	41
ESE	7	7	12	0	0	0	26
SE	12	13	16	2	0	0	43
SSE	8	18	45	5	0	0	76
S	32	103	186	29	1	0	351
SSW	13	41	88	15	4	2	163
SW	7	23	93	26	1	1	151
WSW	8	11	97	31	7	0	154
W	3	16	235	104	11	2	371
WNW	12	29	216	48	1	0	306
NW	6	40	107	10	0	0	163
NNW	5	37	108	8	0	0	158
TOTALS	140	447	1,594	372	36	5	2,594

PERIODS OF CALMS 47 HOURS

STABILITY CLASS: D

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	9	164	349	300	48	5	875
NNE	8	98	205	196	26	4	537
NE	14	163	345	382	73	27	1,004
ENE	12	182	434	322	68	14	1,032
E	19	143	184	57	6	1	410
ESE	21	100	92	27	0	0	240
SE	14	99	138	106	18	6	381
SSE	14	107	340	496	230	64	1,251
S	40	426	1,179	1,613	415	72	3,745
SSW	13	233	580	938	327	60	2,151
SW	14	267	605	857	199	44	1,986
WSW	8	244	560	731	235	54	1,832
W	8	187	591	1,158	355	86	2,385
WNW	6	156	379	611	221	48	1,421
NW	10	137	264	353	78	21	863
NNW	11	118	228	277	55	6	695
TOTALS	221	2,824	6,473	8,424	2,354	512	20,808

PERIODS OF CALMS 113 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

ERIE, PA (14820) NWS DATA 9/1/68 - 8/31/78
PERIOD OF RECORD: 9/1/68 - 8/30/78

STABILITY CLASS: E

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	0	22	40	0	0	0	62
NNE	0	13	17	0	0	0	30
NE	0	33	35	0	0	0	68
ENE	0	64	42	0	0	0	106
E	0	83	29	0	0	0	112
ESE	0	57	11	0	0	0	68
SE	0	54	22	0	0	0	76
SSE	0	74	122	0	0	0	196
S	0	301	482	0	0	0	783
SSW	0	118	179	0	0	0	297
SW	0	92	108	0	0	0	200
WSW	0	32	50	0	0	0	82
W	0	23	34	0	0	0	57
WNW	0	13	24	0	0	0	37
NW	0	22	22	0	0	0	44
NNW	0	18	32	0	0	0	50
TOTALS	0	1,019	1,249	0	0	0	2,268

PERIODS OF CALMS 0 HOURS

STABILITY CLASS: F

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	5	22	0	0	0	0	27
NNE	3	20	0	0	0	0	23
NE	3	17	0	0	0	0	20
ENE	9	53	0	0	0	0	62
E	16	89	0	0	0	0	105
ESE	19	42	0	0	0	0	61
SE	15	55	0	0	0	0	70
SSE	13	84	0	0	0	0	97
S	55	805	0	0	0	0	860
SSW	22	288	0	0	0	0	310
SW	10	81	0	0	0	0	91
WSW	5	30	0	0	0	0	35
W	6	14	0	0	0	0	20
WNW	2	24	0	0	0	0	26
NW	2	16	0	0	0	0	18
NNW	3	17	0	0	0	0	20
TOTALS	188	1,657	0	0	0	0	1,845

PERIODS OF CALMS 100 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

ERIE, PA (14820) NWS DATA 9/1/68 - 8/31/78
PERIOD OF RECORD: 9/1/68 - 8/30/78

STABILITY CLASS: A

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	4	0	0	0	0	0	4
NNE	1	0	0	0	0	0	1
NE	5	0	0	0	0	0	5
ENE	2	0	0	0	0	0	2
E	25	0	0	0	0	0	25
ESE	26	0	0	0	0	0	26
SE	26	0	0	0	0	0	26
SSE	30	0	0	0	0	0	30
S	119	0	0	0	0	0	119
SSW	21	0	0	0	0	0	21
SW	14	0	0	0	0	0	14
WSW	4	0	0	0	0	0	4
W	3	0	0	0	0	0	3
WNW	1	0	0	0	0	0	1
NW	3	0	0	0	0	0	3
NNW	0	0	0	0	0	0	0
TOTALS	284	0	0	0	0	0	284

PERIODS OF CALMS 170 HOURS

STABILITY CLASS: ALL

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	28	318	666	329	48	5	1,394
NNE	17	174	325	216	27	4	763
NE	31	243	470	420	81	27	1,272
ENE	32	326	517	328	70	14	1,287
E	74	339	237	58	6	1	715
ESE	79	209	115	27	0	0	430
SE	69	232	178	108	18	6	611
SSE	67	287	513	501	230	64	1,662
S	262	1,653	1,862	1,642	416	72	5,907
SSW	76	685	857	953	331	62	2,964
SW	46	477	820	883	200	45	2,471
WSW	27	333	722	762	242	54	2,140
W	23	259	909	1,262	366	88	2,907
WNW	24	287	675	659	222	48	1,915
NW	22	271	467	363	78	21	1,222
NNW	21	252	479	285	55	6	1,098
TOTALS	898	6,345	9,812	8,796	2,390	517	28,758

PERIODS OF CALMS 450 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

ERIE, PA (14820) NWS DATA 9/1/68 - 8/31/78
PERIOD OF RECORD: 9/1/68 - 8/30/78

OBSERVATIONS WITH MISSING DATA 0

TOTAL OBSERVATIONS FOR THE PERIOD ARE 29,208

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
0.08	3.27	9.04	71.63	7.76	6.66	1.55

MEAN WIND SPEED 11.5 MPH

<APPENDIX 2B>

MONTHLY AND ANNUAL FREQUENCY

DISTRIBUTIONS FOR PNPP, 10-METER WINDS

APPENDIX 2B

MONTHLY AND ANNUAL JOINT FREQUENCY DISTRIBUTIONS[1] FOR PNPP, 10-METER WINDS

Contents

NOTE:

[1] Stability based on ΔT (60-10-meter) and <Regulatory Guide 1.23>

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

00000080

CEI PERRY 10 METER WINDS (DELTA T 60-10M) 3 YRS COMBINED

PERIOD OF RECORD: 5/1/72 - 8/31/78

STABILITY CLASS: A

ELEVATION: 10 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	2	60	62	6	0	0	130
NNE	5	38	53	7	0	0	103
NE	2	11	43	28	2	0	86
ENE	1	4	19	4	0	0	28
E	4	7	3	0	0	0	14
ESE	4	3	7	0	0	0	14
SE	2	3	14	2	1	0	22
SSE	2	6	22	5	1	0	36
S	0	8	18	8	1	0	35
SSW	2	6	18	4	3	0	33
SW	0	6	26	6	1	1	40
WSW	1	6	44	37	2	0	90
W	2	26	90	48	6	0	172
WNW	2	39	37	8	2	0	88
NW	6	54	43	4	0	0	107
NNW	4	51	55	4	0	0	114
TOTALS	39	328	554	171	19	1	1,112

PERIODS OF CALMS 2 HOURS

STABILITY CLASS: B

ELEVATION: 10 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	3	24	27	3	0	0	57
NNE	4	25	25	7	0	0	61
NE	3	8	31	17	1	0	60
ENE	2	7	14	4	0	0	27
E	3	10	5	0	0	0	18
ESE	2	10	8	2	0	0	22
SE	2	16	15	16	1	0	50
SSE	0	11	17	5	0	0	33
S	0	10	10	5	0	0	25
SSW	0	5	18	12	0	0	35
SW	0	6	18	11	3	0	38
WSW	0	8	52	35	5	0	100
W	1	25	58	36	10	0	130
WNW	1	40	24	8	2	0	75
NW	3	44	24	5	1	0	77
NNW	4	31	25	3	0	0	63
TOTALS	28	280	371	169	23	0	871

PERIODS OF CALMS 0 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

00000080

CEI PERRY 10 METER WINDS (DELTA T 60-10M) 3 YRS COMBINED

PERIOD OF RECORD: 5/1/72 - 8/31/78

STABILITY CLASS: C

ELEVATION: 10 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
	MILES PER HOUR						
N	4	39	20	2	1	0	66
NNE	2	15	23	3	1	0	44
NE	0	20	40	15	0	0	75
ENE	4	10	10	5	0	0	29
E	5	13	8	1	0	0	27
ESE	0	13	7	1	0	0	21
SE	1	14	16	7	2	0	40
SSE	4	16	18	4	0	0	42
S	2	25	22	8	1	0	58
SSW	2	17	23	16	1	0	59
SW	1	10	24	11	3	0	49
WSW	3	28	64	39	13	0	147
W	4	42	64	41	5	0	156
WNW	9	50	40	26	9	1	135
NW	2	50	24	5	1	0	82
NNW	7	34	25	3	0	0	69
TOTALS	50	396	428	187	37	1	1,099

PERIODS OF CALMS 0 HOURS

STABILITY CLASS: D

ELEVATION: 10 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
	MILES PER HOUR						
N	53	190	219	80	9	0	551
NNE	64	181	142	47	11	0	445
NE	77	283	288	143	11	1	803
ENE	111	307	198	80	5	0	701
E	93	251	85	11	0	0	440
ESE	57	142	95	24	13	0	331
SE	42	128	206	127	26	2	531
SSE	37	149	184	93	14	0	477
S	56	255	240	107	7	0	665
SSW	39	282	356	155	13	11	856
SW	71	251	426	307	61	17	1,133
WSW	47	240	386	470	134	34	1,311
W	52	343	464	389	97	37	1,382
WNW	54	244	339	196	76	22	931
NW	44	263	278	157	37	6	785
NNW	48	181	191	135	22	3	580
TOTALS	945	3,690	4,097	2,521	536	133	11,922

PERIODS OF CALMS 34 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

00000080

CEI PERRY 10 METER WINDS (DELTA T 60-10M) 3 YRS COMBINED

PERIOD OF RECORD: 5/1/72 - 8/31/78

STABILITY CLASS: E

ELEVATION: 10 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
	MILES PER HOUR						
N	32	76	48	11	0	0	167
NNE	46	62	17	7	0	0	132
NE	73	81	25	6	3	0	188
ENE	86	115	23	6	0	0	230
E	149	170	22	1	0	0	342
ESE	104	120	57	10	4	0	295
SE	127	226	171	68	13	0	605
SSE	89	277	155	69	5	1	596
S	123	469	368	93	4	3	1,060
SSW	86	388	213	76	10	2	775
SW	80	247	166	79	13	6	591
WSW	41	122	157	72	15	8	415
W	57	99	83	46	12	4	301
WNW	43	65	45	25	10	0	188
NW	38	47	45	14	3	1	148
NNW	34	67	49	16	0	3	169
TOTALS	1,208	2,631	1,644	599	92	28	6,202

PERIODS OF CALMS 49 HOURS

STABILITY CLASS: F

ELEVATION: 10 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
	MILES PER HOUR						
N	8	8	3	0	0	0	19
NNE	5	3	0	0	0	0	8
NE	18	7	1	0	0	0	26
ENE	46	24	7	0	0	0	77
E	156	71	1	0	0	0	228
ESE	113	92	1	0	0	0	206
SE	104	85	5	0	0	0	194
SSE	87	135	8	0	0	0	230
S	117	221	13	0	0	0	351
SSW	68	125	8	0	0	0	201
SW	45	53	4	0	0	0	102
WSW	16	14	0	2	0	1	33
W	19	3	2	0	0	0	24
WNW	5	2	3	0	0	0	10
NW	5	5	1	0	0	0	11
NNW	7	7	0	0	0	0	14
TOTALS	819	855	57	2	0	1	1,734

PERIODS OF CALMS 49 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

00000080

CEI PERRY 10 METER WINDS (DELTA T 60-10M) 3 YRS COMBINED

PERIOD OF RECORD: 5/1/72 - 8/31/78

STABILITY CLASS: G

ELEVATION: 10 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
	MILES PER HOUR						
N	6	3	0	0	0	0	9
NNE	7	1	0	0	0	0	8
NE	15	1	0	0	0	0	16
ENE	51	14	0	0	0	0	65
E	248	65	0	0	0	0	313
ESE	297	59	0	0	0	0	356
SE	300	64	1	0	0	0	365
SSE	250	130	1	0	0	0	381
S	182	78	1	0	0	0	261
SSW	49	22	0	1	0	0	72
SW	27	10	0	0	0	0	37
WSW	8	3	0	0	0	0	11
W	11	0	1	0	0	0	12
WNW	5	1	0	0	0	0	6
NW	4	1	0	0	0	0	5
NNW	2	3	1	0	0	0	6
TOTALS	1,462	455	5	1	0	0	1,923

PERIODS OF CALMS 99 HOURS

STABILITY CLASS: ALL

ELEVATION: 10 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
	MILES PER HOUR						
N	108	400	379	102	10	0	999
NNE	133	325	260	71	12	0	801
NE	188	411	428	209	17	1	1,254
ENE	301	481	271	99	5	0	1,157
E	658	587	124	13	0	0	1,382
ESE	577	439	175	37	17	0	1,245
SE	578	536	428	220	43	2	1,807
SSE	469	724	405	176	20	1	1,795
S	480	1,066	672	221	13	3	2,455
SSW	246	845	636	264	27	13	2,031
SW	224	583	664	414	81	24	1,990
WSW	116	421	703	655	169	43	2,107
W	146	938	762	560	130	41	2,177
WNW	119	441	488	263	99	23	1,433
NW	102	464	415	185	42	7	1,215
NNW	106	374	346	161	22	6	1,015
TOTALS	4,551	8,635	7,156	3,650	707	164	24,863

PERIODS OF CALMS 233 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

00000080

CEI PERRY 10 METER WINDS (DELTA T 60-10M) 3 YRS COMBINED

PERIOD OF RECORD: 5/1/72 - 8/31/78

OBSERVATIONS WITH MISSING DATA 1,184

TOTAL OBSERVATIONS FOR THE PERIOD ARE 25,096

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
4.44	3.47	4.38	47.64	24.91	7.10	8.06

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JANUARY ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.01- 5.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	2

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
3.01- 5.00	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JANUARY ***
STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	0	0	0	0	0	4	3	1	0	0	0	0	0	8
3.01- 5.00	0	0	0	0	3	1	0	0	1	1	3	0	0	0	0	1	10
5.01- 7.00	0	0	0	0	0	2	0	0	0	0	1	1	0	0	0	0	4
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	6
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	3	3	0	0	5	4	5	7	0	0	0	1	28

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	4
0.35- 0.50	1	1	1	3	2	0	1	0	0	0	3	0	1	0	0	1	14
0.51- 0.75	2	1	0	4	1	0	1	0	1	0	2	1	0	0	0	0	13
0.76- 1.00	1	2	1	5	3	0	1	1	0	2	1	0	1	0	0	0	18
1.01- 1.50	5	5	3	9	9	5	4	5	3	5	5	2	7	5	2	6	80
1.51- 2.00	6	3	10	15	7	16	5	3	11	7	2	7	5	6	7	5	115
2.01- 3.00	14	16	25	49	33	20	17	20	32	52	34	41	42	23	22	14	454
3.01- 5.00	55	26	56	74	35	42	35	29	49	111	159	132	149	131	47	48	1,178
5.01- 7.00	18	5	28	28	5	22	23	32	25	42	131	227	190	98	50	28	952
7.01-10.00	4	0	41	9	0	2	15	7	7	13	47	188	117	119	37	11	617
10.01-13.00	2	0	2	4	0	0	1	2	4	5	9	62	35	5	0	2	133
>13.00	0	0	0	0	0	0	0	0	0	6	0	1	2	2	0	0	11
TOTAL	108	59	167	200	95	107	103	99	132	243	393	661	549	389	165	115	3,589

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JANUARY ***
STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	0	0	3	2	1	0	0	0	1	1	0	0	0	0	0	0	8
0.51- 0.75	1	2	3	2	2	2	1	0	1	0	2	0	0	1	1	0	18
0.76- 1.00	1	2	0	1	4	1	1	0	3	1	2	2	0	1	1	0	20
1.01- 1.50	1	2	6	4	2	9	3	4	7	3	4	1	3	1	1	0	51
1.51- 2.00	1	3	4	11	11	8	5	5	14	11	11	3	2	2	1	2	94
2.01- 3.00	5	6	7	14	18	18	17	17	76	45	27	19	9	6	4	5	293
3.01- 5.00	2	7	3	10	9	21	31	25	43	46	48	34	13	10	4	1	307
5.01- 7.00	0	0	2	0	1	5	28	26	37	15	22	25	4	4	0	1	170
7.01-10.00	0	0	1	0	0	4	17	14	6	14	8	21	5	0	0	0	90
10.01-13.00	0	0	0	0	0	0	1	1	1	4	4	3	0	0	0	0	14
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	11	22	29	44	48	68	104	92	189	140	128	108	36	25	12	9	1,067

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	4
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	1	1	1	1	0	2	0	0	0	0	0	0	6
0.76- 1.00	0	0	0	0	2	0	2	0	1	1	0	0	0	0	0	0	6
1.01- 1.50	0	1	1	2	3	1	4	1	7	8	2	1	0	0	0	0	31
1.51- 2.00	0	0	1	6	2	7	2	5	6	2	2	0	1	0	0	0	34
2.01- 3.00	0	0	0	2	7	6	3	6	22	9	4	0	0	0	0	0	59
3.01- 5.00	0	0	0	0	1	1	1	4	3	0	0	0	0	0	1	0	11
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	1	2	10	16	16	13	17	39	22	8	1	1	0	1	0	151

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JANUARY ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	3
0.35- 0.50	1	0	0	1	2	1	3	1	1	0	0	0	0	0	0	0	10
0.51- 0.75	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	4
0.76- 1.00	0	0	1	0	1	1	1	3	3	0	1	0	0	0	0	0	11
1.01- 1.50	0	1	0	0	1	5	4	8	6	0	1	1	0	0	0	0	27
1.51- 2.00	0	0	1	2	2	2	4	8	8	0	0	0	0	0	0	0	27
2.01- 3.00	0	0	0	0	4	1	1	7	13	1	1	0	0	0	0	0	28
3.01- 5.00	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	4
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	1	1	2	4	11	10	14	30	33	1	3	1	0	0	0	0	114

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	13
0.35- 0.50	2	1	4	6	5	1	4	1	2	1	3	0	1	0	0	1	32
0.51- 0.75	3	3	3	7	5	3	4	2	2	2	4	1	0	1	1	0	41
0.76- 1.00	2	4	2	6	10	2	5	4	7	4	4	2	1	1	1	0	55
1.01- 1.50	6	9	10	15	15	21	15	18	23	16	12	5	10	6	3	6	190
1.51- 2.00	7	6	16	34	22	33	16	21	39	20	15	10	8	8	8	7	270
2.01- 3.00	19	22	32	65	62	45	38	50	148	110	67	60	51	29	26	19	843
3.01- 5.00	57	33	59	84	49	65	67	60	98	158	210	166	162	141	52	50	1,511
5.01- 7.00	18	5	30	28	6	29	51	58	62	57	154	253	194	102	50	29	1,126
7.01-10.00	4	0	42	9	0	6	32	21	13	27	55	215	122	120	37	11	714
10.01-13.00	2	0	2	4	0	0	2	3	5	9	13	65	35	5	0	2	147
>13.00	0	0	0	0	0	0	0	0	0	6	0	1	2	2	0	0	11
TOTAL	120	83	200	258	174	205	234	238	399	410	537	778	586	415	178	125	4,953

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JANUARY ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,208

TOTAL NUMBER OF VALID OBSERVATIONS: 4,953

TOTAL NUMBER OF MISSING OBSERVATIONS: 255

PERCENT DATA RECOVERY FOR THIS PERIOD: 95.1%

MEAN WIND SPEED FOR THIS PERIOD: 4.7 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
0.04	0.04	0.57	72.46	21.54	3.05	2.30

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
B	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
C	0	0	0	0	3	3	0	0	5	4	5	7	0	0	0	1	0
D	108	59	167	200	95	107	103	99	132	243	393	661	549	389	165	115	4
E	11	22	29	44	48	68	104	92	189	140	128	108	36	25	12	9	2
F	0	1	2	10	16	16	13	17	39	22	8	1	1	0	1	0	4
G	1	1	2	4	11	10	14	30	33	1	3	1	0	0	0	0	3
TOTAL	120	83	200	258	174	205	234	238	399	410	537	778	586	415	178	125	13

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** FEBRUARY ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	2
3.01- 5.00	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	4
5.01- 7.00	0	0	3	3	0	0	2	0	0	0	3	1	4	0	0	0	16
7.01-10.00	0	0	0	0	0	0	1	0	0	0	0	4	0	0	0	0	5
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	3	6	0	0	3	0	0	2	5	5	4	0	1	0	29

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2
3.01- 5.00	0	0	0	1	1	1	1	0	0	0	1	2	2	1	0	0	10
5.01- 7.00	0	0	2	2	0	0	3	1	0	0	5	0	3	0	0	0	16
7.01-10.00	0	0	0	0	0	0	6	0	0	0	0	2	0	0	0	0	8
10.01-13.00	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	2	4	1	2	11	1	0	0	6	4	5	1	1	0	38

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** FEBRUARY ***
STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	1	2	0	2	1	0	1	1	1	0	0	1	0	10
3.01- 5.00	0	0	3	1	2	0	4	0	0	0	0	0	4	3	1	0	18
5.01- 7.00	0	0	1	3	0	0	1	0	0	0	0	4	7	4	1	0	21
7.01-10.00	0	0	0	0	0	0	5	0	0	0	0	1	0	1	0	0	7
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	4	5	4	0	12	2	0	1	2	6	11	8	3	0	58

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	4
0.35- 0.50	0	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	4
0.51- 0.75	0	0	1	2	1	1	0	1	0	1	0	0	1	0	0	0	8
0.76- 1.00	2	1	0	2	1	1	0	0	1	1	1	1	2	0	0	1	14
1.01- 1.50	3	5	1	4	6	2	2	1	2	2	8	4	3	7	3	3	56
1.51- 2.00	3	9	5	7	10	2	0	1	1	4	9	5	9	15	7	2	89
2.01- 3.00	25	31	23	49	31	7	2	2	9	17	14	33	30	30	50	18	371
3.01- 5.00	68	56	92	79	25	23	34	11	32	62	80	91	138	109	94	81	1,075
5.01- 7.00	26	26	58	59	3	6	18	3	24	21	55	144	151	48	48	17	707
7.01-10.00	3	3	11	39	0	2	5	5	8	5	10	55	61	14	4	3	228
10.01-13.00	0	0	0	4	0	0	1	1	0	1	0	8	9	0	0	0	24
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	130	132	191	245	77	45	62	25	78	114	177	341	405	223	206	125	2,580

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** FEBRUARY ***

STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	6
0.35- 0.50	1	1	2	0	0	0	0	0	0	1	1	0	1	1	2	0	10
0.51- 0.75	2	2	0	0	1	4	3	1	4	3	1	2	0	0	1	1	25
0.76- 1.00	3	0	1	2	1	1	6	2	3	0	3	3	2	0	2	1	30
1.01- 1.50	2	4	5	7	6	4	5	2	5	4	5	6	11	4	3	3	76
1.51- 2.00	5	5	2	6	12	4	6	7	10	12	10	15	8	6	6	1	115
2.01- 3.00	8	11	5	15	21	9	8	20	52	48	33	23	22	15	6	8	304
3.01- 5.00	9	7	12	8	17	15	16	25	54	46	35	59	19	23	11	6	362
5.01- 7.00	0	0	1	3	2	2	10	11	48	22	9	15	5	1	2	0	131
7.01-10.00	0	0	0	0	0	0	1	14	8	6	5	5	7	0	0	0	46
10.01-13.00	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	3
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	30	30	28	41	60	39	55	82	184	142	103	128	77	50	33	20	1,108

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	4
0.35- 0.50	0	0	0	2	1	0	0	2	0	1	0	1	0	0	0	0	7
0.51- 0.75	1	0	1	1	1	1	0	2	1	0	0	0	0	0	1	1	10
0.76- 1.00	0	0	0	1	0	1	0	1	2	0	2	1	1	1	0	0	10
1.01- 1.50	0	1	1	3	6	5	3	5	3	7	5	3	3	1	0	0	46
1.51- 2.00	1	0	2	1	7	2	0	1	7	10	6	2	1	0	0	0	40
2.01- 3.00	2	0	1	8	12	9	3	9	25	18	10	6	2	0	0	0	105
3.01- 5.00	0	0	0	0	0	0	1	1	13	3	6	0	0	0	1	0	25
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	4	1	5	16	27	18	7	21	51	39	29	13	7	2	2	1	247

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** FEBRUARY ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	15
0.35- 0.50	0	0	1	1	2	1	4	4	0	0	0	1	0	1	0	0	15
0.51- 0.75	0	1	0	2	6	1	9	2	4	4	1	2	1	0	1	0	34
0.76- 1.00	0	0	0	0	3	2	3	5	15	5	3	2	0	0	0	0	38
1.01- 1.50	0	0	0	0	7	6	7	9	11	7	3	0	1	0	0	0	51
1.51- 2.00	0	0	1	1	5	11	3	2	5	3	2	0	0	0	0	0	33
2.01- 3.00	0	0	0	3	3	7	2	3	13	6	0	1	0	0	0	0	38
3.01- 5.00	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	1	2	7	26	28	28	27	48	25	9	6	2	1	1	0	226

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	29
0.35- 0.50	1	2	3	3	3	2	4	6	1	2	1	2	2	2	2	0	36
0.51- 0.75	3	3	2	5	9	7	12	7	9	8	2	4	2	0	4	2	79
0.76- 1.00	5	1	1	5	5	5	9	8	21	6	10	7	5	1	2	2	93
1.01- 1.50	5	10	7	14	25	17	17	17	21	21	21	13	18	12	7	6	231
1.51- 2.00	9	14	10	15	34	19	9	11	23	29	27	22	18	21	13	3	277
2.01- 3.00	35	42	29	77	69	33	17	35	99	91	59	64	54	45	57	26	832
3.01- 5.00	77	63	107	92	45	39	56	39	99	111	123	152	163	136	107	87	1,496
5.01- 7.00	26	26	65	70	5	8	34	15	72	43	72	164	170	53	51	17	891
7.01-10.00	3	3	11	39	0	2	18	19	16	11	15	67	68	15	4	3	294
10.01-13.00	0	0	0	4	0	0	2	1	0	1	1	8	11	0	0	0	28
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	164	164	235	324	195	132	178	158	361	323	331	503	511	285	247	146	4,286

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** FEBRUARY ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 4,728

TOTAL NUMBER OF VALID OBSERVATIONS: 4,286

TOTAL NUMBER OF MISSING OBSERVATIONS: 442

PERCENT DATA RECOVERY FOR THIS PERIOD: 90.7%

MEAN WIND SPEED FOR THIS PERIOD: 3.9 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
0.68	0.89	1.35	60.20	25.85	5.76	5.27

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	0	0	3	6	0	0	3	0	0	2	5	5	4	0	1	0	0
B	0	0	2	4	1	2	11	1	0	0	6	4	5	1	1	0	0
C	0	0	4	5	4	0	12	2	0	1	2	6	11	8	3	0	0
D	130	132	191	245	77	45	62	25	78	114	177	341	405	223	206	125	4
E	30	30	28	41	60	39	55	82	184	142	103	128	77	50	33	20	6
F	4	1	5	16	27	18	7	21	51	39	29	13	7	2	2	1	4
G	0	1	2	7	26	28	28	27	48	25	9	6	2	1	1	0	15
TOTAL	164	164	235	324	195	132	178	158	361	323	331	503	511	285	247	146	29

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MARCH ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
1.51- 2.00	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
2.01- 3.00	0	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	4
3.01- 5.00	11	5	3	4	0	0	0	6	2	1	2	0	2	0	2	2	40
5.01- 7.00	1	2	15	2	0	2	0	7	6	0	1	3	4	5	1	3	52
7.01-10.00	0	0	11	1	0	0	0	1	1	1	2	2	3	2	0	0	24
10.01-13.00	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	3
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	12	8	31	8	0	2	1	15	9	2	6	5	10	7	4	6	126

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	1	0	0	0	1	1	0	0	0	0	0	1	1	5
3.01- 5.00	5	3	6	2	0	1	3	1	0	0	4	3	3	5	8	4	48
5.01- 7.00	1	1	9	2	1	0	2	2	3	2	2	3	7	5	2	6	48
7.01-10.00	0	3	4	0	0	0	1	0	2	1	0	2	5	4	2	0	24
10.01-13.00	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	6	7	19	5	1	1	6	5	6	3	6	8	15	14	13	11	126

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MARCH ***

STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	1	2	0	0	0	1	0	0	0	0	0	0	1	5
2.01- 3.00	1	0	1	2	0	0	0	2	2	0	1	1	0	1	6	3	20
3.01- 5.00	7	4	6	4	0	5	5	4	5	2	1	4	16	8	10	6	87
5.01- 7.00	1	2	2	0	1	0	4	8	10	4	2	3	9	13	3	2	64
7.01-10.00	1	2	3	1	0	0	0	1	1	2	6	7	9	7	3	0	43
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0	5
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	10	8	12	8	3	5	9	16	19	8	10	18	34	31	22	12	225

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	6
0.35- 0.50	0	0	1	1	0	2	3	0	0	0	1	0	0	1	0	0	9
0.51- 0.75	0	0	1	3	0	1	1	0	0	0	2	1	2	0	1	0	12
0.76- 1.00	1	0	0	2	2	0	1	0	0	2	1	1	1	1	2	1	15
1.01- 1.50	2	2	2	11	4	2	4	3	1	1	6	1	2	3	6	7	57
1.51- 2.00	9	6	7	12	9	4	4	5	5	0	3	9	8	8	9	6	104
2.01- 3.00	24	33	40	37	34	7	10	13	11	4	16	29	29	33	45	39	404
3.01- 5.00	40	59	116	102	24	20	37	40	27	37	37	87	153	80	77	48	984
5.01- 7.00	13	10	36	51	10	12	44	44	26	28	39	98	98	70	77	27	683
7.01-10.00	10	4	4	11	1	12	32	24	21	16	33	79	57	71	38	2	415
10.01-13.00	0	0	0	0	0	0	2	2	2	2	2	25	7	8	8	0	58
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	1	7	0	0	8
TOTAL	99	114	207	230	84	60	138	131	93	90	140	330	358	282	263	130	2,755

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MARCH ***

STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	9
0.35- 0.50	1	0	0	0	1	0	0	1	2	0	2	0	1	0	1	0	9
0.51- 0.75	2	0	0	0	0	2	3	1	0	1	1	0	0	4	1	0	15
0.76- 1.00	2	1	3	4	3	1	1	0	1	2	0	2	5	2	2	0	29
1.01- 1.50	2	2	2	4	7	2	2	2	5	5	9	6	4	2	5	2	61
1.51- 2.00	1	4	9	9	8	2	5	1	5	6	10	7	9	4	3	2	85
2.01- 3.00	6	12	15	28	37	11	7	17	24	17	34	25	15	8	2	2	260
3.01- 5.00	4	13	13	23	12	12	24	31	75	46	33	25	20	2	6	4	343
5.01- 7.00	0	0	0	1	1	1	23	29	41	21	17	29	11	0	3	0	177
7.01-10.00	0	0	0	0	0	4	21	12	11	12	5	20	4	0	0	0	89
10.01-13.00	0	0	0	0	0	0	7	1	4	2	0	0	0	0	0	0	14
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	18	32	42	69	69	35	93	95	168	112	111	114	69	22	23	10	1,091

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	13
0.35- 0.50	1	0	0	0	0	2	2	0	2	1	2	0	1	0	0	0	11
0.51- 0.75	0	0	0	1	1	1	0	1	3	4	1	1	0	0	0	0	13
0.76- 1.00	0	0	0	5	4	2	2	3	2	2	2	1	1	0	0	0	24
1.01- 1.50	0	1	2	2	9	11	4	2	6	5	3	1	1	1	0	1	49
1.51- 2.00	2	0	2	9	10	8	5	4	3	3	4	2	0	1	1	0	54
2.01- 3.00	0	1	2	5	10	14	11	18	13	15	6	2	1	0	1	1	100
3.01- 5.00	3	3	1	0	2	3	6	5	7	3	2	0	0	0	1	0	36
5.01- 7.00	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	6	5	7	22	36	41	30	33	37	33	20	7	4	2	3	2	301

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MARCH ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	19
0.35- 0.50	0	0	0	1	0	1	3	1	2	2	3	0	1	0	0	0	14
0.51- 0.75	0	0	2	2	5	9	1	2	2	1	0	0	0	0	0	0	24
0.76- 1.00	1	2	1	3	3	6	6	4	4	6	0	0	2	0	0	0	38
1.01- 1.50	1	0	6	9	8	6	10	8	7	1	2	0	1	0	0	1	60
1.51- 2.00	0	2	3	4	10	3	6	2	5	1	3	0	0	0	1	1	41
2.01- 3.00	0	0	0	9	9	2	3	2	0	2	2	0	0	1	0	1	31
3.01- 5.00	1	1	0	1	0	2	0	0	0	0	0	0	1	0	0	0	6
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3	5	12	29	35	29	29	19	20	13	10	0	5	1	1	3	233

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	47
0.35- 0.50	2	0	1	2	1	5	8	2	6	3	8	0	3	1	1	0	43
0.51- 0.75	2	0	3	6	6	13	5	4	5	6	4	2	2	4	2	0	64
0.76- 1.00	4	3	4	14	12	9	10	8	7	12	3	4	9	3	4	1	107
1.01- 1.50	5	5	12	26	28	21	20	15	19	12	20	8	8	6	12	11	228
1.51- 2.00	12	13	21	35	39	17	20	12	19	10	20	18	17	13	14	11	291
2.01- 3.00	31	46	60	83	90	34	32	53	51	38	59	57	45	43	55	47	824
3.01- 5.00	71	88	145	136	38	43	75	87	116	89	79	119	195	95	104	64	1,544
5.01- 7.00	16	15	62	56	13	15	73	90	87	55	61	136	129	93	86	38	1,025
7.01-10.00	11	9	22	13	1	16	54	38	36	32	46	110	78	84	43	2	595
10.01-13.00	0	0	0	0	0	0	9	5	6	4	3	28	8	10	8	0	81
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	1	7	0	0	8
TOTAL	154	179	330	371	228	173	306	314	352	261	303	482	495	359	329	174	4,857

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MARCH ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,208

TOTAL NUMBER OF VALID OBSERVATIONS: 4,857

TOTAL NUMBER OF MISSING OBSERVATIONS: 351

PERCENT DATA RECOVERY FOR THIS PERIOD: 93.3%

MEAN WIND SPEED FOR THIS PERIOD: 4.3 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
2.59	2.59	4.63	56.72	22.46	6.20	4.80

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	12	8	31	8	0	2	1	15	9	2	6	5	10	7	4	6	0
B	6	7	19	5	1	1	6	5	6	3	6	8	15	14	13	11	0
C	10	8	12	8	3	5	9	16	19	8	10	18	34	31	22	12	0
D	99	114	207	230	84	60	138	131	93	90	140	330	358	282	263	130	6
E	18	32	42	69	69	35	93	95	168	112	111	114	69	22	23	10	9
F	6	5	7	22	36	41	30	33	37	33	20	7	4	2	3	2	13
G	3	5	12	29	35	29	29	19	20	13	10	0	5	1	1	3	19
TOTAL	154	179	330	371	228	173	306	314	352	261	303	482	495	359	329	174	47

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** APRIL ***
STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	3	1	0	0	0	0	0	0	0	0	0	1	2	2	5	4	18
3.01- 5.00	6	2	10	3	1	3	1	2	6	1	2	1	14	15	15	8	90
5.01- 7.00	4	4	22	1	0	1	0	4	1	2	5	6	19	5	1	2	77
7.01-10.00	0	0	3	0	0	0	0	0	3	2	0	6	27	1	2	0	44
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2
TOTAL	13	7	35	4	1	4	1	6	10	5	7	17	62	24	23	14	233

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2
2.01- 3.00	2	4	0	0	2	1	0	0	1	0	0	1	2	2	5	2	22
3.01- 5.00	4	4	2	2	1	0	4	3	2	0	2	3	4	10	10	9	60
5.01- 7.00	7	2	10	1	1	3	2	1	5	9	1	9	28	10	2	6	97
7.01-10.00	0	0	2	0	0	0	1	0	0	2	3	14	24	3	1	0	50
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	13	10	14	3	4	4	8	4	8	11	6	28	59	25	18	18	233

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** APRIL ***
STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
1.01- 1.50	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	2	6
1.51- 2.00	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	2
2.01- 3.00	7	0	2	1	1	0	0	0	0	3	0	2	5	0	1	5	27
3.01- 5.00	8	11	6	3	4	0	2	4	3	0	2	12	9	21	20	13	118
5.01- 7.00	1	1	4	6	1	1	2	2	10	6	2	10	21	16	5	2	90
7.01-10.00	0	0	4	0	0	0	0	1	1	1	8	16	14	6	3	1	55
10.01-13.00	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	2
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	17	13	17	10	7	1	4	8	15	10	12	42	50	44	30	23	303

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	3
0.35- 0.50	0	1	0	0	1	0	0	0	0	0	2	0	0	0	1	0	5
0.51- 0.75	0	0	2	0	2	0	0	0	0	0	1	0	0	0	1	0	6
0.76- 1.00	3	0	2	2	1	0	0	0	0	1	4	1	1	0	2	2	19
1.01- 1.50	3	5	3	3	3	4	0	1	2	4	5	1	2	5	2	6	49
1.51- 2.00	3	3	6	8	3	0	0	5	2	3	5	6	4	4	7	11	70
2.01- 3.00	20	24	24	17	15	8	8	5	7	14	18	15	36	24	41	30	306
3.01- 5.00	41	39	76	49	25	14	10	23	18	29	34	70	90	80	89	39	726
5.01- 7.00	13	12	28	26	4	7	24	21	30	55	45	108	84	51	58	37	603
7.01-10.00	4	5	16	17	2	6	36	11	14	36	26	75	57	22	27	13	367
10.01-13.00	3	1	3	4	0	1	6	1	2	2	6	13	18	0	0	0	60
>13.00	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTAL	90	90	160	126	56	40	84	67	75	144	147	289	292	186	228	138	2,215

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** APRIL ***
STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	8
0.35- 0.50	0	0	0	0	1	0	0	2	0	1	1	0	1	0	0	1	7
0.51- 0.75	1	1	1	3	4	0	1	0	0	1	0	1	0	1	1	0	15
0.76- 1.00	2	3	5	0	3	4	1	2	0	1	1	1	3	2	2	0	30
1.01- 1.50	3	4	5	4	9	6	3	2	4	4	3	5	1	6	2	6	67
1.51- 2.00	3	4	5	19	17	9	6	5	7	7	7	7	3	4	2	1	106
2.01- 3.00	8	6	15	15	38	15	11	21	19	17	26	18	17	18	11	8	263
3.01- 5.00	6	15	17	24	13	14	19	43	61	34	31	32	23	10	15	6	363
5.01- 7.00	1	2	4	4	0	9	10	22	34	24	15	38	14	7	2	5	191
7.01-10.00	0	0	0	3	0	3	8	0	11	8	8	15	6	2	0	0	64
10.01-13.00	0	0	0	0	0	0	1	0	0	1	1	2	0	0	0	0	5
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	24	35	52	72	85	60	60	97	136	98	93	119	68	50	35	27	1,119

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	6
0.35- 0.50	0	0	0	1	1	1	1	0	1	0	0	0	1	0	0	1	7
0.51- 0.75	2	2	1	1	3	1	2	1	4	0	1	0	2	0	0	0	20
0.76- 1.00	0	0	1	7	7	1	0	2	2	3	0	0	0	0	0	0	23
1.01- 1.50	0	0	2	6	15	10	8	2	8	4	4	1	1	1	0	0	62
1.51- 2.00	2	3	0	1	14	4	7	2	5	9	9	1	1	0	0	0	58
2.01- 3.00	4	1	2	6	16	15	9	12	16	24	5	1	1	2	1	1	116
3.01- 5.00	2	1	6	3	1	2	2	7	11	7	3	0	1	0	0	1	47
5.01- 7.00	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	2
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	10	7	12	25	57	34	29	26	48	47	22	4	7	3	1	3	341

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** APRIL ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	14
0.35- 0.50	0	0	0	0	2	4	3	3	2	2	0	0	0	0	0	0	16
0.51- 0.75	0	1	2	2	1	6	4	6	11	2	1	1	0	0	0	0	37
0.76- 1.00	1	0	0	4	7	5	9	6	10	9	1	2	1	0	0	0	55
1.01- 1.50	0	0	0	4	12	7	9	6	10	10	2	1	1	0	0	0	62
1.51- 2.00	1	0	0	3	12	6	3	3	10	5	2	2	2	0	0	0	49
2.01- 3.00	1	1	2	13	5	6	7	13	18	3	2	0	0	0	0	0	71
3.01- 5.00	0	0	0	2	0	0	3	0	4	0	0	0	0	0	0	0	9
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3	2	4	28	39	34	38	37	65	31	8	6	4	0	0	0	313

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	31
0.35- 0.50	1	2	0	1	5	5	4	5	3	3	3	0	2	0	1	2	37
0.51- 0.75	3	4	6	6	10	7	7	7	15	3	3	2	2	1	2	0	78
0.76- 1.00	6	3	8	13	18	10	10	11	12	14	6	4	5	2	4	2	128
1.01- 1.50	6	9	10	17	40	27	20	11	24	22	14	8	6	14	5	14	247
1.51- 2.00	9	10	12	31	46	19	17	15	24	24	23	17	10	8	9	13	287
2.01- 3.00	45	37	45	52	77	45	35	51	61	61	51	38	63	48	64	50	823
3.01- 5.00	67	72	117	86	45	33	41	82	105	71	74	118	141	136	149	76	1,413
5.01- 7.00	26	21	68	38	6	21	38	50	81	96	68	172	166	89	68	52	1,060
7.01-10.00	4	5	25	20	2	9	45	12	29	49	45	126	128	34	33	14	580
10.01-13.00	3	1	3	4	0	1	7	1	3	3	7	18	19	0	0	0	70
>13.00	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	3
TOTAL	170	164	294	268	249	177	224	245	357	346	295	505	542	332	335	223	4,757

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** APRIL ***

STABILITY BASED ON: DELTA T   BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,040

TOTAL NUMBER OF VALID OBSERVATIONS: 4,757

TOTAL NUMBER OF MISSING OBSERVATIONS: 283

PERCENT DATA RECOVERY FOR THIS PERIOD: 94.4%

MEAN WIND SPEED FOR THIS PERIOD: 4.3 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
4.90	4.90	6.37	46.56	23.52	7.17	6.58

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	13	7	35	4	1	4	1	6	10	5	7	17	62	24	23	14	0
B	13	10	14	3	4	4	8	4	8	11	6	28	59	25	18	18	0
C	17	13	17	10	7	1	4	8	15	10	12	42	50	44	30	23	0
D	90	90	160	126	56	40	84	67	75	144	147	289	292	186	228	138	3
E	24	35	52	72	85	60	60	97	136	98	93	119	68	50	35	27	8
F	10	7	12	25	57	34	29	26	48	47	22	4	7	3	1	3	6
G	3	2	4	28	39	34	38	37	65	31	8	6	4	0	0	0	14
TOTAL	170	164	294	268	249	177	224	245	357	346	295	505	542	332	335	223	31

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MAY ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
1.51- 2.00	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	3
2.01- 3.00	7	1	0	0	0	0	0	1	0	0	0	1	0	4	7	2	23
3.01- 5.00	2	7	2	0	2	3	11	2	3	3	2	6	26	20	12	4	105
5.01- 7.00	0	3	13	2	1	3	2	2	0	2	2	11	37	6	1	0	85
7.01-10.00	0	0	2	1	0	0	0	1	0	1	3	7	4	0	0	0	19
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	9	11	17	3	3	6	14	6	4	7	7	25	67	30	20	8	237

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
1.01- 1.50	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	2	2	1	0	1	0	2	1	1	1	1	0	1	0	1	0	14
3.01- 5.00	9	12	11	1	1	1	7	4	2	5	3	2	5	16	8	7	94
5.01- 7.00	0	6	11	1	0	1	2	3	4	2	3	2	26	5	1	1	68
7.01-10.00	0	0	4	2	0	0	0	1	1	4	2	2	3	0	0	0	19
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	12	20	27	4	3	2	12	9	8	12	9	6	35	21	10	8	198

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MAY ***
STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0.76- 1.00	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
1.01- 1.50	2	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	4
1.51- 2.00	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	1	4
2.01- 3.00	2	0	1	0	0	1	1	6	1	0	3	2	4	6	6	4	37
3.01- 5.00	6	22	26	5	0	2	3	3	5	9	4	5	24	36	23	13	186
5.01- 7.00	1	5	11	3	0	0	2	3	6	7	0	5	19	8	2	0	72
7.01-10.00	0	0	1	1	0	0	0	0	1	2	1	10	1	0	0	0	17
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	12	27	39	10	1	3	6	12	14	19	8	22	49	51	31	18	322

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	1	1	1	0	0	1	0	1	1	0	3	1	0	0	1	0	11
0.51- 0.75	2	0	0	0	2	0	1	1	2	1	0	3	3	0	0	0	15
0.76- 1.00	1	2	1	4	2	1	2	1	0	0	4	1	3	0	0	1	23
1.01- 1.50	7	7	6	15	6	4	1	1	2	4	6	4	5	9	8	10	95
1.51- 2.00	10	18	11	11	5	5	7	4	2	2	6	14	8	15	8	9	135
2.01- 3.00	41	37	49	33	25	25	13	14	15	21	21	27	53	56	50	40	520
3.01- 5.00	43	52	96	53	14	18	42	37	44	29	23	59	114	94	72	34	824
5.01- 7.00	10	5	37	29	1	5	28	22	22	25	12	49	44	27	13	13	342
7.01-10.00	0	0	8	5	0	1	13	6	5	5	1	31	15	1	0	1	92
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	115	122	209	150	55	60	107	87	93	87	76	189	245	202	152	108	2,057

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MAY ***

STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	9
0.35- 0.50	0	3	0	1	0	0	0	0	0	4	1	0	1	0	0	1	11
0.51- 0.75	2	0	4	1	0	1	1	1	4	2	2	1	2	0	1	1	23
0.76- 1.00	1	2	1	2	3	4	5	0	2	2	2	2	1	4	1	0	32
1.01- 1.50	5	6	6	13	8	11	5	2	10	6	12	8	11	7	3	6	119
1.51- 2.00	4	8	12	17	14	7	8	12	12	13	12	14	20	7	7	3	170
2.01- 3.00	17	11	16	22	29	13	31	25	26	32	23	14	18	17	7	10	311
3.01- 5.00	10	15	13	17	2	14	32	35	42	40	14	14	11	12	15	6	292
5.01- 7.00	3	15	8	0	0	4	12	15	10	7	6	2	3	1	1	2	89
7.01-10.00	0	0	1	0	0	0	2	0	1	0	0	2	0	0	0	0	6
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	42	60	61	73	56	54	96	90	107	106	72	57	67	48	35	29	1,062

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	5
0.35- 0.50	0	2	0	1	0	0	0	0	0	3	0	0	0	0	1	0	7
0.51- 0.75	1	0	1	0	1	1	3	2	3	2	6	2	3	0	0	0	25
0.76- 1.00	1	0	2	6	10	4	5	7	4	4	2	6	0	2	0	0	53
1.01- 1.50	1	2	6	9	17	6	3	3	7	9	9	3	0	0	1	2	78
1.51- 2.00	3	2	2	14	15	6	6	4	3	7	11	3	1	0	3	0	80
2.01- 3.00	0	1	3	7	12	27	18	24	22	15	16	3	0	0	0	1	149
3.01- 5.00	0	2	0	2	0	7	3	8	6	4	5	0	0	1	1	1	40
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	6	9	14	39	55	51	38	48	45	44	49	17	4	3	6	4	437

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MAY ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	19
0.35- 0.50	0	1	1	1	8	6	11	13	4	2	4	1	0	0	0	0	52
0.51- 0.75	1	1	1	3	8	9	20	20	18	8	0	2	2	0	0	0	93
0.76- 1.00	1	0	3	5	13	16	25	12	25	10	6	0	0	0	0	0	116
1.01- 1.50	1	1	2	8	33	27	18	10	17	15	5	2	4	0	0	1	144
1.51- 2.00	0	1	0	7	13	10	9	8	9	4	2	0	0	0	0	0	63
2.01- 3.00	0	0	0	0	8	26	10	16	17	12	0	0	0	0	0	1	90
3.01- 5.00	0	0	0	1	1	2	0	4	0	1	0	0	0	0	0	0	9
5.01- 7.00	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	4	4	7	25	84	96	93	83	90	52	17	5	6	0	0	2	587

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	33
0.35- 0.50	1	7	2	3	8	7	11	14	5	9	8	2	1	0	2	1	81
0.51- 0.75	7	1	6	4	11	11	25	24	27	13	8	8	10	0	1	1	157
0.76- 1.00	4	4	7	17	28	25	38	20	32	16	14	9	4	6	1	1	226
1.01- 1.50	17	16	20	45	65	48	27	16	36	35	32	17	21	16	12	21	444
1.51- 2.00	17	29	25	50	48	28	31	28	27	27	31	31	29	23	18	13	455
2.01- 3.00	69	52	70	62	75	92	75	87	82	81	64	47	76	83	71	58	1,144
3.01- 5.00	70	110	148	79	20	47	98	93	102	91	51	86	180	179	131	65	1,550
5.01- 7.00	15	34	80	35	2	13	46	45	42	43	23	69	129	47	18	16	657
7.01-10.00	0	0	16	9	0	1	15	8	8	12	7	52	23	1	0	1	153
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	200	253	374	304	257	272	366	335	361	327	238	321	473	355	254	177	4,900

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MAY ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,208

TOTAL NUMBER OF VALID OBSERVATIONS: 4,900

TOTAL NUMBER OF MISSING OBSERVATIONS: 308

PERCENT DATA RECOVERY FOR THIS PERIOD: 94.1%

MEAN WIND SPEED FOR THIS PERIOD: 3.2 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
4.84	4.04	6.57	41.98	21.67	8.92	11.98

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	9	11	17	3	3	6	14	6	4	7	7	25	67	30	20	8	0
B	12	20	27	4	3	2	12	9	8	12	9	6	35	21	10	8	0
C	12	27	39	10	1	3	6	12	14	19	8	22	49	51	31	18	0
D	115	122	209	150	55	60	107	87	93	87	76	189	245	202	152	108	0
E	42	60	61	73	56	54	96	90	107	106	72	57	67	48	35	29	9
F	6	9	14	39	55	51	38	48	45	44	49	17	4	3	6	4	5
G	4	4	7	25	84	96	93	83	90	52	17	5	6	0	0	2	19
TOTAL	200	253	374	304	257	272	366	335	361	327	238	321	473	355	254	177	33

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JUNE ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	1	1	1	0	0	0	0	0	0	0	0	0	2	1	1	7
2.01- 3.00	5	4	1	3	1	2	0	3	2	0	0	1	5	9	6	9	51
3.01- 5.00	12	20	7	1	1	0	1	1	7	8	4	8	31	29	25	16	171
5.01- 7.00	0	5	5	0	0	0	1	2	2	2	1	16	17	3	7	0	61
7.01-10.00	1	0	0	0	0	0	0	0	0	0	0	3	1	0	2	0	7
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	18	31	14	5	2	2	2	7	11	10	5	28	54	43	41	26	299

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	4
1.51- 2.00	0	0	1	1	1	0	0	2	0	0	1	0	0	1	0	0	7
2.01- 3.00	3	4	2	0	0	0	0	0	0	0	0	0	2	4	8	3	26
3.01- 5.00	6	8	5	1	2	0	1	5	4	12	3	12	41	26	8	4	138
5.01- 7.00	0	0	3	0	0	0	0	1	1	1	0	6	30	2	4	1	49
7.01-10.00	0	0	1	0	0	0	0	0	1	2	1	4	8	1	3	0	21
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	9	13	13	2	4	0	1	8	6	15	5	22	81	34	23	9	245

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JUNE ***
STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1.01- 1.50	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	2
1.51- 2.00	1	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	4
2.01- 3.00	7	2	3	0	0	0	1	3	4	3	1	3	3	6	11	4	51
3.01- 5.00	8	9	9	2	0	0	2	5	8	6	8	7	45	29	18	10	166
5.01- 7.00	1	1	4	1	0	0	0	1	3	6	0	14	13	5	3	2	54
7.01-10.00	0	0	1	0	0	0	0	0	2	1	3	1	4	1	0	1	14
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	18	12	17	3	1	0	3	9	17	16	12	25	65	43	33	18	292

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	5
0.35- 0.50	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
0.51- 0.75	0	0	1	1	0	0	1	1	1	0	0	1	1	0	0	1	8
0.76- 1.00	1	2	1	0	0	2	0	0	0	1	0	1	2	3	0	1	14
1.01- 1.50	1	11	3	2	4	0	2	2	2	1	6	3	7	3	5	6	58
1.51- 2.00	6	8	9	10	4	3	0	6	7	9	8	6	9	11	9	3	108
2.01- 3.00	19	30	28	26	7	10	14	16	30	30	31	29	39	46	53	28	436
3.01- 5.00	30	27	41	24	2	2	19	40	63	54	52	83	100	89	74	44	744
5.01- 7.00	7	1	10	11	0	0	8	11	18	17	31	23	39	26	32	19	253
7.01-10.00	2	0	0	0	0	0	1	0	3	3	4	21	7	25	15	7	88
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2	0	7
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	66	79	93	74	17	17	45	76	125	115	132	167	204	208	190	109	1,722

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JUNE ***

STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	4
0.35- 0.50	0	0	0	2	0	1	2	0	1	0	2	1	0	0	0	3	12
0.51- 0.75	1	2	1	2	1	1	2	2	1	2	0	0	2	0	1	0	18
0.76- 1.00	0	3	2	3	3	3	2	1	2	1	6	2	2	1	1	0	32
1.01- 1.50	2	1	6	6	10	5	10	4	9	8	7	5	7	3	7	4	94
1.51- 2.00	5	2	9	13	3	7	7	11	12	14	13	8	5	1	3	3	116
2.01- 3.00	12	11	15	7	11	7	35	58	72	72	41	19	9	13	11	27	420
3.01- 5.00	11	6	3	3	0	4	38	46	125	46	38	18	29	22	11	28	428
5.01- 7.00	1	0	0	0	0	0	0	0	13	15	6	5	5	0	7	1	53
7.01-10.00	0	0	0	0	0	0	0	0	0	1	2	1	1	0	0	0	5
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	32	25	36	36	28	28	96	122	235	159	115	59	60	40	42	66	1,183

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	6
0.35- 0.50	0	1	0	3	1	4	5	4	2	1	0	0	1	2	2	0	26
0.51- 0.75	1	1	0	3	2	2	4	7	3	1	0	2	0	0	0	0	26
0.76- 1.00	0	1	2	5	7	5	2	6	8	4	5	2	2	0	0	0	49
1.01- 1.50	0	0	1	1	11	8	6	7	14	5	6	5	2	1	0	1	68
1.51- 2.00	2	0	0	2	7	8	11	8	13	10	4	2	3	0	0	0	70
2.01- 3.00	2	0	1	4	2	10	17	43	43	29	12	1	0	0	0	0	164
3.01- 5.00	0	0	0	0	0	0	3	5	19	5	1	0	0	2	0	0	35
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	5	3	4	18	30	37	48	80	102	55	28	12	9	5	2	1	445

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JUNE ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	19
0.35- 0.50	0	1	0	4	9	6	10	10	8	3	3	1	0	1	0	1	57
0.51- 0.75	1	0	2	1	6	13	13	18	14	6	1	1	0	1	0	0	77
0.76- 1.00	0	0	3	0	15	24	21	12	17	2	3	0	0	1	0	1	99
1.01- 1.50	0	1	1	9	23	32	19	24	12	10	4	2	0	0	1	0	138
1.51- 2.00	0	0	1	1	8	17	21	16	17	4	0	0	0	1	0	0	86
2.01- 3.00	0	0	0	0	3	9	16	28	48	5	2	0	0	0	0	0	111
3.01- 5.00	0	0	0	0	0	0	0	8	9	0	0	0	0	0	0	0	17
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	1	2	7	15	64	101	100	116	125	30	13	4	0	4	1	2	604

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	34
0.35- 0.50	0	2	0	9	10	11	17	14	12	4	5	2	1	3	2	4	96
0.51- 0.75	3	3	4	7	9	16	20	28	19	9	1	4	3	1	1	1	129
0.76- 1.00	2	7	8	8	25	34	25	20	27	8	14	5	6	5	1	2	197
1.01- 1.50	3	14	12	18	50	45	37	37	37	24	23	15	16	7	13	13	364
1.51- 2.00	14	11	21	28	23	35	39	43	49	37	26	16	17	18	14	7	398
2.01- 3.00	48	51	50	40	24	38	83	151	199	139	87	53	58	78	89	71	1,259
3.01- 5.00	67	70	65	31	5	6	64	110	235	131	106	128	246	197	136	102	1,699
5.01- 7.00	9	7	22	12	0	0	9	15	37	41	38	64	105	36	53	23	471
7.01-10.00	3	0	2	0	0	0	1	0	6	7	10	30	21	27	20	8	135
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	5	3	0	8
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	149	165	184	153	146	185	295	418	621	400	310	317	473	377	332	231	4,790

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JUNE ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,040

TOTAL NUMBER OF VALID OBSERVATIONS: 4,790

TOTAL NUMBER OF MISSING OBSERVATIONS: 250

PERCENT DATA RECOVERY FOR THIS PERIOD: 95.0%

MEAN WIND SPEED FOR THIS PERIOD: 3.1 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
6.24	5.11	6.10	35.95	24.70	9.29	12.61

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	18	31	14	5	2	2	2	7	11	10	5	28	54	43	41	26	0
B	9	13	13	2	4	0	1	8	6	15	5	22	81	34	23	9	0
C	18	12	17	3	1	0	3	9	17	16	12	25	65	43	33	18	0
D	66	79	93	74	17	17	45	76	125	115	132	167	204	208	190	109	5
E	32	25	36	36	28	28	96	122	235	159	115	59	60	40	42	66	4
F	5	3	4	18	30	37	48	80	102	55	28	12	9	5	2	1	6
G	1	2	7	15	64	101	100	116	125	30	13	4	0	4	1	2	19
TOTAL	149	165	184	153	146	185	295	418	621	400	310	317	473	377	332	231	34

Revision 12
January, 2003

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JULY ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
1.51- 2.00	2	0	0	0	0	0	0	1	0	0	0	0	2	0	1	1	7
2.01- 3.00	15	1	1	0	1	2	2	1	0	0	1	3	5	5	9	16	62
3.01- 5.00	41	35	9	1	5	5	2	1	6	0	1	3	24	38	49	40	260
5.01- 7.00	5	0	3	0	0	0	0	0	0	1	1	1	12	7	2	7	39
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	63	36	13	1	6	8	4	3	6	1	3	7	43	51	61	64	370

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
1.51- 2.00	2	0	0	0	1	1	0	0	0	0	0	0	0	2	1	1	8
2.01- 3.00	8	3	1	1	1	1	1	0	1	1	1	1	4	9	13	7	53
3.01- 5.00	14	19	5	3	1	3	1	2	2	4	1	7	27	34	13	12	148
5.01- 7.00	1	0	4	1	0	0	0	0	0	1	0	2	10	0	5	2	26
7.01-10.00	0	0	0	0	0	0	0	0	0	1	0	1	2	0	0	0	4
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	25	22	10	6	3	5	2	2	3	7	2	11	44	45	32	22	241

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JULY ***

STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	2
1.01- 1.50	0	0	0	0	1	0	0	0	0	0	0	0	2	2	0	2	7
1.51- 2.00	1	3	0	0	0	0	0	1	0	1	0	0	1	2	2	6	17
2.01- 3.00	19	6	3	0	3	4	0	2	2	1	3	5	11	19	19	16	113
3.01- 5.00	20	11	9	1	1	6	2	6	2	7	6	19	23	24	14	13	164
5.01- 7.00	0	0	4	0	0	0	1	0	0	0	1	18	6	2	3	4	39
7.01-10.00	0	0	0	0	0	0	0	0	0	0	3	1	1	0	0	0	5
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	40	20	16	1	6	10	3	9	4	9	13	43	44	50	38	41	347

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
0.51- 0.75	1	0	1	0	0	0	0	1	1	0	1	0	0	0	0	1	6
0.76- 1.00	3	3	5	6	1	2	1	0	2	0	1	1	0	3	1	0	29
1.01- 1.50	9	3	4	8	4	0	3	2	2	6	5	7	7	2	3	2	67
1.51- 2.00	13	12	9	13	7	0	3	2	8	7	7	8	9	11	6	9	124
2.01- 3.00	42	28	26	15	19	10	8	25	21	26	26	31	43	28	30	33	411
3.01- 5.00	40	15	37	21	20	16	23	28	53	66	65	55	74	48	34	63	658
5.01- 7.00	5	0	2	2	1	0	2	0	4	19	18	27	22	16	7	14	139
7.01-10.00	0	0	0	0	0	0	0	0	1	0	2	5	1	0	1	0	10
10.01-13.00	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	114	61	84	65	52	28	40	58	92	124	126	135	156	108	82	122	1,448

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JULY ***

STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	6
0.35- 0.50	0	2	2	0	2	1	0	0	1	1	0	0	0	0	1	0	10
0.51- 0.75	0	2	2	1	3	0	4	0	2	0	5	2	1	1	0	1	24
0.76- 1.00	3	1	3	7	3	3	0	3	4	6	1	1	2	2	2	1	42
1.01- 1.50	3	3	10	13	18	5	7	12	6	6	8	6	6	1	1	0	105
1.51- 2.00	6	10	10	9	13	12	13	9	21	21	16	10	9	3	1	3	166
2.01- 3.00	21	20	8	8	11	20	33	41	65	76	58	14	10	9	11	14	419
3.01- 5.00	28	7	0	2	2	8	17	26	106	67	42	32	9	5	8	29	388
5.01- 7.00	0	0	0	0	0	0	3	0	18	17	5	6	3	0	1	6	59
7.01-10.00	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	2
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	61	45	35	40	52	49	77	91	223	195	135	72	40	21	25	54	1,221

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	6
0.35- 0.50	0	0	0	1	10	1	3	2	5	2	1	0	2	2	0	1	30
0.51- 0.75	3	1	2	2	10	10	5	5	6	4	3	2	0	1	1	0	55
0.76- 1.00	0	1	2	2	6	11	10	8	13	5	6	2	3	2	0	0	71
1.01- 1.50	0	0	1	10	18	15	12	11	7	6	7	1	1	1	0	0	90
1.51- 2.00	1	0	1	2	8	6	23	9	17	12	5	4	1	2	1	0	92
2.01- 3.00	0	0	0	1	5	13	14	37	37	27	6	1	0	0	1	0	142
3.01- 5.00	0	0	0	0	1	1	1	1	4	1	2	0	0	0	0	0	11
5.01- 7.00	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	4	2	6	18	58	57	68	73	90	57	30	10	7	8	3	1	498

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JULY ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	32
0.35- 0.50	0	1	4	2	8	21	12	14	13	3	1	0	1	0	0	0	80
0.51- 0.75	0	2	1	4	22	35	43	25	28	4	0	0	0	1	2	0	167
0.76- 1.00	1	0	0	3	20	35	34	31	21	12	3	0	0	1	0	0	161
1.01- 1.50	0	0	0	1	21	47	29	35	20	10	3	0	0	0	0	0	166
1.51- 2.00	0	0	0	1	5	11	20	28	13	3	1	1	0	0	0	0	83
2.01- 3.00	2	0	0	0	4	4	6	30	15	3	1	1	0	0	0	0	66
3.01- 5.00	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3	3	5	11	80	153	144	164	111	35	9	2	1	2	2	0	757

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	45
0.35- 0.50	1	3	6	3	20	23	15	16	19	6	2	1	3	2	1	1	122
0.51- 0.75	4	5	6	7	35	45	52	31	37	8	9	4	1	3	3	2	252
0.76- 1.00	7	5	10	19	31	52	45	42	40	23	11	4	5	9	3	1	307
1.01- 1.50	12	6	15	32	62	67	51	60	35	28	23	14	17	7	4	4	437
1.51- 2.00	25	25	20	25	34	30	59	50	59	44	29	23	22	20	12	20	497
2.01- 3.00	107	58	39	25	44	54	64	136	141	134	96	56	73	70	83	86	1,266
3.01- 5.00	143	87	60	28	30	39	46	65	174	145	117	116	157	149	118	157	1,631
5.01- 7.00	11	0	13	3	1	0	6	0	23	38	25	54	53	25	18	33	303
7.01-10.00	0	0	0	0	0	0	0	0	1	2	5	8	4	0	1	0	21
10.01-13.00	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	310	189	169	142	257	310	338	400	529	428	318	280	335	285	243	304	4,882

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JULY ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,208

TOTAL NUMBER OF VALID OBSERVATIONS: 4,882

TOTAL NUMBER OF MISSING OBSERVATIONS: 326

PERCENT DATA RECOVERY FOR THIS PERIOD: 93.7%

MEAN WIND SPEED FOR THIS PERIOD: 2.7 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
7.58	4.94	7.11	29.66	25.01	10.20	15.51

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	63	36	13	1	6	8	4	3	6	1	3	7	43	51	61	64	0
B	25	22	10	6	3	5	2	2	3	7	2	11	44	45	32	22	0
C	40	20	16	1	6	10	3	9	4	9	13	43	44	50	38	41	0
D	114	61	84	65	52	28	40	58	92	124	126	135	156	108	82	122	1
E	61	45	35	40	52	49	77	91	223	195	135	72	40	21	25	54	6
F	4	2	6	18	58	57	68	73	90	57	30	10	7	8	3	1	6
G	3	3	5	11	80	153	144	164	111	35	9	2	1	2	2	0	32
TOTAL	310	189	169	142	257	310	338	400	529	428	318	280	335	285	243	304	45

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** AUGUST ***
STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
1.01- 1.50	0	1	0	0	1	0	0	1	0	0	0	0	0	0	1	0	4
1.51- 2.00	1	3	1	0	0	1	0	0	0	0	0	1	1	1	4	0	13
2.01- 3.00	19	14	3	0	1	2	0	0	3	1	1	3	6	7	9	8	77
3.01- 5.00	25	37	19	3	0	1	3	4	3	1	2	7	12	12	9	22	160
5.01- 7.00	0	8	0	0	0	0	0	0	0	2	0	7	11	1	3	1	33
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	45	63	23	3	3	4	3	5	6	4	3	18	30	21	26	31	289

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
1.01- 1.50	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	1	5
1.51- 2.00	0	3	0	0	0	0	1	0	0	0	0	0	0	3	1	1	9
2.01- 3.00	6	9	1	2	4	1	2	1	0	0	0	1	4	10	9	12	62
3.01- 5.00	15	24	13	2	0	2	4	3	3	7	2	23	32	7	7	5	149
5.01- 7.00	1	1	1	1	0	0	0	0	0	5	1	8	9	3	5	0	35
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	23	38	15	5	4	4	7	4	4	12	3	34	46	23	22	19	263

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** AUGUST ***
STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
1.01- 1.50	0	0	0	1	0	1	0	1	0	0	0	0	0	0	1	1	5
1.51- 2.00	2	0	1	1	0	2	0	0	0	1	0	2	0	2	1	2	14
2.01- 3.00	7	4	7	4	5	1	3	3	3	2	2	2	7	10	6	8	74
3.01- 5.00	17	10	10	2	0	1	7	4	7	8	9	20	37	7	16	9	164
5.01- 7.00	0	3	1	0	0	0	0	0	0	1	0	5	7	2	2	1	22
7.01-10.00	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	26	17	19	8	5	5	10	8	10	15	11	30	51	21	26	21	283

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	3
0.35- 0.50	1	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	4
0.51- 0.75	0	2	1	0	1	0	1	0	1	2	1	1	0	0	0	0	10
0.76- 1.00	2	3	2	2	0	0	0	0	1	0	1	2	2	1	1	2	19
1.01- 1.50	7	3	9	8	9	0	2	6	3	1	7	10	4	6	1	4	80
1.51- 2.00	7	11	12	4	3	7	4	6	4	5	5	10	9	8	5	11	111
2.01- 3.00	21	21	26	21	13	15	20	21	33	34	30	20	35	37	26	18	391
3.01- 5.00	41	32	37	8	0	12	22	26	59	46	52	76	92	40	25	25	593
5.01- 7.00	9	5	3	0	0	0	1	0	1	14	8	25	28	5	30	19	148
7.01-10.00	0	0	0	0	0	0	0	0	0	0	6	5	4	1	7	1	24
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	88	77	91	43	26	34	50	59	103	102	110	149	175	98	95	80	1,383

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** AUGUST ***

STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	3
0.35- 0.50	0	0	0	1	0	1	0	3	1	1	2	0	1	1	2	1	14
0.51- 0.75	2	2	3	2	1	1	3	1	1	1	1	1	1	1	0	1	22
0.76- 1.00	2	1	1	6	6	3	4	5	3	2	3	0	0	1	0	0	37
1.01- 1.50	3	5	9	15	15	14	9	13	9	11	12	8	3	4	0	1	131
1.51- 2.00	4	8	6	9	24	14	25	12	24	27	12	10	11	2	1	2	191
2.01- 3.00	20	16	6	12	8	10	25	55	72	92	64	31	14	6	8	13	452
3.01- 5.00	36	10	8	2	0	4	14	30	102	70	42	30	13	13	8	22	404
5.01- 7.00	11	4	0	0	0	0	0	1	2	2	7	16	8	0	0	8	59
7.01-10.00	3	1	0	0	0	0	0	0	0	0	1	2	0	0	0	2	9
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	81	47	33	47	54	47	80	120	214	206	144	98	51	28	19	50	1,322

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	10
0.35- 0.50	1	0	1	4	4	5	2	2	2	2	1	0	1	0	0	0	25
0.51- 0.75	2	3	6	5	8	3	5	6	4	3	0	2	0	0	0	0	47
0.76- 1.00	1	0	0	4	18	13	3	5	9	5	0	0	1	0	0	0	59
1.01- 1.50	0	1	2	11	21	12	8	6	23	9	3	1	0	0	0	0	97
1.51- 2.00	0	0	0	4	10	18	26	11	21	30	10	4	0	1	1	1	137
2.01- 3.00	0	0	1	1	8	24	18	37	38	37	7	2	0	1	0	0	174
3.01- 5.00	1	0	0	0	1	3	1	0	1	1	4	0	0	0	0	0	12
5.01- 7.00	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	5	4	10	29	70	78	63	68	98	87	25	9	2	2	1	1	562

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** AUGUST ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	28
0.35- 0.50	1	0	0	2	12	17	17	8	10	1	0	1	1	0	0	0	70
0.51- 0.75	0	0	0	2	25	48	41	22	16	4	2	0	0	0	0	1	161
0.76- 1.00	0	0	0	2	24	50	39	36	11	2	1	0	2	0	0	0	167
1.01- 1.50	0	1	2	6	49	38	36	31	20	7	1	0	0	0	0	1	192
1.51- 2.00	0	0	0	4	15	12	21	26	18	4	0	0	0	0	0	1	101
2.01- 3.00	0	0	0	0	8	3	12	47	20	5	1	0	0	0	0	0	96
3.01- 5.00	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	1	1	2	16	133	168	166	170	98	23	5	1	3	0	0	3	818

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	45
0.35- 0.50	3	0	2	7	16	23	19	13	14	4	3	1	4	1	2	1	113
0.51- 0.75	4	7	10	9	35	52	50	29	22	11	4	4	1	1	0	2	241
0.76- 1.00	5	4	3	14	49	66	46	46	25	9	5	3	5	2	1	2	285
1.01- 1.50	11	12	22	41	95	66	55	58	55	28	23	19	8	10	3	8	514
1.51- 2.00	14	25	20	22	52	54	77	55	67	67	27	27	21	17	13	18	576
2.01- 3.00	73	64	44	40	47	56	80	164	169	171	105	59	66	71	58	59	1,326
3.01- 5.00	135	113	87	17	1	23	51	67	178	133	111	156	186	79	65	83	1,485
5.01- 7.00	21	21	5	1	0	0	1	2	3	24	16	61	63	11	40	29	298
7.01-10.00	3	1	0	0	0	0	0	0	0	2	7	9	4	1	7	3	37
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	269	247	193	151	295	340	379	434	533	449	301	339	358	193	189	205	4,920

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** AUGUST ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,208

TOTAL NUMBER OF VALID OBSERVATIONS: 4,920

TOTAL NUMBER OF MISSING OBSERVATIONS: 288

PERCENT DATA RECOVERY FOR THIS PERIOD: 94.5%

MEAN WIND SPEED FOR THIS PERIOD: 2.7 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
5.87	5.35	5.75	28.11	26.87	11.42	16.63

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	45	63	23	3	3	4	3	5	6	4	3	18	30	21	26	31	1
B	23	38	15	5	4	4	7	4	4	12	3	34	46	23	22	19	0
C	26	17	19	8	5	5	10	8	10	15	11	30	51	21	26	21	0
D	88	77	91	43	26	34	50	59	103	102	110	149	175	98	95	80	3
E	81	47	33	47	54	47	80	120	214	206	144	98	51	28	19	50	3
F	5	4	10	29	70	78	63	68	98	87	25	9	2	2	1	1	10
G	1	1	2	16	133	168	166	170	98	23	5	1	3	0	0	3	28
TOTAL	269	247	193	151	295	340	379	434	533	449	301	339	358	193	189	205	45

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** SEPTEMBER ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	3
1.51- 2.00	0	2	0	0	2	0	1	0	0	0	0	0	0	0	2	1	8
2.01- 3.00	12	4	1	0	2	0	0	1	1	1	0	1	3	8	5	11	50
3.01- 5.00	16	20	10	6	5	0	3	2	5	7	12	7	20	19	13	10	155
5.01- 7.00	5	1	1	1	0	0	0	0	3	5	1	5	20	4	0	1	47
7.01-10.00	0	0	0	0	0	0	0	0	0	0	1	2	1	0	0	1	5
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	33	27	12	7	9	0	5	3	9	13	15	15	44	31	20	25	268

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	3
1.51- 2.00	1	2	1	1	0	1	0	1	0	0	0	0	0	1	0	1	9
2.01- 3.00	8	1	2	1	0	0	0	0	1	2	1	2	3	3	2	5	31
3.01- 5.00	5	8	5	2	0	2	4	2	7	5	1	2	14	12	8	12	89
5.01- 7.00	2	0	0	0	0	0	3	0	1	7	3	5	6	9	1	1	38
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	16	11	8	4	0	4	7	3	9	14	5	9	23	25	12	20	170

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** SEPTEMBER ***

STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
1.01- 1.50	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0	2	6
1.51- 2.00	0	1	1	0	0	0	1	1	2	0	0	0	0	0	0	4	10
2.01- 3.00	4	3	2	0	1	1	3	3	2	1	2	2	6	3	5	3	41
3.01- 5.00	12	6	8	0	1	3	2	5	11	5	3	8	12	11	12	10	109
5.01- 7.00	3	0	4	0	0	0	0	0	4	9	2	2	6	4	2	0	36
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	4
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	19	11	15	0	2	4	7	9	19	16	8	12	27	20	20	19	208

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	3
0.35- 0.50	0	0	0	1	1	0	0	1	0	0	0	0	0	1	0	0	4
0.51- 0.75	0	1	1	0	0	0	0	1	0	0	2	0	0	0	0	0	5
0.76- 1.00	0	1	0	3	4	1	1	1	1	0	1	0	2	0	0	1	16
1.01- 1.50	4	4	12	7	9	5	2	0	1	3	2	2	2	3	0	3	59
1.51- 2.00	4	5	5	11	10	4	5	3	7	7	8	9	6	5	2	3	94
2.01- 3.00	30	34	20	17	21	17	24	15	20	21	33	27	18	23	16	16	352
3.01- 5.00	111	51	25	34	11	18	28	32	40	55	48	41	75	63	52	54	738
5.01- 7.00	24	6	7	8	1	2	20	8	14	19	11	26	25	29	43	34	277
7.01-10.00	0	0	0	0	0	0	0	1	1	1	1	4	7	8	10	5	38
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	173	102	70	81	57	47	80	62	84	106	106	109	135	132	124	116	1,587

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** SEPTEMBER ***
STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	7
0.35- 0.50	1	0	1	0	1	0	2	1	0	2	0	1	0	0	1	1	11
0.51- 0.75	0	2	1	3	2	0	1	4	1	0	2	0	1	1	0	0	18
0.76- 1.00	1	0	1	4	6	5	1	0	2	1	0	1	2	0	0	3	27
1.01- 1.50	4	3	9	8	10	5	17	7	10	8	5	4	3	1	1	4	99
1.51- 2.00	8	5	5	11	29	9	21	16	11	13	15	7	4	2	2	2	160
2.01- 3.00	11	10	12	21	31	30	40	44	62	91	56	19	9	7	5	15	463
3.01- 5.00	32	8	8	10	2	5	41	59	109	73	37	53	24	30	23	34	548
5.01- 7.00	3	1	0	0	0	0	4	3	13	8	9	12	11	11	8	18	101
7.01-10.00	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2	0	4
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	60	29	37	57	81	54	127	134	208	196	125	97	55	52	42	77	1,438

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	3
0.35- 0.50	0	1	0	1	1	0	1	2	0	0	0	0	1	0	0	1	8
0.51- 0.75	1	1	0	2	4	2	2	1	3	1	0	0	2	0	0	0	19
0.76- 1.00	1	0	1	3	9	5	9	5	3	1	2	0	2	0	1	0	42
1.01- 1.50	1	0	1	7	13	16	10	6	4	6	2	1	0	0	0	2	69
1.51- 2.00	0	1	0	3	18	14	5	10	8	12	1	1	0	0	1	1	75
2.01- 3.00	1	0	3	1	9	22	21	36	45	32	8	0	0	1	0	2	181
3.01- 5.00	1	0	0	0	0	5	1	9	16	12	0	0	0	0	1	0	45
5.01- 7.00	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	2
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	5	3	5	17	54	64	49	69	80	64	13	2	5	1	4	6	444

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** SEPTEMBER ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	8
0.35- 0.50	0	0	0	0	3	6	10	5	2	1	1	0	0	0	1	0	29
0.51- 0.75	0	0	1	0	3	19	25	21	12	2	0	0	0	0	0	1	84
0.76- 1.00	0	1	2	0	11	28	22	16	16	2	2	0	0	0	0	0	100
1.01- 1.50	0	0	0	4	22	48	34	34	18	3	2	1	0	0	0	0	166
1.51- 2.00	1	0	0	0	4	17	17	22	20	0	0	0	0	0	0	0	81
2.01- 3.00	1	0	0	0	3	10	14	26	28	5	3	0	0	0	0	0	90
3.01- 5.00	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	6
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2	1	3	4	46	128	122	128	98	13	8	1	0	0	1	2	565

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	21
0.35- 0.50	1	1	1	2	6	6	13	9	2	3	2	1	1	1	2	2	53
0.51- 0.75	1	4	3	5	9	21	28	27	16	3	4	0	3	1	0	1	126
0.76- 1.00	2	2	4	10	30	39	33	22	22	4	5	1	6	1	1	4	186
1.01- 1.50	9	8	22	26	54	75	65	47	33	21	12	8	5	5	2	13	405
1.51- 2.00	14	16	12	26	63	45	50	53	48	32	24	17	10	8	7	12	437
2.01- 3.00	67	52	40	40	67	80	102	125	159	153	103	51	39	45	33	52	1,208
3.01- 5.00	177	93	56	52	19	33	79	113	190	157	101	111	145	135	109	120	1,690
5.01- 7.00	37	8	12	9	1	2	27	11	36	48	26	50	68	57	55	55	502
7.01-10.00	0	0	0	0	0	0	0	1	1	1	3	6	12	8	13	6	51
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	308	184	150	170	249	301	397	408	507	422	280	245	289	261	223	265	4,680

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** SEPTEMBER ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,040

TOTAL NUMBER OF VALID OBSERVATIONS: 4,680

TOTAL NUMBER OF MISSING OBSERVATIONS: 360

PERCENT DATA RECOVERY FOR THIS PERIOD: 92.9%

MEAN WIND SPEED FOR THIS PERIOD: 3.1 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
5.73	3.63	4.44	33.91	30.73	9.49	12.07

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	33	27	12	7	9	0	5	3	9	13	15	15	44	31	20	25	0
B	16	11	8	4	0	4	7	3	9	14	5	9	23	25	12	20	0
C	19	11	15	0	2	4	7	9	19	16	8	12	27	20	20	19	0
D	173	102	70	81	57	47	80	62	84	106	106	109	135	132	124	116	3
E	60	29	37	57	81	54	127	134	208	196	125	97	55	52	42	77	7
F	5	3	5	17	54	64	49	69	80	64	13	2	5	1	4	6	3
G	2	1	3	4	46	128	122	128	98	13	8	1	0	0	1	2	8
TOTAL	308	184	150	170	249	301	397	408	507	422	280	245	289	261	223	265	21

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** OCTOBER ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	3
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	2
1.51- 2.00	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
2.01- 3.00	1	1	0	0	0	0	0	0	2	1	0	0	2	0	0	3	10
3.01- 5.00	5	5	4	0	2	2	3	8	2	12	9	4	16	10	2	1	85
5.01- 7.00	0	0	6	0	0	0	2	4	0	2	6	3	6	1	0	0	30
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	3
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	6	6	10	1	4	4	5	12	4	15	15	9	26	11	2	4	134

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	2
1.51- 2.00	0	1	0	0	1	0	1	0	0	0	0	0	0	0	1	0	4
2.01- 3.00	0	5	1	0	1	6	2	3	1	1	0	0	2	1	2	0	25
3.01- 5.00	3	3	10	2	0	4	11	7	6	5	7	5	8	6	5	4	86
5.01- 7.00	0	0	2	2	1	0	1	2	2	0	2	5	6	3	1	1	28
7.01-10.00	0	0	0	0	0	0	0	0	1	0	0	5	0	0	0	0	6
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3	9	13	4	3	10	16	12	10	7	9	15	16	10	9	6	152

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** OCTOBER ***
STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
1.51- 2.00	0	2	0	0	1	3	1	0	0	0	1	0	0	0	1	0	9
2.01- 3.00	2	1	1	0	4	0	4	1	3	0	0	1	3	5	2	2	29
3.01- 5.00	2	5	19	2	2	3	1	7	5	5	5	4	11	7	9	6	93
5.01- 7.00	0	0	8	3	0	0	0	4	2	2	8	7	12	3	3	0	52
7.01-10.00	0	0	0	0	0	0	0	0	0	3	1	5	1	0	0	0	10
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	4	9	28	5	8	6	6	12	10	10	15	18	27	15	15	8	196

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	1	0	0	0	1	0	1	0	0	0	0	1	0	4
0.51- 0.75	0	0	0	0	1	0	1	0	0	1	1	1	0	0	1	0	6
0.76- 1.00	0	2	1	1	4	2	1	0	1	0	1	1	2	1	0	0	17
1.01- 1.50	2	1	2	2	3	4	3	4	4	2	5	1	2	3	1	2	41
1.51- 2.00	3	4	6	4	10	3	4	6	4	1	5	3	8	5	2	2	70
2.01- 3.00	24	13	32	24	32	18	15	21	29	34	20	12	32	28	26	15	375
3.01- 5.00	49	17	49	31	15	26	41	42	63	65	65	39	68	91	72	72	805
5.01- 7.00	25	5	9	7	0	0	12	25	57	51	76	44	104	106	126	38	685
7.01-10.00	5	0	0	0	0	0	8	11	5	7	16	15	49	57	61	21	255
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	2	3	6	3	0	14
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	108	42	99	70	65	53	85	110	163	162	189	118	268	297	293	150	2,272

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** OCTOBER ***

STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	4
0.51- 0.75	2	0	1	4	2	1	3	3	1	0	0	2	1	0	1	2	23
0.76- 1.00	0	0	3	2	2	2	1	1	2	3	1	0	1	1	0	0	19
1.01- 1.50	2	3	5	2	12	8	7	4	5	6	5	3	0	1	1	1	65
1.51- 2.00	1	6	15	8	18	15	6	13	6	21	5	1	1	3	2	4	125
2.01- 3.00	8	15	5	23	38	44	45	37	71	92	35	15	8	6	5	13	460
3.01- 5.00	11	6	7	10	8	24	64	74	143	128	57	36	22	18	14	26	648
5.01- 7.00	1	0	2	2	0	1	27	12	22	21	23	6	20	10	13	4	164
7.01-10.00	0	0	0	0	0	0	5	5	4	2	1	4	13	17	7	1	59
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	25	30	38	51	81	96	158	149	254	273	128	68	69	56	43	51	1,571

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	3
0.35- 0.50	0	0	0	2	2	1	1	0	2	0	0	0	0	0	0	0	8
0.51- 0.75	0	1	0	0	2	1	1	3	1	2	0	0	0	1	0	0	12
0.76- 1.00	0	0	1	1	4	2	4	0	1	0	0	0	1	0	0	0	14
1.01- 1.50	0	0	0	5	16	14	5	5	6	1	0	1	0	0	0	2	55
1.51- 2.00	0	0	2	1	8	24	5	6	8	14	5	0	0	1	0	1	75
2.01- 3.00	1	0	0	1	14	26	22	22	35	31	7	0	0	0	2	0	161
3.01- 5.00	0	0	0	0	1	6	5	3	12	1	3	1	0	0	0	0	32
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	1	1	3	10	47	74	43	39	65	49	15	2	1	2	2	3	360

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** OCTOBER ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	3
0.35- 0.50	0	0	1	0	1	3	1	1	1	1	0	1	0	1	0	0	11
0.51- 0.75	0	1	0	1	7	6	1	4	3	1	1	0	0	0	0	0	25
0.76- 1.00	0	0	1	0	6	14	13	10	1	3	0	0	0	0	1	0	49
1.01- 1.50	0	1	1	1	17	15	16	18	10	1	1	0	0	0	0	0	81
1.51- 2.00	0	0	0	2	6	18	9	11	4	1	0	1	0	0	0	0	52
2.01- 3.00	0	0	0	1	6	11	17	16	16	3	2	0	0	0	0	0	72
3.01- 5.00	0	0	0	0	0	0	1	10	2	1	0	0	0	0	0	0	14
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	2	3	5	43	67	58	70	37	11	4	2	0	1	1	0	307

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	7
0.35- 0.50	0	0	1	3	4	5	2	2	3	2	1	2	0	1	1	0	27
0.51- 0.75	2	2	1	5	12	10	6	10	5	4	2	3	2	1	2	3	70
0.76- 1.00	0	2	6	4	16	20	19	11	5	6	2	1	4	2	1	0	99
1.01- 1.50	4	6	8	11	50	41	32	31	25	11	11	5	2	4	2	5	248
1.51- 2.00	4	13	23	15	45	63	26	36	22	37	16	5	9	9	6	7	336
2.01- 3.00	36	35	39	49	95	105	105	100	157	162	64	28	47	40	37	33	1,132
3.01- 5.00	70	36	89	45	28	65	126	151	233	217	146	89	125	132	102	109	1,763
5.01- 7.00	26	5	27	14	1	1	42	47	83	76	115	65	148	123	143	43	959
7.01-10.00	5	0	0	0	0	0	13	16	10	12	18	31	64	74	68	22	333
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	3	6	6	3	0	18
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	147	99	194	146	251	310	371	404	543	527	375	232	407	392	365	222	4,992

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** OCTOBER ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,208

TOTAL NUMBER OF VALID OBSERVATIONS: 4,992

TOTAL NUMBER OF MISSING OBSERVATIONS: 216

PERCENT DATA RECOVERY FOR THIS PERIOD: 95.9%

MEAN WIND SPEED FOR THIS PERIOD: 3.9 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
2.68	3.04	3.93	45.51	31.47	7.21	6.15

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	6	6	10	1	4	4	5	12	4	15	15	9	26	11	2	4	0
B	3	9	13	4	3	10	16	12	10	7	9	15	16	10	9	6	0
C	4	9	28	5	8	6	6	12	10	10	15	18	27	15	15	8	0
D	108	42	99	70	65	53	85	110	163	162	189	118	268	297	293	150	0
E	25	30	38	51	81	96	158	149	254	273	128	68	69	56	43	51	1
F	1	1	3	10	47	74	43	39	65	49	15	2	1	2	2	3	3
G	0	2	3	5	43	67	58	70	37	11	4	2	0	1	1	0	3
TOTAL	147	99	194	146	251	310	371	404	543	527	375	232	407	392	365	222	7

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** NOVEMBER ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.01- 5.00	2	0	0	0	0	0	0	0	1	0	5	4	3	3	0	0	18
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	2
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2	0	0	0	0	0	0	0	1	0	6	6	3	3	0	0	21

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	1	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	6
3.01- 5.00	0	3	1	0	4	1	1	0	2	2	5	4	4	3	1	3	34
5.01- 7.00	1	0	0	0	0	0	0	1	0	2	2	1	6	0	2	0	15
7.01-10.00	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	3
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2	4	1	1	4	1	1	2	2	4	8	6	13	4	4	3	60

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** NOVEMBER ***

STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
1.51- 2.00	0	0	0	0	1	0	0	0	0	1	0	1	0	0	1	0	4
2.01- 3.00	3	1	0	0	0	2	0	0	1	2	0	1	1	6	1	0	18
3.01- 5.00	0	7	2	2	3	2	1	0	6	2	1	3	5	11	4	0	49
5.01- 7.00	1	0	2	2	0	0	3	0	3	1	6	3	9	3	1	0	34
7.01-10.00	0	0	0	0	0	0	0	0	0	0	1	2	7	3	0	0	13
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	4	8	4	4	4	4	6	0	10	6	8	10	22	23	7	0	120

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	3
0.51- 0.75	0	1	1	0	0	1	0	0	1	0	0	0	0	1	0	0	5
0.76- 1.00	0	0	0	0	4	2	0	1	0	2	1	1	4	1	1	1	18
1.01- 1.50	2	5	3	3	7	4	2	2	4	4	1	0	3	0	2	1	43
1.51- 2.00	2	8	7	8	11	9	4	2	8	5	6	4	3	5	12	4	98
2.01- 3.00	31	23	21	22	52	21	21	26	53	36	21	13	33	39	23	23	458
3.01- 5.00	75	60	62	59	64	47	50	45	85	132	82	54	101	96	84	39	1,135
5.01- 7.00	18	3	13	26	4	10	51	43	62	92	130	74	111	116	100	36	889
7.01-10.00	6	11	1	3	0	1	23	17	8	11	64	76	99	46	64	15	445
10.01-13.00	1	0	0	0	0	0	0	0	0	0	3	12	1	7	19	2	45
>13.00	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2
TOTAL	135	112	108	121	143	95	151	136	221	282	308	237	355	311	305	121	3,141

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** NOVEMBER ***
STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	0	0	1	0	0	1	0	0	0	1	0	1	0	0	0	0	4
0.51- 0.75	1	0	1	1	3	0	1	1	3	0	0	0	1	0	1	1	14
0.76- 1.00	2	0	0	0	3	2	3	0	4	0	0	0	1	0	2	0	17
1.01- 1.50	0	1	2	9	6	8	10	4	6	3	3	2	0	0	2	0	56
1.51- 2.00	0	2	5	5	18	18	13	16	9	6	1	5	2	2	3	2	107
2.01- 3.00	2	1	10	22	29	24	18	34	43	37	33	3	5	4	7	3	275
3.01- 5.00	0	0	2	13	15	18	37	31	67	65	46	21	14	7	3	2	341
5.01- 7.00	0	0	0	0	0	4	24	26	41	25	25	18	10	6	2	1	182
7.01-10.00	0	0	2	0	0	0	6	3	7	14	12	11	7	2	0	0	64
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	3	6
>13.00	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	4
TOTAL	5	4	23	50	74	75	112	115	180	151	120	66	41	22	20	12	1,071

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	0	0	0	1	0	0	4	1	2	0	0	0	0	0	0	0	8
0.51- 0.75	0	1	1	0	0	1	2	1	0	1	0	0	0	0	0	0	7
0.76- 1.00	1	0	1	1	4	5	5	5	1	0	1	0	0	0	1	0	25
1.01- 1.50	0	0	1	2	11	15	7	4	2	3	1	0	0	0	0	0	46
1.51- 2.00	0	0	2	1	11	14	9	9	3	7	0	0	0	0	0	0	56
2.01- 3.00	0	1	1	3	7	14	7	6	19	17	11	0	0	0	0	0	86
3.01- 5.00	0	0	0	1	2	2	3	5	5	0	0	0	0	0	0	0	18
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	1	2	6	9	35	51	37	31	32	28	13	1	0	0	1	0	248

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 -8/31/82

*** NOVEMBER ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	3
0.35- 0.50	0	0	1	1	0	1	2	3	0	0	0	0	0	0	0	0	8
0.51- 0.75	1	0	0	1	3	2	9	6	5	0	0	1	0	0	0	0	28
0.76- 1.00	0	0	2	1	2	5	6	9	6	1	0	0	0	0	0	0	32
1.01- 1.50	0	0	0	3	9	10	9	10	8	0	0	0	0	0	0	0	49
1.51- 2.00	0	0	0	0	4	6	6	4	5	5	0	0	0	0	0	0	30
2.01- 3.00	0	0	0	2	5	0	3	3	12	0	0	2	0	0	0	0	27
3.01- 5.00	0	0	0	0	1	1	0	0	3	0	0	0	0	0	0	0	5
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	1	0	3	8	24	25	35	35	39	6	0	3	0	0	0	0	182

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	5
0.35- 0.50	0	1	2	2	1	2	6	4	2	1	0	2	0	0	0	0	23
0.51- 0.75	2	2	3	2	6	4	12	8	9	1	0	1	1	1	1	1	54
0.76- 1.00	3	0	3	2	13	14	14	15	11	3	2	1	5	1	4	1	92
1.01- 1.50	2	6	6	17	33	37	30	20	20	10	5	2	3	0	4	1	196
1.51- 2.00	2	10	14	14	45	47	32	31	25	24	7	10	5	7	16	6	295
2.01- 3.00	37	27	32	50	93	61	49	70	128	92	65	19	40	49	32	26	870
3.01- 5.00	77	70	67	75	89	71	92	81	169	201	139	86	127	120	92	44	1,600
5.01- 7.00	20	3	15	28	4	14	78	70	106	120	164	97	136	125	105	37	1,122
7.01-10.00	6	11	3	3	0	1	29	20	15	25	78	91	114	51	64	15	526
10.01-13.00	1	0	0	0	0	0	0	0	0	0	3	14	3	9	19	5	54
>13.00	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	6
TOTAL	150	130	145	193	284	251	342	319	485	477	463	329	434	363	337	136	4,843

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 -8/31/82

*** NOVEMBER ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,040

TOTAL NUMBER OF VALID OBSERVATIONS: 4,843

TOTAL NUMBER OF MISSING OBSERVATIONS: 197

PERCENT DATA RECOVERY FOR THIS PERIOD: 96.1%

MEAN WIND SPEED FOR THIS PERIOD: 4.3 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
0.43	1.24	2.48	64.86	22.11	5.12	3.76

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	2	0	0	0	0	0	0	0	1	0	6	6	3	3	0	0	0
B	2	4	1	1	4	1	1	2	2	4	8	6	13	4	4	3	0
C	4	8	4	4	4	4	6	0	10	6	8	10	22	23	7	0	0
D	135	112	108	121	143	95	151	136	221	282	308	237	355	311	305	121	0
E	5	4	23	50	74	75	112	115	180	151	120	66	41	22	20	12	1
F	1	2	6	9	35	51	37	31	32	28	13	1	0	0	1	0	1
G	1	0	3	8	24	25	35	35	39	6	0	3	0	0	0	0	3
TOTAL	150	130	145	193	284	251	342	319	485	477	463	329	434	363	337	136	5

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** DECEMBER ***
STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.01- 5.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
5.01- 7.00	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	1	0	0	0	0	0	0	0	0	1	0	2	0	1	0	0	6

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.01- 5.00	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	1	0	1	0	0	0	0	0	0	0	0	0	2	0	0	4

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** DECEMBER ***
STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	1	2	1	3	0	0	0	0	0	0	0	0	0	0	7
3.01- 5.00	2	1	0	0	1	1	0	0	0	0	0	2	1	1	0	0	9
5.01- 7.00	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0	0	4
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1	0	5
10.01-13.00	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2	1	1	2	2	4	0	0	2	1	0	2	4	4	1	0	26

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	7
0.35- 0.50	1	0	0	1	0	0	1	1	1	0	0	1	1	0	0	1	8
0.51- 0.75	0	0	1	1	1	1	3	0	1	2	0	0	2	0	0	1	13
0.76- 1.00	1	0	5	5	2	0	0	2	0	0	5	0	0	2	1	1	24
1.01- 1.50	4	3	6	7	12	11	8	6	5	4	4	0	4	0	4	1	79
1.51- 2.00	7	8	9	12	13	14	10	7	9	6	8	4	1	3	2	7	120
2.01- 3.00	20	20	24	44	44	28	24	31	41	30	39	22	21	17	10	24	439
3.01- 5.00	41	42	41	38	55	42	29	37	98	168	179	111	99	79	70	57	1,186
5.01- 7.00	26	21	3	3	2	10	43	34	62	108	149	105	116	109	116	29	936
7.01-10.00	9	6	0	3	2	7	7	15	18	35	69	98	72	90	102	44	577
10.01-13.00	0	0	0	1	0	1	0	0	2	1	12	30	32	14	11	1	105
>13.00	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	4
TOTAL	109	100	89	115	131	114	125	133	237	354	465	373	350	314	316	166	3,498

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** DECEMBER ***
STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	10
0.35- 0.50	1	1	1	0	3	4	3	0	0	0	1	1	0	2	1	2	20
0.51- 0.75	0	1	2	2	4	4	5	3	4	0	0	2	0	1	1	1	30
0.76- 1.00	0	1	1	0	3	4	2	3	8	2	1	1	0	0	0	1	27
1.01- 1.50	1	5	3	7	5	13	5	8	8	4	2	4	1	2	2	2	72
1.51- 2.00	1	2	3	4	12	12	10	14	10	10	8	4	4	2	0	2	98
2.01- 3.00	4	1	10	21	25	24	21	45	36	53	15	5	6	3	0	0	269
3.01- 5.00	4	1	4	10	11	25	36	42	92	62	38	10	4	2	0	2	343
5.01- 7.00	2	1	2	0	0	7	24	53	48	43	38	17	11	5	3	1	255
7.01-10.00	0	0	1	0	0	1	8	13	12	21	12	9	4	3	1	1	86
10.01-13.00	0	0	0	0	0	0	0	0	0	3	3	3	2	0	0	0	11
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	13	13	27	44	63	94	114	181	218	198	118	56	32	20	8	12	1,221

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	3
0.51- 0.75	0	0	0	0	1	2	0	1	0	1	0	0	0	0	1	0	6
0.76- 1.00	0	1	0	0	3	0	4	1	2	2	0	0	0	0	0	0	13
1.01- 1.50	0	0	2	0	1	6	2	1	4	0	1	0	0	0	0	1	18
1.51- 2.00	0	0	0	2	0	0	3	3	3	0	1	0	0	0	0	0	12
2.01- 3.00	0	0	0	3	4	6	6	7	3	2	0	0	0	0	0	0	31
3.01- 5.00	0	0	1	10	0	4	5	0	1	1	0	0	0	0	0	0	22
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	1	3	15	10	18	21	14	13	6	2	2	0	0	1	1	109

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** DECEMBER ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
0.76- 1.00	0	0	1	1	3	1	3	0	0	0	0	0	0	0	0	0	9
1.01- 1.50	0	0	0	1	1	2	3	2	0	0	0	0	0	0	0	0	9
1.51- 2.00	0	0	0	0	0	1	2	2	0	0	0	0	0	0	0	0	5
2.01- 3.00	0	0	0	2	0	1	0	6	0	1	0	0	0	0	0	0	10
3.01- 5.00	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
5.01- 7.00	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	1	4	5	5	9	10	0	2	0	0	0	0	0	0	36

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	20
0.35- 0.50	2	1	1	1	4	4	5	2	1	0	1	2	1	2	1	3	31
0.51- 0.75	0	1	3	3	7	7	8	4	5	3	0	2	2	1	2	2	50
0.76- 1.00	1	2	7	6	11	5	9	6	10	4	6	1	0	2	1	2	73
1.01- 1.50	6	8	11	16	19	32	18	17	17	8	7	4	5	2	6	4	180
1.51- 2.00	8	10	12	18	25	27	25	26	22	16	17	8	5	5	2	9	235
2.01- 3.00	24	21	35	72	74	62	51	89	80	86	54	27	27	20	10	24	756
3.01- 5.00	47	45	46	58	67	72	71	79	191	231	217	124	104	82	70	59	1,563
5.01- 7.00	28	22	5	3	2	17	67	87	111	154	187	124	129	114	119	30	1,199
7.01-10.00	9	6	1	3	2	8	15	28	30	56	81	108	77	98	104	45	671
10.01-13.00	0	0	0	1	0	1	0	0	3	4	15	33	34	15	11	1	118
>13.00	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	4
TOTAL	125	116	121	181	211	235	269	338	470	562	585	435	386	341	326	179	4,900

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** DECEMBER ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,208

TOTAL NUMBER OF VALID OBSERVATIONS: 4,900

TOTAL NUMBER OF MISSING OBSERVATIONS: 308

PERCENT DATA RECOVERY FOR THIS PERIOD: 94.1%

MEAN WIND SPEED FOR THIS PERIOD: 4.7 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
0.12	0.08	0.53	71.39	24.92	2.22	0.73

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	1	0	0	0	0	0	0	0	0	1	0	2	0	1	0	0	1
B	0	1	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0
C	2	1	1	2	2	4	0	0	2	1	0	2	4	4	1	0	0
D	109	100	89	115	131	114	125	133	237	354	465	373	350	314	316	166	7
E	13	13	27	44	63	94	114	181	218	198	118	56	32	20	8	12	10
F	0	1	3	15	10	18	21	14	13	6	2	2	0	0	1	1	2
G	0	0	1	4	5	5	9	10	0	2	0	0	0	0	0	0	0
TOTAL	125	116	121	181	211	235	269	338	470	562	585	435	386	341	326	179	20

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** ANNUAL ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	2	0	0	0	0	0	0	1	0	1	0	4
0.76- 1.00	0	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	4
1.01- 1.50	1	1	0	1	2	1	1	1	0	1	1	0	0	2	2	3	17
1.51- 2.00	3	7	2	1	3	1	2	1	1	1	0	1	3	3	8	4	41
2.01- 3.00	62	26	8	4	5	6	3	6	8	4	3	10	23	35	41	53	297
3.01- 5.00	120	131	64	21	16	14	24	26	35	33	40	41	148	146	127	103	1,089
5.01- 7.00	15	23	68	9	1	6	7	19	12	17	21	54	130	32	15	14	443
7.01-10.00	1	0	16	2	0	0	1	2	4	4	6	28	37	4	4	1	110
10.01-13.00	0	0	0	0	0	0	0	1	0	0	1	1	1	1	0	0	5
>13.00	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2
TOTAL	202	189	158	38	28	31	38	57	60	60	72	137	343	223	198	178	2,014

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
0.76- 1.00	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	3
1.01- 1.50	2	2	1	1	2	2	1	0	0	1	0	0	2	0	2	3	19
1.51- 2.00	3	6	2	2	3	2	3	3	0	0	1	0	0	7	3	4	39
2.01- 3.00	30	29	8	7	9	10	7	7	7	5	3	5	19	29	42	30	247
3.01- 5.00	61	85	58	16	11	15	37	27	28	40	29	63	140	120	68	60	858
5.01- 7.00	13	10	42	10	3	4	13	11	16	29	19	41	131	37	23	18	420
7.01-10.00	0	3	11	2	0	0	8	1	5	10	7	33	43	10	6	0	139
10.01-13.00	0	0	0	0	0	0	1	1	0	0	0	1	2	1	0	0	6
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	109	135	122	39	28	33	71	50	57	85	59	143	337	204	144	116	1,732

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** ANNUAL ***

STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3
0.51- 0.75	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	3
0.76- 1.00	1	0	0	0	1	0	0	2	1	0	1	1	0	2	0	0	9
1.01- 1.50	2	2	0	1	4	1	3	1	0	2	0	0	4	4	2	8	34
1.51- 2.00	4	6	3	3	5	5	2	2	3	3	1	4	1	7	6	14	69
2.01- 3.00	52	17	21	10	17	12	14	21	22	16	14	20	40	56	58	45	435
3.01- 5.00	82	86	98	22	17	24	29	38	53	45	42	84	187	158	127	81	1,173
5.01- 7.00	8	12	41	18	2	3	13	18	39	37	22	72	111	60	25	11	492
7.01-10.00	1	2	9	2	0	0	5	2	5	11	23	49	41	21	8	2	181
10.01-13.00	0	0	0	0	0	0	0	0	2	0	0	5	0	2	0	0	9
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	152	126	172	56	46	45	66	85	125	115	104	235	384	310	226	161	2,408

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	36
0.35- 0.50	5	5	4	7	5	4	5	4	5	1	9	4	4	2	3	2	69
0.51- 0.75	5	5	10	11	9	4	9	5	8	7	10	8	9	1	3	3	107
0.76- 1.00	15	16	18	32	24	11	7	6	6	9	21	10	20	12	8	11	226
1.01- 1.50	49	54	54	79	76	41	33	33	31	37	60	35	48	46	37	51	764
1.51- 2.00	73	95	96	115	92	67	46	50	68	56	72	85	79	96	76	72	1,238
2.01- 3.00	311	310	338	354	326	186	176	209	301	319	303	299	411	384	392	298	4,917
3.01- 5.00	634	476	728	572	290	280	370	390	631	854	876	898	1,253	1,000	790	604	10,646
5.01- 7.00	194	99	234	250	31	74	274	243	345	491	705	950	1,012	701	700	311	6,614
7.01-10.00	43	29	81	87	5	31	140	97	91	132	279	652	546	454	366	123	3,156
10.01-13.00	6	1	5	13	0	2	10	6	10	11	33	152	105	45	44	5	448
>13.00	0	0	0	0	0	0	0	0	0	6	1	5	5	9	0	0	26
TOTAL	1,335	1,090	1,568	1,520	858	700	1,070	1,043	1,496	1,923	2,369	3,098	3,492	2,750	2,419	1,480	28,247

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** ANNUAL ***
STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	66
0.35- 0.50	4	7	10	6	10	9	7	7	6	12	11	5	5	4	8	9	120
0.51- 0.75	14	14	19	21	23	16	28	17	22	10	14	11	9	10	9	8	245
0.76- 1.00	17	14	21	31	40	33	27	17	34	21	20	15	19	14	13	6	342
1.01- 1.50	28	39	68	92	108	90	83	64	84	68	75	58	50	32	28	29	996
1.51- 2.00	39	59	85	121	179	117	125	121	141	161	120	91	78	38	31	27	1,533
2.01- 3.00	122	120	124	208	296	225	291	414	618	672	445	205	142	112	77	118	4,189
3.01- 5.00	153	95	90	132	91	164	369	467	1,019	723	461	364	201	154	118	166	4,767
5.01- 7.00	22	23	19	10	4	33	165	198	327	220	182	189	105	45	42	47	1,631
7.01-10.00	3	1	5	3	0	12	68	61	60	79	55	91	48	24	10	4	524
10.01-13.00	0	0	0	0	0	0	9	2	5	10	9	9	8	1	1	3	57
>13.00	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	4
TOTAL	402	372	441	624	751	699	1,172	1,368	2,316	1,976	1,392	1,042	665	434	337	417	14,474

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	63
0.35- 0.50	2	4	1	16	21	14	20	14	16	10	4	1	7	4	3	3	140
0.51- 0.75	11	10	12	15	34	26	25	31	28	21	11	9	7	2	3	1	246
0.76- 1.00	4	3	10	35	74	49	46	43	48	27	20	12	11	5	2	0	389
1.01- 1.50	2	6	20	58	141	119	72	53	91	63	43	18	8	5	1	9	709
1.51- 2.00	11	6	12	46	110	111	102	72	97	116	58	19	8	5	7	3	783
2.01- 3.00	10	4	14	42	106	186	149	257	318	256	92	16	4	4	5	5	1,468
3.01- 5.00	7	6	8	16	9	34	32	48	98	38	26	1	1	3	5	2	334
5.01- 7.00	0	0	0	0	0	0	0	1	4	0	0	3	1	0	1	0	10
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	47	39	77	228	495	539	446	519	700	531	254	80	47	28	27	23	4,143

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** ANNUAL ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	163
0.35- 0.50	2	3	8	13	47	67	76	63	43	15	12	5	3	3	1	1	362
0.51- 0.75	3	6	9	19	88	148	167	127	113	32	6	7	3	2	3	2	735
0.76- 1.00	4	3	14	19	108	187	182	144	129	52	20	4	5	2	1	1	875
1.01- 1.50	2	5	12	46	203	243	194	195	139	64	24	7	7	0	1	3	1,145
1.51- 2.00	2	3	6	25	84	114	121	132	114	30	10	4	2	1	1	2	651
2.01- 3.00	4	1	2	30	58	80	91	197	200	46	14	4	0	1	0	2	730
3.01- 5.00	1	1	0	4	2	5	5	31	26	2	0	0	1	0	0	0	78
5.01- 7.00	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	3
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	19	22	51	156	590	844	836	889	764	242	86	31	21	9	7	12	4,742

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 10.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	330
0.35- 0.50	14	20	23	42	83	94	108	88	70	38	37	15	19	13	15	15	694
0.51- 0.75	34	35	50	66	154	196	229	181	171	71	41	35	29	15	19	15	1,341
0.76- 1.00	41	37	63	118	248	281	263	213	219	109	82	42	55	35	24	18	1,848
1.01- 1.50	86	109	155	278	536	497	387	347	345	236	203	118	119	89	73	106	3,684
1.51- 2.00	135	182	206	313	476	417	401	381	424	367	262	204	171	157	132	126	4,354
2.01- 3.00	591	507	515	655	817	705	731	1,111	1,474	1,318	874	559	639	621	615	551	12,283
3.01- 5.00	1,058	880	1,046	783	436	536	866	1,027	1,890	1,735	1,474	1,451	1,931	1,581	1,235	1,016	18,945
5.01- 7.00	253	167	404	297	41	120	472	490	743	795	949	1,309	1,490	875	806	402	9,613
7.01-10.00	48	35	122	96	5	43	222	163	165	236	370	853	715	513	394	130	4,110
10.01-13.00	6	1	5	13	0	2	20	10	17	21	43	169	116	50	45	8	526
>13.00	0	0	0	0	0	0	0	0	0	6	1	11	5	9	0	0	32
TOTAL	2,266	1,973	2,589	2,661	2,796	2,891	3,699	4,011	5,518	4,932	4,336	4,766	5,289	3,958	3,358	2,387	57,760

CEI PNPP 7 SITE YEAR 10-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** ANNUAL ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 10.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 61,344

TOTAL NUMBER OF VALID OBSERVATIONS: 57,760

TOTAL NUMBER OF MISSING OBSERVATIONS: 3,584

PERCENT DATA RECOVERY FOR THIS PERIOD: 94.2%

MEAN WIND SPEED FOR THIS PERIOD: 3.7 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
3.49	3.00	4.17	48.90	25.06	7.17	8.21

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	202	189	158	38	28	31	38	57	60	60	72	137	343	223	198	178	2
B	109	135	122	39	28	33	71	50	57	85	59	143	337	204	144	116	0
C	152	126	172	56	46	45	66	85	125	115	104	235	384	310	226	161	0
D	1,335	1,090	1,568	1,520	858	700	1,070	1,043	1,496	1,923	2,369	3,098	3,492	2,750	2,419	1,480	36
E	402	372	441	624	751	699	1,172	1,368	2,316	1,976	1,392	1,042	665	434	337	417	66
F	47	39	77	228	495	539	446	519	700	531	254	80	47	28	27	23	63
G	19	22	51	156	590	844	836	889	764	242	86	31	21	9	7	12	163
TOTAL	2,266	1,973	2,589	2,661	2,796	2,891	3,699	4,011	5,518	4,932	4,336	4,766	5,289	3,958	3,358	2,387	330

<APPENDIX 2C>

MONTHLY AND ANNUAL JOINT FREQUENCY

DISTRIBUTIONS FOR PNPP, 60-METER WINDS

APPENDIX 2C

MONTHLY AND ANNUAL JOINT FREQUENCY DISTRIBUTIONS[1] FOR PNPP, 60-METER WINDS

Contents

NOTE:

[1] Stability based on ΔT (60-10 meters) and <Regulatory Guide 1.23>

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

00000080

CEI PERRY 10 METER WINDS (DELTA T 60-10M) 3 YRS COMBINED

PERIOD OF RECORD: 5/1/72 - 8/31/78

STABILITY CLASS: A

ELEVATION: 60 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	2	38	42	6	4	0	92
NNE	1	21	55	18	3	0	98
NE	5	14	38	36	15	0	108
ENE	0	2	14	5	3	1	25
E	2	2	9	3	0	0	16
ESE	0	4	4	4	0	0	12
SE	1	7	8	9	0	0	25
SSE	2	4	13	16	1	1	37
S	1	4	17	11	5	2	40
SSW	1	4	9	18	0	2	34
SW	1	5	9	9	3	6	33
WSW	2	4	32	43	23	2	106
W	2	14	59	46	15	4	140
WNW	0	27	38	21	4	0	90
NW	5	29	47	5	2	2	90
NNW	1	42	41	6	2	0	92
TOTALS	26	221	435	256	80	20	1,038

PERIODS OF CALMS 0 HOURS

STABILITY CLASS: B

ELEVATION: 60 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
		MILES PER HOUR					
N	4	26	23	7	1	0	61
NNE	0	11	12	3	1	0	27
NE	2	13	42	16	11	0	84
ENE	4	5	4	6	4	0	23
E	1	6	9	0	0	0	16
ESE	2	4	11	2	1	0	20
SE	0	7	24	7	3	0	41
SSE	1	8	13	11	2	1	36
S	0	1	13	11	4	0	29
SSW	0	3	7	10	9	0	29
SW	0	1	11	16	4	3	35
WSW	0	2	26	29	17	3	77
W	1	12	34	36	19	10	112
WNW	1	19	36	17	2	2	77
NW	2	25	20	5	2	3	57
NNW	3	27	15	6	2	0	53
TOTALS	21	170	300	182	82	22	777

PERIODS OF CALMS 0 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

00000080

CEI PERRY 10 METER WINDS (DELTA T 60-10M) 3 YRS COMBINED

PERIOD OF RECORD: 5/1/72 - 8/31/78

STABILITY CLASS: C

ELEVATION: 60 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	4	15	19	2	3	0	43
NNE	3	8	18	4	0	0	33
NE	3	13	28	20	8	1	73
ENE	3	7	15	13	1	0	39
E	1	7	5	3	0	0	16
ESE	0	10	15	3	0	0	28
SE	1	10	10	7	1	0	29
SSE	1	6	10	15	6	0	38
S	1	4	22	24	6	2	59
SSW	1	10	24	22	7	2	66
SW	2	8	23	13	4	1	51
WSW	2	7	27	33	21	13	103
W	4	18	51	36	14	9	132
WNW	3	41	34	19	14	5	116
NW	2	39	28	11	8	3	91
NNW	5	22	22	4	1	0	54
TOTALS	36	225	351	229	94	36	971

PERIODS OF CALMS 0 HOURS

STABILITY CLASS: D

ELEVATION: 60 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	33	119	188	159	68	24	591
NNE	15	85	111	56	28	14	309
NE	44	130	227	179	67	21	668
ENE	39	125	248	167	78	14	671
E	51	168	248	70	4	2	543
ESE	31	99	160	55	10	5	360
SE	22	66	132	141	71	34	466
SSE	9	48	116	133	85	32	423
S	14	88	171	176	68	13	530
SSW	31	83	234	268	111	29	756
SW	33	124	302	382	206	93	1,140
WSW	26	113	225	346	266	186	1,164
W	35	190	304	354	202	168	1,253
WNW	37	141	195	191	121	127	812
NW	28	170	231	204	137	103	873
NNW	24	98	138	147	82	19	508
TOTALS	474	1,847	3,230	3,028	1,604	884	11,067

PERIODS OF CALMS 11 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

00000080

CEI PERRY 10 METER WINDS (DELTA T 60-10M) 3 YRS COMBINED

PERIOD OF RECORD: 5/1/72 - 8/31/78

STABILITY CLASS: E

ELEVATION: 60 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	17	28	55	30	4	3	137
NNE	15	37	40	18	6	4	120
NE	24	57	61	26	8	2	178
ENE	17	48	85	36	8	1	195
E	31	86	141	21	0	0	279
ESE	20	50	94	19	7	0	190
SE	24	70	133	138	52	11	428
SSE	12	42	165	179	55	22	475
S	38	61	239	375	87	24	824
SSW	22	64	272	389	97	21	865
SW	25	78	284	212	62	39	700
WSW	30	68	122	160	64	47	491
W	23	61	84	81	35	26	310
WNW	20	62	50	34	21	17	204
NW	19	37	51	25	15	11	158
NNW	14	45	53	37	7	2	158
TOTALS	351	894	1,929	1,780	528	230	5,712

PERIODS OF CALMS 17 HOURS

STABILITY CLASS: F

ELEVATION: 60 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	7	10	3	1	0	0	21
NNE	7	7	3	2	0	0	19
NE	9	14	5	0	0	0	28
ENE	7	21	27	4	0	0	59
E	12	36	74	27	0	0	149
ESE	8	26	69	17	0	0	120
SE	13	31	62	47	0	0	153
SSE	11	30	48	47	1	0	137
S	15	32	80	114	0	0	241
SSW	9	31	94	112	1	0	247
SW	15	48	86	65	2	0	216
WSW	13	31	56	9	1	0	110
W	6	17	22	4	1	1	51
WNW	3	14	5	0	0	0	22
NW	4	7	4	0	0	0	15
NNW	10	10	3	0	0	0	23
TOTALS	149	365	641	449	6	1	1,611

PERIODS OF CALMS 10 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

00000080

CEI PERRY 10 METER WINDS (DELTA T 60-10M) 3 YRS COMBINED

PERIOD OF RECORD: 5/1/72 - 8/31/78

STABILITY CLASS: G

ELEVATION: 60 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	14	19	3	0	0	0	36
NNE	9	26	8	0	0	0	43
NE	22	34	18	1	0	0	75
ENE	10	49	28	4	0	0	91
E	29	55	57	16	0	0	157
ESE	21	53	82	28	0	0	184
SE	23	56	64	21	0	0	184
SSE	17	49	48	46	2	0	162
S	20	55	78	82	1	0	236
SSW	17	64	71	45	0	0	197
SW	29	85	101	27	1	1	244
WSW	16	52	21	3	0	0	92
W	17	42	16	2	0	0	77
NNW	12	17	1	0	0	0	30
NW	17	18	3	0	0	0	38
NNW	6	17	0	1	0	0	26
TOTALS	281	691	619	276	4	1	1,872

PERIODS OF CALMS 8 HOURS

STABILITY CLASS: ALL

ELEVATION: 10 METERS DELTA T (60.0 - 10.0) METERS

DIRECTION	1-3	4-7	8-12	13-18	19-24	>24	TOTAL
			MILES PER HOUR				
N	81	255	333	205	80	27	981
NNE	50	195	247	101	38	18	649
NE	109	275	419	278	109	24	1,214
ENE	80	257	421	235	94	16	1,103
E	127	360	543	140	4	2	1,176
ESE	82	246	435	128	18	5	914
SE	84	247	453	370	127	45	1,326
SSE	53	187	413	447	152	56	1,308
S	89	245	620	793	171	41	1,959
SSW	81	259	711	864	225	54	2,194
SW	105	349	816	724	282	143	2,419
WSW	91	277	509	623	392	251	2,143
W	88	354	570	559	286	218	2,075
WNW	76	321	359	282	162	151	1,351
NW	77	325	384	250	164	122	1,322
NNW	65	261	272	201	94	21	914
TOTALS	1,338	4,413	7,505	6,200	2,398	1,194	23,048

PERIODS OF CALMS 30 HOURS

* NUS CORPORATION ENVIRONMENTAL SAFEGUARDS DIVISION *

00000080

CEI PERRY 60 METER WINDS (DELTA T 60-10M) 3 YRS COMBINED
PERIOD OF RECORD: 5/1/72 - 8/31/78

OBSERVATIONS WITH MISSING DATA 3,182

TOTAL OBSERVATIONS FOR THE PERIOD ARE 23,098

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
4.49	3.36	4.20	47.98	24.80	7.02	8.14

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JANUARY ***
STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
2.01- 3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.01- 5.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	2

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.01- 5.00	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JANUARY ***

STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	4
3.01- 5.00	0	0	0	0	1	1	0	0	0	1	3	1	0	0	0	1	8
5.01- 7.00	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	4
7.01-10.00	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	3
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	6
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	1	5	0	0	0	4	5	9	0	0	0	1	25

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	5
0.35- 0.50	0	1	1	1	1	0	2	0	0	0	0	0	1	1	2	1	11
0.51- 0.75	0	0	1	1	3	1	0	0	0	1	1	0	1	0	0	0	9
0.76- 1.00	0	1	0	0	3	3	2	4	1	2	0	0	0	0	0	2	18
1.01- 1.50	3	1	5	4	6	1	1	2	3	2	5	3	5	3	2	3	49
1.51- 2.00	5	2	4	5	6	5	4	3	3	4	5	4	6	6	5	1	68
2.01- 3.00	10	13	18	25	28	15	20	14	12	15	21	17	20	25	18	15	286
3.01- 5.00	34	20	36	64	57	37	36	21	29	38	96	56	79	54	36	27	720
5.01- 7.00	43	11	16	38	22	19	32	23	38	50	131	145	152	99	36	40	895
7.01-10.00	9	5	25	28	10	16	10	34	24	34	110	201	198	117	64	9	894
10.01-13.00	8	8	19	26	0	1	5	10	8	9	26	114	74	76	25	2	411
>13.00	3	0	0	6	0	0	0	2	8	11	13	75	51	8	0	0	177
TOTAL	115	62	125	198	136	98	112	113	126	166	408	615	587	389	188	100	3,543

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JANUARY ***

STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	3
0.51- 0.75	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	3
0.76- 1.00	1	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	4
1.01- 1.50	1	1	1	2	1	1	2	2	3	4	1	2	1	1	1	0	24
1.51- 2.00	1	1	3	1	2	1	1	5	3	1	2	2	2	1	1	0	27
2.01- 3.00	1	3	4	6	8	5	6	7	5	13	20	1	6	6	6	2	99
3.01- 5.00	5	7	7	8	22	16	23	23	18	37	46	27	7	17	3	8	274
5.01- 7.00	0	2	2	2	7	17	23	20	24	52	76	42	13	2	4	0	286
7.01-10.00	1	0	0	1	0	5	21	34	38	16	19	29	9	5	0	0	178
10.01-13.00	0	0	0	1	0	1	6	19	8	15	15	19	2	0	0	0	86
>13.00	0	0	0	0	0	0	0	2	2	3	5	7	2	0	0	0	21
TOTAL	10	14	18	22	40	46	83	113	102	142	184	130	42	32	16	11	1,007

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
0.51- 0.75	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	2
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	3
1.01- 1.50	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	3
1.51- 2.00	0	1	0	0	0	0	1	1	1	0	3	1	0	2	2	0	12
2.01- 3.00	0	0	0	0	3	3	0	1	1	1	5	1	0	0	0	0	15
3.01- 5.00	0	1	2	3	7	8	4	6	11	9	8	6	1	2	0	0	68
5.01- 7.00	0	0	0	0	2	4	2	1	10	6	17	2	0	1	0	0	45
7.01-10.00	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	2	3	3	12	15	8	9	25	16	35	11	3	5	2	1	151

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JANUARY ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	3
0.76- 1.00	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
1.01- 1.50	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	3
1.51- 2.00	0	0	0	1	0	0	1	1	0	2	2	1	1	1	0	0	10
2.01- 3.00	0	0	0	1	1	1	4	2	2	4	2	2	4	0	0	0	23
3.01- 5.00	0	0	0	0	3	7	2	3	10	13	13	1	2	1	0	0	55
5.01- 7.00	0	0	0	0	1	0	0	1	3	6	6	0	0	0	0	0	17
7.01-10.00	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	2
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	2	6	9	7	8	17	25	25	5	7	3	0	0	115

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	9
0.35- 0.50	0	1	1	2	1	0	3	0	1	0	0	1	1	1	2	1	15
0.51- 0.75	0	0	2	1	4	2	1	0	0	2	1	0	2	1	0	1	17
0.76- 1.00	1	1	0	0	3	3	2	6	1	2	2	1	0	0	1	3	26
1.01- 1.50	4	2	7	6	7	2	3	4	8	6	8	5	7	4	3	3	79
1.51- 2.00	6	4	7	7	8	6	8	10	7	7	12	8	9	10	8	1	118
2.01- 3.00	11	16	22	32	40	24	30	24	20	36	48	22	30	31	24	17	427
3.01- 5.00	39	28	45	75	90	70	65	53	68	98	166	91	89	74	39	36	1,126
5.01- 7.00	43	13	18	40	32	42	57	45	75	114	232	189	165	102	40	40	1,247
7.01-10.00	10	5	25	29	10	23	31	68	64	50	129	232	207	123	64	9	1,079
10.01-13.00	8	8	19	27	0	2	11	29	16	24	41	139	76	76	25	2	503
>13.00	3	0	0	6	0	0	0	4	10	14	18	82	53	8	0	0	198
TOTAL	125	78	146	225	195	174	211	243	270	353	657	770	639	430	206	113	4,844

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/ 1/72 - 8/31/82

*** JANUARY ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,208

TOTAL NUMBER OF VALID OBSERVATIONS: 4,844

TOTAL NUMBER OF MISSING OBSERVATIONS: 364

PERCENT DATA RECOVERY FOR THIS PERIOD: 93.0%

MEAN WIND SPEED FOR THIS PERIOD: 6.4 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
0.04	0.02	0.52	73.14	20.79	3.12	2.37

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
B	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
C	0	0	0	0	1	5	0	0	0	4	5	9	0	0	0	1	0
D	115	62	125	198	136	98	112	113	126	166	408	615	587	389	188	100	5
E	10	14	18	22	40	46	83	113	102	142	184	130	42	32	16	11	2
F	0	2	3	3	12	15	8	9	25	16	35	11	3	5	2	1	1
G	0	0	0	2	6	9	7	8	17	25	25	5	7	3	0	0	1
TOTAL	125	78	146	225	195	174	211	243	270	353	657	770	639	430	206	113	9

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** FEBRUARY ***
STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
1.01- 1.50	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
3.01- 5.00	0	0	1	2	0	0	0	0	0	0	0	0	1	0	0	0	4
5.01- 7.00	0	0	1	0	1	0	0	0	0	0	0	3	0	0	0	0	5
7.01-10.00	0	0	1	1	0	0	0	0	0	0	0	2	5	0	0	0	9
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	3	3	1	0	0	0	0	1	1	9	6	0	0	0	24

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
3.01- 5.00	0	0	0	0	1	1	1	0	0	0	2	0	1	1	0	0	7
5.01- 7.00	0	0	1	1	1	0	0	0	0	0	1	0	4	0	0	0	8
7.01-10.00	0	0	0	2	0	0	0	2	0	0	0	4	1	0	0	0	9
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTAL	0	0	1	3	2	1	2	2	0	0	3	5	8	1	1	0	29

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** FEBRUARY ***
STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	2
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
1.51- 2.00	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
2.01- 3.00	0	0	0	0	1	1	1	1	0	0	0	1	0	0	0	0	5
3.01- 5.00	0	0	1	1	0	0	1	1	1	1	1	0	2	3	2	0	14
5.01- 7.00	0	0	2	2	1	0	0	0	0	0	0	2	4	2	1	0	14
7.01-10.00	0	0	0	0	0	0	0	3	0	0	0	2	4	0	4	0	13
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	3	3	2	1	3	5	1	2	2	7	11	5	7	0	52

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	1	1	0	0	0	0	0	0	1	1	0	0	1	0	0	0	5
0.51- 0.75	1	0	0	0	1	1	1	0	0	4	3	0	1	0	0	0	12
0.76- 1.00	1	0	1	0	1	0	0	0	1	0	2	0	1	0	0	0	7
1.01- 1.50	4	2	1	4	0	1	0	0	0	1	3	4	3	1	2	1	27
1.51- 2.00	6	5	5	1	6	12	0	0	2	2	4	5	10	9	5	2	74
2.01- 3.00	13	20	10	10	10	9	3	3	2	7	17	10	25	30	27	7	203
3.01- 5.00	45	46	31	53	62	33	25	10	13	31	34	47	84	52	57	50	673
5.01- 7.00	46	32	63	77	17	19	14	11	17	36	74	65	94	56	79	59	759
7.01-10.00	24	18	48	56	1	5	5	11	17	21	42	142	124	45	27	6	592
10.01-13.00	1	2	17	17	0	0	1	4	8	4	11	34	43	10	3	0	155
>13.00	0	0	3	1	0	0	0	2	0	0	2	7	11	1	0	0	27
TOTAL	142	126	179	219	98	80	49	41	61	107	192	314	397	204	200	125	2,536

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** FEBRUARY ***
STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
0.51- 0.75	1	1	3	2	1	0	0	0	0	0	1	1	0	0	0	1	11
0.76- 1.00	1	2	0	1	0	1	0	0	1	2	1	2	1	1	0	0	13
1.01- 1.50	2	4	3	1	2	0	1	1	6	3	2	2	1	4	1	3	36
1.51- 2.00	1	0	3	2	4	3	5	2	3	2	2	3	6	2	1	0	39
2.01- 3.00	2	5	11	4	14	13	8	5	6	3	13	13	11	15	6	4	133
3.01- 5.00	12	10	4	7	35	22	10	14	30	45	56	32	31	21	8	10	347
5.01- 7.00	2	1	7	3	10	8	7	24	43	44	36	40	16	19	9	10	279
7.01-10.00	0	0	1	2	0	3	7	22	35	49	17	36	7	3	7	0	189
10.01-13.00	0	0	0	0	0	0	3	12	9	5	2	5	0	2	3	0	41
>13.00	0	0	0	0	0	0	0	1	0	1	2	0	2	0	0	0	6
TOTAL	21	23	32	22	66	50	41	81	133	154	132	135	75	67	35	28	1,097

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	3
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
0.51- 0.75	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	3
0.76- 1.00	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	3
1.01- 1.50	1	0	1	0	0	0	1	2	0	0	2	1	0	1	0	0	9
1.51- 2.00	0	2	1	1	0	0	0	2	0	0	0	3	0	0	0	0	9
2.01- 3.00	0	0	1	1	0	3	4	1	1	2	7	3	4	0	1	0	28
3.01- 5.00	1	1	5	6	6	12	10	2	5	13	18	17	8	2	3	3	112
5.01- 7.00	0	0	0	1	1	6	6	3	13	8	26	12	2	0	0	0	78
7.01-10.00	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2	4	9	9	7	21	22	11	19	27	54	36	14	4	4	3	249

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** FEBRUARY ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	1	0	1	0	1	0	0	0	0	1	1	1	1	0	7
0.51- 0.75	0	1	1	0	1	0	0	0	1	0	0	0	0	0	1	0	5
0.76- 1.00	0	0	0	1	3	0	2	0	0	0	1	0	2	2	0	0	11
1.01- 1.50	1	0	1	0	4	2	0	1	1	0	2	1	0	1	2	2	18
1.51- 2.00	1	2	1	3	4	0	2	2	0	1	3	1	3	1	1	1	26
2.01- 3.00	1	0	2	7	4	3	4	5	4	4	6	4	6	2	0	1	53
3.01- 5.00	0	1	1	7	2	4	5	5	5	6	19	9	9	1	0	0	74
5.01- 7.00	0	0	0	0	0	6	1	5	3	3	8	4	0	0	0	0	30
7.01-10.00	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3	4	7	18	19	15	15	19	14	14	39	20	21	8	5	4	225

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	7
0.35- 0.50	1	1	1	0	1	0	1	0	1	1	0	2	2	2	1	0	14
0.51- 0.75	2	3	5	2	3	1	1	1	1	5	4	1	1	0	1	1	32
0.76- 1.00	2	2	1	2	4	1	3	0	2	3	6	4	4	3	0	0	37
1.01- 1.50	8	6	6	5	6	3	2	4	7	5	9	9	4	7	6	6	93
1.51- 2.00	8	9	10	7	14	15	8	6	5	5	9	12	19	12	7	3	149
2.01- 3.00	16	25	24	22	29	29	21	15	13	16	44	31	46	47	34	12	424
3.01- 5.00	58	58	43	76	106	72	52	32	54	96	130	105	136	80	70	63	1,231
5.01- 7.00	48	33	74	84	31	39	28	43	76	91	145	126	120	77	89	69	1,173
7.01-10.00	24	18	50	61	1	8	12	39	52	73	59	186	141	48	38	6	816
10.01-13.00	1	2	17	17	0	0	4	16	17	9	13	43	45	12	6	0	202
>13.00	0	0	3	1	0	0	0	3	0	1	4	7	14	1	0	0	34
TOTAL	168	157	234	277	195	168	132	159	228	305	423	526	532	289	252	160	4,212

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** FEBRUARY ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 4,728

TOTAL NUMBER OF VALID OBSERVATIONS: 4,212

TOTAL NUMBER OF MISSING OBSERVATIONS: 516

PERCENT DATA RECOVERY FOR THIS PERIOD: 89.1%

MEAN WIND SPEED FOR THIS PERIOD: 5.5 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
0.57	0.69	1.23	60.21	26.04	5.91	5.34

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	0	0	3	3	1	0	0	0	0	1	1	9	6	0	0	0	0
B	0	0	1	3	2	1	2	2	0	0	3	5	8	1	1	0	0
C	0	0	3	3	2	1	3	5	1	2	2	7	11	5	7	0	0
D	142	126	179	219	98	80	49	41	61	107	192	314	397	204	200	125	2
E	21	23	32	22	66	50	41	81	133	154	132	135	75	67	35	28	2
F	2	4	9	9	7	21	22	11	19	27	54	36	14	4	4	3	3
G	3	4	7	18	19	15	15	19	14	14	39	20	21	8	5	4	0
TOTAL	168	157	234	277	195	168	132	159	228	305	423	526	532	289	252	160	7

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MARCH ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
1.51- 2.00	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2.01- 3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.01- 5.00	0	1	3	3	0	2	1	8	0	1	0	0	1	0	0	2	22
5.01- 7.00	0	0	8	3	0	0	0	3	2	1	1	0	3	3	0	0	24
7.01-10.00	0	0	15	2	0	1	0	5	2	0	0	6	2	2	0	0	35
10.01-13.00	0	0	2	0	0	0	0	2	1	0	1	0	1	1	4	0	12
>13.0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	3
TOTAL	1	2	28	8	0	3	1	18	5	2	4	7	7	6	5	2	99

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	2	5
3.01- 5.00	1	1	4	1	1	1	2	2	0	0	0	2	0	3	4	3	25
5.01- 7.00	0	0	6	1	0	1	0	3	2	3	2	4	6	3	0	1	32
7.01-10.00	1	0	5	4	0	0	2	1	3	1	2	1	7	2	3	3	35
10.01-13.00	0	0	0	0	0	0	0	1	0	0	0	0	6	0	1	0	8
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2	1	15	7	1	2	4	8	5	4	4	7	19	8	9	9	105

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MARCH ***

STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	2
2.01- 3.00	1	0	1	2	0	0	0	0	0	1	0	0	0	1	1	2	9
3.01- 5.00	2	1	2	3	0	2	2	3	3	0	1	1	5	6	3	4	38
5.01- 7.00	0	2	2	3	1	0	5	5	11	4	1	5	19	11	6	2	77
7.01-10.00	1	0	3	3	0	0	1	5	8	4	2	2	7	5	2	0	43
10.01-13.00	0	0	0	1	0	0	0	1	0	1	5	6	6	0	6	0	26
>13.00	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	0	6
TOTAL	4	3	8	13	2	2	9	14	22	10	9	16	41	23	18	8	202

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	3
0.51- 0.75	0	0	0	1	0	0	2	1	0	0	1	0	0	0	0	0	5
0.76- 1.00	0	0	1	0	1	1	2	1	0	1	1	0	2	1	1	3	15
1.01- 1.50	3	1	1	3	5	0	0	2	0	1	3	3	1	1	1	3	28
1.51- 2.00	5	1	4	3	4	1	0	2	1	2	2	1	2	6	4	3	41
2.01- 3.00	15	25	10	18	17	11	4	10	3	5	2	9	13	21	32	24	219
3.01- 5.00	30	34	60	74	34	24	11	15	11	10	21	50	75	51	45	30	575
5.01- 7.00	20	21	48	70	43	3	18	41	18	33	34	61	135	39	52	28	664
7.01-10.00	14	6	17	48	10	7	34	60	32	29	21	95	92	71	78	24	638
10.01-13.00	1	0	2	6	0	4	25	23	6	6	13	51	36	30	38	4	245
>13.00	0	0	0	0	0	0	1	3	1	2	8	21	21	11	7	0	75
TOTAL	88	88	143	223	115	51	98	158	72	90	106	291	377	231	258	119	2,509

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MARCH ***

STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	3
0.51- 0.75	1	0	0	0	1	0	0	0	0	0	0	1	0	0	2	0	5
0.76- 1.00	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0	0	4
1.01- 1.50	1	0	1	0	1	0	0	4	1	0	1	1	3	1	0	0	14
1.51- 2.00	0	2	3	0	2	1	5	0	2	0	1	4	2	1	3	1	27
2.01- 3.00	3	4	8	7	7	6	4	3	5	5	8	5	5	6	12	5	93
3.01- 5.00	3	10	26	29	39	9	13	9	18	14	22	36	19	10	1	3	261
5.01- 7.00	5	3	9	23	12	10	23	19	30	57	38	38	5	6	2	0	280
7.01-10.00	0	0	2	1	1	2	26	30	49	45	35	35	24	2	0	0	252
10.01-13.00	0	0	0	0	0	0	13	16	16	14	5	14	7	0	0	0	85
>13.00	0	0	0	0	0	0	3	9	3	2	0	1	0	0	0	0	18
TOTAL	13	20	49	62	63	29	88	90	124	137	111	136	65	26	20	9	1,044

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
0.51- 0.75	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
0.76- 1.00	1	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	4
1.01- 1.50	2	0	0	1	2	1	1	1	1	1	1	0	0	0	0	0	11
1.51- 2.00	0	1	0	0	3	0	1	2	0	2	2	2	0	3	2	0	18
2.01- 3.00	0	1	3	5	2	2	2	2	3	6	4	5	1	3	1	1	41
3.01- 5.00	0	1	2	10	19	8	5	5	6	7	4	12	3	1	0	1	84
5.01- 7.00	0	1	0	3	7	4	18	11	18	21	16	6	2	0	0	0	107
7.01-10.00	0	0	0	0	2	0	1	1	5	1	2	0	0	0	0	0	12
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	4	5	5	19	35	15	29	22	33	39	29	26	6	7	4	2	281

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MARCH ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	3
0.35- 0.50	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0.51- 0.75	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
0.76- 1.00	1	2	0	1	0	1	1	0	0	0	0	0	0	0	1	0	7
1.01- 1.50	0	3	0	0	1	2	0	1	0	0	3	0	0	0	0	1	11
1.51- 2.00	1	2	1	1	2	1	1	0	1	1	2	2	2	0	0	0	17
2.01- 3.00	0	5	2	2	6	4	3	4	5	8	7	5	6	2	0	0	59
3.01- 5.00	1	1	5	3	16	15	10	10	5	4	5	8	2	0	1	0	86
5.01- 7.00	0	0	0	5	9	6	3	6	1	0	1	5	1	0	0	0	37
7.01-10.00	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3	13	9	12	35	29	19	21	13	13	18	20	11	2	2	1	224

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	7
0.35- 0.50	1	1	1	1	1	1	1	0	0	1	0	1	0	0	0	0	9
0.51- 0.75	1	0	0	1	1	0	4	1	1	0	1	1	0	0	2	0	13
0.76- 1.00	2	3	1	2	1	2	4	1	0	2	2	1	2	1	3	3	30
1.01- 1.50	6	4	2	4	9	3	1	8	2	2	8	4	4	2	2	4	65
1.51- 2.00	7	7	8	5	12	3	7	4	4	5	7	9	6	10	9	4	107
2.01- 3.00	19	35	24	35	32	23	13	20	16	25	21	24	25	33	47	34	426
3.01- 5.00	37	49	102	123	109	61	44	52	43	36	53	109	105	71	54	43	1,091
5.01- 7.00	25	27	73	108	72	24	67	88	82	119	93	119	171	62	60	31	1,221
7.01-10.00	16	6	42	58	14	10	65	102	99	80	62	139	132	82	83	27	1,017
10.01-13.00	1	0	4	7	0	4	38	43	23	21	24	71	56	31	49	4	376
>13.00	0	0	0	0	0	0	4	12	4	4	10	25	25	11	7	0	102
TOTAL	115	132	257	344	251	131	248	331	274	295	281	503	526	303	316	150	4,464

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MARCH ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,208

TOTAL NUMBER OF VALID OBSERVATIONS: 4,464

TOTAL NUMBER OF MISSING OBSERVATIONS: 744

PERCENT DATA RECOVERY FOR THIS PERIOD: 85.7%

MEAN WIND SPEED FOR THIS PERIOD: 6.1 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
2.22	2.35	4.53	56.21	23.39	6.29	5.02

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	1	2	28	8	0	3	1	18	5	2	4	7	7	6	5	2	0
B	2	1	15	7	1	2	4	8	5	4	4	7	19	8	9	9	0
C	4	3	8	13	2	2	9	14	22	10	9	16	41	23	18	8	0
D	88	88	143	223	115	51	98	158	72	90	106	291	377	231	258	119	1
E	13	20	49	62	63	29	88	90	124	137	111	136	65	26	20	9	2
F	4	5	5	19	35	15	29	22	33	39	29	26	6	7	4	2	1
G	3	13	9	12	35	29	19	21	13	13	18	20	11	2	2	1	3
TOTAL	115	132	257	344	251	131	248	331	274	295	281	503	526	303	316	150	7

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** APRIL ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	2	0	0	0	0	0	0	0	0	0	2	0	0	3	2	3	12
3.01- 5.00	3	1	3	2	0	0	1	1	3	0	0	2	11	14	11	9	61
5.01- 7.00	3	5	18	2	1	4	1	6	2	0	3	4	9	7	3	3	71
7.01-10.00	1	1	13	0	0	0	0	0	2	1	4	12	21	0	2	0	57
10.01-13.00	0	0	0	0	0	0	0	0	3	1	0	1	10	1	0	0	16
>13.00	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	3
TOTAL	9	7	34	4	1	4	2	7	10	2	9	21	53	25	18	15	221

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	3	2	0	0	0	1	1	0	0	0	0	0	1	1	3	4	16
3.01- 5.00	6	1	0	0	0	3	4	2	1	0	0	2	3	5	8	7	42
5.01- 7.00	9	3	14	0	0	1	2	1	1	5	4	2	15	13	2	2	74
7.01-10.00	3	0	4	1	0	1	1	0	4	5	3	5	25	4	1	3	60
10.01-13.00	0	0	1	0	0	0	0	0	0	1	1	6	12	2	0	0	23
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
TOTAL	21	6	19	1	0	6	8	3	6	11	8	15	58	26	14	16	218

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** APRIL ***

STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2
0.51- 0.75	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2
0.76- 1.00	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1.01- 1.50	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
2.01- 3.00	6	2	1	1	2	0	0	0	0	1	0	3	0	3	2	5	26
3.01- 5.00	8	5	5	2	2	0	1	3	2	2	2	2	3	17	14	12	80
5.01- 7.00	0	3	8	5	1	1	1	5	3	1	4	3	19	7	3	2	66
7.01-10.00	1	0	6	1	0	1	1	0	7	5	4	7	24	13	3	1	74
10.01-13.00	1	0	1	0	0	0	0	0	1	0	4	3	8	3	1	0	22
>13.00	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	0	4
TOTAL	17	12	22	10	6	2	3	9	14	10	14	18	56	45	24	20	282

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	2
0.51- 0.75	1	0	1	1	1	0	0	0	0	0	1	0	0	0	0	0	5
0.76- 1.00	1	0	1	1	0	0	0	0	0	0	0	2	0	2	0	1	8
1.01- 1.50	0	1	4	1	2	2	0	0	3	3	2	1	4	4	5	3	35
1.51- 2.00	6	4	6	1	2	2	0	0	1	0	5	0	2	6	4	6	45
2.01- 3.00	19	17	10	10	11	3	1	2	5	6	12	10	17	13	25	17	178
3.01- 5.00	22	28	48	34	29	8	12	9	11	11	15	20	49	49	52	32	429
5.01- 7.00	15	18	48	39	11	12	4	12	10	25	25	46	55	54	45	38	457
7.01-10.00	14	3	29	22	3	5	17	13	20	39	69	74	102	43	38	37	528
10.01-13.00	5	0	1	9	0	4	28	13	8	19	24	24	57	11	11	8	222
>13.00	2	2	3	3	0	1	4	2	2	3	2	15	20	8	1	0	68
TOTAL	85	73	151	121	59	37	66	51	60	107	155	192	306	191	181	142	1,979

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** APRIL ***
STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
0.51- 0.75	0	0	0	1	0	1	0	0	0	0	0	0	0	1	1	0	4
0.76- 1.00	0	1	1	1	2	0	0	0	1	0	0	0	0	2	1	0	9
1.01- 1.50	1	2	1	2	1	3	2	0	0	0	2	1	0	1	4	3	23
1.51- 2.00	1	2	5	1	0	3	4	1	3	2	0	2	2	1	3	3	33
2.01- 3.00	6	6	4	7	5	6	3	3	1	3	4	4	4	10	7	5	78
3.01- 5.00	11	7	15	31	38	24	17	7	15	12	19	17	16	13	15	13	270
5.01- 7.00	5	6	11	18	18	10	14	24	36	28	33	33	16	14	8	8	282
7.01-10.00	0	0	3	4	4	7	8	26	38	38	32	42	26	9	1	2	240
10.01-13.00	0	0	0	3	0	0	6	3	10	9	9	10	13	4	0	0	67
>13.00	0	0	0	0	0	0	1	1	0	1	3	3	2	0	0	0	11
TOTAL	24	24	40	68	69	54	55	65	104	93	102	112	79	55	40	34	1,018

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	1	1	0	0	0	0	0	1	1	0	0	1	5
0.76- 1.00	1	1	0	0	1	0	2	1	0	0	0	1	0	0	0	1	8
1.01- 1.50	0	2	1	0	1	2	0	3	0	0	0	0	0	0	0	1	10
1.51- 2.00	1	1	2	2	0	1	0	1	0	0	0	1	2	0	2	1	14
2.01- 3.00	3	4	1	7	4	4	5	2	1	0	2	1	2	2	0	0	38
3.01- 5.00	2	1	5	16	26	6	9	4	6	5	13	12	6	1	2	1	115
5.01- 7.00	1	0	1	3	7	15	9	3	8	14	17	7	1	1	0	0	87
7.01-10.00	0	0	0	0	0	0	3	4	6	10	5	1	0	0	0	0	29
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	8	9	10	28	40	29	28	18	21	29	37	24	12	4	4	5	307

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** APRIL ***

STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
0.51- 0.75	1	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	4
0.76- 1.00	1	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	4
1.01- 1.50	0	0	0	1	1	1	0	2	1	1	1	5	0	2	2	1	18
1.51- 2.00	2	0	1	1	0	0	0	2	1	5	2	0	1	1	4	3	23
2.01- 3.00	3	1	1	6	5	1	3	2	6	5	3	5	8	3	1	1	54
3.01- 5.00	0	1	3	2	14	16	14	6	4	8	19	19	8	0	0	0	114
5.01- 7.00	0	0	0	0	7	11	10	9	6	9	4	3	0	0	0	0	59
7.01-10.00	0	0	0	0	0	0	0	3	8	1	0	0	0	0	0	0	12
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	7	2	5	10	27	30	27	24	27	29	29	34	18	6	8	6	291

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	5
0.35- 0.50	0	1	0	0	1	0	0	0	0	1	0	0	1	1	0	1	6
0.51- 0.75	2	0	1	2	3	3	0	1	1	0	1	1	1	1	2	1	20
0.76- 1.00	4	3	2	2	3	0	2	1	1	0	0	5	1	4	1	2	31
1.01- 1.50	1	5	7	5	5	8	2	5	4	4	5	7	5	8	11	8	90
1.51- 2.00	10	7	14	5	2	6	4	4	5	7	7	3	8	9	13	13	117
2.01- 3.00	42	32	17	31	27	15	13	9	13	15	23	23	32	35	40	35	402
3.01- 5.00	52	44	79	87	109	57	58	32	42	38	68	74	96	99	102	74	1,111
5.01- 7.00	33	35	100	67	45	54	41	60	66	82	90	98	115	96	61	53	1,096
7.01-10.00	19	4	55	28	7	14	30	46	85	99	117	141	198	69	45	43	1,000
10.01-13.00	6	0	3	12	0	4	34	16	22	30	38	44	100	21	12	8	350
>13.00	2	2	3	3	0	1	5	3	3	5	5	20	25	9	2	0	88
TOTAL	171	133	281	242	202	162	189	177	242	281	354	416	582	352	289	238	4,316

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** APRIL ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,040

TOTAL NUMBER OF VALID OBSERVATIONS: 4,316

TOTAL NUMBER OF MISSING OBSERVATIONS: 724

PERCENT DATA RECOVERY FOR THIS PERIOD: 85.6%

MEAN WIND SPEED FOR THIS PERIOD: 6.0 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
5.12	5.05	6.53	45.85	23.59	7.11	6.74

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SEQ	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	9	7	34	4	1	4	2	7	10	2	9	21	53	25	18	15	0
B	21	6	19	1	0	6	8	3	6	11	8	15	58	26	14	16	0
C	17	12	22	10	6	2	3	9	14	10	14	18	56	45	24	20	0
D	85	73	151	121	59	37	66	51	60	107	155	192	306	191	181	142	2
E	24	24	40	68	69	54	55	65	104	93	102	112	79	55	40	34	0
F	8	9	10	28	40	29	28	18	21	29	37	24	12	4	4	5	1
G	7	2	5	10	27	30	27	24	27	29	29	34	18	6	8	6	2
TOTAL	171	133	281	242	202	162	189	177	242	281	354	416	582	352	289	238	5

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MAY ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
1.51- 2.00	0	0	0	0	0	0	0	1	0	1	0	0	1	1	0	0	4
2.01- 3.00	2	2	0	0	0	0	0	1	0	1	0	1	1	0	1	5	14
3.01- 5.00	2	3	3	0	0	1	5	1	2	1	0	6	16	14	12	7	73
5.01- 7.00	0	4	7	0	0	2	8	3	2	4	3	15	27	8	3	0	86
7.01-10.00	0	0	9	3	0	3	1	2	0	0	1	10	14	6	1	0	50
10.01-13.00	0	0	0	1	0	0	0	1	0	0	4	3	0	0	0	0	9
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	4	9	19	4	0	6	14	9	4	7	8	35	59	29	19	12	238

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1.01- 1.50	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	2
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2.01- 3.00	1	0	3	0	1	0	0	2	0	1	0	0	0	0	1	2	11
3.01- 5.00	7	6	11	0	0	0	4	2	1	4	2	3	7	8	5	6	66
5.01- 7.00	1	2	14	2	0	1	6	4	2	4	4	1	19	6	2	1	69
7.01-10.00	0	0	10	3	0	0	1	2	2	1	1	5	13	1	0	0	39
10.01-13.00	0	0	1	0	0	0	0	1	1	2	3	1	1	0	0	0	10
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	10	8	39	6	1	1	11	12	6	12	10	10	40	15	9	9	199

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MAY ***

STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
1.51- 2.00	0	0	1	0	0	0	1	0	1	1	0	0	0	0	1	1	6
2.01- 3.00	0	0	0	1	0	2	2	1	1	1	1	0	4	3	8	5	29
3.01- 5.00	11	13	23	2	0	0	2	5	2	9	3	3	21	32	15	7	148
5.01- 7.00	1	3	13	4	0	0	3	3	2	4	2	3	18	8	5	3	72
7.01-10.00	0	1	8	5	0	1	1	2	6	5	0	8	10	6	0	0	53
10.01-13.00	0	0	0	0	0	0	0	0	3	1	1	6	0	0	0	0	11
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	12	18	45	12	0	3	9	11	15	21	7	20	53	49	30	17	322

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	1	2	0	0	0	0	1	0	0	0	0	0	0	0	4
0.51- 0.75	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	2
0.76- 1.00	4	0	3	0	3	0	0	2	1	1	1	1	0	3	0	1	20
1.01- 1.50	8	3	6	4	5	1	0	0	0	2	4	3	6	5	3	6	56
1.51- 2.00	11	8	9	7	2	1	1	1	2	2	2	7	4	15	10	8	90
2.01- 3.00	20	24	29	15	19	11	10	8	5	6	13	15	35	41	42	30	323
3.01- 5.00	33	48	84	69	36	30	14	21	19	22	26	56	104	83	53	40	738
5.01- 7.00	18	11	50	47	7	16	27	28	31	31	20	42	62	19	24	20	453
7.01-10.00	9	7	26	32	2	4	29	23	25	23	14	53	38	22	11	6	324
10.01-13.00	0	0	7	4	0	0	11	6	7	4	0	23	11	0	0	1	74
>13.00	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
TOTAL	103	101	215	181	74	63	93	89	91	91	80	200	261	188	143	112	2,085

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MAY ***

STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
0.51- 0.75	3	0	1	0	0	0	0	0	1	0	2	0	0	0	0	1	8
0.76- 1.00	0	1	2	0	2	0	0	1	1	0	0	0	1	0	1	0	9
1.01- 1.50	3	1	1	1	1	1	2	2	2	3	2	5	3	6	2	0	35
1.51- 2.00	6	0	2	3	7	1	2	3	3	3	0	3	5	2	4	5	49
2.01- 3.00	7	9	19	9	15	4	2	4	8	8	7	15	13	19	11	7	157
3.01- 5.00	11	17	23	27	41	19	20	25	22	24	36	23	23	21	21	8	361
5.01- 7.00	8	6	9	13	10	11	24	31	43	61	25	18	11	2	8	2	282
7.01-10.00	4	13	6	2	1	1	25	27	29	24	9	5	4	0	1	1	152
10.01-13.00	0	1	4	0	0	0	4	1	2	0	0	2	1	0	0	0	15
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	42	48	67	55	78	37	79	94	111	123	81	71	61	50	48	24	1,069

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
0.51- 0.75	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	4
0.76- 1.00	0	0	0	0	1	0	2	0	1	0	0	0	0	0	0	1	5
1.01- 1.50	0	0	0	0	0	2	1	0	2	0	1	0	0	1	2	1	10
1.51- 2.00	4	3	2	1	1	0	0	0	1	1	2	2	0	4	1	2	24
2.01- 3.00	3	1	7	4	4	3	3	3	2	1	12	6	3	5	3	0	60
3.01- 5.00	2	3	8	14	36	3	9	9	10	5	15	20	9	2	2	2	149
5.01- 7.00	0	0	3	5	13	22	23	15	28	28	20	7	1	0	0	0	165
7.01-10.00	0	0	0	0	0	1	8	2	7	4	5	2	0	0	0	0	29
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	10	7	20	24	55	31	46	29	51	40	55	37	13	12	9	9	448

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MAY ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	4
0.35- 0.50	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	4
0.51- 0.75	0	0	1	0	0	2	0	0	1	0	0	0	0	0	0	0	4
0.76- 1.00	0	0	2	1	0	0	1	0	1	2	2	3	2	0	1	1	16
1.01- 1.50	1	1	2	0	1	2	0	2	4	1	3	5	4	2	2	3	33
1.51- 2.00	1	2	4	5	10	0	6	3	1	2	6	2	8	4	3	2	59
2.01- 3.00	5	2	2	7	11	7	9	7	3	9	17	14	13	7	8	4	125
3.01- 5.00	1	4	10	8	26	27	21	5	9	15	31	28	8	1	0	1	195
5.01- 7.00	1	0	2	1	11	22	21	18	7	22	16	1	1	0	0	0	123
7.01-10.00	0	0	0	0	0	5	5	4	7	3	4	0	0	0	0	0	28
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	10	9	23	22	59	65	63	39	33	55	80	54	36	14	14	11	591

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	4
0.35- 0.50	1	1	1	2	1	0	0	0	1	1	1	1	0	0	0	2	12
0.51- 0.75	4	0	2	1	0	2	0	0	2	1	2	0	1	0	1	3	19
0.76- 1.00	5	1	7	1	6	0	3	3	4	3	3	4	3	3	2	3	51
1.01- 1.50	12	5	9	6	7	6	3	5	8	6	10	13	13	14	12	10	139
1.51- 2.00	22	13	18	16	20	2	10	8	8	10	10	14	18	26	20	18	233
2.01- 3.00	38	38	60	36	50	27	26	26	19	27	50	51	69	75	74	53	719
3.01- 5.00	67	94	162	120	139	80	75	68	65	80	113	139	188	161	108	71	1,730
5.01- 7.00	29	26	98	72	41	74	112	102	115	154	90	87	139	43	42	26	1,250
7.01-10.00	13	21	59	45	3	15	70	62	76	60	34	83	79	35	13	7	675
10.01-13.00	0	1	12	5	0	0	15	9	13	7	8	35	13	0	0	1	119
>13.00	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
TOTAL	191	200	428	304	267	206	315	283	311	349	321	427	523	357	272	194	4,952

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** MAY ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,208

TOTAL NUMBER OF VALID OBSERVATIONS: 4,952

TOTAL NUMBER OF MISSING OBSERVATIONS: 256

PERCENT DATA RECOVERY FOR THIS PERIOD: 95.1%

MEAN WIND SPEED FOR THIS PERIOD: 4.8 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
4.81	4.02	6.50	42.10	21.59	9.05	11.93

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	4	9	19	4	0	6	14	9	4	7	8	35	59	29	19	12	0
B	10	8	39	6	1	1	11	12	6	12	10	10	40	15	9	9	0
C	12	18	45	12	0	3	9	11	15	21	7	20	53	49	30	17	0
D	103	101	215	181	74	63	93	89	91	91	80	200	261	188	143	112	0
E	42	48	67	55	78	37	79	94	111	123	81	71	61	50	48	24	0
F	10	7	20	24	55	31	46	29	51	40	55	37	13	12	9	9	0
G	10	9	23	22	59	65	63	39	33	55	80	54	36	14	14	11	4
TOTAL	191	200	428	304	267	206	315	283	311	349	321	427	523	357	272	194	4

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JUNE ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
1.51- 2.00	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4
2.01- 3.00	3	1	3	2	1	0	1	3	2	0	0	0	2	7	5	4	34
3.01- 5.00	9	18	4	0	2	0	0	1	3	1	1	9	12	21	19	16	116
5.01- 7.00	0	11	8	0	0	0	1	1	6	8	4	11	29	6	7	2	94
7.01-10.00	0	1	0	0	0	0	1	2	0	1	0	16	7	0	2	3	33
10.01-13.00	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	16	31	15	2	3	0	3	9	11	10	5	36	51	34	34	25	285

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
1.01- 1.50	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	2
1.51- 2.00	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2.01- 3.00	3	0	1	0	0	1	1	1	0	0	1	0	0	4	6	1	19
3.01- 5.00	5	8	5	0	2	0	0	2	3	3	2	5	24	16	8	5	88
5.01- 7.00	0	1	0	2	0	0	2	1	3	9	3	10	36	6	5	0	78
7.01-10.00	0	0	2	1	0	0	0	1	1	5	0	6	15	1	1	1	34
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	1	3	0	2	1	7
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	8	9	11	4	2	2	3	5	7	17	6	22	78	27	22	9	232

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JUNE ***

STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
1.01- 1.50	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	2
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
2.01- 3.00	1	3	2	0	0	0	0	2	2	0	1	0	2	5	8	5	31
3.01- 5.00	5	7	10	2	0	0	2	1	8	3	4	6	26	20	15	10	119
5.01- 7.00	0	3	2	1	0	0	0	2	6	7	5	6	24	4	3	0	63
7.01-10.00	0	0	5	0	0	0	0	1	2	6	1	8	7	2	2	2	36
10.01-13.00	0	0	0	0	0	0	0	0	0	0	1	4	3	1	2	1	12
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	7	13	19	3	0	0	3	6	18	16	12	25	62	33	31	18	266

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	2
0.51- 0.75	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	3
0.76- 1.00	3	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	5
1.01- 1.50	4	4	5	0	2	0	0	0	0	2	3	4	4	1	3	1	33
1.51- 2.00	2	5	4	7	3	5	0	2	0	3	1	4	5	7	7	5	60
2.01- 3.00	14	23	17	18	12	4	2	3	4	10	13	19	21	31	38	16	245
3.01- 5.00	19	28	33	22	11	5	16	11	30	36	49	45	69	61	49	29	513
5.01- 7.00	14	12	28	17	2	0	3	28	37	48	27	56	33	35	34	31	405
7.01-10.00	9	1	1	5	1	0	2	11	14	15	27	33	39	14	29	14	215
10.01-13.00	6	0	0	0	0	0	0	0	1	0	3	12	12	12	15	3	64
>13.00	0	0	0	0	0	0	0	0	0	0	1	0	0	4	11	0	16
TOTAL	71	73	89	69	32	15	24	55	86	114	124	175	184	165	186	99	1,562

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JUNE ***

STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
0.51- 0.75	0	0	2	0	0	0	1	0	0	1	2	0	0	0	0	0	6
0.76- 1.00	0	0	0	0	1	2	0	0	1	0	1	2	0	0	1	0	8
1.01- 1.50	1	0	0	3	3	0	2	1	1	1	2	0	0	0	2	0	16
1.51- 2.00	1	0	1	3	4	2	2	0	1	1	1	5	2	1	1	2	27
2.01- 3.00	7	4	5	9	9	7	5	3	3	6	7	13	8	8	8	10	112
3.01- 5.00	12	10	23	7	17	9	12	30	37	39	42	20	18	13	15	33	337
5.01- 7.00	7	3	3	2	2	0	15	41	106	112	52	19	16	4	6	24	412
7.01-10.00	3	0	1	0	0	0	3	10	34	38	16	7	3	0	2	5	122
10.01-13.00	0	0	0	0	0	0	0	0	0	0	1	5	1	0	1	0	8
>13.00	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	2
TOTAL	31	17	35	24	36	20	40	85	183	200	124	71	48	26	37	74	1,051

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
0.51- 0.75	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2
0.76- 1.00	1	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	4
1.01- 1.50	1	0	0	2	1	1	1	3	1	0	1	0	1	3	0	2	17
1.51- 2.00	1	0	0	3	3	0	1	1	1	0	2	0	1	1	1	1	16
2.01- 3.00	2	2	1	2	5	2	0	4	9	6	10	8	6	3	5	2	67
3.01- 5.00	1	2	4	4	9	13	8	9	14	14	13	13	3	1	1	1	110
5.01- 7.00	0	0	0	1	0	7	12	17	41	50	18	3	1	0	0	0	150
7.01-10.00	0	0	0	0	0	0	0	1	7	12	3	1	0	0	0	0	24
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	6	4	5	13	18	26	22	35	75	82	47	25	12	8	7	6	392

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JUNE ***

STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2
0.51- 0.75	0	0	0	1	1	0	0	0	2	0	0	2	0	1	0	0	7
0.76- 1.00	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	3
1.01- 1.50	0	1	2	1	2	2	3	1	3	0	0	3	0	1	2	1	22
1.51- 2.00	1	2	2	6	3	2	3	0	2	1	3	2	3	3	4	1	38
2.01- 3.00	2	12	6	1	11	7	9	6	12	8	12	4	9	5	6	2	112
3.01- 5.00	2	2	1	6	15	20	16	15	21	23	41	4	2	2	2	0	172
5.01- 7.00	0	0	0	1	6	15	27	19	25	46	23	3	0	0	0	0	165
7.01-10.00	0	0	0	0	0	0	0	7	12	9	5	0	0	0	0	0	33
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	5	17	12	17	38	47	58	49	77	87	84	18	14	12	15	4	554

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	0	0	0	1	0	2	1	0	0	1	0	0	1	0	0	0	6
0.51- 0.75	0	0	3	1	2	2	1	0	2	1	2	3	0	1	0	0	18
0.76- 1.00	5	0	1	2	1	3	0	1	3	0	1	4	0	0	2	0	23
1.01- 1.50	6	5	7	6	8	4	7	7	5	3	6	7	5	5	8	5	94
1.51- 2.00	8	7	10	19	13	9	6	3	4	5	7	11	11	13	14	9	149
2.01- 3.00	32	45	35	32	38	21	18	22	32	30	44	44	48	63	76	40	620
3.01- 5.00	53	75	80	41	56	47	54	69	116	119	152	102	154	134	109	94	1,455
5.01- 7.00	21	30	41	24	10	22	60	109	224	280	132	108	139	55	55	57	1,367
7.01-10.00	12	2	9	6	1	0	6	33	70	86	52	71	71	17	36	25	497
10.01-13.00	7	0	0	0	0	0	0	0	1	0	5	2	20	13	20	5	93
>13.00	0	0	0	0	0	0	0	0	0	1	1	0	0	4	12	0	18
TOTAL	144	164	186	132	129	110	153	244	457	526	402	372	449	305	332	235	4,342

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JUNE ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.00 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,040

TOTAL NUMBER OF VALID OBSERVATIONS: 4,342

TOTAL NUMBER OF MISSING OBSERVATIONS: 698

PERCENT DATA RECOVERY FOR THIS PERIOD: 86.2%

MEAN WIND SPEED FOR THIS PERIOD: 4.9 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
6.56	5.34	6.13	35.97	24.21	9.03	12.76

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	16	31	15	2	3	0	3	9	11	10	5	36	51	34	34	25	0
B	8	9	11	4	2	2	3	5	7	17	6	22	78	27	22	9	0
C	7	13	19	3	0	0	3	6	18	16	12	25	62	33	31	18	0
D	71	73	89	69	32	15	24	55	86	114	124	175	184	165	186	99	1
E	31	17	35	24	36	20	40	85	183	200	124	71	48	26	37	74	0
F	6	4	5	13	18	26	22	35	75	82	47	25	12	8	7	6	1
G	5	17	12	17	38	47	58	49	77	87	84	18	14	12	15	4	0
TOTAL	144	164	186	132	129	110	153	244	457	526	402	372	449	305	332	235	2

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JULY ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
1.51- 2.00	1	1	0	0	0	0	0	1	0	0	0	0	1	0	1	0	5
2.01- 3.00	12	1	1	0	0	2	0	0	0	0	0	1	3	4	7	8	39
3.01- 5.00	36	19	6	1	7	3	4	2	2	0	0	2	14	40	38	30	204
5.01- 7.00	2	17	16	0	1	4	0	0	2	3	2	2	16	8	7	4	84
7.01-10.00	2	0	0	0	0	0	0	0	0	0	0	2	7	1	0	2	14
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	53	38	23	1	8	10	4	3	4	3	2	7	41	53	54	44	348

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
1.01- 1.50	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
2.01- 3.00	7	4	1	0	1	1	1	0	0	1	0	1	2	6	6	4	35
3.01- 5.00	15	11	5	2	2	0	2	1	2	3	0	4	18	27	12	11	115
5.01- 7.00	1	7	2	0	0	3	0	0	1	1	2	3	10	5	3	2	40
7.01-10.00	0	1	0	0	0	0	0	0	0	1	0	1	10	0	2	2	17
10.01-13.00	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	23	24	8	3	3	4	3	1	3	7	2	9	40	39	23	20	212

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JULY ***

STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2
1.01- 1.50	1	0	1	0	0	1	0	0	0	0	0	0	0	2	0	0	5
1.51- 2.00	5	1	1	0	0	1	0	1	0	0	0	1	0	3	1	2	16
2.01- 3.00	12	3	2	0	2	2	1	0	2	0	3	0	5	15	11	9	67
3.01- 5.00	16	20	5	3	1	3	1	2	2	9	4	5	22	13	11	14	131
5.01- 7.00	0	2	5	0	0	4	2	2	1	2	8	4	10	10	7	5	62
7.01-10.00	1	0	0	0	0	0	0	0	0	2	0	6	5	1	1	1	17
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	36	26	14	3	3	11	4	5	5	13	15	17	43	44	31	31	301

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	1	0	1	0	0	0	1	1	0	1	0	0	0	0	0	0	5
0.76- 1.00	0	0	1	1	0	2	0	2	1	0	1	0	1	0	1	0	10
1.01- 1.50	2	2	4	3	3	1	1	1	0	1	2	2	1	3	2	1	29
1.51- 2.00	9	6	4	4	8	1	1	2	3	2	5	6	6	9	5	4	75
2.01- 3.00	25	26	14	20	18	6	2	7	2	10	12	14	24	17	25	20	242
3.01- 5.00	28	20	42	9	18	19	16	23	26	40	45	32	63	42	27	33	483
5.01- 7.00	25	14	13	7	7	9	7	19	28	47	36	27	32	11	8	23	313
7.01-10.00	8	0	1	0	0	1	2	2	2	23	13	17	21	16	5	11	122
10.01-13.00	0	0	0	0	0	0	0	0	1	1	0	3	1	0	1	0	7
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	98	68	80	44	54	39	30	57	63	125	114	101	149	98	74	92	1,286

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JULY ***

STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	2
0.51- 0.75	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	3
0.76- 1.00	0	1	2	0	0	0	0	0	0	0	0	0	0	1	1	1	6
1.01- 1.50	1	1	1	1	4	2	1	3	0	1	3	1	0	0	1	0	20
1.51- 2.00	0	3	2	5	5	3	4	0	1	2	2	4	2	1	1	1	36
2.01- 3.00	6	10	8	10	8	9	2	4	6	3	4	9	3	12	4	2	100
3.01- 5.00	25	18	17	13	18	18	20	29	28	49	51	34	19	10	11	19	379
5.01- 7.00	22	10	1	1	1	4	23	29	76	133	48	31	7	7	5	19	417
7.01-10.00	1	0	0	0	0	0	2	5	19	33	12	8	7	0	1	3	91
10.01-13.00	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	55	44	32	30	36	36	52	70	131	224	120	88	38	32	24	45	1,057

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
0.51- 0.75	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2
0.76- 1.00	0	1	0	2	0	0	1	1	0	0	1	0	0	0	0	0	6
1.01- 1.50	0	2	0	1	3	0	0	2	2	1	3	1	1	4	0	0	20
1.51- 2.00	0	2	3	2	3	2	1	2	1	3	1	2	4	1	2	1	30
2.01- 3.00	2	6	5	5	8	4	9	2	5	3	8	7	1	1	1	0	67
3.01- 5.00	1	0	5	8	19	15	14	9	13	25	25	16	4	3	5	1	163
5.01- 7.00	0	0	0	0	4	7	13	23	36	28	20	6	0	0	0	1	138
7.01-10.00	0	0	0	0	0	0	0	1	6	0	0	0	0	0	0	0	7
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3	11	13	18	37	28	39	40	64	60	58	32	10	9	8	4	434

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JULY ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2
0.51- 0.75	2	0	1	0	0	1	0	1	0	0	1	0	1	2	1	0	10
0.76- 1.00	1	0	2	1	1	1	2	1	1	1	1	0	2	1	2	0	17
1.01- 1.50	2	3	4	4	5	5	3	3	2	1	6	4	6	2	4	2	56
1.51- 2.00	1	2	5	4	2	7	6	6	6	4	4	7	3	2	3	0	62
2.01- 3.00	5	8	10	15	15	10	23	18	10	14	18	15	6	5	6	11	189
3.01- 5.00	3	4	3	11	22	29	22	14	24	23	34	32	6	0	0	2	229
5.01- 7.00	0	0	0	2	3	23	20	29	29	20	14	1	1	0	0	0	142
7.01-10.00	0	0	0	0	0	0	0	1	6	1	0	0	0	0	0	0	8
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	14	17	26	37	48	77	76	73	78	64	78	59	25	12	16	15	717

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	0	0	1	0	0	1	0	0	2	0	0	1	0	0	0	0	5
0.51- 0.75	3	1	3	0	0	1	2	2	0	1	1	0	1	3	1	1	20
0.76- 1.00	2	2	5	5	1	4	3	4	2	1	3	0	4	2	4	1	43
1.01- 1.50	6	9	10	9	15	9	5	9	4	4	14	8	8	11	8	4	133
1.51- 2.00	16	15	15	15	18	14	12	12	11	11	12	20	16	17	13	8	225
2.01- 3.00	69	58	41	50	52	34	38	31	25	31	45	47	44	60	60	54	739
3.01- 5.00	124	92	83	47	87	87	79	80	97	149	159	125	146	135	104	110	1,704
5.01- 7.00	50	50	37	10	16	54	65	102	173	234	130	74	76	41	30	54	1,196
7.01-10.00	12	1	1	0	0	1	4	9	33	60	25	34	50	18	9	19	276
10.01-13.00	0	0	0	0	0	0	0	0	1	5	0	4	1	0	1	0	12
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	282	228	196	136	189	205	208	249	348	496	389	313	346	287	230	251	4,355

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** JULY ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,208

TOTAL NUMBER OF VALID OBSERVATIONS: 4,355

TOTAL NUMBER OF MISSING OBSERVATIONS: 853

PERCENT DATA RECOVERY FOR THIS PERIOD: 83.6%

MEAN WIND SPEED FOR THIS PERIOD: 4.3 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
7.99	4.87	6.91	29.53	24.27	9.97	16.46

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	53	38	23	1	8	10	4	3	4	3	2	7	41	53	54	44	0
B	23	24	8	3	3	4	3	1	3	7	2	9	40	39	23	20	0
C	36	26	14	3	3	11	4	5	5	13	15	17	43	44	31	31	0
D	98	68	80	44	54	39	30	57	63	125	114	101	149	98	74	92	0
E	55	44	32	30	36	36	52	70	131	224	120	88	38	32	24	45	0
F	3	11	13	18	37	28	39	40	64	60	58	32	10	9	8	4	0
G	14	17	26	37	48	77	76	73	78	64	78	59	25	12	16	15	2
TOTAL	282	228	196	136	189	205	208	249	348	496	389	313	346	287	230	251	2

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** AUGUST ***
STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
1.51- 2.00	0	2	1	0	1	0	1	0	0	0	0	1	0	1	3	1	11
2.01- 3.00	3	6	2	0	0	0	1	0	0	1	1	1	1	5	3	7	31
3.01- 5.00	34	31	19	4	2	2	0	1	9	0	1	5	6	12	10	21	157
5.01- 7.00	4	14	14	1	0	0	3	1	0	2	1	4	13	3	0	0	60
7.01-10.00	1	6	0	0	0	0	0	0	0	0	0	2	8	0	3	0	20
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	42	59	36	5	4	2	5	2	9	3	4	13	28	21	19	29	281

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1.51- 2.00	1	0	0	0	0	1	0	0	0	0	0	0	2	0	1	1	6
2.01- 3.00	7	4	1	1	4	0	1	1	0	0	0	0	1	1	3	15	39
3.01- 5.00	14	16	19	1	1	2	5	3	4	2	1	8	11	15	7	7	116
5.01- 7.00	0	4	11	2	1	0	1	1	1	8	2	12	18	4	2	0	67
7.01-10.00	0	1	1	1	0	0	0	0	0	1	0	5	7	2	2	1	21
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	23	25	32	5	6	3	7	5	5	11	3	26	39	22	15	24	251

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** AUGUST ***

STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
1.01- 1.50	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	1	4
1.51- 2.00	2	0	1	0	0	1	0	1	0	0	1	1	0	3	3	2	15
2.01- 3.00	5	2	3	3	2	3	3	2	0	2	2	0	1	2	5	6	41
3.01- 5.00	11	14	12	6	1	1	2	2	5	7	2	13	16	9	11	14	126
5.01- 7.00	0	3	3	2	0	0	1	4	6	2	4	7	20	6	4	0	62
7.01-10.00	0	0	2	1	0	0	0	0	0	1	0	5	6	0	0	1	16
10.01-13.00	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	19	19	21	13	3	5	7	9	12	14	10	26	43	20	23	24	268

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	4
0.51- 0.75	0	1	1	0	0	0	0	0	0	0	1	1	0	1	1	0	6
0.76- 1.00	0	1	0	1	2	1	1	1	0	0	1	0	1	0	0	0	9
1.01- 1.50	3	4	1	1	2	1	2	2	2	3	1	4	0	3	3	1	33
1.51- 2.00	8	4	3	7	6	5	0	1	4	2	1	11	4	7	5	4	72
2.01- 3.00	17	13	20	16	8	12	8	9	15	8	4	18	19	14	21	18	220
3.01- 5.00	15	35	35	24	8	12	19	20	38	35	45	41	60	37	19	9	452
5.01- 7.00	27	10	28	4	0	5	12	14	35	34	34	29	62	19	22	19	354
7.01-10.00	12	13	7	1	0	0	1	0	1	5	14	20	30	9	27	10	150
10.01-13.00	0	0	0	0	0	0	0	0	0	0	2	6	6	1	6	1	22
>13.00	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTAL	83	81	95	54	26	37	43	47	95	87	104	130	182	92	104	63	1,324

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** AUGUST ***
STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	3
0.51- 0.75	2	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	6
0.76- 1.00	0	0	0	1	0	0	1	0	0	0	0	0	1	1	0	0	4
1.01- 1.50	2	0	2	1	6	0	0	0	2	3	0	3	0	2	0	0	21
1.51- 2.00	2	3	2	2	3	1	1	1	3	1	1	1	1	2	0	1	25
2.01- 3.00	4	5	4	13	12	13	10	4	11	6	9	11	8	4	0	3	117
3.01- 5.00	16	22	14	18	28	20	23	40	44	68	71	41	26	14	3	17	465
5.01- 7.00	27	20	8	4	0	3	6	26	112	95	88	35	15	9	7	16	471
7.01-10.00	10	9	12	0	0	0	5	4	11	11	13	18	23	2	2	7	127
10.01-13.00	0	4	0	0	0	0	0	0	0	0	0	3	1	0	0	0	8
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	63	63	42	39	49	37	46	75	183	184	183	115	76	35	13	44	1,248

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	3
0.51- 0.75	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2
0.76- 1.00	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	3
1.01- 1.50	0	1	1	1	1	1	2	2	1	2	0	3	1	1	0	0	17
1.51- 2.00	0	0	1	2	5	1	2	0	2	3	1	1	3	0	1	1	23
2.01- 3.00	3	2	4	2	8	4	7	2	6	9	8	3	2	1	3	1	65
3.01- 5.00	1	0	5	17	36	20	13	22	16	18	26	24	6	0	1	2	207
5.01- 7.00	0	1	0	5	5	9	23	23	37	43	45	14	0	0	0	0	205
7.01-10.00	0	0	0	0	0	0	2	2	5	0	0	2	0	0	0	0	11
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	4	4	12	28	55	35	49	51	68	76	83	48	12	2	5	4	536

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** AUGUST ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	3
0.35- 0.50	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3
0.51- 0.75	0	0	2	1	0	1	1	3	1	1	2	0	1	0	0	0	13
0.76- 1.00	3	1	0	0	1	0	2	2	3	0	3	2	3	0	2	0	22
1.01- 1.50	1	0	6	1	5	2	5	1	6	5	8	4	1	1	1	1	48
1.51- 2.00	4	3	3	3	6	8	7	2	3	5	5	2	5	1	2	2	61
2.01- 3.00	6	9	7	7	15	9	7	12	7	11	18	9	7	1	3	7	135
3.01- 5.00	5	9	9	14	42	37	43	19	41	24	38	9	3	0	4	0	297
5.01- 7.00	0	0	0	2	8	25	24	19	40	30	20	1	0	0	0	0	169
7.01-10.00	0	0	0	0	0	2	1	3	8	5	0	0	0	0	0	0	19
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	19	24	27	28	77	84	90	61	109	81	95	27	20	3	12	10	770

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	5
0.35- 0.50	1	2	0	1	0	1	0	0	0	1	2	2	0	2	0	1	13
0.51- 0.75	2	1	3	1	0	1	1	3	2	1	6	2	2	1	2	0	28
0.76- 1.00	4	2	1	2	3	1	4	3	3	0	6	3	5	1	2	0	40
1.01- 1.50	7	5	10	5	15	4	10	5	12	13	9	14	2	7	4	3	125
1.51- 2.00	17	12	11	14	21	17	11	5	12	11	9	17	15	14	15	12	213
2.01- 3.00	45	41	41	42	49	41	37	30	39	37	42	42	39	28	38	57	648
3.01- 5.00	96	127	113	84	118	94	105	107	157	154	184	141	128	87	55	70	1,820
5.01- 7.00	58	52	64	20	14	42	70	88	231	214	194	102	128	41	35	35	1,388
7.01-10.00	23	29	22	3	0	2	9	9	25	23	27	52	74	13	34	19	364
10.01-13.00	0	4	0	0	0	0	0	0	0	2	2	10	7	1	6	1	33
>13.00	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
TOTAL	253	275	265	172	220	203	247	250	481	456	482	385	400	195	191	198	4,678

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** AUGUST ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,208

TOTAL NUMBER OF VALID OBSERVATIONS: 4,678

TOTAL NUMBER OF MISSING OBSERVATIONS: 530

PERCENT DATA RECOVERY FOR THIS PERIOD: 89.8%

MEAN WIND SPEED FOR THIS PERIOD: 4.5 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
6.01	5.37	5.73	28.30	26.68	11.46	16.46

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	42	59	36	5	4	2	5	2	9	3	4	13	28	21	19	29	0
B	23	25	32	5	6	3	7	5	5	11	3	26	39	22	15	24	0
C	19	19	21	13	3	5	7	9	12	14	10	26	43	20	23	24	0
D	83	81	95	54	26	37	43	47	95	87	104	130	182	92	104	63	1
E	63	63	42	39	49	37	46	75	183	184	183	115	76	35	13	44	1
F	4	4	12	28	55	35	49	51	68	76	83	48	12	2	5	4	0
G	19	24	27	28	77	84	90	61	109	81	95	27	20	3	12	10	3
TOTAL	253	275	265	172	220	203	247	250	481	456	482	385	400	195	191	198	5

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** SEPTEMBER ***
STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	3
2.01- 3.00	4	6	2	2	2	0	1	0	0	1	0	1	0	0	3	4	26
3.01- 5.00	15	13	8	1	6	1	2	1	4	1	3	1	16	13	14	16	115
5.01- 7.00	9	4	9	2	3	0	2	1	5	9	6	3	13	11	3	0	80
7.01-10.00	4	0	0	1	0	0	0	0	3	2	2	5	12	3	1	0	33
10.01-13.00	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	33	24	22	6	11	1	5	2	12	14	12	10	41	27	21	22	263

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	3
1.51- 2.00	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3
2.01- 3.00	5	3	3	2	0	1	0	1	1	2	0	1	2	5	1	4	31
3.01- 5.00	8	6	4	0	2	1	1	2	3	3	0	0	11	5	9	5	60
5.01- 7.00	3	1	4	0	1	1	1	1	5	3	0	2	3	14	3	3	45
7.01-10.00	1	0	0	0	0	0	2	2	0	5	4	2	6	3	2	0	27
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	20	10	12	3	4	3	4	6	9	13	4	5	22	27	15	13	170

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** SEPTEMBER ***
STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
0.51- 0.75	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
0.76- 1.00	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
1.51- 2.00	0	0	0	2	0	0	1	1	0	0	0	0	0	0	0	4	8
2.01- 3.00	1	2	2	0	0	0	1	3	2	0	0	0	2	4	5	2	24
3.01- 5.00	12	7	5	1	0	2	2	3	6	6	3	8	12	9	10	9	95
5.01- 7.00	3	1	4	0	0	4	2	0	7	7	1	2	2	5	3	4	45
7.01-10.00	2	0	3	0	0	0	0	1	3	6	2	1	5	5	3	0	31
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	19	10	14	3	0	6	6	8	18	20	7	14	21	23	21	21	211

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
0.51- 0.75	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	3
0.76- 1.00	0	0	0	2	1	2	1	0	0	0	0	0	1	0	0	0	7
1.01- 1.50	2	3	5	4	4	2	1	0	1	0	0	0	2	2	0	0	26
1.51- 2.00	2	0	4	3	6	1	1	0	1	3	4	2	5	1	2	1	36
2.01- 3.00	16	8	10	10	16	6	9	5	10	14	9	10	8	13	5	8	157
3.01- 5.00	44	31	28	31	26	19	34	26	21	30	46	32	36	47	34	27	512
5.01- 7.00	71	44	25	17	9	16	13	11	29	41	44	25	39	35	28	35	482
7.01-10.00	44	14	10	9	0	2	18	18	15	16	20	37	27	23	41	22	316
10.01-13.00	3	0	0	0	0	0	0	1	1	5	0	5	3	8	8	2	36
>13.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	4
TOTAL	183	101	83	76	62	48	78	61	78	109	124	112	121	129	121	95	1,581

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** SEPTEMBER ***
STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	2
0.51- 0.75	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	3
0.76- 1.00	0	0	0	0	0	0	0	0	2	1	1	1	0	2	0	1	8
1.01- 1.50	0	0	1	0	1	1	1	1	2	1	2	0	1	0	0	2	13
1.51- 2.00	2	0	1	0	2	1	1	2	6	2	2	1	3	0	0	4	27
2.01- 3.00	6	5	8	5	9	5	4	16	5	7	4	7	8	2	1	3	95
3.01- 5.00	24	18	13	15	34	23	29	44	38	48	37	17	16	6	13	15	390
5.01- 7.00	26	12	14	16	10	19	37	62	99	148	87	36	14	9	19	35	643
7.01-10.00	10	0	1	4	0	0	9	18	41	24	14	42	12	14	18	12	219
10.01-13.00	1	0	0	0	0	0	0	1	0	5	3	2	6	2	1	3	24
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	69	35	38	40	56	51	81	146	193	236	150	106	61	35	52	75	1,425

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	3
1.01- 1.50	1	3	1	0	2	3	0	1	2	0	1	0	0	0	1	1	16
1.51- 2.00	0	0	0	1	0	2	0	2	1	1	2	1	0	1	0	0	11
2.01- 3.00	1	2	5	2	4	5	3	5	1	2	2	1	2	1	1	3	40
3.01- 5.00	4	3	2	7	20	11	16	12	13	21	20	3	4	2	1	1	140
5.01- 7.00	2	0	0	0	11	27	22	18	40	48	26	2	0	0	0	1	197
7.01-10.00	0	0	0	0	0	0	4	5	17	4	3	0	0	0	1	0	34
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	8	9	8	10	38	48	45	43	74	76	55	7	6	4	4	6	443

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** SEPTEMBER ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	1	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	5
0.51- 0.75	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	2	5
0.76- 1.00	0	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0	4
1.01- 1.50	1	0	2	2	4	1	1	2	3	1	1	0	1	0	1	1	21
1.51- 2.00	1	0	2	1	3	4	1	6	3	3	4	2	2	0	0	0	32
2.01- 3.00	6	4	6	6	10	14	6	8	9	15	11	8	9	2	1	2	117
3.01- 5.00	5	5	7	10	13	25	25	25	20	34	32	11	3	2	0	3	220
5.01- 7.00	0	0	0	0	2	19	15	21	39	31	17	1	0	0	0	1	146
7.01-10.00	0	0	0	0	0	0	0	7	11	3	1	0	0	0	0	0	22
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	14	9	18	19	34	64	48	70	86	88	67	23	16	5	2	9	572

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	3
0.35- 0.50	2	1	0	0	1	2	0	0	0	0	0	0	2	1	0	1	10
0.51- 0.75	0	0	5	0	1	1	1	2	1	1	2	0	0	0	0	2	16
0.76- 1.00	1	1	1	2	2	2	1	1	2	2	2	2	1	2	0	2	24
1.01- 1.50	6	7	9	6	12	7	3	4	8	2	5	0	4	2	2	5	82
1.51- 2.00	7	0	7	8	11	8	4	11	11	9	13	6	10	2	2	11	120
2.01- 3.00	39	30	36	27	41	31	24	38	28	41	26	28	31	27	17	26	490
3.01- 5.00	112	83	67	65	101	82	109	113	105	143	141	72	98	84	81	76	1,532
5.01- 7.00	114	62	56	35	36	86	92	114	224	287	181	71	71	74	56	79	1,638
7.01-10.00	61	14	14	14	0	2	33	51	90	60	46	87	62	48	66	34	682
10.01-13.00	4	0	0	0	0	0	0	2	1	11	3	10	9	10	9	5	64
>13.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	4
TOTAL	346	198	195	157	205	221	267	336	470	556	419	277	288	250	236	241	4,665

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** SEPTEMBER ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,040

TOTAL NUMBER OF VALID OBSERVATIONS: 4,665

TOTAL NUMBER OF MISSING OBSERVATIONS: 375

PERCENT DATA RECOVERY FOR THIS PERIOD: 92.6%

MEAN WIND SPEED FOR THIS PERIOD: 5.1 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
5.64	3.64	4.52	33.89	30.55	9.50	12.26

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	33	24	22	6	11	1	5	2	12	14	12	10	41	27	21	22	0
B	20	10	12	3	4	3	4	6	9	13	4	5	22	27	15	13	0
C	19	10	14	3	0	6	6	8	18	20	7	14	21	23	21	21	0
D	183	101	83	76	62	48	78	61	78	109	124	112	121	129	121	95	0
E	69	35	38	40	56	51	81	146	193	236	150	106	61	35	52	75	1
F	8	9	8	10	38	48	45	43	74	76	55	7	6	4	4	6	2
G	14	9	18	19	34	64	48	70	86	88	67	23	16	5	2	9	0
TOTAL	346	198	195	157	205	221	267	336	470	556	419	277	288	250	236	241	3

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** OCTOBER ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
1.01- 1.50	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	1	0	0	0	0	1	0	0	1	0	0	0	1	1	0	2	7
3.01- 5.00	5	4	3	0	1	0	1	5	5	6	4	1	9	9	1	1	55
5.01- 7.00	0	0	6	1	1	1	1	6	1	3	10	2	8	5	0	1	46
7.01-10.00	0	0	4	0	0	0	2	1	3	1	4	3	4	1	0	0	23
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	6	4	13	1	2	2	5	12	11	10	18	7	22	16	1	4	134

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	2
1.51- 2.00	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	3
2.01- 3.00	0	0	1	0	0	2	2	1	0	1	0	0	1	2	1	0	11
3.01- 5.00	3	7	8	2	0	4	12	6	4	2	4	1	4	2	4	1	64
5.01- 7.00	0	0	5	0	0	1	2	4	3	3	2	3	9	7	1	4	44
7.01-10.00	0	0	2	2	0	0	1	1	5	0	1	5	4	1	0	0	22
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	5
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3	8	16	4	0	8	18	12	12	6	8	13	19	12	7	6	152

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** OCTOBER ***
STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2
2.01- 3.00	0	2	3	0	1	3	1	2	1	0	0	0	2	2	4	0	21
3.01- 5.00	0	3	7	5	6	3	3	4	4	2	2	0	5	6	5	6	61
5.01- 7.00	1	1	12	0	1	0	1	4	3	6	7	6	5	7	3	4	61
7.01-10.00	0	0	6	3	0	0	0	3	2	1	4	8	7	4	4	0	42
10.01-13.00	0	0	0	0	0	0	0	0	0	3	0	3	1	0	0	0	7
>13.00	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3
TOTAL	1	6	29	8	8	6	5	13	10	12	13	21	20	19	16	11	198

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	1	0	0	1	1	0	0	0	0	0	0	0	2	0	0	1	6
0.76- 1.00	1	0	2	0	1	0	0	0	0	0	1	0	1	0	1	0	7
1.01- 1.50	3	0	2	1	0	0	1	0	0	2	1	0	3	1	2	1	17
1.51- 2.00	1	1	2	0	0	0	3	2	1	1	5	4	2	3	2	1	28
2.01- 3.00	7	3	10	10	15	9	2	3	8	7	6	4	9	11	8	11	123
3.01- 5.00	37	13	26	38	39	21	23	31	36	42	28	20	41	41	44	40	520
5.01- 7.00	33	6	15	39	13	10	31	41	48	53	55	33	31	44	74	51	577
7.01-10.00	25	2	9	13	1	1	8	28	53	58	88	41	78	96	160	58	719
10.01-13.00	2	0	1	0	0	0	7	7	4	9	14	15	31	54	65	18	227
>13.00	0	0	0	0	0	0	2	0	0	0	0	5	9	26	9	0	51
TOTAL	110	25	67	102	70	41	77	112	150	172	198	122	207	276	365	181	2,275

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** OCTOBER ***

STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	3
0.51- 0.75	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0.76- 1.00	0	0	0	1	1	0	0	0	1	0	0	0	2	0	1	0	6
1.01- 1.50	0	0	0	1	0	4	0	2	3	0	2	0	0	0	0	0	12
1.51- 2.00	1	0	0	3	2	1	1	1	1	2	0	1	0	1	0	2	16
2.01- 3.00	2	5	6	5	6	6	7	4	3	6	4	5	7	4	3	4	77
3.01- 5.00	12	19	14	17	58	22	30	30	44	52	51	13	12	8	15	21	418
5.01- 7.00	8	9	4	15	17	18	47	49	106	157	79	28	19	10	15	15	596
7.01-10.00	1	1	0	4	0	2	37	44	77	78	37	28	21	17	20	2	369
10.01-13.00	0	0	0	0	0	0	7	6	7	3	2	4	7	16	11	0	63
>13.00	0	0	0	0	0	0	0	0	0	0	0	1	3	5	1	0	10
TOTAL	24	35	25	47	84	53	129	136	242	298	175	80	71	62	66	44	1,573

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
0.51- 0.75	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	1	0	1	0	0	0	1	2	0	0	0	0	0	0	1	6
1.51- 2.00	0	0	2	0	1	0	0	0	1	0	2	0	2	0	0	0	8
2.01- 3.00	1	0	1	5	3	3	0	4	0	1	3	2	1	1	2	1	28
3.01- 5.00	0	1	2	6	34	15	9	12	10	7	15	3	1	0	0	3	118
5.01- 7.00	0	1	0	1	13	26	23	15	33	33	31	4	2	0	0	0	182
7.01-10.00	0	0	0	0	0	2	2	3	8	0	2	0	0	0	0	0	17
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	1	4	8	13	51	46	34	35	54	41	53	9	6	1	2	5	363

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** OCTOBER ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
0.51- 0.75	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
0.76- 1.00	0	0	3	0	0	0	2	1	0	1	0	0	1	0	1	0	9
1.01- 1.50	1	1	1	0	3	1	4	3	0	0	1	0	2	0	0	0	17
1.51- 2.00	0	0	0	0	0	0	1	5	3	0	2	0	0	1	0	0	12
2.01- 3.00	0	1	0	0	1	2	3	4	3	6	7	4	2	2	1	2	38
3.01- 5.00	0	0	3	1	6	6	17	17	14	24	16	0	2	0	0	2	108
5.01- 7.00	0	0	0	0	3	17	17	10	32	13	11	0	0	0	0	0	103
7.01-10.00	0	0	0	0	0	0	0	2	12	1	1	0	0	0	0	0	16
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2	2	7	4	13	26	44	42	64	45	38	4	7	3	2	4	307

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	0	0	3	3	0	0	0	0	0	0	0	0	0	1	0	0	7
0.51- 0.75	2	2	1	2	1	0	0	0	0	0	0	0	2	0	1	1	12
0.76- 1.00	1	0	5	1	2	0	2	1	2	1	1	0	4	0	3	0	23
1.01- 1.50	4	2	4	3	3	5	7	6	5	2	5	0	5	1	2	2	56
1.51- 2.00	2	2	4	3	3	2	5	8	6	3	9	6	4	5	2	5	69
2.01- 3.00	11	11	21	20	26	26	15	18	16	21	20	15	23	23	19	20	305
3.01- 5.00	57	47	63	69	144	71	95	105	117	135	120	38	74	66	69	74	1,344
5.01- 7.00	42	17	42	56	48	73	122	129	226	268	195	76	74	73	93	75	1,609
7.01-10.00	26	3	21	22	1	5	50	82	160	139	137	85	114	119	184	60	1,208
10.01-13.00	2	0	1	0	0	0	14	13	11	15	16	27	40	70	76	18	303
>13.00	0	0	0	0	0	0	2	0	0	0	0	9	12	31	10	0	64
TOTAL	147	84	165	179	228	182	312	362	543	584	503	256	352	389	459	255	5,002

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** OCTOBER ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,208

TOTAL NUMBER OF VALID OBSERVATIONS: 5,002

TOTAL NUMBER OF MISSING OBSERVATIONS: 206

PERCENT DATA RECOVERY FOR THIS PERIOD: 96.0%

MEAN WIND SPEED FOR THIS PERIOD: 6.1 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
2.68	3.04	3.96	45.48	31.45	7.26	6.14

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	6	4	13	1	2	2	5	12	11	10	18	7	22	16	1	4	0
B	3	8	16	4	0	8	18	12	12	6	8	13	19	12	7	6	0
C	1	6	29	8	8	6	5	13	10	12	13	21	20	19	16	11	0
D	110	25	67	102	70	41	77	112	150	172	198	122	207	276	365	181	0
E	24	35	25	47	84	53	129	136	242	298	175	80	71	62	66	44	2
F	1	4	8	13	51	46	34	35	54	41	53	9	6	1	2	5	0
G	2	2	7	4	13	26	44	42	64	45	38	4	7	3	2	4	0
TOTAL	147	84	165	179	228	182	312	362	543	584	503	256	352	389	459	255	2

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** NOVEMBER ***
STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.01- 5.00	2	0	0	0	0	0	0	0	0	1	1	2	3	2	0	0	11
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	3	3	1	1	0	0	8
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2	0	0	0	0	0	0	0	0	1	4	6	5	3	0	0	21

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	1	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	4
3.01- 5.00	0	4	0	0	4	1	1	1	1	0	3	1	1	4	1	0	22
5.01- 7.00	2	0	0	0	0	1	0	0	0	0	4	1	4	1	0	2	15
7.01-10.00	0	0	0	0	0	0	0	0	1	3	1	0	4	3	0	0	12
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	3
TOTAL	3	4	1	0	4	2	1	1	2	3	8	4	10	10	3	2	58

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** NOVEMBER ***
STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
1.51- 2.00	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	2
2.01- 3.00	1	1	0	0	1	1	0	0	0	1	0	1	2	2	3	0	13
3.01- 5.00	1	3	2	1	2	2	1	0	2	3	1	0	4	7	3	0	32
5.01- 7.00	0	0	5	3	1	3	2	0	2	3	4	0	7	4	2	1	37
7.01-10.00	1	0	0	0	0	0	1	1	1	1	3	4	4	3	2	0	21
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	1	5	2	1	0	9
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
TOTAL	3	4	7	4	4	7	4	1	5	9	8	6	23	20	12	1	118

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	3
0.76- 1.00	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	2
1.01- 1.50	1	2	2	0	3	1	0	0	0	1	0	1	2	2	1	0	16
1.51- 2.00	1	4	1	0	1	0	5	3	2	0	4	0	2	1	4	2	30
2.01- 3.00	19	7	11	8	22	17	6	4	13	8	8	8	10	12	16	15	184
3.01- 5.00	49	48	35	23	63	37	24	26	39	46	36	27	46	45	49	32	625
5.01- 7.00	29	30	41	43	51	33	34	21	55	113	87	45	47	67	84	39	819
7.01-10.00	18	10	16	21	4	5	46	43	43	100	141	84	94	109	116	53	903
10.01-13.00	6	8	3	0	0	0	12	20	7	17	46	59	57	73	73	10	391
>13.00	1	0	0	0	0	0	2	6	0	0	2	16	12	18	21	1	79
TOTAL	124	109	110	96	145	93	129	123	159	285	324	240	271	328	364	152	3,053

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** NOVEMBER ***
STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
0.51- 0.75	1	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	4
0.76- 1.00	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	3
1.01- 1.50	0	0	0	1	2	0	0	1	1	1	1	1	0	0	0	1	9
1.51- 2.00	1	0	0	4	3	0	2	0	3	0	2	1	0	0	3	0	19
2.01- 3.00	0	4	3	5	5	6	13	2	3	3	2	2	1	4	0	5	58
3.01- 5.00	2	1	6	20	32	22	24	22	31	35	25	11	10	9	5	5	260
5.01- 7.00	0	0	0	14	19	10	29	30	69	68	38	15	10	6	1	2	311
7.01-10.00	0	0	0	0	0	3	27	27	57	54	50	21	20	5	3	1	268
10.01-13.00	0	0	1	0	0	0	5	7	11	8	17	15	4	1	0	0	69
>13.00	1	0	1	0	0	0	2	0	0	0	1	0	7	4	0	2	18
TOTAL	6	5	12	45	62	41	102	90	177	170	136	66	52	29	12	16	1,022

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	2
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
0.76- 1.00	0	0	0	1	2	0	0	0	0	0	0	0	1	0	1	0	5
1.01- 1.50	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	0	4
1.51- 2.00	0	1	0	1	2	2	1	0	0	1	2	0	0	0	2	0	12
2.01- 3.00	0	0	1	4	5	4	5	0	4	2	1	2	1	1	0	0	30
3.01- 5.00	0	0	1	3	25	14	11	8	12	2	6	3	1	2	1	0	89
5.01- 7.00	0	0	0	0	7	8	16	6	16	19	16	4	1	0	0	0	93
7.01-10.00	0	0	0	0	0	1	0	0	7	2	0	0	0	0	0	0	10
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTAL	0	1	2	9	41	29	33	14	41	27	26	9	5	3	4	1	247

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** NOVEMBER ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	2
1.01- 1.50	0	0	1	1	1	2	0	0	0	0	0	0	1	0	1	0	7
1.51- 2.00	0	0	0	2	2	0	3	1	2	1	2	2	1	0	1	1	18
2.01- 3.00	0	2	1	3	4	2	1	7	0	0	3	1	2	1	0	0	27
3.01- 5.00	0	2	2	10	7	6	12	13	8	4	5	7	5	1	0	1	83
5.01- 7.00	0	0	0	0	3	2	2	5	6	8	6	7	0	0	0	0	39
7.01-10.00	0	0	0	0	0	1	0	1	0	3	0	0	0	0	0	0	5
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	4	4	16	17	13	18	28	16	16	16	17	9	2	3	2	181

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	4
0.35- 0.50	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
0.51- 0.75	1	0	1	1	1	0	0	0	1	1	0	0	1	0	0	1	8
0.76- 1.00	0	0	1	2	3	1	0	1	1	0	0	0	1	1	2	0	13
1.01- 1.50	1	2	3	2	6	3	0	1	3	3	2	2	4	2	2	1	37
1.51- 2.00	2	5	1	7	8	2	11	4	7	3	10	3	3	1	11	3	81
2.01- 3.00	21	14	17	20	37	30	25	13	20	14	14	15	16	20	20	20	316
3.01- 5.00	54	58	46	57	133	82	73	70	93	91	77	51	70	70	59	38	1,122
5.01- 7.00	31	30	46	60	81	57	83	62	148	211	158	75	70	79	87	44	1,322
7.01-10.00	19	10	16	21	4	10	74	72	109	163	195	110	122	120	121	54	1,220
10.01-13.00	6	8	4	0	0	0	17	27	18	25	63	76	68	76	74	10	472
>13.00	2	0	1	0	0	0	4	6	0	0	3	16	20	26	22	3	103
TOTAL	138	127	136	170	273	185	287	257	400	511	522	348	375	395	398	174	4,700

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** NOVEMBER ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,040

TOTAL NUMBER OF VALID OBSERVATIONS: 4,700

TOTAL NUMBER OF MISSING OBSERVATIONS: 340

PERCENT DATA RECOVERY FOR THIS PERIOD: 93.3%

MEAN WIND SPEED FOR THIS PERIOD: 6.5 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
0.45	1.23	2.51	64.96	21.74	5.26	3.85

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	2	0	0	0	0	0	0	0	0	1	4	6	5	3	0	0	0
B	3	4	1	0	4	2	1	1	2	3	8	4	10	10	3	2	0
C	3	4	7	4	4	7	4	1	5	9	8	6	23	20	12	1	0
D	124	109	110	96	145	93	129	123	159	285	324	240	271	328	364	152	1
E	6	5	12	45	62	41	102	90	177	170	136	66	52	29	12	16	1
F	0	1	2	9	41	29	33	14	41	27	26	9	5	3	4	1	2
G	0	4	4	16	17	13	18	28	16	16	16	17	9	2	3	2	0
TOTAL	138	127	136	170	273	185	287	257	400	511	522	348	375	395	398	174	4

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** DECEMBER ***

STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.01- 5.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
TOTAL	0	0	1	0	0	0	0	1	0	0	1	1	0	1	0	0	5

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.01- 5.00	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
5.01- 7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	4

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** DECEMBER ***
STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.01- 3.00	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	3
3.01- 5.00	0	2	1	0	3	1	0	0	0	0	0	2	0	1	0	0	10
5.01- 7.00	0	0	0	0	0	1	0	0	0	0	0	0	3	0	0	0	4
7.01-10.00	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	3
10.01-13.00	0	0	0	0	0	0	0	0	1	0	0	0	1	2	0	0	4
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTAL	0	2	2	0	3	3	1	0	2	0	1	2	5	3	1	0	25

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	3
0.35- 0.50	0	0	0	0	2	3	0	0	0	1	1	2	0	0	0	0	9
0.51- 0.75	0	0	1	1	0	1	1	0	0	0	0	0	2	1	0	0	7
0.76- 1.00	1	0	0	0	1	0	1	0	0	0	0	4	0	0	1	2	10
1.01- 1.50	2	3	6	2	4	7	4	4	1	1	1	0	0	2	1	2	40
1.51- 2.00	2	0	3	3	6	3	2	0	0	2	1	3	1	1	2	1	30
2.01- 3.00	10	6	14	11	17	12	17	9	12	7	10	12	4	5	3	8	157
3.01- 5.00	39	19	52	37	71	54	39	31	48	54	69	28	47	24	36	35	683
5.01- 7.00	41	34	31	8	28	27	18	26	66	118	145	82	79	51	55	45	854
7.01-10.00	18	10	13	3	2	7	27	48	42	110	193	113	98	78	105	42	909
10.01-13.00	16	9	1	2	2	2	6	17	9	24	52	78	55	59	72	22	426
>13.00	2	0	0	0	1	1	2	3	1	1	23	45	40	33	7	1	160
TOTAL	131	81	121	67	134	117	117	138	179	318	495	367	326	254	282	158	3,288

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** DECEMBER ***

STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	9
0.35- 0.50	0	0	1	1	0	0	1	2	1	3	0	0	1	0	1	1	12
0.51- 0.75	0	0	0	1	4	2	2	0	1	2	1	2	0	1	0	0	16
0.76- 1.00	0	0	2	1	2	1	0	2	1	0	1	0	2	2	0	0	14
1.01- 1.50	0	0	3	2	4	3	4	1	4	3	1	0	2	0	2	3	32
1.51- 2.00	0	1	0	1	1	2	2	3	2	1	2	3	2	1	6	2	29
2.01- 3.00	1	0	5	2	8	6	6	7	9	7	4	5	7	4	4	1	76
3.01- 5.00	3	1	16	10	25	17	31	41	35	35	20	13	6	5	1	1	260
5.01- 7.00	4	0	2	10	12	19	24	40	74	100	39	12	5	2	0	1	344
7.01-10.00	0	0	3	1	0	2	18	35	42	59	46	18	3	3	0	2	232
10.01-13.00	2	0	0	0	0	0	4	18	18	22	16	7	7	2	0	0	96
>13.00	0	0	0	0	0	0	1	2	4	5	4	5	0	1	0	0	22
TOTAL	10	2	32	29	56	52	93	151	191	237	134	65	35	21	14	11	1,142

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	1
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2
0.51- 0.75	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2
0.76- 1.00	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
1.01- 1.50	1	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	5
1.51- 2.00	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	4
2.01- 3.00	0	0	0	0	3	0	2	5	1	2	3	0	0	0	0	0	16
3.01- 5.00	0	0	0	1	3	1	6	3	2	5	7	0	2	0	0	0	30
5.01- 7.00	0	0	0	3	10	8	3	4	5	2	2	0	0	0	0	0	37
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	1	0	0	5	17	12	14	12	9	9	14	2	4	0	0	0	100

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** DECEMBER ***
STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.76- 1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01- 1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.51- 2.00	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	2
2.01- 3.00	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	3
3.01- 5.00	0	0	0	0	1	1	2	0	4	2	0	0	0	0	0	0	10
5.01- 7.00	0	0	0	0	1	1	0	0	2	1	0	0	0	0	0	0	5
7.01-10.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.01-13.00	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	2	2	2	1	7	4	3	0	0	0	0	0	21

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	13
0.35- 0.50	0	0	1	1	2	3	1	3	1	4	1	4	1	0	1	1	24
0.51- 0.75	0	0	1	2	5	4	3	0	1	2	1	2	2	2	0	0	25
0.76- 1.00	1	0	2	1	3	2	1	2	1	0	1	4	2	2	1	2	25
1.01- 1.50	3	3	10	6	8	11	9	5	6	4	2	0	2	2	3	5	79
1.51- 2.00	2	1	3	4	7	5	6	3	2	4	6	6	3	2	8	3	65
2.01- 3.00	11	6	20	13	28	19	26	22	23	16	18	17	11	9	7	9	255
3.01- 5.00	42	22	70	48	103	74	78	75	89	96	96	43	55	30	37	36	994
5.01- 7.00	45	34	33	21	51	56	45	70	147	221	186	94	87	53	55	46	1,244
7.01-10.00	18	10	16	4	2	9	45	83	85	169	241	131	103	81	106	44	1,147
10.01-13.00	18	9	1	2	2	2	10	35	28	46	69	86	64	64	72	22	530
>13.00	2	0	0	0	1	1	3	5	5	6	27	50	41	35	7	1	184
TOTAL	142	85	157	102	212	186	227	303	388	568	648	437	371	280	297	169	4,585

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** DECEMBER ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 5,208

TOTAL NUMBER OF VALID OBSERVATIONS: 4,585

TOTAL NUMBER OF MISSING OBSERVATIONS: 623

PERCENT DATA RECOVERY FOR THIS PERIOD: 88.0%

MEAN WIND SPEED FOR THIS PERIOD: 6.7 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
0.11	0.09	0.55	71.71	24.91	2.18	0.46

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	0	0	1	0	0	0	0	1	0	0	1	1	0	1	0	0	0
B	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0
C	0	2	2	0	3	3	1	0	2	0	1	2	5	3	1	0	0
D	131	81	121	67	134	117	117	138	179	318	495	367	326	254	282	158	3
E	10	2	32	29	56	52	93	151	191	237	134	65	35	21	14	11	9
F	1	0	0	5	17	12	14	12	9	9	14	2	4	0	0	0	1
G	0	0	0	0	2	2	2	1	7	4	3	0	0	0	0	0	0
TOTAL	142	85	157	102	212	186	227	303	388	568	648	437	371	280	297	169	13

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** ANNUAL ***
STABILITY CLASS A

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
0.51- 0.75	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	4
0.76- 1.00	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	3
1.01- 1.50	1	1	1	0	1	0	1	2	0	1	0	0	1	0	4	0	13
1.51- 2.00	5	4	1	0	1	0	2	2	0	1	1	1	2	2	5	3	30
2.01- 3.00	27	16	8	4	3	3	3	4	3	3	4	4	8	20	21	33	164
3.01- 5.00	106	90	50	13	18	9	14	20	28	11	10	28	89	125	105	102	818
5.01- 7.00	18	55	87	9	7	11	16	21	20	30	33	47	119	52	23	10	558
7.01-10.00	8	8	42	7	0	4	4	10	10	5	12	59	80	14	9	5	277
10.01-13.00	1	0	2	1	0	0	0	3	4	2	5	9	13	2	4	0	46
>13.00	0	0	0	0	0	0	0	0	0	0	2	3	1	1	0	0	7
TOTAL	166	174	194	34	30	28	40	63	66	53	68	152	313	216	171	153	1,921

STABILITY CLASS B

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.51- 0.75	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	2
0.76- 1.00	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3
1.01- 1.50	2	1	0	2	1	1	1	1	0	0	1	0	0	1	1	3	15
1.51- 2.00	3	1	3	1	0	2	0	0	0	0	0	0	2	1	2	2	17
2.01- 3.00	27	13	11	4	6	6	7	7	1	5	1	3	7	19	23	32	172
3.01- 5.00	59	60	57	6	13	14	32	21	19	17	14	26	80	86	58	45	607
5.01- 7.00	16	18	57	8	3	9	14	15	18	36	24	38	124	59	18	15	472
7.01-10.00	5	2	24	14	0	1	7	9	16	22	12	34	92	17	11	10	276
10.01-13.00	0	0	2	0	0	0	0	2	1	4	4	15	26	3	3	1	61
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	3	2	1	0	6
TOTAL	113	95	155	37	23	33	61	55	55	84	56	116	334	188	118	108	1,631

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** ANNUAL ***

STABILITY CLASS C

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	0
0.35- 0.50	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	1	4
0.51- 0.75	0	0	0	0	1	0	1	1	0	2	0	0	0	0	0	1	6
0.76- 1.00	5	1	0	0	0	1	0	0	0	0	2	2	1	0	0	1	13
1.01- 1.50	1	0	3	2	0	1	2	0	1	0	1	1	1	2	2	1	18
1.51- 2.00	7	1	3	3	1	2	3	3	1	2	1	3	1	8	6	10	55
2.01- 3.00	27	15	15	7	9	13	10	11	8	9	7	6	18	37	47	34	273
3.01- 5.00	66	75	73	26	16	15	17	24	35	43	26	41	116	123	89	77	862
5.01- 7.00	5	18	56	20	5	15	17	25	41	36	38	38	131	64	37	21	567
7.01-10.00	6	1	33	13	0	4	4	16	30	31	17	52	79	39	22	5	352
10.01-13.00	1	0	1	1	0	0	0	1	5	7	11	33	25	8	10	1	104
>13.00	0	0	0	0	0	0	0	0	1	1	0	5	5	3	1	0	16
TOTAL	118	113	184	72	32	51	54	81	122	131	103	181	378	284	214	152	2,270

STABILITY CLASS D

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	16
0.35- 0.50	3	3	2	3	4	4	4	0	2	4	1	2	3	3	2	2	42
0.51- 0.75	4	1	8	6	8	3	6	2	0	6	8	2	8	2	1	1	66
0.76- 1.00	11	2	9	6	13	10	7	10	4	4	7	8	7	7	4	9	118
1.01- 1.50	35	26	42	27	36	17	10	11	10	19	25	25	31	28	25	22	389
1.51- 2.00	58	40	49	41	50	36	17	16	20	23	39	47	49	71	55	38	649
2.01- 3.00	185	185	173	171	193	115	84	77	91	103	127	146	205	233	260	189	2,537
3.01- 5.00	395	370	510	478	454	299	269	244	321	395	510	454	753	586	501	384	6,923
5.01- 7.00	382	243	406	406	210	169	213	275	412	629	712	656	821	529	541	428	7,032
7.01-10.00	204	89	202	238	34	53	199	291	288	473	752	910	941	643	701	292	6,310
10.01-13.00	48	27	51	64	2	11	95	101	60	98	191	424	386	334	317	71	2,280
>13.00	8	2	6	10	1	2	12	18	12	17	52	185	164	109	59	2	659
TOTAL	1,333	988	1,458	1,450	1,005	719	916	1,045	1,220	1,771	2,424	2,859	3,368	2,545	2,466	1,438	27,021

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** ANNUAL ***

STABILITY CLASS E

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	20
0.35- 0.50	1	0	2	4	2	2	2	3	3	4	0	5	2	2	1	1	34
0.51- 0.75	8	3	8	5	6	4	3	2	3	5	7	5	1	3	4	3	70
0.76- 1.00	2	6	8	6	9	4	2	4	9	3	5	6	7	9	6	2	88
1.01- 1.50	12	9	14	15	26	15	15	18	25	20	19	16	11	15	13	12	255
1.51- 2.00	16	12	22	25	35	19	30	18	31	17	15	30	27	13	23	21	354
2.01- 3.00	45	60	85	82	106	86	70	62	65	70	86	90	81	94	62	51	1,195
3.01- 5.00	136	140	178	202	387	221	252	314	360	458	476	284	203	147	111	153	4,022
5.01- 7.00	114	72	70	121	118	129	272	395	818	1,055	639	347	147	90	84	132	4,603
7.01-10.00	30	23	29	19	6	25	188	282	470	469	300	289	159	60	55	35	2,439
10.01-13.00	3	5	5	4	0	1	48	83	81	84	70	86	49	27	16	3	565
>13.00	1	0	1	0	0	0	7	15	9	13	15	17	16	10	2	2	108
TOTAL	368	330	422	483	695	506	889	1,196	1,874	2,198	1,632	1,175	703	470	377	415	13,753

STABILITY CLASS F

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	12
0.35- 0.50	1	1	2	1	0	1	0	0	1	1	1	3	0	1	0	2	15
0.51- 0.75	1	2	2	0	2	4	3	1	1	1	1	1	2	0	1	4	26
0.76- 1.00	3	3	1	4	5	1	6	2	3	2	6	3	1	0	2	3	45
1.01- 1.50	6	9	5	7	10	11	7	15	15	5	10	5	4	10	3	6	128
1.51- 2.00	6	11	11	13	18	8	9	11	8	11	19	13	12	12	13	6	181
2.01- 3.00	15	18	29	37	49	37	40	31	34	35	65	39	23	18	17	8	495
3.01- 5.00	12	13	41	95	240	126	114	101	118	131	170	129	48	16	16	15	1,385
5.01- 7.00	3	3	4	22	80	143	170	139	285	300	254	67	10	2	0	2	1,484
7.01-10.00	0	0	0	0	2	4	20	19	69	36	20	6	2	0	1	0	179
10.01-13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
TOTAL	47	60	95	179	406	335	369	319	534	522	546	266	103	59	53	46	3,951

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** ANNUAL ***

STABILITY CLASS G

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	15
0.35- 0.50	2	2	3	3	2	3	1	0	0	1	2	2	2	2	1	1	27
0.51- 0.75	4	1	5	3	4	6	1	4	8	1	4	2	2	4	3	2	54
0.76- 1.00	6	3	9	4	5	2	10	8	5	5	7	8	11	3	9	1	96
1.01- 1.50	7	9	19	10	27	20	16	16	21	9	27	22	15	9	15	12	254
1.51- 2.00	12	13	19	27	32	22	31	28	22	26	36	21	29	14	18	10	360
2.01- 3.00	28	44	37	55	83	60	72	76	62	84	105	71	72	30	26	30	935
3.01- 5.00	17	29	44	72	167	193	189	132	165	180	253	128	50	8	7	9	1,643
5.01- 7.00	1	0	2	11	54	147	140	142	193	189	126	26	3	0	0	1	1,035
7.01-10.00	0	0	0	0	1	8	7	29	65	26	11	1	0	0	0	0	148
10.01-13.00	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
>13.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	77	101	138	185	375	461	467	435	541	521	572	281	184	70	79	66	4,568

STABILITY CLASS ALL

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION IN HOURS AT 60.00 METERS

SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
CALM																	63
0.35- 0.50	7	8	9	11	8	10	7	4	6	10	4	12	8	8	4	7	123
0.51- 0.75	17	7	27	14	21	17	14	10	12	15	21	10	13	9	10	11	228
0.76- 1.00	28	15	27	22	32	19	25	24	22	14	27	28	27	19	21	16	366
1.01- 1.50	64	55	84	63	101	65	52	63	72	54	83	69	63	65	63	56	1,072
1.51- 2.00	107	82	108	110	137	89	92	78	82	80	111	115	122	121	122	90	1,646
2.01- 3.00	354	351	358	360	449	320	286	268	264	309	395	359	414	451	456	377	5,771
3.01- 5.00	791	777	953	892	1,295	877	887	856	1,046	1,235	1,459	1,090	1,339	1,091	887	785	16,260
5.01- 7.00	539	409	682	597	477	623	842	1,012	1,787	2,275	1,826	1,219	1,355	796	703	609	15,751
7.01-10.00	253	123	330	291	43	99	429	656	948	1,062	1,124	1,351	1,353	773	799	347	9,981
10.01-13.00	53	32	61	70	2	12	143	190	151	195	282	567	499	374	350	76	3,057
>13.00	9	2	7	10	1	2	19	33	22	31	69	210	190	125	63	4	797
TOTAL	2,222	1,861	2,646	2,440	2,566	2,133	2,796	3,194	4,412	5,280	5,401	5,030	5,383	3,832	3,478	2,378	55,115

CEI PNPP 7 SITE YEARS 60-METER WINDS DELTA T
SITE IDENTIFIER: CEI-P
DATA PERIOD EXAMINED: 5/1/72 - 8/31/82

*** ANNUAL ***

STABILITY BASED ON: DELTA T BETWEEN 60.0 AND 10.0 METERS
WIND MEASURED AT: 60.0 METERS
WIND THRESHOLD AT: 0.75 MPH

TOTAL NUMBER OF OBSERVATIONS: 61,344

TOTAL NUMBER OF VALID OBSERVATIONS: 55,115

TOTAL NUMBER OF MISSING OBSERVATIONS: 6,229

PERCENT DATA RECOVERY FOR THIS PERIOD: 89.8%

MEAN WIND SPEED FOR THIS PERIOD: 5.6 M/S

TOTAL NUMBER OF OBSERVATIONS WITH BACKUP DATA: 0

PERCENTAGE OCCURRENCE OF STABILITY CLASSES

A	B	C	D	E	F	G
3.49	2.96	4.12	49.03	24.95	7.17	8.29

DISTRIBUTION OF WIND DIRECTION VS. STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	166	174	194	34	30	28	40	63	66	53	68	152	313	216	171	153	0
B	113	95	155	37	23	33	61	55	55	84	56	116	334	188	118	108	0
C	118	113	184	72	32	51	54	81	122	131	103	181	378	284	214	152	0
D	1,333	988	1,458	1,450	1,005	719	916	1,045	1,220	1,771	2,424	2,859	3,368	2,545	2,466	1,438	16
E	368	330	422	483	695	506	889	1,196	1,874	2,198	1,632	1,175	703	470	377	415	20
F	47	60	95	179	406	335	369	319	534	522	546	266	103	59	53	46	12
G	77	101	138	185	375	461	467	435	541	521	572	281	184	70	79	66	15
TOTAL	2,222	1,861	2,646	2,440	2,566	2,133	2,796	3,194	4,412	5,280	5,401	5,030	5,383	3,832	3,478	2,378	63

<APPENDIX 2D>

BEDROCK DEFORMATION IN THE COOLING WATER TUNNEL

PREFACE

<Appendix 2D> incorporates in entirety the contents of GAI Report No. 2063, Bedrock Deformation in the Cooling Water Tunnels, Perry Nuclear Power Plant, North Perry Ohio, October 1979. Some of this reports' appendices and figures have been resequenced. Significant text changes were made in Paragraph 3 of Page 26 and Sections 4.2 through 4.2.3 of the main body of the report.

GAI REPORT NO. 2063

Prepared for Cleveland Electric Illuminating Co.

BEDROCK DEFORMATION IN THE COOLING WATER TUNNELS PERRY NUCLEAR POWER PLANT NORTH PERRY, OHIO

OCTOBER 1979

Compiled by

L. D. Schultz
Project Geologist
Perry Nuclear Power Plant
Gilbert Associates, Inc.

Reviewed by

W. J. Santamour
Geotechnical Section Supervisor
Gilbert Associates, Inc.

Approved for Release by

P. B. Gudikunst
Project Manager
Perry Nuclear Power Plant
Gilbert Associates, Inc.

Revision 12
January, 2003

GAI Report No. 2063

THE CLEVELAND ELECTRIC ILLUMINATING COMPANY
PERRY NUCLEAR POWER PLANT

BEDROCK DEFORMATION IN THE COOLING WATER TUNNELS PERRY NUCLEAR POWER PLANT NORTH PERRY, OHIO

OCTOBER 1979

Compiled by: Lane D. Schultz

L. D. Schultz
Project Geologist
Gilbert Associates

Reviewed by: ____________

W. J. Santamour
Geotechnical Section Supervisor
Gilbert Associates, Inc.

Approved by: Paul B Gudikunst

P. B. Gudikunst
Project Manager
Gilbert Associates, Inc.

Revision 12
January, 2003

<u>TABLE OF CONTENTS</u>

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

1.0 SUMMARY

Geological, geophysical and seismological studies were conducted on and in the vicinity of a fault observed in the intake and discharge tunnels at the Perry Nuclear Power Plant site of The Cleveland Electric Illuminating Company. The Perry site is located on the shore of Lake Erie, approximately 35 miles northeast of Cleveland. The general location of the site is shown on <Figure 2D-1>.

A comprehensive investigative program evolved as a result of the bedrock deformation exposed during the excavation phase of tunnel construction. Deterministic fault study objectives, extent, origin and age, were realized as a consequence of a series of interrelated geologic and geophysical research and engineering. The nature of fault-plane geometry and its gouge and mineralogical as well as chemical constituents were studied. After site specific data had been assembled, the localized anomalous deformation was interpreted in context of its regional geologic setting.

The extent of faulting was defined on the basis of the following: (1) planned, tunnel mapping program (scale 1:120); (2) detailed mapping of tunnel deformation segments (scale 1:12); (3) exploratory borings; (4) geophysical logging of borings; (5) shoreline reconnaissance; (6) offshore magnetic survey; (7) lake bottom reconnaissance mapping and review of seismic track line data; and (8) comparative isotopic analyses of Lake Erie water and fault seepage.

Fault zone gouge and fractured rock samples were obtained for X-ray diffraction, clay-mineralogical determinations, SEM (scanning electron microscope) microcrack analysis, and miscellaneous engineering property determinations including consolidation pressure analysis. No radioactive isotopes, which could have been dated, were identified in fault zone samples. With respect to the site area and locale studies,

the following were performed or prepared: (1) in situ borehole (TX-11) stress measurements to determine existing site stress field orientation and magnitude; (2) structural contour maps of "Big Lime" upper and basal (-50 ft) horizons and isopachous map of intervening interval for Lake and portions of adjacent Ashtabula, Geauga and Cuyahoga Counties; (3) evaluation of microseismicity in northeastern Ohio; (4) literature and field review of area salt mines and interviews with mine personnel (Mr. Jaroslav Vaverka, resident mining engineer, Cleveland mine, International Salt Company and Mr. B. C. Cummings, resident chief engineer, Painesville mine, Morton Salt Division of Morton Norwick).

Independent opinions based on their field inspection of the tunnel deformation and literature review were obtained from the following geologists recognized for their expertise in the indicated disciplines:

Dr. Robert G. LaFleur
Pleistocene Geology and Sedimentology
Rensselaer Polytechnical Institute

Mr. James Murphy
Areal Geology and Stratigraphy of Northeastern Ohio
Ohio Historical Society

Dr. Barry Voight
Structural Geology
Pennsylvania State University

It is concluded on the bases of data and interpretation of the aforementioned studies and other site and regional geological, geophysical and seismological information that the last movement on the cooling water tunnel bedrock deformation was not tectonic. It occurred during Pleistocene time probably associated with deglaciation-rebound

rather than ice advance compression. On the basis of geometry alone it is possible that the initial deformation was a pre-Pleistocene event. The presence of the fault deformation intersecting the tunnels was considered during design review and redesign was not required.

2.0 INTRODUCTION

2.1 STATEMENT OF PROBLEM

Tunnel excavations for the plant cooling water system exposed low-angle thrust faulting of minor displacement in the Chagrin shale beneath Lake Erie. The presence of faulting within the intake and discharge tunnels did not greatly hinder tunneling operations. Additional rock bolts and tunnel shields were installed in tunnel fault segments to insure crown stability. Methane and water, which had been stored within fault zone fracture porosity, were discharged upon intersection of the intake tunnel fault segment by a horizontal exploratory boring drilled in advance of the tunnel boring machine. Both conditions were short term, within anticipated limits and controlled by normal pumping and ventilation.

Geologic mapping (scale 1:120) of the tunnels was conducted concurrent with tunneling consistent with PSAR (Preliminary Safety Analysis Report) commitments (<Figure 2D-2>, 24 sheets). After faulting had been intersected by the tunnel boring machine and the bedrock mapped, preliminary interpretations and the mapping data were forwarded to the NRC (Nuclear Regulatory Commission) in a timely manner. The extent, age and origin of faulting were not well understood following its initial encounter within the intake tunnel. More than four months elapsed between faulting exposed in the intake and discharge tunnels, respectively.

The fault plane exposed in the intake tunnel subsequently has been determined to have a strike of approximately N51°E which projects in the

vicinity of the discharge tunnel deformation. Based on the similarity of structural style, flexural slip, and brittle failure attributable to compression, and assuming minor warping of the fault plane along its strike, it is probable that the fault plane is continuous between both tunnels. This determination could not be concluded prior to completion of all tunnel excavations which was accomplished nearly six months after exposing the first deformation.

The origin of the deformation could not be readily determined on the basis of known regional geology. Results of site and regional studies (field and literature) conducted during the preconstruction phase are reported in the PSAR. On the basis of these studies and the opinions of university professors, bedrock in northeastern Ohio is not known to have undergone significant faulting. Professors contacted during the preparation of the PSAR are listed as follows:

Prof. Eugene J. Synuk, Kent State University,
Prof. Murray R. McComas, Kent State University,
Prof. Tom Lewis, Cleveland State University, and
Prof. Charles M. Somerson, Ohio State University.

In this area a nearly ubiquitous veneer of glacial and glaciolacustrine deposits obscure bedrock except where incised by stream erosion. Accessible outcrops do not reveal evidence of having experienced tectonism, either late Paleozoic associated with the Alleghenian (Appalachian) Orogeny or any other. Subsurface data, geological and geophysical, do not imply the presence of a regional fault system which could have been interpreted to be genetically related to tunnel faulting. The general lack of information to the contrary suggested that this portion of the Central Lowland Physiographic Province is tectonically stable having undergone little if any tectonic deformation.

Shallow bedrock deformation, consisting of small-scale folding and faulting, had been revealed as a consequence of plant foundation

excavation during 1975 and 1976. It has been demonstrated by field relationships that this deformation was caused by the direct action of late Wisconsinan glaciation. Similarity of evidence of glacially induced deformation has been found elsewhere in the same bedrock unit within northeastern Ohio.

Within this context, investigations were undertaken to determine the lateral and vertical extent of the tunnel fault, origin and age of deformation, and effect that this deformation could have had on the tunnel design. Many conventional age dating techniques could not be employed because of mineralogy and stratigraphy. Consequentially, in conducting the tunnel faulting study innovative and conventional investigative techniques were employed in supplementing the existing state of site and regional knowledge available for analysis and interpretation.

2.2 INVESTIGATIVE CHRONOLOGY

A comprehensive investigative program evolved as a result of the bedrock deformation exposed during the excavation phase of tunnel construction. Deterministic fault study objectives previously outlined were realized as a consequence of a series of interrelated geologic and geophysical research and engineering. Concurrent with, and subsequent to, tunnel excavations, the nature of the fault plane geometry, gouge and country rock mineralogical as well as chemical constituents were revealed. After the necessary site specific data had been assembled, the localized anomalous deformation was interpreted in context of its regional geologic setting.

Tunneling activities began in July 1977 after the main shafts and temporary access shafts had been excavated by conventional “drill and shoot” methods. “Drill and shoot” methods were also employed in providing sufficient room at the base of the temporary access shafts for assembling tunnel excavation machines. A DOSCO Roadheader MK-2A

tunneling machine excavated 426 lineal feet of bedrock mostly south of the temporary access shafts. The remaining 2,600 feet of tunneling was accomplished with a Jarva circular bore tunneling machine. The excavation phase was completed in November 1978. Tunnel advancement was documented during the geologic mapping program and is shown on <Figure 2D-2>. Tunnel and shaft components of the cooling water system are shown on <Figure 2D-3>.

Tunnel heading advancement was initiated from the intake tunnel access shaft. First, the segment between this access shaft and service water pumphouse intake riser was completed. Then the connecting tunnel to the emergency service water pumphouse was excavated. Both tunnel segments were excavated with the Roadheader MK-2A machine, which was dismantled and removed upon their completion, and reassembled in the discharge tunnel temporary access shaft. Subsequently, tunnel segments between the discharge tunnel access shaft to the discharge riser in the discharge tunnel entrance structure and a connecting tunnel from this segment to the emergency service water pumphouse were excavated. Bedrock conditions in these segments were quite good with minimal crown overbreak. Predictably minor, discontinuous and closed vertical to near vertical joints, minimal groundwater seepage, and short term gas emissions (predominantly methane) were experienced in these tunnel segments. None of these conditions were beyond an anticipated range.

Advancement of the intake tunnel heading to the north from the temporary access shaft began in September 1977 with the Roadheader. In April 1978 the tunneling advancement rate greatly accelerated with the employment of the Jarva. As a routine procedure for these tunneling operations, horizontal exploration boreholes were drilled in advance of the heading. Probe borings which intersected the first tunnel segment containing bedrock deformation yielded gaseous emissions and groundwater. In addition, the variability of probe hole drilling resistance suggested an atypical condition. During the week of April 17, 1978, the Jarva

intersected the tunnel fault segment which could not be observed until April 25, 1978, subsequent to sufficient advancement of the Jarva.

A fault plane, oriented normal to the intake tunnel bearing and dipping approximately 16 degrees to the southeast, was identified by the site resident geologists and confirmed by the Project Geologist and an internal project consultant. The apparent displacement, with a thrust sense of motion, was estimated to be less than two feet and the throw less than one foot. The fault plane width was estimated between 0.5 and 18 inches, although the latter was presumed more indicative of gently flexed and/or abruptly kinked or otherwise simply fractured rock. A gray-clay gouge of tough leathery consistency containing small angular shale fragments was observed within the fault zone. This descriptive information was communicated to the NRC.

Samples of gouge were collected and X-ray mineralogical identification conducted on the two micron and smaller size fraction. Results demonstrated a mineralogical assemblage typical of Chagrin shale as reported in the PSAR. On the basis of the mineralogical data, proximity and physical resemblance between the intake tunnel fault and onshore deformation, and lack of contradictory evidence, a common origin for deformation exposed in the open-onshore and tunnel excavations was suggested. However, the intake tunnel fault exposure occurs more than 100 feet deeper than the deepest known onshore deformation. For this reason other deformational mechanisms, notably stress relief and tectonics, remained plausible origins.

Advancement of the discharge tunnel heading in a northerly direction from the temporary access shaft began in January 1978 with the Roadheader machine, which was withdrawn in February after sufficient room was provided for assembling the Jarva. The Jarva began excavating in August 1978. In late August a tunnel segment was exposed and observed to have been only mildly deformed by compression. A second

discharge tunnel segment, more deformed than the first, was encountered. The two discharge tunnel segments containing deformation are separated by approximately 200 feet.

The zones of warping with very small displacement and thrust faulting, respectively, identified in the discharge tunnel were mapped and reported to the NRC. The discharge tunnel fault lies on strike projection with the intake tunnel fault, suggesting that they are the same structure. The zone of minor compressional features preceding the main discharge tunnel deformation was presumed to be either en echelon or a splay of the northeasterly striking thrust fault. Concurrent with exposure of the discharge tunnel deformation, a lake bottom survey and shoreline reconnaissance were conducted. Neither revealed evidence of surface faulting.

More investigative work followed, including a series of exploratory borings, onshore and offshore geophysics, conventional and isotopic analysis of groundwater seepage discharged from the fault, and SEM (scanning electron microscope) analysis of fault gouge. Results of these studies demonstrated that the fault plane maintained a low-angle inclination beneath the intake tunnel more than 600 feet to the southeast. It is uncertain if a deep onshore boring, located at the crest of the shoreline bluff and offset 100 feet from the intake tunnel, intersected the fault. This boring was drilled sufficiently deep so that it should have intersected the fault unless the fault plane attitude changed or the fault zone thins and becomes conformable with bedding.

Borings located approximately one mile west of the plant area along the shoreline and on projection with the fault trace at the bedrock surface did not intersect faulting. Neither the onshore nor offshore magnetic surveys revealed evidence of faulting. Saline discharges from the tunnel fault were determined by isotopic analysis to be meteoric but not Lake Erie water. Preliminary SEM analysis of fault zone gouge showed

that new mineral growth bridges had formed across microcracks interpreted to have formed syngenetic with faulting or at least the last fault movement.

A geophysical signature of the fault was provided by compressional wave low-velocity zones. Undeformed bedrock exhibited a relatively high velocity. No low velocity zones were identified in the onshore borings, geophysically logged. It also appeared that a low level of gamma radiation was correlative with fault zone gouge. Longitudinal velocity measurements in the tunnels across the fault indicated that the bedrock was sound in spite of the discontinuity. The velocity values are within the range of those reported in the PSAR for preconstruction site exploration.

Three geologists independently reviewed the tunnel faulting prior to construction of the concrete liner. They determined that the deformation was brittle rather than soft sediment and was not penecontemporaneous with deposition. Other origins, including direct and indirect glacial action and tectonic, were considered.

A very deep onshore boring was drilled slightly east of the discharge tunnel. In situ stress measurements employing the hydrofracture technique were performed within the borehole. Subsequent laboratory testing of core from the boring supplemented the in situ test data. The field and laboratory testing programs were directed by Dr. Jean-Claude Roegiers (Department of Civil Engineering, University of Toronto). Dr. Roegiers also evaluated the in situ stress and laboratory data.

Other aspects of the investigative program included discussions with local resident salt mine engineers, and geologists with knowledge of regional surface and subsurface geology; laboratory determination of gouge physical properties; continuing literature review; and various geological, geophysical and engineering analyses. Very detailed mapping

combined with photographic, video tape and sound track reproduction of the tunnel bedrock deformation serve as permanent documentation.

2.3 GEOLOGIC SETTING

The Perry Nuclear Power Plant site is situated on the northwestern flank of the Appalachian geosyncline in the Central Lowlands Physiographic Province adjacent to Lake Erie. Bedrock directly beneath the site is the Chagrin shale member of the Ohio Shale formation (Upper Devonian). Regionally, these rocks dip gently to the southeast at a gradient of approximately 20 to 40 feet per mile. The Precambrian crystalline basement occurs at a depth slightly greater than 5,000 feet. To the south the Devonian strata are overlain by successively younger Paleozoic sediments <Figure 2D-4>.

Lake Erie, which lies several hundred yards north of the plant area, has a maximum depth of approximately 210 feet and an average depth of 58 feet. The western end of the Lake is extremely shallow and is immediately underlain by resistant carbonate bedrock. From the general vicinity of Sandusky, Ohio, to the east beyond the Pennsylvania boundary, Lake Erie has been eroded into Upper Devonian shales which overlie the relatively more resistant rocks comprising the lake bottom strata of the western portion.

In northeastern Ohio glacial drift and glaciolacustrine sediments overlying bedrock reach a maximum thickness of 250 feet. The site is located on the Lake Plains Section, a physiographic subdivision of the Central Lowlands province formerly submerged during higher Lake Erie levels. Here, bedrock overburden deposits ranging in thickness from 55 to 60 feet consist of dense till and lacustrine sediments, respectively. A steep bluff contiguous to the shoreline exposes 40 to 45 feet of overburden stratigraphy (<Figure 2D-5> for glacial deposits).

Secondary structures demonstrative of bedrock deformation in the site vicinity, as well as throughout northeastern Ohio, are rare. This is attributable to the nearly ubiquitous veneer of glacial deposits obscuring bedrock, the minimal effect of the Alleghenian (Appalachian) Orogeny on Paleozoic strata in this region, and the attenuation of Alleghenian orogenic stresses during their northwestward propagation beyond the Appalachian Structural Front.

Most of the subsurface structural interpretations for these regions are founded on deep well data. It is reported by Stone and Webster, based on personal communication with A. Janssens, formerly employed by the Ohio Geological Survey, that the sedimentary sequence above the Middle Devonian Delaware Formation is affected by folding. Structural contours of the Delaware and Dayton Formations prepared by Stone and Webster show persistent small structures, probably folds, especially in Portage County, Ohio (Reference 1). Structural contour maps of the "Big Lime" top (Delaware) and a definable geophysical base (Packer Shell) approximately 50 feet below the stratigraphic base of the "Big Lime," and an isopachous map of the intervening interval were prepared to determine subsurface structure in Lake, and adjacent counties <Figure 2D-6>, <Figure 2D-7>, and <Figure 2D-8>. "Big Lime" is a shortened drillers' expression for the thick Silurian-Devonian carbonate and evaporate sequence known as "Big Niagaran Lime." The only anomalous structures revealed are located in central Ashtabula County. Apparent thickening of the "Big Lime" in this region, due to faulting or folding, may be attributable to Appalachian orogenic stresses. No shallow deformation in that locale is known.

Salt mining has exposed deformation within the Salina beds. Heimlick describes minor folds, amplitude of six inches, and wave length less than twelve inches, locally overturned, in the production interval of the International Salt Co. mine in Cleveland (Reference 2). Structural contours of the salt production interval for the Morton Salt Division of Morton Norwick mine in the Painesville area reveal northeasterly

trending synclinal troughs interpreted by Jacoby to be salt flowage preceding faulting in response to Appalachian tectonism (Reference 3). However, large scale folding in Lake County of either the salt or overlying shale strata is not present in surface or subsurface exposures, nor interpreted from subsurface geological or geophysical data.

Faulting is nearly as anomalous as fold structures but does affect Paleozoic strata to the south and has been exposed in the International Salt Company mine in Cleveland to the west. More locally, Jacoby reports that a high angle thrust fault intersects the salt production interval of the Morton Salt Division of Morton Norwick mine in Fairport Harbor, approximately eight miles southwest of the Perry site (Reference 3). He does not believe that this fault is pervasive vertically through the Oriskany Sandstone of Middle Devonian age.

Rock cores from salt strata exploratory borings in the Painesville area occasionally intersect displacements within the "Big Lime" of a very minor nature, amounting to a few inches at most, which are completely healed. Donald R. Richner, consulting geologist, has examined these discontinuities, which range from very minor to miniscule, consisting mainly of stylolites and minor slips with traces of slickensides but having observable displacements of two inches at most. He has not seen any evidence that these discontinuities were of a tectonic origin. Those observed above and below the Salina salt beds appear to result from penecontemporaneous deformation (Reference 4).

Geologists are in agreement that the faulting and folding exposed in the International Salt Co. and Morton Salt Division of Morton Norwick mines in Cleveland and Painesville, respectively, are attributable to dissolutioning of the salt during sediment lithification (Reference 2)(Reference 3)(Reference 4). Subsequent failure of the overlying strata resulted in graben structures, slumping and

down-warping dependent upon overlying lithology. Locally, salt flowage into fractures and irregularly shaped cavities is evident.

The only well-documented fault near the site locale is a relatively minor localized overthrust with approximately one foot of displacement in the Bedford shale (Mississippian age), known as the Gabor Fault (Prosser) (Reference 5). The minor thrust fault described by Prosser was observed in the field on the east bank of Bates Creek, also known as Warners Creek. The strike of this fault is northeast. Three faults, not reported in the literature, were found on the west bank of the Paine Creek about one mile north of the Bates (Warners) Creek fault. These faults, two gravity faults, and a small bedding thrust fault, named Hell Hollow 1, 2 and 3, were found to be associated with slumping. These site locale faults are shown on <Figure 2D-9>.

Field investigations and literature studies were completed to determine the characteristics, origin and age of both the Bates (Warners) Creek and Hell Hollow faults. Those faults were determined to be of surficial nature, limited in extent and unrelated to deep-seated faulting. Their origin is concluded to have been glacially induced at Bates Creek and related to bedrock slumping at Hell Hollow.

Geologic mapping, inspection and evaluation of bedrock foundations, including excavation cuts and foundation grade, for the plant area structures were initiated in August 1975. Several localized areas of deformed bedrock were revealed as a consequence of the excavation. The deformation consisted of folds and faults within the Chagrin shale. Vertically, the lower limit of the onshore deformation was established at a horizon defined by the deepest foundation excavations, specifically those for the condensate demineralizer and heater bay buildings. The upper limit of this deformation terminates at the base of a boulder layer, which maintains grade at approximate Elevation 570 feet and is pervasive throughout the plant site. The boulder layer defines the base of structureless lower till. Below the boulder layer and above

competent shale, a six- to eight-foot thick transitory interval was mapped in which the lower till has been incorporated within contorted, blocky, and weathered shale. The relationship of the onshore deformation to tunnel faulting is shown on <Figure 2D-10>.

3.0 METHODS OF INVESTIGATION

The purpose of the studies was four-fold: first, to determine lateral extent of the fault observed in the intake and discharge tunnels at the Perry site; second, to analyze the type and degree of fracturing within and adjacent to the fault; third, to examine in detail the seismicity of the area surrounding the Perry plant; and fourth, to investigate the origin of deformation.

The following techniques were used in determining the extent of the fault on land and on the bottom of Lake Erie:

- Literature review and personal communications with geologists cognizant of area geology (surface and subsurface)
- Exploratory borings
- Shoreline reconnaissance
- A video survey of the bottom of Lake Erie in the vicinity of the updip projection
- Detailed geologic tunnel mapping of deformation
- Microcrack analyses of fault zone samples
- Analysis of water from the fault and from Lake Erie
- Evaluation of published and unpublished geophysical data

- Magnetic (total field) profiling (both onshore and offshore)
- Borehole (in hole) logging of (compressional) wave velocity
- In situ seismic velocity measurements
- An evaluation of the seismicity in the area surrounding the Perry plant was made on a very detailed search on period newspapers and other document
- In situ borehole stress measurements to determine stress field orientation, magnitude and gradient (vertical)

The detailed mapping, lake bottom survey and geophysical and seismological studies were performed by the Weston Geophysical Corporation.

3.1 GEOLOGIC

3.1.1 LITERATURE REVIEW AND PERSONAL COMMUNICATIONS

Published and unpublished sources were reviewed in order to learn more about the surface and subsurface bedrock structure in northeastern Ohio. These activities were supplemented by personal communications with resident engineers at two salt mines (Mr. Jaroslav Vaveeka, Cleveland mine, International Salt Company and Mr. B. C. Cummings, Painesville mine, Morton Salt Division of Morton Norwick) and Mr. Robert G. Van Horn, Head Regional Geology Section, Division of Geological Survey, Ohio Department of Natural Resources. Two consultant geologists, Mr. Donald R. Richner and Mr. Charles R. Jacoby, with considerable experience of subsurface geology from exploratory drilling and mining operations in northeastern Ohio, were also contacted.

Finally, three independent reviews of the cooling water tunnel faulting were performed by the following recognized for their respective specializations:

Dr. Robert LaFleur
Pleistocene Geology and Sedimentology
Rensselaer Polytechnic Institute

Mr. James Murphy
Areal Geology and Stratigraphy of Northeastern Ohio
Ohio Historical Society

Dr. Barry Voight
Structural Geology
Pennsylvania State University

Mr. Murphy had been contacted previously to provide independent opinions during Applicant evaluations of bedrock faulting in the site locale and onshore plant area bedrock deformation exposed by excavation. He had also arranged for radiocarbon dating of comminuted plant material obtained from the site lacustrine deposits. Results of this dating (14,480 310 B.P.) established an age somewhat older than previously assumed for the retreat of Hiram ice and a minimum age for the onshore plant excavation deformation.

Data and evaluations of an offshore shoreline parallel survey, especially in the vicinity of the site, conducted by the Coastal Engineering Research Center, were forwarded by Mr. S. Jeffress Williams, marine geologist, Geotechnical Engineering Branch. The survey consisted of high resolution seismic reflection profiling suitable for evaluating abrupt elevation changes in the lake floor or acoustic contrasts of sediments, both potential indicators of faulting (Reference 6).

3.1.2 EXPLORATORY BORINGS

The TX-test boring series was conceived for the purpose of tracing the downdip extent of faulting intersecting the cooling water tunnels at the site <Figure 2D-11>. Drilling operations occurred within the intake tunnel excavation, on the shoreline bluff and along the beach west of the site. TX-1 through 6 were in-tunnel, the first test holes of the series. Limiting conditions dictated the use of a powered drill, mounted on a steel "A" frame, stabilized by two expanding rods braced against the tunnel crown. This system implemented an NX-size, diamond bit, single-tube core barrel. Both air and water were supplied by existing utility lines used in tunnel construction. An additional air line was used to dissipate natural gas inflows encountered in drilling. Drilling operations on the shoreline bluff (TX-7, 11 and 12) were conducted from truck mounted drill rigs. TX-8, 9 and 10 were drilled on the beach from an ATV (all terrain vehicle) mounted rig.

In-tunnel borings were laid out at progressively greater distances south of where the fault plane intersects the intake tunnel invert. TX-1 was located five feet south of the fault-invert contact, assuring advance through the fault plane would occur at a very shallow depth. In order to establish characteristic indicators of test hole advance through faulted rock, close attention was paid to all aspects of sampling in the initial hole. After each core run a gas detection meter was used to measure concentrations of methane emitted from the drill water. This device was also used for safety purposes. Cognizance of indicators from TX-1's advance aided in interpreting intervals in subsequent holes where faulted rock was projected to greater depths.

Test borings drilled from the shoreline bluff sought to encounter the fault at greater depths than those of the in-tunnel boring group (several hundred feet rather than 2 to 90 feet below tunnel invert elevation).

The group of test borings located on the beach was designed to encounter a shallow southwesterly projection of the fault based on limited strike measurements attained from exposures in both tunnels and previous TX-series borings.

Several types of in-hole testing were performed in TX-series holes. Weston Geophysical Corporation conducted gamma and sonic velocity logging to confirm fault zone identification. In addition to this, a long steel “feeler” probe (length, 10 feet) was implemented in shallow holes TX-1, 2 and 3. A hydrofracture in situ stress measurement study was performed in the deepest boring of the TX series (730 feet). This effort was planned and directed by Dr. Jean-Claude Roegiers (Project Consultant). Instrumentation was supplied by Serv-Kor, Inc. and pressurized fluid capability by Halliburton Services.

All rock core samples of the TX-series were logged in detail and photographed. All pertinent and representative core was wrapped in clear plastic.

3.1.3 SHORELINE RECONNAISSANCE

Continuous shoreline reconnaissance southwest and northeast of the site was performed with the objective of identifying evidence of offset or structural disturbance in the lacustrine and till deposits exposed by the shoreline parallel bluff contiguous to Lake Erie. Reconnaissance was conducted a considerable distance beyond the land surface projection of the intake and discharge tunnel faulting <Figure 2D-12>.

3.1.4 VIDEO EXAMINATION OF LAKE BOTTOM FEATURES

An underwater camera survey of the lake floor was conducted to permit close examination of the lake bottom by a diver, and provide visual aid and documentation for other technical personnel. The intent was to examine the bedrock surface for the presence of structural features.

The floor of Lake Erie, offshore of the Perry Nuclear Power Plant, essentially consists of a bedrock surface with a very thin covering of silt. Locally, the bedrock surface is covered by concentrations of boulders and cobbles.

The video survey consisted of two parallel east-west traverse lines, labeled Lines A and B, approximately 800 feet in length and 200 feet apart, previously located and horizontally surveyed offshore of the Perry Nuclear Power Plant. The lines were selected to cover the vicinity of the updip projection of the fault noted in the intake tunnel, and to cross the projected continuation of the fault to the east.

Each traverse line consisted of five relatively evenly-spaced stations. The video coverage was circular in fashion around each station to a maximum radius of approximately 75 feet. <Figure 2D-13> shows the location of the traverse lines and stations, as well as the area of coverage around each station.

The diver, equipped with an underwater compass, described and noted the orientation of bottom features as he moved relative to the lake floor. A two-way communication system with surface monitor permitted the surface operator and other technical personnel to discuss the bottom conditions with the diver at the time of the survey, and to request detailed examination of specific features of interest. In all instances, the original videotapes have been retained in their entirety.

3.1.5 DETAILED GEOLOGIC MAPPING IN THE INTAKE AND DISCHARGE TUNNELS

Four hundred lineal feet of tunnel wall rock exposure were mapped to study and document the nature of bedrock deformation encountered in the intake and discharge tunnels at the Perry Nuclear Power Plant. The field mapping was carried out in the period from February 15 through 27, 1979. One structure was mapped in the intake tunnel at Stations 10+25

to 10+95. Two bedrock structures were mapped in the discharge tunnel at Stations 11+40 to 12+00 and 13+00 to 13+70. Both walls were mapped in each area. Rock bolts, straps, and wire mesh on the crown, and muck and rails on the invert prevented mapping of these surfaces. Approximately 7 vertical feet of wall were mapped on each tunnel wall. <Figure 2D-14> and <Figure 2D-15> show the location of intervals mapped in the intake and discharge tunnels, respectively.

Mapping was carried out subsequent to placement of stations every 5 feet, as well as three constant elevation lines at 2-foot intervals, along the entire mapped tunnel wall area. Survey control for the stations and elevations lines allowed all mappable features to be located by a standard 6-foot rule and transferred to cross section paper at a scale of 1 foot to 1 inch. The minimum resolution of the beds mapped was 0.5 inches or approximately 1.0 centimeter.

Photomosaics of the entire mapped areas were composed from professionally taken photographs. Closeup photomosaics of the fault zones in both tunnels provide detailed documentation of these structures. The mapped areas of both tunnels were videotaped; approximately 3-1/2 hours of videotape were acquired. In all instances, the original videotapes have been retained in their entirety.

3.1.6 MICROCRACK ANALYSIS

A microcrack analysis was performed on samples of gouge obtained from the faults in the intake and discharge tunnels at the Perry site. These investigations were performed by Dr. Gene Simmons whose complete report is included as <Appendix 2D A> to this report. The following is a summary of the methods of investigation employed by Dr. Simmons.

Microcrack samples were acquired by Dr. Simmons and Weston personnel from the fault zone in both the intake and discharge tunnels.

The samples were acquired in such a way as to minimize production of microcracks during sampling. Upon acquisition, the samples were carefully packed and transported to Dr. Simmons' laboratory for analysis.

Laboratory analysis of the samples involved examination of individual microcracks with a scanning electron microscope (SEM) to determine crack length and extent of filling. An electron dispersive X-ray system (EDX) was used to determine the elemental composition of the material filling the observed cracks.

The details of the sampling procedure and laboratory analysis for the microcrack studies are discussed by Dr. Simmons in his report, <Appendix 2D A> to this study.

3.1.7 WATER ANALYSIS

Chemical analyses of intake and discharge tunnel faulting seepage samples were performed. Ionic concentrations were obtained for chloride, sulfate and sodium. In addition, salinity and pH measurements were conducted on each sample. Comparative evaluation of data provided information on trends.

The isotopic ratios of D/H and $^{18}O/^{16}O$ were measured with a mass spectrograph for three water samples from the fault in the intake tunnel, one sample from the fault in the discharge tunnel, and two samples from Lake Erie. A sulfur isotope analysis was attempted on samples of water from the intake and discharge tunnels and from Lake Erie. The sulfur analysis did not succeed because of the lack of sufficient sulfur for analysis in any of the tunnel samples.

<Appendix 2D B> to this report prepared by Dr. Gene Simmons presents the basis of the technique for the hydrogen and oxygen isotype analysis.

3.2 GEOPHYSICAL STUDIES

3.2.1 EVALUATION OF PUBLISHED AND UNPUBLISHED DATA

Published and unpublished geophysical data for the immediate vicinity of the Perry nuclear site were examined for any anomalies which could be related to the fault noted in the intake and discharge tunnels. The examination consisted of a review of published and unpublished geological and geophysical data, as well as federal and state government reports and data files.

3.2.2 MAGNETIC SURVEYS

3.2.2.1 Offshore

Total field magnetometer data were obtained over the projected strike of the fault to determine whether or not an associated magnetic signature was present. A shipborne magnetic survey of Lake Erie consisted of 17 lines, perpendicular to the projected strike, at 200-foot intervals <Figure 2D-16>. Coverage was essentially continuous along each profile, and the data were displayed by means of a strip charge recorder at a vertical scale of 200 gammas/inch.

3.2.2.2 Onshore

For onshore coverage, four separate lines were traversed with readings taken every 25 feet <Figure 2D-17>. Lines were operated along existing roads, which resulted in profiles oriented at 45° to the projected strike.

All data were obtained with a proton-precession magnetometer. For a further discussion of the magnetic survey method refer to <Appendix 2D C>, Section 2.0.

3.2.3 BOREHOLE LOGS

Gamma radiation and velocity logs were obtained in drill holes located in the intake tunnel and on the shore. <Figure 2D-11> is a borehole location map. The objective of these measurements was to locate geologic units to be used as markers in determining the offset of the fault and/or to provide means of locating the fault itself.

The velocity logger measures the difference in the travel time for seismic energy, moving up a drill hole from a common source to reach two geophones separated by a known distance. It provides a rapid, accurate measure of the in situ seismic velocities ("P" and "S" wave values) in the material between the two geophones. For a further discussion of seismic velocity logging refer to <Appendix 2D C>, Section 4.0.

Measurements were made at 1/2-foot intervals adjacent to the projection of the fault and at 1-foot intervals for a distance of 10 to 20 feet away from the projection. Selected boreholes (TX-6, TX-4 and TX-7) were logged at a 1-foot interval for their entire length.

The gamma logging was accomplished with a probe which measures the gamma radiation incident on an enclosed scintillation sensor as it moves up the hole. In sedimentary rock sequences, the instrument responds primarily to shale content, because radioactive elements tend to concentrate in shales and clays. At the site, the logs were obtained using two rates of ascent up the hole (20 ft/min and 3 ft/min). The slower rate provides a smaller sampling interval and, thus, greater resolution. For further discussion of gamma radiation logging refer to <Appendix 2D C>, Section 3.0.

3.2.4 IN SITU VELOCITY MEASUREMENTS

A seismic in situ velocity survey was conducted to examine the condition of the tunnel wall in both the intake and discharge tunnels in the vicinity of the fault.

Seismic velocity values are diagnostic of rock conditions in tunnels and provide a comparison between rock in and adjacent to the fault and rock located some distance from the fault. For further discussion of in situ velocity measurements refer to <Appendix 2D C>, Section 4.0.

In the intake tunnel, a 6-geophone spread (each geophone has 3 components) and a 12-geophone spread (each geophone has one horizontal and one vertical component) were used. Geophones were separated by 10-foot intervals, and each spread was centered on the observed fault <Figure 2D-18>. In the discharge tunnel, data were obtained across the fault and across a fracture zone located 100 feet south of the fault <Figure 2D-19>. Two spreads were used across the fault, both with 12 (two-component) geophones. The first had 10-foot spacings with the fault located 10 feet south of the center of the spread; the second had 5-foot spacings for higher resolution and was centered on the fault. The velocity measurements across the fracture zone were obtained with a 12-geophone spread with 5-foot spacings centered on the fracture zone.

Three-component geophones, which detect vibration energy along vertical, radial and transverse alignments, were placed on pedestals drilled into both the intake and discharge tunnel walls. Seismic energy was generated by a hammer blow against the tunnel wall adjacent to a geophone.

3.3 EVALUATION OF LOCAL SEISMICITY AROUND THE PERRY NUCLEAR POWER PLANT SITE

A detailed examination of the local seismicity around the Perry site was performed with the purpose of evaluating the validity of each epicentral location and intensity for all reported events.

A parallel compilation of all cataloged entries was made, and subsequently a local newspaper search was initiated to collect additional supporting evidence for each event. The details on the

sources of the data base and the texts of all new material acquired are presented in <Appendix 2D D>. A separate summary evaluation was then prepared for each historical event within the 50-mile radius of the site, taking into account cataloged entries as well as the entire file of supporting evidence.

3.4 IN SITU STRESS MEASUREMENTS

Hydraulic fracturing was performed in test boring TX-11 in order to determine the magnitude and orientation of the in situ principal stresses. Eight intervals were fractured between a depth of 394 and 718 feet. TX-11 boring rock cores were subsequently tested in the laboratory in order to provide confirmatory tensile stress data of the field data. The in situ borehole stress program was planned and directed by Dr. J. C. Roegiers, Department of Civil Engineering, University of Toronto. The in situ stress program methods results and conclusions are appended to this report <Appendix 2D E>.

4.0 RESULTS

4.1 GEOLOGIC

4.1.1 LITERATURE REVIEW AND PERSONAL COMMUNICATIONS

As reviewed in <Section 2.3>, Geologic Setting, bedrock throughout northeastern Ohio is not known to have been significantly affected by late Paleozoic orogenic stresses or any other tectonic disturbance. Faulting in the sequence of evaporite and carbonate rocks comprising the Salina Group has been exposed in salt mines within the region. These faults are attributed to dissolution of salt beds followed by failure of the overlying carbonate beds. Structures of this type are generally believed to have been developed shortly after sediment lithification. Alternatively, late Paleozoic orogenic stresses may have been

sufficiently high to have caused salt flowage which induced brittle deformation of the interbedded, more competent carbonate beds.

Salina Group strata begin at a depth of approximately 1,750 feet beneath the site. Correlations between site borings and regional exploratory drill holes do not suggest the existence of any pervasive fault or fault system. Neither top and bottom structure contour nor isopachous maps of the "Big Lime" support the concept of a regional fault or fault system <Figure 2D-6>, <Figure 2D-7>, and <Figure 2D-8>. In the context of regional geology there is no basis for lateral extrapolation or deepening of the tunnel faulting. Shallow bedrock deformation is exposed in outcrop seven to eight miles south of the site and had been exposed in plant area excavations. However, these structures terminate with depth on undeformed strata. The outcrop exposure deformation was the result of glacial shove and loading (Bates Creek) and slump (Hell Hollow). Plant area bedrock deformation was caused by late Wisconsinan glacial shove and loading. A minimum age of 14,480,310 B.P. (Hiram ice) for the plant area deformation is inferred from a radiocarbon date of the organic debris interbedded within lacustrine sediments.

Independent opinions provided by the three reviewing geologists are in agreement that the tunnel faulting is not penecontemporaneous but is most likely caused by localized stresses created during Pleistocene time by either the advance of the ice sheet(s) and concomitant depression of the crust, or in reaction to removal of weight of the overlying ice (glacial rebound). In addition, Dr. Robert LaFleur was requested to review the data, interpretations and conclusions of earlier investigations regarding the stated origin of the Bates Creek, Hell Hollow and plant area deformation. He concurs that the Bates Creek and plant area deformation are the result of glacial shove and loading (active glaciotectonics) and the Hell Hollow vertical faults were the result of post glacial slumping. These opinions had been stated in the earlier investigations by Mr. James Murphy. Dr. LaFleur does not believe the tunnel faulting is demonstrative of either active or passive

glaciotectonics. In his opinion the deeper tunnel faulting is a response to the state of stress imposed by glaciation during advance or subsequent to recession (glacial rebound). Dr. Barry Voight considered other modes of Paleozoic deformation in addition to late Paleozoic tectonism including Mesozoic-Tertiary tectonics and miscellaneous Pleistocene - Recent faulting mechanisms. Opinions of the three reviewers are attached to this report in <Appendix 2D F>.

4.1.2 EXPLORATORY BORINGS

Fault zone indicators, revealed in the advance of TX-1, 2 and 3, were as follows: (1) increased vibration in drill rods; (2) a creamy grey influx to a normally light grey drill wash; (3) platy clay particles in drill wash; (4) a release of gas when the core barrel was pulled after the run; (5) a 0 to 80 percent recovery in the cored fault zone (recovery in undisturbed rock was consistently very high); (6) highly broken, rotated rock frags speckled with remnant grey clay for those portions of the fault zone that were recovered; and (7) a change in the dip to normally flat lying laminae, above, and below the fault zone.

All indicators did not occur in each boring where a fault zone was suggested. In fact, only the loss of recovery and the character of rock that was recovered from suspect fault zones remained consistent throughout those borings. Using these indicators, a fault zone was detected in all of the in-tunnel borings, TX-1 through 6. The boring locations and depth where faulted rock was identified revealed a constant fault plane dip of 17 degrees SE. Low gamma radiation levels and low P-wave (compressional) velocity values coincided with zones of disturbed rock at elevations where a fault zone was logged from drilling program indicators in TX-2, 3, 4, and 6. TX-1 was too shallow to log geophysically and TX-5 caved at the fault preventing geophysical logging of the suspect zone.

The constant 17 degree fault plane dip derived from TX-1 through 6 aided in the location of TX-7 through 12. TX-7 was initially advanced to a depth of 395 feet from the shoreline bluff. Increased rod vibration, loss of core recovery, remnant clay on broken, rotated shale fragments, and a stuck core barrel (eventually retrieved and coated on the bottom three feet with a thin grey clay) indicated a disturbed zone from 371.3 to 372.4 in TX-7. Geophysical logging, however, did not confirm this zone. It is suspected that a lack of proper drill water circulation may have caused increased friction at the core barrel, falsely suggesting a zone of disturbance.

TX-8, 9 and 10 were drilled along the beach west of the site. Both TX-8 and 10 encountered zones of broken rock with what appeared to be minimal clay remnants from depths of 65.85 to 66.7 feet and 63.5 to 64.9 feet, respectively. The core characteristics were not interpreted by either the geologist who logged the core or other geologists who subsequently reviewed the core as evidence of faulting. The absence of faulting in these borings, as interpreted on the basis of direct geologic evidence, was confirmed by geophysical logging which did not reveal faulted strata.

TX-11 was drilled approximately 1,060 feet southeast along dip direction of the intake tunnel fault exposure. This boring was the deepest of the TX series, drilled to a depth of 730 feet down from the shoreline bluff. No naturally disturbed rock was encountered in the entire borehole length. Three runs of core were disturbed by uncontrollable core barrel handling because of gas inflows. Hydrofract stress measurements were performed in this hole in test intervals between 394 and 718 feet.

Angle hole TX-12 was drilled from approximately the same location as TX-7. The drill rig employed a wire-line, double barrel system. The double barrel was actually able to core the fault zone materials with very little loss in recovery from 376.4 to 380.0 feet. This boring confirmed the continuation of a 17 degree SE fault plane dip,

approximately 230 feet horizontally southeast of the last confirmed fault zone occurrence in tunnel-boring TX-4. Cored fault zone materials included angular shale fragments within several grey, clayey, gouge seams, broken fractured rock, and rock laminae with multiple dips. TX-12 was completed at an angle depth of 480.0 feet.

After the completion of TX-12, TX-7 was reamed and extended 100 feet using the double barrel, wire-line system. A disturbed zone was encountered from 412.8 to 413.9 feet, vertical depth. Unlike TX-12 a gouge zone was not recovered. Increased drill rod vibration, a 100 psi increase in drill water pressure, 50 percent loss in recovery, and broken rotated rock, speckled with grey clay remnants suggested a zone of disturbance. If this zone represents the fault, its location marks an increase in fault plane dip between TX-12 and the extended TX-7.

Geologic logs of TX-series borings are attached as <Appendix 2D G>.

4.1.3 SHORELINE RECONNAISSANCE

Traverses northeast and southwest of the plant area along the shoreline and headward in stream cuts emerging at the beach revealed no offsets or structural disturbance of the exposed lacustrine and till deposits. A boulder layer which occurs at the base of structureless lower till is not offset and maintains a constant elevation within the lake facing bluff. An absence of bedrock outcrops and maintenance of boulder layer elevation are demonstrative of the lack of surface faulting.

4.1.4 VIDEO EXAMINATION OF LAKE BOTTOM FEATURES

The video survey of the Lake Erie bottom in the vicinity of the updip projection of the fault did not indicate the presence of any long continuous fractures parallel to the projected fault trace. Those fractures which are noted show no evidence of lateral or vertical offset and seem to close with depth. <Figure 2D-20> shows a schematic diagram of the fracturing on the Lake Erie bottom.

4.1.5 DETAILED GEOLOGIC MAPPING IN THE INTAKE AND DISCHARGE TUNNELS

4.1.5.1 Stratigraphy

Chagrin shale at Perry, is on the order of 800 feet thick (Reference 7) based on reported thicknesses of 500 feet at Cleveland and 1,200 feet at the Ohio-Pennsylvania border <Figure 2D-21>. Accordingly, the sequence of strata exposed in the tunnels is assigned here to the stratigraphic center of the Chagrin and is considered representative of the unit. This placement is consistent with the absence, within the tunnels, of marginal lithologic sequences and fossiliferous strata.

In both tunnels, the strata dip westward to northwestward about 2 degrees (for the detailed mapping sections see <Figure 2D-22> and <Figure 2D-23>. Most of the units are quite persistent in down-tunnel directions, and because the tunnels are random exposures of the internal geometry of the Chagrin, there is reason to assume that the observed units and sequences are equally persistent from east to west, and that a part of the mapped sequence should appear in both tunnels. Inasmuch as attempts to establish a correlation between tunnels were unsuccessful, it is concluded that the strata exposed in the intake tunnel pass below the discharge tunnel, and that the described sections are separated by a very short interval of unexplored strata. These relationships and detailed descriptions of the mapped intervals are presented on <Figure 2D-24>, <Figure 2D-25>, and <Figure 2D-26>.

The Chagrin strata exposed in the tunnels were subdivided to provide a framework within which folding and faulting in the tunnels could be described and interpreted. Unit boundaries were selected according to their mapability across tunnel wall exposures smeared during excavation and subsequently stained and otherwise obscured by minor surficial weathering. There is no genetic significance implied in their selection.

Bedding characteristics and stratigraphic relationships were examined to determine depositional modes and the role of penecontemporaneous deformation in the genesis of the folds and faults. The characteristics considered most significant in their regard are: (1) the attitude of the strata; (2) their thickness; (3) their composition and texture; and (4) the detailed nature of their boundaries.

The near-horizontal attitude of the strata and their marked planarity indicate clearly that the immediate substrate during deposition was similarly flat and featureless, a relatively stable distal shelf environment considerably removed from a postulated northerly source of clastic detritus. Minimal sand-size material reached this part of the shelf, and sedimentary structures and bedforms related to sand deposition are nowhere apparent. There is scant evidence, for example, of bedload transport of detritus, and none whatsoever of either outbuilding or proximal deposition from density currents, any of which would have produced a geometry significantly different from the planar parallel configuration of the tunnel sequence. Virtually all sediment exposed in the tunnel reaching the site area must have been deposited from periodic suspension clouds by processes of vertical accretion.

Bedforms and stratigraphic patterns indicate that sedimentary cycles begin at the sharply defined upper boundaries of prominent siltstones or siltstone-shale bedsets. These commonly exhibit asymmetrical ripple marks and, very locally, are truncated to a limited extent; overall, they suggest modification by bottom currents of low velocity and constant direction. These apparently were effective in distributing the limited amounts of available silt over fairly wide areas, probably through ripple migration; but, for the most part, were not competent to substantially modify the deposits or entrain the silt once deposited. The presence of thin shale laminae within many siltstone beds suggests that even winnowing was at times an ineffective process. During such periods of maximum current intensity, suspended detrital clay and

buoyant organic debris must have been carried farther basinward and incorporated in the more distal black shale equivalents of the Chagrin.

Although the siltstones lend themselves readily to megascopic and microscopic analyses and are revealing of process-related structures, shale is everywhere the dominant lithologic-type comprising the lower, thicker part of each cycle. These are mainly dark-gray, clay shales with planar to broadly wavy, very sharply defined laminae, 1 mm to 2 cm thick, of purplish to brownish, clay shale. The laminae, reportedly sideritic in composition, impart a "banded" aspect to the beds; there is no discernible disparity in texture between the shale types to indicate fluctuations in depositional processes. Instead, the "banding" likely reflects oscillations in geochemical parameters and possibly detrital clay mineral composition. The shales, therefore, are considered simple beds deposited under uniform sedimentological conditions, and rapid, spasmodic, or uneven deposition of mud are essentially ruled out by their internal structure. Additionally, the general absence of load structures at shale-siltstone boundaries suggests that the mud substrate was quite viscous at times of silt deposition and also that the basin was seismically inactive.

Thickness variations in these strata are restricted to the attenuation and pinch-out of some of the more prominent siltstone beds. These are sedimentary in origin, locally modified by compaction of the section. Their effects on the thickness of the mapping units is negligible.

The indicated depositional setting, dominated by the process of slow vertical accretion, winnowing, sub-elevation, and bypassing, virtually precludes the possibility of rapid sedimentation at or near the site during Chagrin sediment deposition. Localized buildups of clastic sediment and primary slopes steep enough to generate adjustments by slumping are clearly inconsistent with the conditions postulated. Moreover, had faulting occurred prior to total consolidation, the adjacent strata, given their clayey composition, would certainly have

been thrown into a series of folds and pull-apart structures, lithologic boundaries would have been grooved and polished, and shale thicknesses would have been considerably affected. In particular, those strata between the main fault and the main splay (intake tunnel, Station 10+50 to Station 10+80) would certainly have been markedly distorted. None of these criteria for penecontemporaneous faulting are met in this instance. Instead, the strata are little affected to within very short distances of the fault itself where the bedforms exhibit brittle deformation as subsequently discussed.

4.1.5.2 Tunnel Structural Geology

Tunnel excavation for the intake and discharge tunnel structures exposed three limited zones of bedrock deformation in the Chagrin shale <Figure 2D-14>, <Figure 2D-15>, and <Figure 2D-27>. This deformation is characterized by low-angle thrusting, fracturing and small-scale folding. Deformation in the intake tunnel extends from Station 10+85 to Station 10+55 <Figure 2D-28>. Similar deformation occurs in the discharge tunnel from Station 13+65 to Station 13+25 <Figure 2D-29>. In the discharge tunnel from Station 11+50 to Station 11+80 <Figure 2D-30>, an interval of disturbed rock is recognized. <Figure 2D-31> contains geologic maps of the intake and discharge tunnel deformation.

4.1.5.2.1 Intake Tunnel Structure

Bedrock deformation exposed in the intake tunnel extends from Station 10+85 to Station 10+55 <Figure 2D-22>. Deformation consists of a low-angle thrust fault which strikes and dips approximately N51E, 18S <Figure 2D-32>. Stratigraphic offset is 1.4 feet with the strata to the southeast, upthrown. The throw becomes slightly less (i.e., 0.8 feet) towards the crown of the tunnel.

The brittle nature of this deformation is exemplified by the development of fractured and broken drag folds, kinks, and angular/flaggy fragments of siltstone and shale adjacent to and in the prominent gouge zone and dip-slip striations <Figure 2D-22> and <Figure 2D-32>.

The gouge is light gray, plastic clay with angular fragments of siltstone and shale derived from the adjacent strata. (<Appendix 2D H> for laboratory testing of gouge samples.) Gouge development is greatest where the main fault component is inclined and thinnest where the fault is bedding parallel. Associated with thrusting are numerous thin (0.1 feet) splays of gouge along which the strata have been offset. Offsets are somewhat variable but are on the order of 0.1 feet to 0.3 feet. In all instances, these stringers/splays are initiated at the main fault zone and die into bedding planes away from the deformation.

Drag folding is both well developed and quite pronounced. Locally, a faint axial plane cleavage is developed at the fold hinges. Drag folds are asymmetric, northwest verging and exhibit a distinct bedding plane parting facility. Thin seams of gouge occur in the hinge area and parallel to this facility. Orientations of drag fold axes are parallel to the strike of faulting.

Numerous striations are recognized on both the hanging wall and foot wall <Figure 2D-32>. Striations indicate the fault movement is dip slip and does not exhibit any strike-slip component. Striations are primarily developed along the bedding parallel sections of the fault but are also recognized in the inclined sections.

To the immediate south of the intake tunnel thrust, an asymmetric syncline is exposed <Figure 2D-28> and <Figure 2D-32>. Based on limited exposure, deformation associated with folding dies out up section and increases down section. The east wall of the intake tunnel exhibits a greater degree of fold deformation than the west wall. This fold is characterized by bedding parallel flexural slip and minor

northwest-dipping thrusting on the northwest limb of the fold <Figure 2D-28> and <Figure 2D-32>. Offset is minimal (0.1 feet to 0.2 feet), with thrusts merging with bedding planes.

Detailed examination of the intake tunnel fault <Figure 2D-28> indicates that the hanging wall is apparently more deformed than the footwall; deformation is brittle in nature and appears to diminish up section.

4.1.5.2.2 Discharge Tunnel Structure

Two zones of bedrock deformation are exposed in the discharge tunnel <Figure 2D-29> and <Figure 2D-30>. Both structures are the result of compression. The structure closest to the shoreline is very minor and essentially a kink fold with very minor displacement along the hinge line. The second and farthest offshore structure is similar to the intake tunnel fault.

The nearshore structure is located approximately at Station 11+70 <Figure 2D-30>. Most of the deformation was accommodated by abrupt monoclinal strata bending. The hinge line (plane of deformation) has a strike and dip of N16E, 35SE <Figure 2D-27>. Stratigraphic offset dies out below the tunnel crown into a fractured/flexed zone immediately overlain by flat-lying strata. At the invert, the stratigraphic offset (mostly attributable to monoclinal flexure) is approximately 0.4 feet with the southeastern strata upthrown. Distinctly zigzag in character, the structure exhibits gouge, localized fracturing, and flexuring of adjacent strata <Figure 2D-30>.

The gouge is similar to that developed elsewhere in the tunnels but quite thin (0.1 feet). Apart from the variation in strike and displacement magnitude <Figure 2D-27>, the style and the sense of offset are similar to other zones of deformation exposed in the tunnels.

The main zone of deformation in the discharge tunnel extends from Station 13+25 to Station 13+60 <Figure 2D-29>. Deformation is remarkably similar in style and nature to the intake exposure. The discharge thrust strikes and dips N61E, 13SE with the strata to the southeast upthrown approximately 0.8 feet <Figure 2D-31>. Associated with faulting are drag folds, fracturing and well developed gouge <Figure 2D-23>. The gouge is light gray, plastic and contains angular, randomly oriented fragments of siltstone and shale derived from the adjacent strata. Gouge development, as in the intake tunnel, is a function of the geometry of the fault plane. The thinnest gouge zones occur where the fault is bedding parallel while the thickest zones occur where the fault plane steepens.

Drag folds are quite prominent, with a northwest-verging sense and fold axes parallel to the strike of the fault. Hinge areas of the drag folds show a slight axial plane cleavage and the development of bedding parallel flexural-slip gouge.

Fracturing is intense in the vicinity of Station 13+40 where the fault plane is essentially bedding parallel. Associated with this fracturing are numerous small gouge-filled offsets. Stratigraphic analysis indicates that the strata here have been overthickened slightly due to thrusting.

Numerous splays/stringers of gouge trend out from the fault zone and exhibit minor offsets (0.1 feet to 0.4 feet). These splays/stringers, which die into bedding, become more frequent toward the crown of the tunnel and account for the diminished offset along the fault plane.

Striations are recognized on both the hanging and footwalls. Striation orientations indicate a dip-slip motion with no evidence of a strike-slip component <Figure 2D-33>.

Based on structural style, orientation and sense of offset, the two main thrusts exposed in the tunnels are apparently the same structure. Faulting is distinctly brittle with deformation confined to the immediate vicinity of the faulting <Figure 2D-33>. The small-scale thrust at Station 11+70 in the discharge tunnel may be an en echelon structure or a splay off the main fault. However, based on limited structural data, the latter is favored.

4.1.6 MICROCRACK ANALYSIS

Dr. Gene Simmons performed an analysis of microcracks observed within gouge obtained from the fault zone in the intake and discharge tunnels at the site. Dr. Simmons' complete report is included as <Appendix 2D A> to this report. The following is a summary of the results of the Simmons' investigations.

Specimens of the gouge and the adjacent country rock were prepared in a form suitable for the examination of microcracks and elemental compositions of individual minerals by the SEM. Two types of cracks were observed. The first type is caused by unavoidable desiccation of the sample. Desiccation cracks occur subsequent to sampling and are unrelated to tunnel deformation and are recognized as such on the basis of criteria developed previous to the present studies. The second type of crack appears to be related to the last movement on the fault and always contains new mineral growths that extend completely across the crack.

Approximately 350 cracks of the type produced by faulting were examined in six samples. Every crack examined contained approximately one percent new mineral growth.

On the basis of previous observations of several thousand microcracks in a wide variety of rock types, healed microcracks appear to be ubiquitous in rocks. Evidently, the microcracks begin to heal immediately on

forming. The degree of healing can be a measure of the amount of time that has been available for the microcrack to heal. The exact mathematical description of the function that relates degree of filling to elapsed time since the crack was formed is unknown, but is likely S-shaped and asymptotic to the zero and 100 percent values. Two data points have been obtained - one point at one million years (possibly two to five million years) from sandstone at the Satsop site (Reference 8), the other at 18.5 million years from shocked rock at Ries Crater, Germany (Reference 9).

The rate of healing of microcracks is very likely a function of temperature, pressure, mineralogy, and the composition and flow rate of pore fluids. Fortunately, the conditions at the Perry site and at the Satsop site are quite similar, and the degree of filling of the cracks at each site are comparable. Therefore, the data obtained previously for the Satsop site form a suitable basis on which to estimate the age of the microfractures in the gouge zone at Perry.

On the basis of a thorough examination of the microcracks in six representative samples of the gouge and country rock from the fault, or faults, in the intake tunnel and the discharge tunnel and from the fracture zone in the discharge tunnel, it is concluded that the time of last movement of each of these faults is approximately one million years and may be as old as two to five million years.

4.1.7 WATER ANALYSIS

Chemical analyses of tunnel faulting seepages indicate a salinity concentration ranging from 14.4 to 8.4 percent during the period of April 17, 1978 to March 6, 1979. Both the intake and discharge tunnel seepages indicated decreases in salinity, chloride and sodium concentrations with time. No apparent trend for relatively low sulfate concentrations was established. Measurements of pH were uniform ranging between 7.2 and 8.0. Table 1 contains the results of these analyses.

Salts within Chagrin shale groundwater are not uncommon for northeastern Ohio. Compositionally, no salts are known within the Chagrin shale member of Ohio Shale formation. Salt bearing strata of the Salina Group occur more than 1,650 feet below the tunnel. Even though tunnel faulting is not presumed to extend into the Salina salt beds, the impervious character of the Chagrin shale including the tunnel fault zones would tend to confine the upward flow of salt-saturated groundwater from a great depth. It is more probable that sediment pore water residuum has been diluted by meteoric recharge water in a manner originally suggested by L. U. DeSitter in 1947 (Reference 10). This contention is supported by the isotopic ratio results subsequently discussed.

The isotopic ratios of D/H and $^{18}O/^{16}O$ were measured with a mass spectograph for three samples of water from the fault in the intake tunnel, one sample from the fault in the discharge tunnel, and two samples from Lake Erie. The three samples from the intake tunnel differ insignificantly from each other and from the sample from the discharge tunnel. The two lake samples differ insignificantly from each other. However, the waters from the fault(s) differ significantly from the lake water. All three water samples have a meteoric origin. A sulfur isotope analysis was attempted unsuccessfully on the waters from the fault and Lake Erie. The data obtained indicate a high sulfur content for the lake waters and essentially no sulfur in the waters from the fault.

The interpretation of the present set of data is that the 'fault water' is not Lake Erie water. <Appendix 2D B>, prepared by Dr. Simmons, presents the details of the results for the hydrogen and oxygen isotope analysis.

4.2 GEOPHYSICAL STUDIES

4.2.1 EVALUATION OF PUBLISHED AND UNPUBLISHED GEOPHYSICAL DATA

A review has been made of the available published and unpublished geophysical data for the immediate site area of the Perry site. These data include shipborne, high resolution, seismic reflection surveying (Reference 6)(Reference 11)(Reference 15), shipborne magnetic data (Reference 12)(Reference 15), aeromagnetic surveys (Reference 13)(Reference 14), and gravity data (Reference 15)(Reference 16).

The seismic reflection surveys indicate no evidence of either abrupt changes in the Paleozoic bedrock surface beneath the lake or disruptions of the overlying unconsolidated lake bottom sediments (Reference 6)(Reference 11)(Reference 15). Several profiles which would have crossed the projection of the faults noted in the intake and discharge tunnels did not indicate vertical offset (Reference 6).

The resolution of the seismic reflection survey is discussed in each study. Williams (Reference 6), with regard to the high resolution seismic reflection survey performed by the U.S. Army Coastal Engineering Research Center, states "...in the vicinity of the Perry Power Plant. The records don't exhibit enough sub-bottom penetration into the shale bedrock to expose fault features, but I don't see abrupt changes in the lake floor or acoustic contrasts of sediments to suggest that faults are present." Wall (Reference 11)(Reference 15), with regard to the reflection seismic survey carried out under his direction in 1960, states on Page 3 of (Reference 15) that (1) "The sub-bottom sounding system as it was set up and operated on ship was adversely affected by the shallow depth of the lake. The fact that the water depth, which did not exceed 100 feet, was close to the "thumper" hydrophone separation led to a nonlinear printout of the PDR (precision depth recorder). In addition, the use of a PDR (precision depth recorder) with a scale range of 2,400 feet resulted in all the data being compressed into the top 2

or 3 inches of the record thus making it difficult to sort out and read accurately." Wall goes on to state on Page 92 of (Reference 11) that "discrepancies in depths to these reflections {Wall is describing several sub-bottom reflectors he noted} at the intersections {of track lines} were generally less than 6 feet."

A shipborne magnetic survey in the site area, which consisted of three north-south profile lines at five-mile spacings and one east-west line, shows no evidence for any linear trends parallel to the projected trace of the intake and discharge faults (Reference 12)(Reference 15).

Resolution of the shipborne magnetic surveys was described by Wall on Page 52 of (Reference 15) and Peters and Wall on Page 2 of (Reference 12) as follows: "Discrepancies in the magnetic data at track intersection averaged about 50 gammas." Wall on Page 60 of (Reference 15) goes on to state "...that the sources of the observed magnetic anomalies must lie within the Precambrian basement rock."

Similarly, the aeromagnetic surveys which were parallel to the projected trace of the fault and widely spaced (flight line separation on the order of five to ten miles) do not suggest any linear magnetic anomalies in the near-site area of the Perry plant (Reference 13)(Reference 14).

Meyers on Page 40 of (Reference 14) states in his discussion of the instrumentation employed for the aeromagnetic surveys performed by both Ahern (Reference 13) and himself that "...each reading can only be assumed accurate to within 3 gammas." Meyers (Reference 14) also noted on Page 32 that "the flight lines plotted are accurate to 1.0 miles." Finally, he notes on Page 97 of (Reference 14) that "these bodies {which cause the anomalies}...would have depths of burial between 1.4 and 1.6 kilometers below lake surface."

The shipborne gravity data reported by Wall consist of a single traverse in the site area (Reference 15). The relatively widely spaced shipborne

gravity data are interpreted by Wall as indicative of lithologic variations within the Precambrian basement and not indicative of structure. Wall's interpretation is similar to Heiskanen and Uotila (Reference 17), who interpreted most of the gravity anomalies in Ohio as reflective or lithologic variations in the Precambrian basement.

With regard to scatter within the gravity data, Wall on Page 84 of (Reference 15) states that "it {scatter} does not exceed ±10 dial division or about 3 milligals." He goes on to state on Page 55 that "while the data do not warrant a detailed interpretation, it can be shown that for the most part the origin of the observed anomalies must lie within the Precambrian crystalline rocks." O'Hara et al (Reference 16), supports Wall's conclusions with regard to the origin of the gravity anomalies in the Lake Erie region.

4.2.2 MAGNETIC SURVEY

The magnetic profiles taken from Lake Erie traverses <Figure 2D-34>, <Figure 2D-35>, <Figure 2D-36>, <Figure 2D-37>, <Figure 2D-38>, <Figure 2D-39>, <Figure 2D-40>, <Figure 2D-41>, and <Figure 2D-42>, display a generally flat signature. All of the significant peaks appear to be related to cultural influences such as drill barges and metal pipes. There are no significant anomalies which are associated with the projection of the fault on the lake bottom. Offsets as small as those noted in the tunnels (one to two feet) would, however, probably not be detectable.

The land magnetic profiles <Figure 2D-43>, <Figure 2D-44>, <Figure 2D-45>, <Figure 2D-46>, <Figure 2D-47>, and <Figure 2D-48>, show generally erratic signatures which are attributed primarily to cultural sources. There is no fault-related magnetic signature.

4.2.3 BOREHOLE LOGS

Units which could be used as marker beds, as a result of either an anomalous velocity or radiation level, were not detected in the geologic section <Figure 2D-49> and <Figure 2D-50>. This is probably because of the relative macroscopic homogeneity of the Chagrin shale as evidenced by the thinness of the individual beds within the Chagrin. Offset which could be associated with the fault could not be determined.

In borings TX-3, TX-4 and TX-6, velocity logs show low velocity values associated with the fault. No such velocity "lows" are observed outside the tunnel in either the down-dip (TX-7) or along the strike (TX-8, TX-9 TX-10) projection of the fault. Outside the fault zone, the measured velocity is 10,500+ fps. Within the fault zone, the velocity that was measured is approximately 6,000 fps; this lower velocity value at the fault zone is probably due to the PVC casing and the actual velocity value of the zone may be even lower.

In the tunnel drill holes (TX-3, TX-4 and TX-6), a low level of gamma radiation can be associated with the fault. However, the signature is not very marked. It appears that certainly the low P-wave velocity values can, and possibly the low radiation levels may, be used as distinguishing characteristics of the fault.

4.3 EVALUATION OF LOCAL SEISMICITY AROUND THE PERRY NUCLEAR POWER PLANT SITE

A detailed study of the local seismicity around the Perry site was made with some significant observations <Appendix 2D D>. In brief, the local historical seismicity is low: less than 50 events over a period of a century and a half, and no intensity larger than Intensity V Modified Mercalli. In general, assigned intensities can be considered conservative, and epicentral coordinates relatively uncertain. This uncertainty results, in part, from soil amplification and population

distribution which make it difficult in many cases to delineate a clear epicentral area. As a consequence of this epicentral uncertainty, apparent alignments or clustering of epicenters have no reliable tectonic significance. Details on local seismicity evaluations are presented in <Appendix 2D D>.

4.4 IN SITU STRESS MEASUREMENTS

Data regarding the orientation and magnitude of the complete stress tensor were obtained for the test intervals between 394 and 718 feet in TX-11. The direction of σ_1 was consistent with stress orientations over a regional basis. The stress magnitudes (the horizontal stresses are the maximum and intermediate principal stresses) fall within the limits of stresses measured in other parts of northeastern and north central United States and in southern Canada. The vertical component corresponds closely to the anticipated overburden pressure.
At the shallower depths, the tendency for $\sigma_1 \sim \sigma_2 \sim \sigma_3$ is well defined and extrapolations of existing measurements to the surface are reasonable. No high stress magnitudes were experienced in either the tunnel or plant area excavations or concluded from measurements of extensometers installed in the bedrock walls of the emergency service water pumphouse. These conclusions regarding stresses in plant structure excavations are consistent with the extrapolation of the deeper in situ borehole measurements. Below a depth of approximately 600 feet, both σ_{Hmin} and σ_{Hmax} show an increase in gradient, with the gradient for σ_{Hmax} being larger. Data conclusions and an overview of the hydraulic fracturing technique are attached as <Appendix 2D E>.

5.0 CONCLUSIONS

Based on structural style, orientation and sense of offset, the thrust fault exposed in each tunnel is apparently the same feature or en echelon. Faulting is distinctly brittle with deformation confined to the immediate vicinity of the fault plane. The zigzag fracture pattern

and accompanying evidences of flexure characterizing the more southerly discharge tunnel deformation may be an en echelon structure, but more probably represents a splay from the main fault.

Paleozoic Tectonics, Mesozoic-Tertiary Tectonics and Pleistocene-Recent faulting mechanisms were considered. Regarding mid-Paleozoic deformation, the concept of soft sediment deformation can be ruled out by the brittle nature of observed deformation. The tunnel fault formed following lithification of the shale sequence. Notwithstanding interpretation regarding age, pre-Pleistocene tectonics are evaluated primarily in consideration of geometric data on tunnel fault strike and shallow dip. Alleghenian (Appalachian) orogenic compressional stresses propagated northwesterly, employing Salina salt bed decollements, would be technically feasible. Upward propagation of faulting at low dip angles, as with the tunnel faulting, would be compatible. Alternatively, southeasterly gravitational movement during late Paleozoic or early Mesozoic time was possible when overburden pressure and formation temperatures were about at peak values. Again, a majority of the lateral movement would be expected to occur upon the Salina salts. Relatively high loading conditions existing during glaciation with high stress gradients near ice sheet boundaries may have activated flowage deformation within the salt which resulted in underthrusting of the more competent overlying strata. Other mechanisms associated with deeper rooted deformation such as basement-block faulting and differential warping of Paleozoic strata would tend to produce normal faulting in overlying formations, not thrust faults.

Data regarding the age of faulting were derived from field and laboratory studies. An age determination from fault gouge mineralization could not be undertaken because none of the constituent minerals contained radioactive isotopes suitable for dating. However, on the basis of syn and/or post-deformational mineral growth extending completely across fault zone microcracks related to the last movement on

the fault, Dr. Simmons concludes that the time of last movement for each of the tunnel fault segments is approximately one million years but may be as old as two to five million years or as young as 0.8 million years.

Comparisons of the Perry microcrack data to similar data from other locales were employed in age determinations. Allowances for variability in factors such as temperature, pressure, and chemical environment and uncertainty related to mineral growth rates could suggest a greater range in estimated formation time. Notwithstanding the foregoing consideration, it is not reasonable to postulate a Recent age for last fault movement. Microcrack mineral growth bridges, some of which are quite delicate, remained intact and unruptured during the period of historical seismicity.

During faulting, the orientation of the maximum principal stress was oriented normal to fault strike. In situ stress measurements employing the hydrofracture technique demonstrate that the stress field orientation has changed since faulting. The maximum principal stress consistent with the prevailing regional stress field is parallel to fault strike. The magnitude of vertical stresses measured is as expected for calculated overburden pressure. Reorientation of the stress field must have occurred during Pleistocene time in response to glaciation. Deposits of three major stages are recognized in northeastern Ohio. No Nebraskan stage deposits have been identified in Ohio. It is not known which major ice advance or minor recessional-readvance cycle altered the stress field prevailing during the last fault movement. This method of qualitatively dating the last fault movement is in agreement with the microcrack study.

Dr. Voight hypothesizes on the basis of maximum past consolidation pressure of the fault gouge that the associated overburden pressure was not substantial but on the order inferred from an ice sheet considerably thinner than that estimated for northeastern Ohio at the Laurentide maximum. On this basis the last fault movement is more likely

associated with deglaciation-rebound than an ice sheet advance. However, rock-to-rock contacts across the fault zone, as well as the step-like pattern of faulting, were documented during detailed mapping of the deformed tunnel segments. Furthermore, Dr. Voight suggests from extrapolations of fault displacement data that approximately 70 feet of undeformed bedrock overlie the updip projection of faulting. Therefore, it is doubtful whether the fault gouge would have experienced maximum overburden loading during any of the major or minor glacial stage advances when ice thicknesses exceeded several thousand feet. Hence, the ages of movement for the fault based on gouge consolidation tests is not reliable.

The most reasonable interpretation of all the data is that the tunnel deformation or at least the last movement on the fault was a Pleistocene event associated with glaciation. Candidate mechanisms include ice-sheet traction, differential down-bowing with glacial advance, differential rebound with glacial retreat, surficial stress-relief or "pop-up" and subsurface salt tectonics, the latter as previously discussed. More probable were glacio-isostatic uplift and surficial stress relief during deglaciation rebound. Recurrent movement on deeper-seated pre-Pleistocene structures or faults, either by direct propagation or by en echelon deformation could have been possible. Both of the latter would have been activated by glacial ice loading or unloading. The conclusions of these investigations, the opinions of the independent reviewing geologists and lack of evidence to the contrary are consistent; the fault is not capable as defined in <10 CFR 100, Appendix A>.

6.0 REFERENCES

1. Stone and Webster Engineering Corporation, October 1978, Regional geology of the Salina Basin, Report of Geologic Project Manager - Salina Basin, Phase I August 1977 - January 1978, Vol. 1.

2. Heimlick, R. A., R. W. Manus, and C. H. Jacoby, 1974, General geology of the International Salt Mine, Cleveland, Ohio: in Heimlick, R. A. and R. M. Feldman, (eds), Selected field trips in northeastern Ohio: Ohio Department of Natural Resources, Division of Geological Survey, Survey Guidebook No. 2, p. 5-17, 59 p.

3. Jacoby, C. H., 1979, personal and written communications.

4. Richner, D. R., 1974, Minor discontinuities reported in the core description of Diamond Alkali Core Hole #202, Perry Township, Ohio, unpublished report.

5. Prosser, Charles S., 1912, The Devonian and Mississippian formations of northeastern Ohio: Ohio Geological Survey Bulletin, 15 p.

6. Williams, S. Jeffress, 1978 and 1979, personal and written communications.

7. Cushing, H. P., F. Leverett, and F. R. Van Horn, 1931, Geology and mineral resources of the Cleveland District, Ohio: Geological Society of America Bulletin 818, p. 33-35.

8. Weston Geophysical Research, Inc., 1978, Feasibility of Dating the faults in the foundation of WNP 3 at the WNP 3 and 5 (Satsop) Site of Washington Public Power Supply System: report prepared for EBASCO Services Incorporated and submitted to Washington Public Power Supply System, 26 pp.

9. Padovani, E. R., M. L. Batzle, and G. Simmons, 1979, Characteristics of microcracks in samples from the drill hole Nordlingen 1973 in the Ries Crater, Germany. Proceedings, Lunar Science Conference, 9th, in press.

10. Blatt, Middleton and Murray, 1972, Origin of Sedimentary Rocks: Englewood, N.J., Prentice-Hall, p. 338.

11. Wall, R. E., 1968, A sub-bottom reflection survey in the Central Basin of Lake Erie: Geological Society of America Bulletin, V. 79, p. 91-106.

12. Peter, G. and R. E. Wall, 1961, Magnetic Total Intensity Measurements on Lake Erie: Lamont-Doherty Geophysical Observatory Technical Report, pp. 9.

13. Ahern, J. L., 1975, Aeromagnetic reconnaissance survey of Lake Erie: Ohio State University, Columbus, Ohio, unpublished M. S. Thesis, 153 p.

14. Meyers, C. D., 1977, Aeromagnetic reconnaissance survey of Lake Erie: Ohio State University, Columbus, Ohio, unpublished M. S. Thesis, 172 p.

15. Wall, R. E., 1965, Geophysical Investigations in the Central Lake Erie Basin: University of Ohio, Unpublished Ph.D. Thesis, Columbus, 66 pp.

16. O'Hara, N. W., F. Mequid, and W. J. Hinze, 1974, Gravity and Magnetic Observations from the Lake Erie and Lake Ontario Region: Geological Society of America Abstracts with Programs, V. 6, p. 896.

17. Heiskanen, W. A., and U. A. Uotila, 1956, Gravity Survey of the state of Ohio: State of Ohio, Department of Natural Resources, Division of Geological Survey, Report of Investigations, No. 30, 34 p.

<APPENDIX 2D A>

A STUDY OF THE MICROCRACKS ASSOCIATED WITH FAULTING

AT THE PERRY NUCLEAR POWER PLANT SITE

by

Dr. Gene Simmons

April 1979

A STUDY OF THE MICROCRACKS ASSOCIATED WITH FAULTING AT THE PERRY NUCLEAR POWER PLANT SITE

1.0 INTRODUCTION

A small fault was discovered during the excavation of the intake tunnel for the emergency cooling water at the Perry nuclear site. Samples of the fault gouge and adjacent shale were collected in July 1978 by Dr. Gene Simmons and Weston personnel. Those samples were examined briefly with the scanning electron microscope (SEM) using techniques for the study of microcracks that have been recently developed by Dr. Simmons and colleagues. A report on the preliminary findings of that investigation was submitted to the Nuclear Regulatory Commission on November 1, 1978.

During the excavation of the tunnel for the discharge of emergency cooling water at the Perry nuclear site, a fault was intersected at approximately the location of the projection along strike of the fault present in the intake tunnel. In addition, a small fracture zone was recognized approximately 200 feet south of the fault. Samples were obtained in October 1978, January 1979 and March 1979 by Dr. Simmons and Weston personnel.

2.0 SUMMARY AND CONCLUSIONS

Specimens of the gouge and the adjacent country rock were prepared in a form suitable for the examination of microcracks and elemental compositions of individual minerals in the SEM. Two types of cracks were observed. The first type, due to the desiccation of the sample, appears to be unavoidable, but is readily recognizable on the basis of

objective criteria developed previous to the present studies. The second type of crack appears to be related to the last movement on the fault and always contains new mineral growths that extend completely across the crack.

Approximately 350 cracks of the type produced by faulting were examined in six samples. Every crack examined contained approximately one percent new mineral growth.

On the basis of previous observations of several thousand microcracks in a wide variety of rock types, healed microcracks appear to be ubiquitous in rocks. Evidently, the microcracks begin to heal immediately on forming. The degree of healing can be a measure of the amount of time that has been available for the microcrack to heal. The exact mathematical description of the function that relates degree of filling to elapsed time since the crack was formed in unknown, but is likely S-shaped and asymptotic to the zero and 100 percent values. Two data points have been obtained - one point at 1 million years (possibly 2 to 5 million years) from sandstone at the Satsop site, the other at 18.5 million years from shocked rock at the Ries Crater, Germany.

The rate of healing of microcracks is very likely a function of temperature, pressure, mineralogy, and the composition and flow rate of pore fluids. Fortunately, the conditions at the Perry site and at the Satsop site are quite similar, and the degree of filling of the cracks at each site are comparable. Therefore, the data obtained previously for the Satsop site are a suitable basis on which to estimate the age of the microfractures in the gouge zone at Perry.

On the basis of a thorough examination of the microcracks in six representative samples of the gouge and country rock from the fault, or faults, in the intake tunnel and the discharge tunnel and from the fracture zone in the discharge tunnel, it is our conclusion that the

time of last movement of each of these faults is conservatively estimated at approximately 1 million years and may be as old as 2 to 5 million years.

3.0 BASIS OF METHOD

Displacement of rock along fault surfaces, in the laboratory as well as in the field, appears to produce microfractures. For examples of representative laboratory studies, reference is made to the work of Griggs and Handin (1960), Conrad and Friedman (1976), Jackson and Dunn (1974). The examination of natural specimens from faults by Engelder (1974), Swain and Jackson (1976) and Stearns (1972) demonstrates the applicability of the laboratory results to rock *in situ*.

Work done during the past decade on microcracks (Simmons and Richter, 1976; Richter and Simmons, 1977; Simmons *et al*., 1975; Batzle and Simmons, 1976, 1977; and Wang and Simmons, 1978) has shown clearly that healed and partially healed microcracks in rocks are ubiquitous. Apparently, the microcracks began to heal immediately upon forming.

The degree of healing, as measured by the volume percentage of new mineral growth that fills the microcracks, is an indication of the amount of time that has elapsed since the formation of the microcrack. The general form of the function that relates degree of filling to elapsed time, shown on Figure 1, can be deduced in the following manner. The initial rate is low because of the difficulty of nucleation. The final rate is low because the transfer of fluid from residual cavities (i.e., fluid inclusions) must occur by diffusion of water through solid phases. Thus, the functional form of the curve is asymptotic at both zero percent filling and at one hundred percent filling. During the intermediate phase, the rate is controlled by both the availability and

fluid phase. Because the rate of many processes is described adequately by an Arrhenius-type relation (Kingery et al., 1976, Chapter 9), we suggest that the rate of sealing of microcracks is described satisfactorily by

$$\ln(c/co) = K(t - t_o)$$

$$K = A\exp(-Q/RT)$$

where c/co is the volume fraction of filling

K is the reaction rate

t is time

A and Q are experimentally determined constants

R is the gas constant

T is absolute temperature.

At the present time, we have two data points that appear to lie on the curve during the intermediate period. They are shown on Figure 2 and are connected with a straight line. Both data points lie in the intermediate region because in each case the new mineral growth had extended completely across the open microcracks, but an open channelway still exists throughout the microcracks. Additional confidence is derived from the observation that apparent degree of filling of a 0.2 mybp crack shown by Swain and Jackson (1976), Figure 4 is very small.

The data for the low end of the curve were obtained on a sample of sandstone from the Satsop site (Weston Geophysical Research, Inc., 1978). The cracks were produced during the compaction phase of the

sandstone. The stratigraphic unit (the Montesano formation) that was deposited above the sandstone was dated on the basis of fossils (Rau, 1967) as at least 1 million years and possibly 2 to 5 million years. Because the creation of compaction fractures must have ceased when the unit began uplift, the youngest age for any compaction-induced fracture must be the age of the youngest overlying formation, approximately 1 million years. The minerals that were examined in the study of the sample from Satsop included quartz, feldspar and pyroxene. These minerals, as a group, contain Al, Si, Fe, K, Ca, Na, and Ti. The maximum depth of burial was approximately 3,000 to 3,500 feet. The thermal gradient at the site was probably 15° to 25°C/km. Therefore, the maximum temperature to which the sample had been exposed was probably 20° to 30°C, an estimate that is consistent with, but somewhat higher than, the temperature estimated from the metamorphic grade of the organic material contained in the sandstone.

The data for the high end of the curve are based on data reported by Padovani et al. (1979) for a series of core samples from the 3,500-foot hole drilled in the Ries Crater, Germany. The Ries Crater and the microcracks in the rocks from the Ries Grater were produced when a meteorite hit the earth 18.5 million years ago. The age was obtained with radiometric techniques. Figure 3 shows a typical crack in the mineral amphibole partially filled with grains of the mineral chlorite. Cracks were observed in quartz and feldspar also. The degree of filling was highest in quartz, intermediate in feldspar and lowest in amphibole. The host grains for the partially sealed microcracks contained the elements Al, Si, Fe, Mg, K, Ca, Na. The thermal gradient at the present time in the Ries Crater is 15° to 25°C/km. Thus, the maximum temperature at present to which the samples in situ have been exposed is approximately 20° to 25°C.

The time required for nucleation in the cracks in the rocks from the Ries Crater may have been very short. The meteorite impact produced a high temperature associated with the shock waves that lasted a few

microseconds to perhaps a few milliseconds. In addition, a significant volume of the rocks in the vicinity of the impact and sampled by the drill would have been exposed to a temperature that might have been as high as 100° to 200°C for intervals of time of the order of hundreds or perhaps thousands of years. The higher temperatures would likely have shortened greatly the amount of time required for the nucleation of the new mineral growths in individual microcracks. We have included the uncertainty of this effect in the error bar that is shown for this data point on Figure 3 by indicating that the degree of filling might appear to be too large for a sample whose age is 18.5 million years, but which used 5 million years for the nucleation time.

4.0 PROCEDURES

4.1 SAMPLE COLLECTION

The sample for this study were collected with methods designed to minimize, or perhaps prevent completely, the creation of open microfractures in the material which had very low strength. Two different techniques were used. In the first technique, we used a jackhammer to line-drill a large block of rock. The concept for this procedure was that the jackhammer would damage material relatively near the drilled holes which could then be removed and discarded. The procedure, illustrated on Figure 4, appears to have been successful for several samples but was not successful for all samples. Some samples simply disintegrated within a few days after collection.

In the second procedure, we used a small masonry saw to remove completely, the specimen from the rock mass in situ. A series of photographs on Figure 5 illustrates the second technique. This procedure, though rather time consuming for large samples, was highly successful.

4.2 SPECIMEN PREPARATION

The rock and gouge while *in situ* contain free water in the cracks and pores. The examination of the material in the SEM requires that the free water be removed. Therefore, a major problem in the preparation of the specimens for the examination with the SEM is the removal of the free water without creating open microfractures or destroying any delicate structures that existed in the microcracks while the material was still *in situ*. This problem appears to have been overcome completely in our specimen preparation (as judged on the basis that no open microfracture without new mineral growth was observed and that many microcracks with delicate structures of new mineral growth were observed). We used Buehler isomet diamond saws operated at very low speeds, drying furnaces kept at temperatures below 45°C, and epoxies that cure at room temperature.

4.3 SEM PROCEDURES

The procedures for the examination of specimens in the scanning electron microscope are described for general specimens by Hearle *et al*. (1972) and for rock samples by Simmons and Richter (1976), Richter and Simmons (1977) and Batzle and Simmons (1976, 1977). We include here only a brief description of the procedures. The SEM consists of an electron source, focusing and rastoring coils, a movable stage for supporting the specimen, various detectors, and associated electronics for amplifying, displaying, and recording the detected signal. The major systems of an SEM are shown on Figure 6 schematically. A typical image is shown on Figure 7. Unlike a photographic image, the SEM image is generated sequentially in time by the detection and recording of the intensity of the image at individual points. The intensity is controlled by the composition of the material at the point, the topographic roughness of the surface of the material at the point, and (to a lesser extent) by the crystallographic orientation of the material at the point.

The detector in the scanning electron microscope may be sensitive to secondary electrons, backscattered electrons or x-rays. Most of the work done on the Perry samples was done with secondary electrons or with the x-ray detector. With the x-ray detector, one also uses associated electronics to measure the energy spectrum of the x-rays that are emitted by the specimen. Because each element produces x-rays with characteristic energies, the spectrum of energies can be used to obtain semiquantitative estimates of the elemental composition of the specimen. Typical spectra are shown on Figure 8.

5.0 SAMPLE LOCATIONS

Representative samples of the various faults were collected from the intake tunnel and the discharge tunnel. Samples of the fracture zone in the discharge tunnel were also collected. The sample locations are shown on the intake and discharge tunnel wall maps (Figure 17, 18 and 19) of the main body of Weston Geophysical’s text.

6.0 RESULTS

6.1 DESCRIPTION OF GOUGE

The gouge zone contains lithic fragments set in a matrix of clay-sized (1 to 4 microns) grains. A typical image is shown on Figure 9. The texture and minerals of the lithic fragments are identical to those of the adjacent country rock. The gouge matrix contains the same clay mineral (illite) as the country rock and also contains gypsum and feldspar. Crystals of NaCl, observed in the gouge zone but not in the country rock, are believed to have crystallized from saline water after collection.

6.2 MICROCRACKS

Two types of cracks were observed in the samples from the Perry site. One set, termed desiccation cracks, was produced during the drying of the specimen and appears to be unavoidable. The other set, termed fault-cracks, was not produced during the drying of the sample and appears to have been produced by the last movement of the fault.

Desiccation cracks had been observed previously in other samples. On Figure 10, an example of desiccation cracks in clay-like minerals (chlorite in this case) are shown for a specimen described by Wang and Simmons (1978). These cracks developed during examination of the specimen with the SEM. They were actually observed during the time that they formed; hence, their origin is known unequivocally. Desiccation cracks have distinct characteristics: (1) they are relatively wide in comparison with their lengths; (2) their walls are very irregular, but opposite walls would fit exactly when restored to the contacting position; (3) they are relatively short (typically a few microns); and (4) they are often curved. The criteria for the recognition of desiccation cracks are unambiguous. An example of desiccation cracks in the Perry samples is shown on Figure 11 and may be compared with the cracks on Figure 10.

Examples of the other type of cracks observed in the Perry samples are shown on Figures 12, 13 and 14. These cracks are typical representatives of approximately 350 cracks that were examined in the Perry samples. Every individual crack in the set of 350 cracks contained new mineral growths that spanned completely the fracture. No open microcrack without new mineral growth was observed - except, of course, the desiccation cracks.

6.3 AGE OF MICROCRACKS

The age of the microcracks can be obtained from the degree of filling, approximately one percent. The value is the same as the value for the compaction fractures in the sandstone at the Satsop site. If the factors that control rate of fracture filling are approximately the same for the two sites (as they are), then the ages of the cracks are the same. The factors are compared in Table 1, and we conclude that they are quite similar for the two sites. Therefore, the age of the microcracks associated with faulting at the Perry site is approximately 1 million years.

Although our estimates of the several parameters that affect the rate of healing or microfractures are similar for the Perry and Satsop sites, they are not identical. Therefore, some possible error exists in the estimate of the date of last fracturing for the Perry site. In our opinion, and based on our experience of working on microcracks in a variety of rocks during the past 10 years, the date might be as young as 0.8 million years and as old as 5 million years.

6.4 SLICKENSIDES

Samples that contained slickensides were examined with the SEM. A typical image is shown on Figure 15. The grooves appear to have been created by grains of pyrite that were embedded in a surface that moved with respect to another adjacent surface. The mineral pyrite was identified on the basis of elemental composition (feS) and crystal morphology (octahedra).

7.0 REFERENCES

Batzle, M. L. and G. Simmons, 1976, "Microfractures in Rocks from Two Geothermal Areas," Earth Plante. Sci. Lett., 30, 71-93.

Batzle, M. L. and G. Simmons, 1977, "Geothermal Systems: Rocks, Fluids, Fractures," in The Earth's Crust: Its Nature and Physical Properties, Geophys. Monogr. Ser., Vol. 20, edited by J. G. Heacock, AGU, Washington, DC, 233-242.

Conrad, R. E. and M. Friedman, 1976, "Microscopic Feather Fractures in the Faulting Process," Tectonophysics, 33, 187-198.

Engelder, J. T., 1976, "Cataclasis and the Generation of Fault Gouge," Geol. Soc. Am. Bull., 85, 1515-1522.

Griggs, D. and J. Handin, 1960, "Observations on Fracture and a Hypothesis of Earthquakes," in Rock Deformation (A Symposium), Geol. Soc. Am. Mem. 79, edited by D. Griggs and J. Handin, G.S.A., New York, 347-364.

Hearle, J. W. S., J. T. Sparrow, and P. M. Cross, 1972, The Use of the Scanning Electron Microscope, Pergamon Press, New York, 278 pp.

Jackson, R. E. and D. E. Dunn, 1974, "Experimental Sliding Friction and Cataclasis of Foliated Rock," Int. J. Rock Mech. Min. Sci. & Geomech. Abstr., 11, 235-249.

Kingery, W. D., H. K. Bowen, and D. R. Uhlmann, 1976, "Introduction to Ceramics," 2nd Edition, Wiley, New York.

Padovani, E. R., M. L. Batzle, and G. Simmons, 1979, "Characteristics of Microcracks in Samples from the Drill Hole Nordlingen 1973 in the Ries Crater, Germany," Proc. Lunar Sci. Conf. 9th, in press.

Rau, W. W., 1967, "Geology of the Wynoochee Valley Quadrangel" Wash. Div. Mines and Geol., 56, 51 p, 1 pl.

Richter, D. and G. Simmons, 1977, "Microcracks in Crustal Igneous Rocks: Microscopy," in The Earth's Crust: Its Nature and Physical Properties, Geophys. Monogr. Ser., Vol. 20, edited by J. G. Heacock, AGU, Washington, DC, 149-180.

Simmons, G., R. Siegfried, and D. Richter, 1976, "Characteristics of Microcracks in Lunar Samples," Proc. Lunar Sci. Conf. 6th, 3227-3254.

Simmons, G. and D. Richter, 1976, "Microcracks in Rock," in The Physics and Chemistry of Minerals and Rocks, edited by R. G. J. Strens, Wiley-Interscience, New York, 105-137.

Stearns, D. W., 1972, "Structural Interpretation of the Fractures Associated with the Bonita Fault," in Guidebook of East-Central New Mexico, edited by V. C. Kelly and F. D. Trauger, New Mexico Geological Society, 161-164.

Swain, M. V. and R. E. Jackson, 1976, "Wear-like Features on Natural Fault Surfaces," Wear, 37, 63-68.

Wang, H. and G. Simmons, 1978, "Microcracks in Crystalline Rock from 5.3-km depth in the Michigan Basin," J. Geophys. Res., 83, 5849-5856.

Weston Geophysical Research, Inc., 1978, "Feasibility of Dating the Faults in the Foundation of WNP 3 at the WNP 3 and 5 (Satsop) site of Washington Public Power Supply System," report prepared for EBASCO Services Incorporated and submitted to Washington Public Power Supply System, 26 pp.

TABLE 1

COMPARISON OF PERRY AND SATSOP SITES WITH RESPECT TO FACTORS AFFECTING RATE OF FRACTURE HEALING

Factor	Perry	Satsop
Host Minerals	Illite (based on EDX)	Quartz, Feldspar, Pryroxene
Elements in Host(s)	Al, Si, K, Fe	Na, Mg, Al, Si, K, Ca, Fe
Elements in Growth Minerals	Al, Si, K, Fe	Not measured
Maximum Temperature	288° to 293°K	288° to 293°K
Maximum Lithostatic Pressure	~300 bars	~300 bars
Width of Microcracks	1 to 5 microns	1 to 5 microns

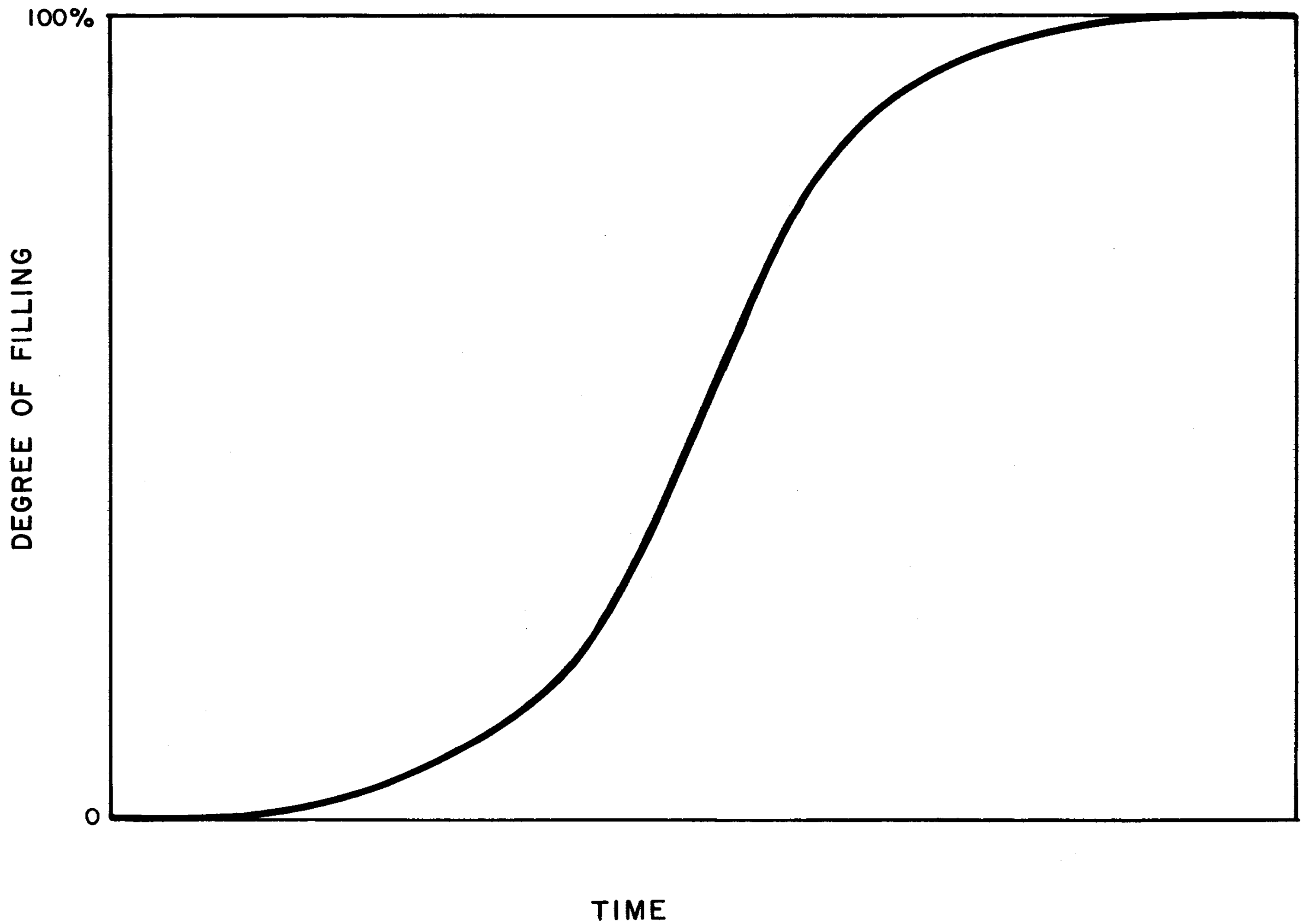


Figure 1 Healing of microcracks versus time. The curve is schematic and intended only to show general shape. The cracks are created at time t_o and are healed completely at t_c.

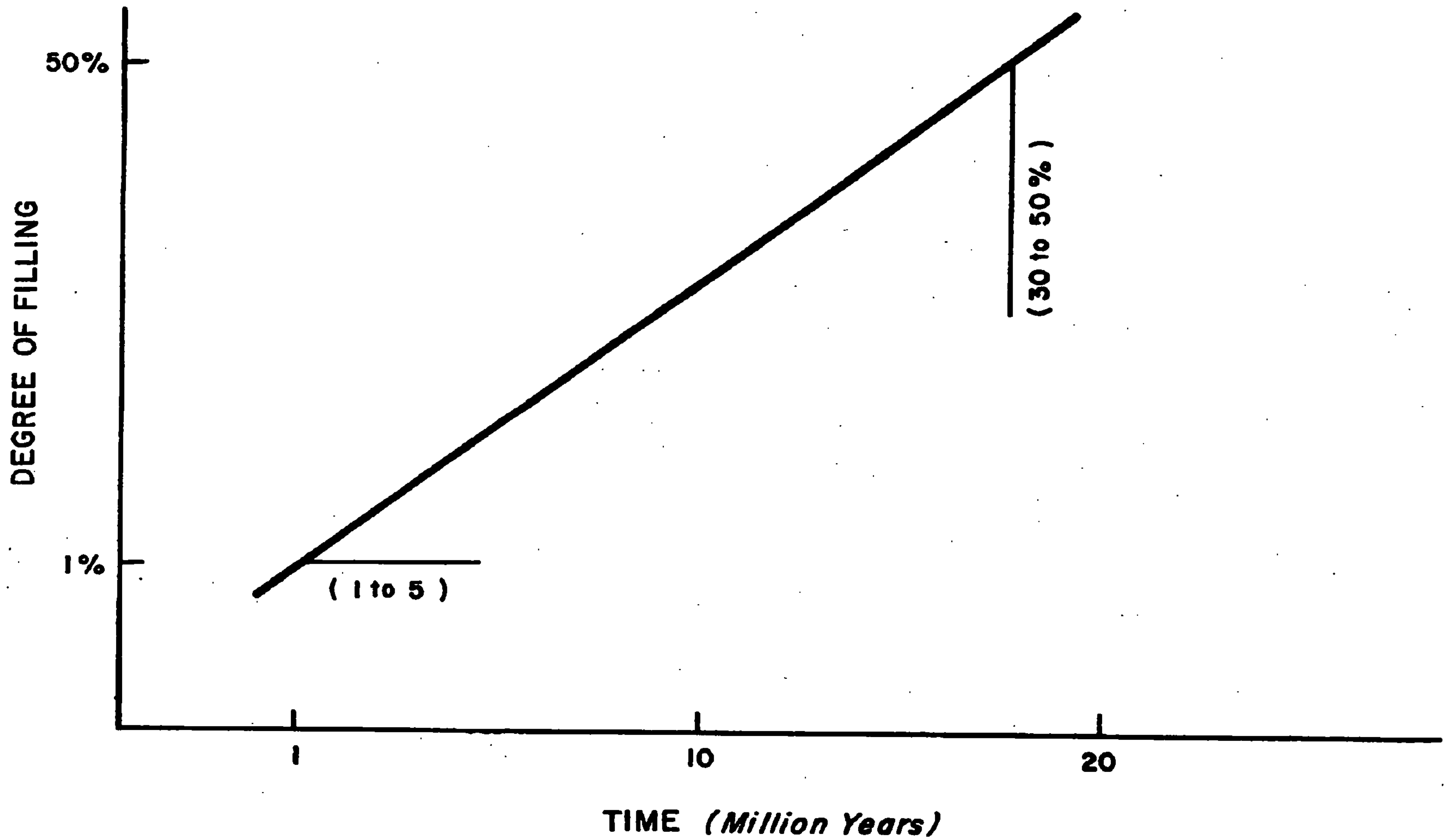


Figure 2 Current data for healing of microcracks. See text for discussion of the error bars.

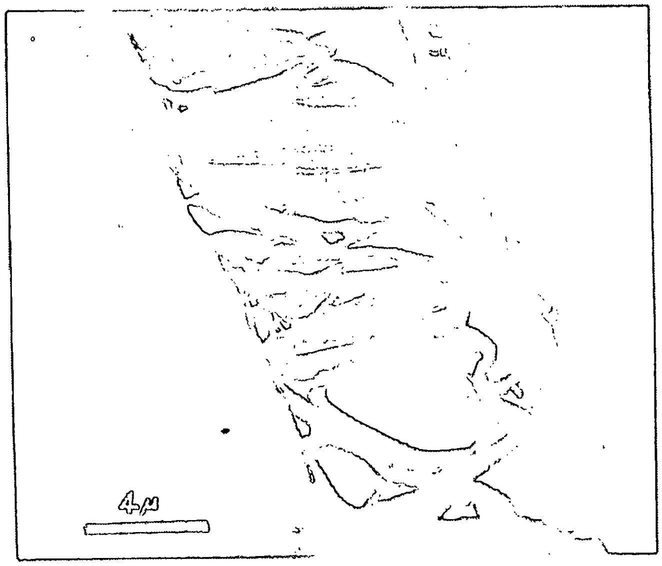


Figure 3 Partially healed microcracks from Ries Crater, Germany. SEM micrograph. Host grain is amphibole. New mineral growth is chlorite. The sample is described by Padovani <u>et al.</u> (1979).

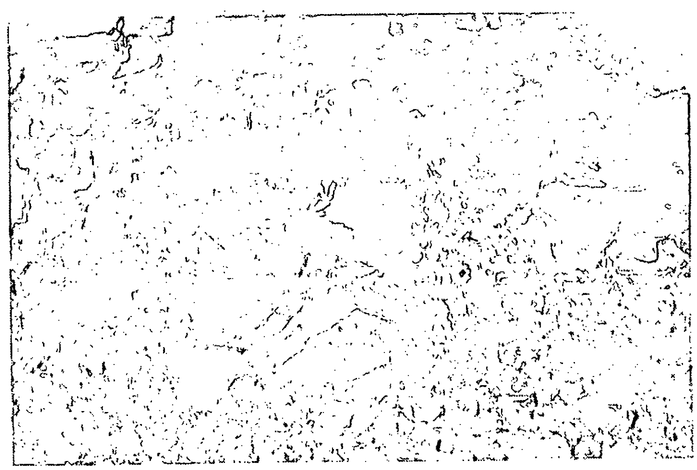


Figure 4 Sample number 4, partially outlined with holes that have been drilled with a jackhammer, still <u>in situ</u>. Note the gouge zone that is contained in this sample. The webs between the individual holes were later removed. A chisel was used to split a bedding plane at the base of the sample, freeing the sample completely.

Figure 5 Sample number 25, partially sawn, still <u>in situ</u>. After the rear cut had been made, the sample was freed by splitting gently along a bedding plane. Note the gouge zone that extends diagonally across the sample.

THE DESIGN AND USE OF THE SCANNING ELECTRON MICROSCOPE 51

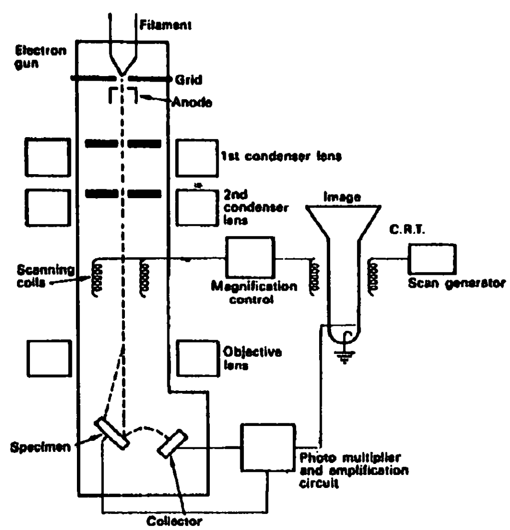


FIG. 3.2. Block diagram of a typical SEM.

Figure 6 Block diagram of a typical scanning electron microscope. The image on the cathode ray tube is recorded photographically. An x-ray detector may be substituted for the collector.

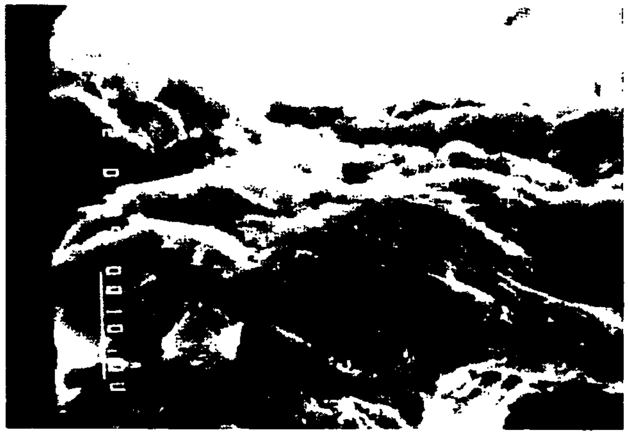


Figure 7 Typical micrograph obtained with a scanning electron microscope. PNPP sample 1. This image was made with a specimen from the gouge zone in the intake tunnel at the Perry Nuclear Site. The deformed crystals near the center of the micrograph are probably gypsum.

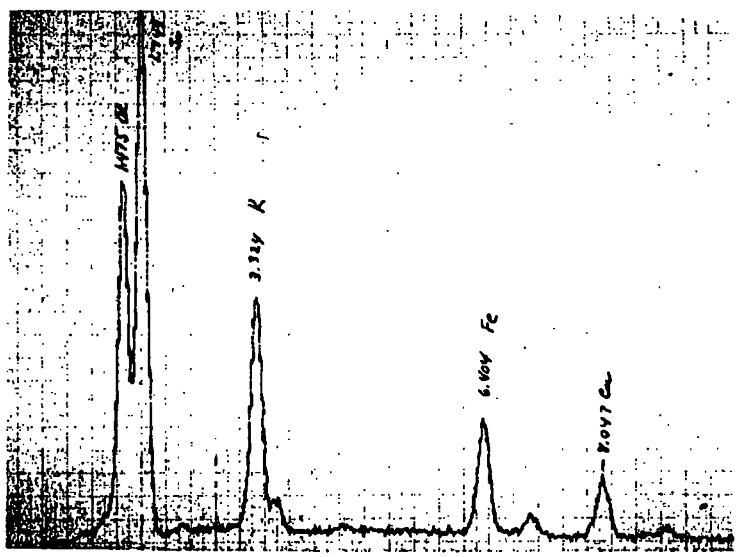
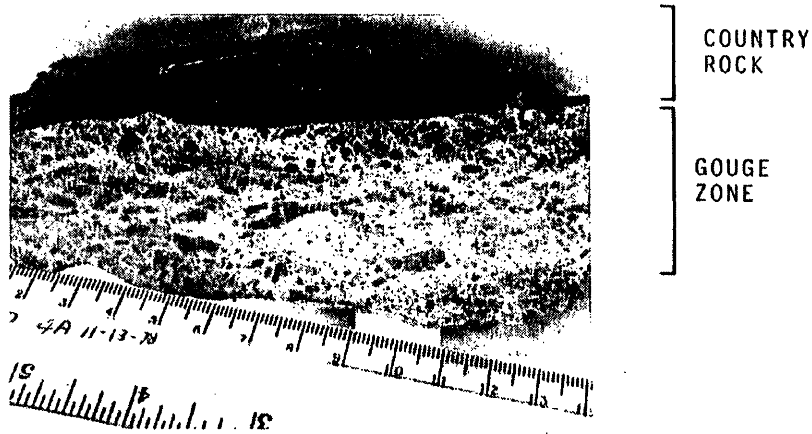


Figure 8 Typical x-ray spectrum obtained with energy dispersive systems. This spectrum was obtained from clay minerals in the gouge zone. The abscissa is energy (of x-rays) and the ordinate is counts per channel. The identification of the individual peaks is shown on the figure. The peak for copper is due to contamination within the system and not to the presence of copper in the specimen. The mineral is probably illite.

9a



9b

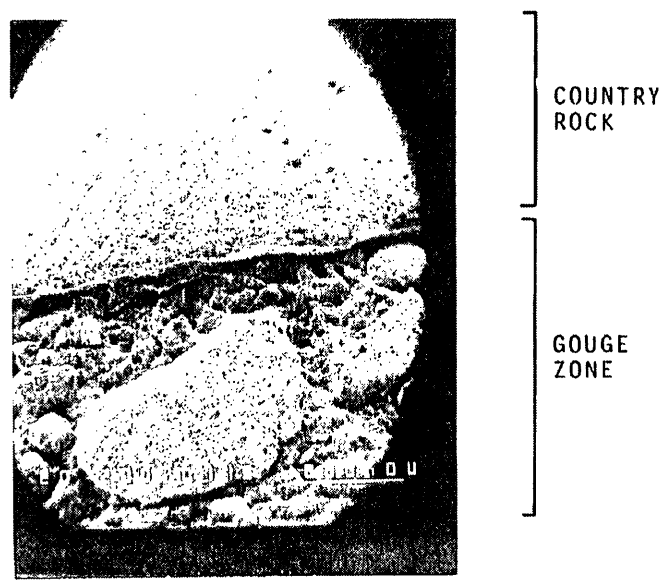


Figure 9 Figure 9a is an enlargement of an optical photograph and shows in small scale the many features that are present in the gouge and can be readily recognized on a freshly sawn surface. Note the abundant lithic fragments of shale that are set in the fine-grained matrix. Figure 9b is an SEM micrograph of the gouge (area differs from 9a).

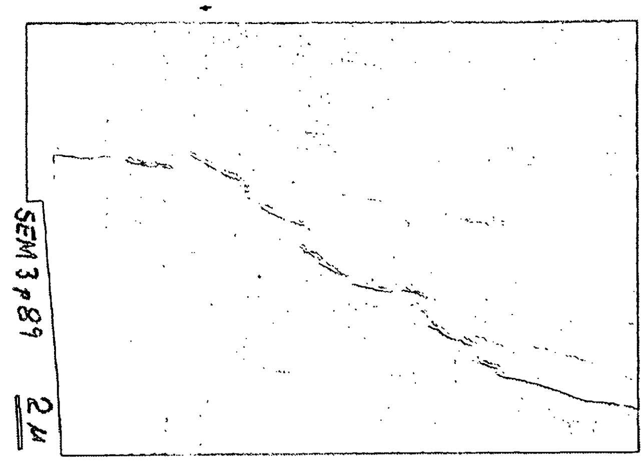


Figure 10 Desiccation cracks observed in a sample of chlorite. These cracks were observed in the SEM during formation.

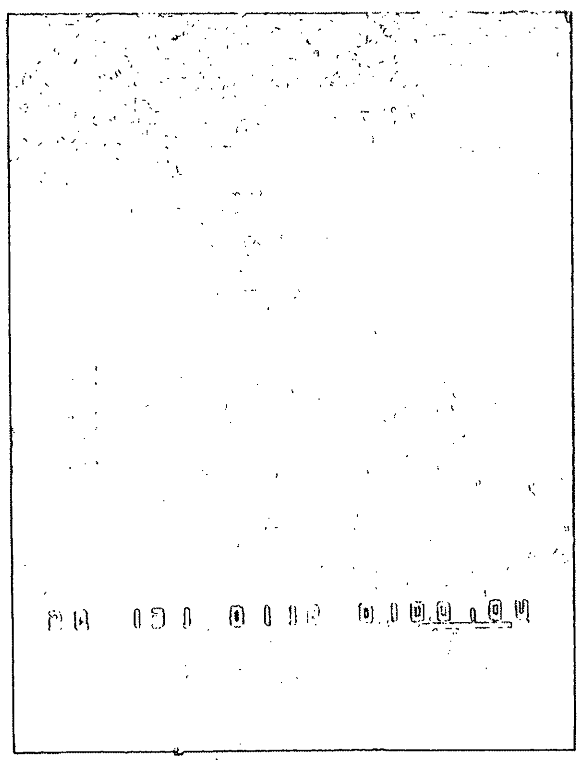
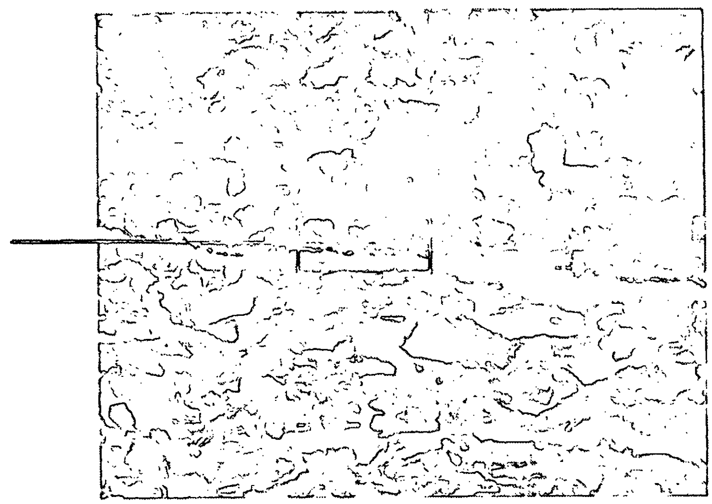


Figure 11 Crack produced during collection or specimen preparation.

12a



12b

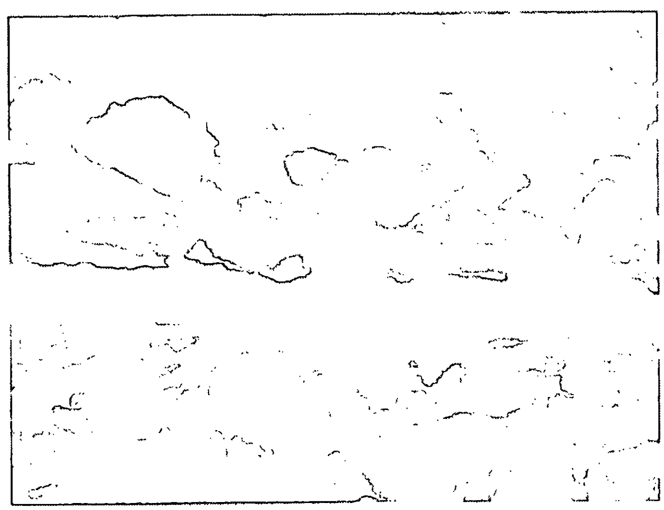
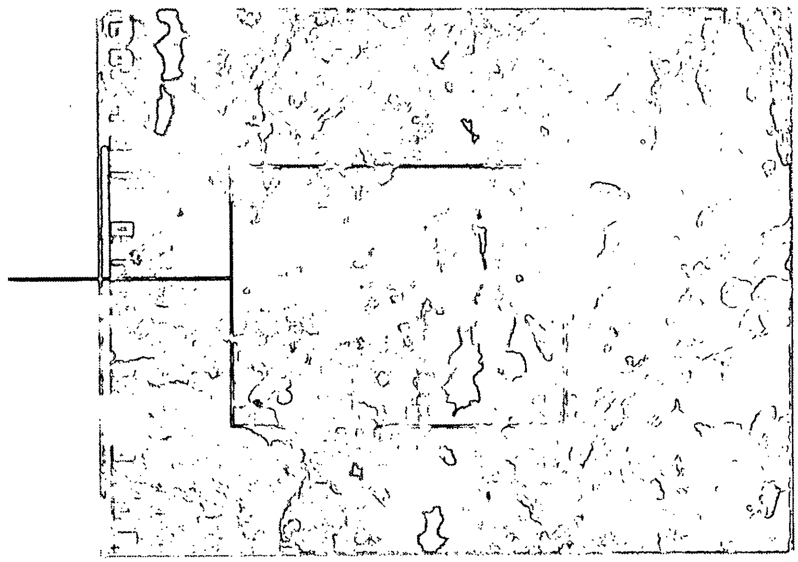


Figure 12 A typical microcrack in the Perry samples. This crack occurs along the boundary between the gouge zone and the adjacent country rock. The enlargement (12b) shows that new mineral growth has occurred with the crack, an indication that the crack was not disturbed during the collection and specimen preparation.

13a



13b

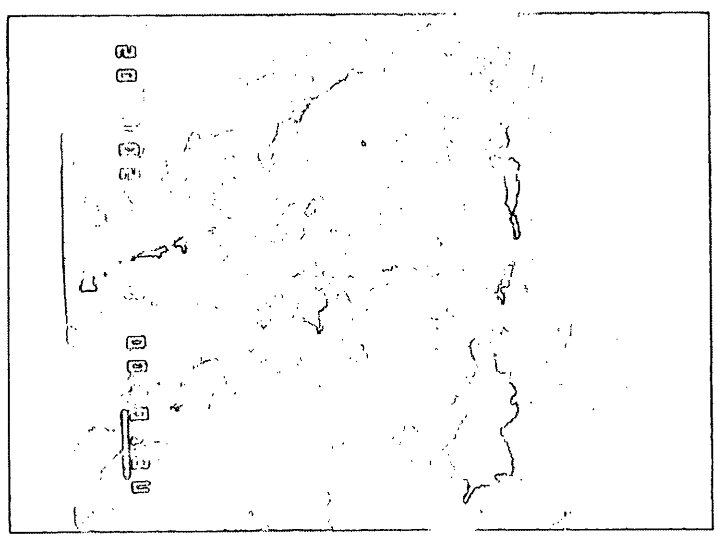
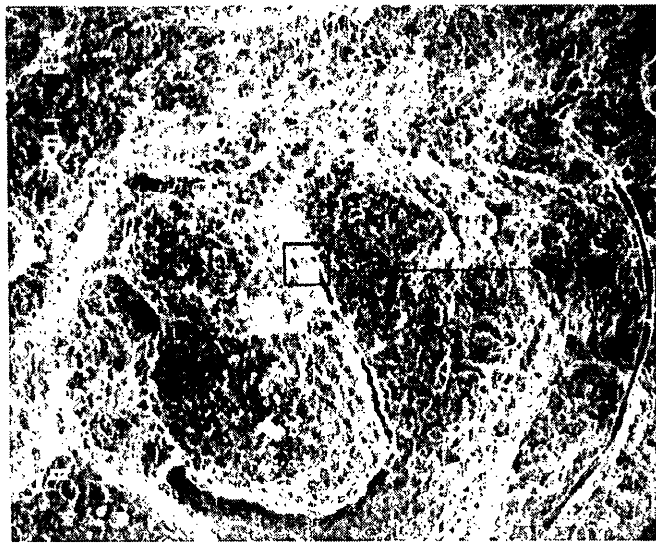


Figure 13 Microcrack in Perry sample. This variant for the microcracks in the Perry samples is relatively short and contains new mineral growths that span completely the microfracture. Note that many crystals can be seen projecting into the crack from the walls (13b).

14a



14b

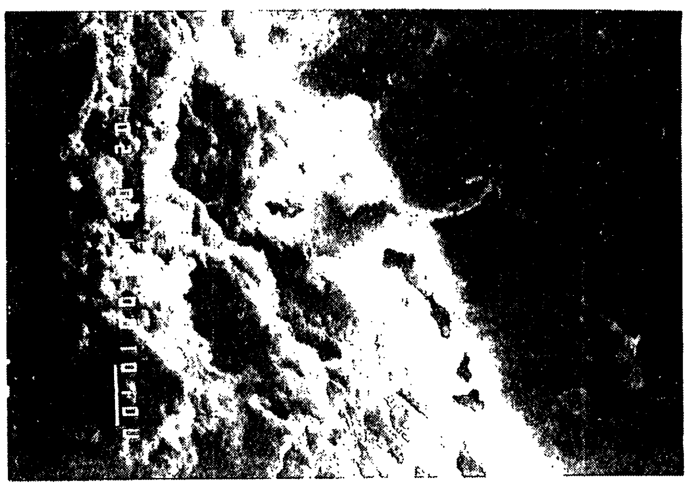
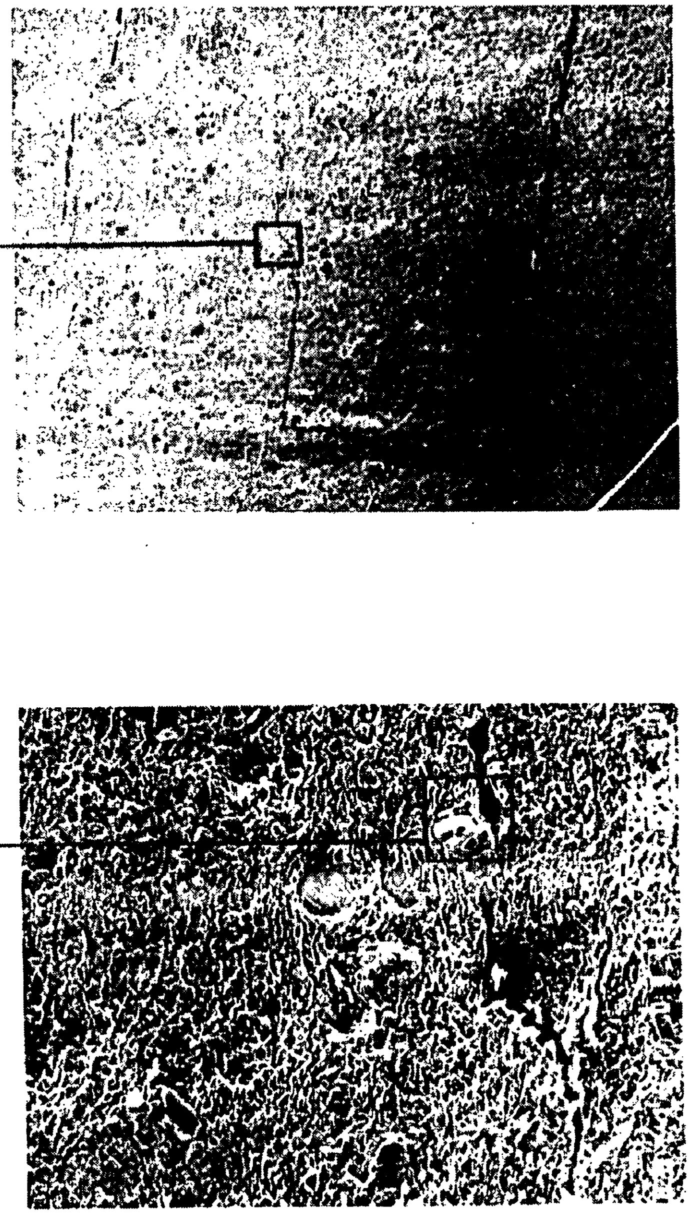


Figure 14 A microcrack in the Perry samples (14a) at higher magnification (14b).

15a

15b



15b

15c

Figure 15 Slickensides in the Perry samples. The slickensides appear to have been formed by pyrite grains that are stronger than the shale. In 15b and 15c individual grains of pyrite can be readily observed.

15c

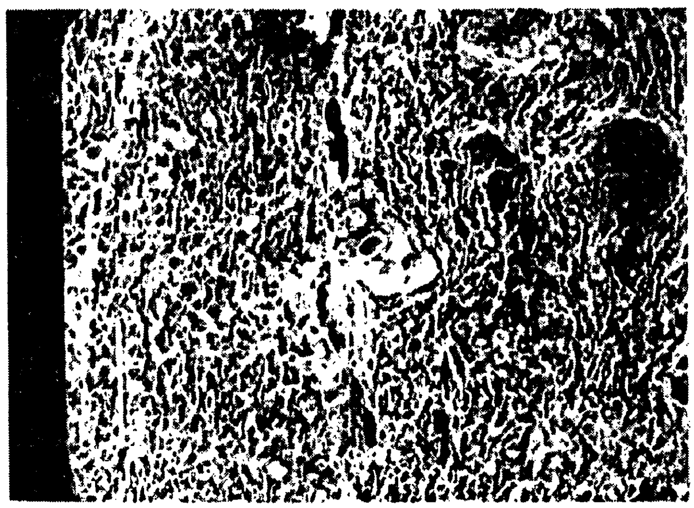


Figure 15 Slickensides in the Perry samples. The slickensides appear to have been formed by pyrite grains that are stronger than the shale. In 15b and 15c individual grains of pyrite can be readily observed.

<APPENDIX 2D B>

STUDY OF THE ISOTOPIC COMPOSITION OF WATER FROM THE FAULT

IN THE INTAKE AND DISCHARGE TUNNELS

AT THE PERRY NUCLEAR POWER PLANT

by

Dr. Gene Simmons

April 1979

APPENDIX 2D B

STUDY OF THE ISOTOPIC COMPOSITION OF WATER FROM THE FAULT IN THE INTAKE AND DISCHARGE TUNNELS AT THE PERRY NUCLEAR POWER PLANT

1.0 INTRODUCTION

A small fault was intersected by the intake tunnel for emergency cooling water at the Perry Nuclear Power Plant site. A small fault was also intersected by the discharge tunnel at the approximate location expected from the projection of the fault in the intake tunnel. Water enters each tunnel in the vicinity of the fault and its isotopic composition may be a useful guide to the vertical extent of the fault.

2.0 SUMMARY AND CONCLUSIONS

The isotopic ratios of D/H and $^{18}O/^{16}O$ were measured with a mass spectograph for three samples of water from the fault in the intake tunnel, one sample from the fault in the discharge tunnel, and two samples from Lake Erie. The three samples from the intake tunnel differ insignificantly from each other and from the sample from the discharge tunnel. The two lake samples differ insignificantly from each other. However, the waters from the fault(s) differ significantly from the lake water. All three samples are meteric.

The interpretation of the present set of data is that the 'fault water' is not Lake Erie water.

3.0 BASIS OF TECHNIQUE

The isotopic ratios of Deuterium to Hydrogen (D/H) and of Oxygen-18 to Oxygen-16 ($^{18}O/^{16}O$) in water have been shown to depend on the source of the water (e.g., Epstein and Mayeda, 1953; Craig, 1961). The ratios are measured with a mass spectrometer. Experimental details of the measuring techniques are given by Epstein (1959). The ratios are normally reported by differences relative to a standard defined by Craig (1961) and termed SMOW, an acronym derived from standard mean ocean water, where

$$\delta^{18}O = \frac{\left(^{18}O/^{16}O\right)_{spl} - \left(^{18}O/^{16}O\right)_{SMOW}}{\left(^{18}O/^{16}O\right)_{SMOW}} \times 10^{3} ‰$$

$$\delta D = \frac{\left(D/H\right)_{spl} - \left(D/H\right)_{SMOW}}{\left(D/H\right)_{SMOW}} \times 10^{3} ‰$$

and the subscript spl indicates values of the sample.

Craig (1961) showed that the isotopic variations in meteoric waters could be represented by the equation

$$\delta D = 8\delta^{18}O + 10$$

Figure 1 is a plot of his data.

Clayton et al. (1966) examined the isotopic ratios of saline waters from several sedimentary basins. Their data are summarized on Figure 2.

4.0 DATA AND DISCUSSION

The isotopic ratios relative to standard mean ocean water, SMOW, are given in Table 1. They are also shown on Figure 3.

TABLE 1

SAMPLE	δD_{SMOW} (0/00)	$\delta^{18}O_{SMOW}$ (0/00)
F1	-73.3 0/00	-11.5 0/00
F2	-73.5 0/00	-11.4 0/00
L1	-54.0 0/00	-7.4 0/00
L4	-52.3 0/00	-7.6 0/00
IF4	-70.6 0/00	-11.7 0/00
FD10	-79.3 0/00	-11.4 0/00

The isotopic ratios of all three water samples are near the Craig (1961) curve for meteric water. Therefore, the water from the fault is meteoric water.

The ratios for F1, F2 and IF-4 are very close to each other. If we take the differences to be an indication of experimental precision, then the isotopic ratios for the water from the fault in the discharge tunnel differ from the values for the intake tunnel by approximately the experimental error. We therefore conclude that the waters from the

fault(s) in the two tunnels have a common source, which is not Lake Erie. The data are consistent with a single fault intersecting both tunnels.

The ratio of the water from the fault differs significantly from the ratio of the sample of Lake Erie water. Sample L1 was collected near the lake surface, L2 near the bottom. Both samples were obtained near the projection of the fault in the intake tunnel dip to the lake bottom. On the basis that the isotopic ratios of the waters from the fault in both tunnels differ greatly from the ratio for water from Lake Erie, we conclude that the fault water is not Lake Erie water.

5.0 REFERENCES

Clayton, R. N., I. Friedman, D. L. Graf, T. K. Mayeda, W. F. Meents, and N. F. Shimp, 1966, "The Origin of Saline Formation Waters," J. Geophys. Res., 71, 3869-3882.

Craig, H., 1961, "Isotopic Variations in Meteoric Waters," Science, 133, 1702-1703.

Epstein, S., 1959, "The Variations of the O^{18}/O^{16} Ratio in Nature and Some Geologic Implications, in Abelson, P. H. (editor)," Researches in Geochemistry, John Wiley and Sons, New York, 217-240.

Epstein, S. and T. Mayeda, 1953, "Variation of O^{18} Content of Waters from Natural Sources," Geochimica et Cosmochimica Acta, 4, 213-224.

Faure, G., 1977, Principles of Isotope Geology, John Wiley and Sons, New York, 464 pp.

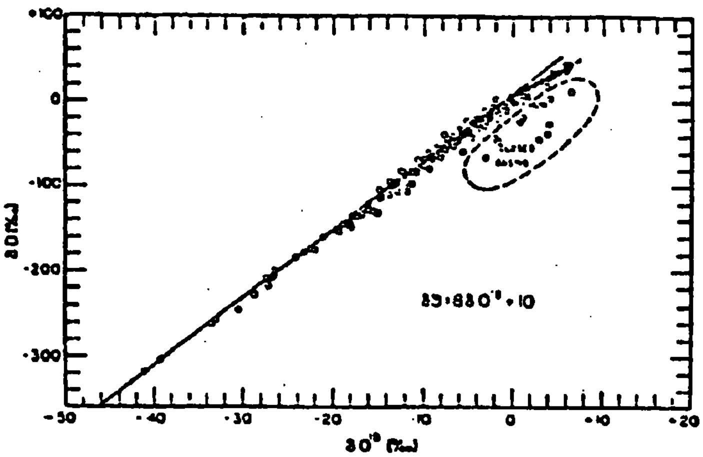


FIGURE 1 Deuterium and oxygen-18 variations in rivers, lakes, rain, and snow, relative to 'standard mean ocean water' (SMOW). Points which fit the dashed line at the upper end of the curve are rivers and lakes from East Africa. (After Craig, 1961)

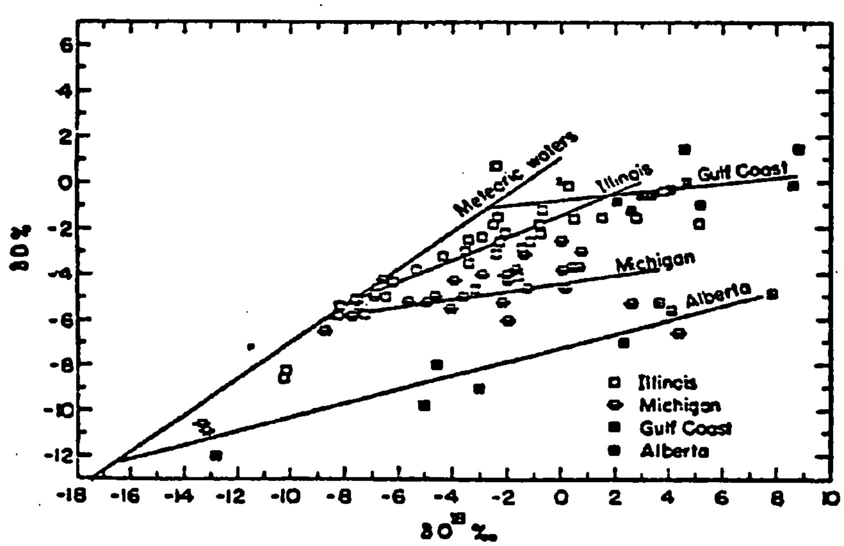


FIGURE 2 Isotopic compositions of brines. The 'meteoric waters' line is the line determined by Craig (1961) and shown on Figure 1. (After Clayton et al., 1966)

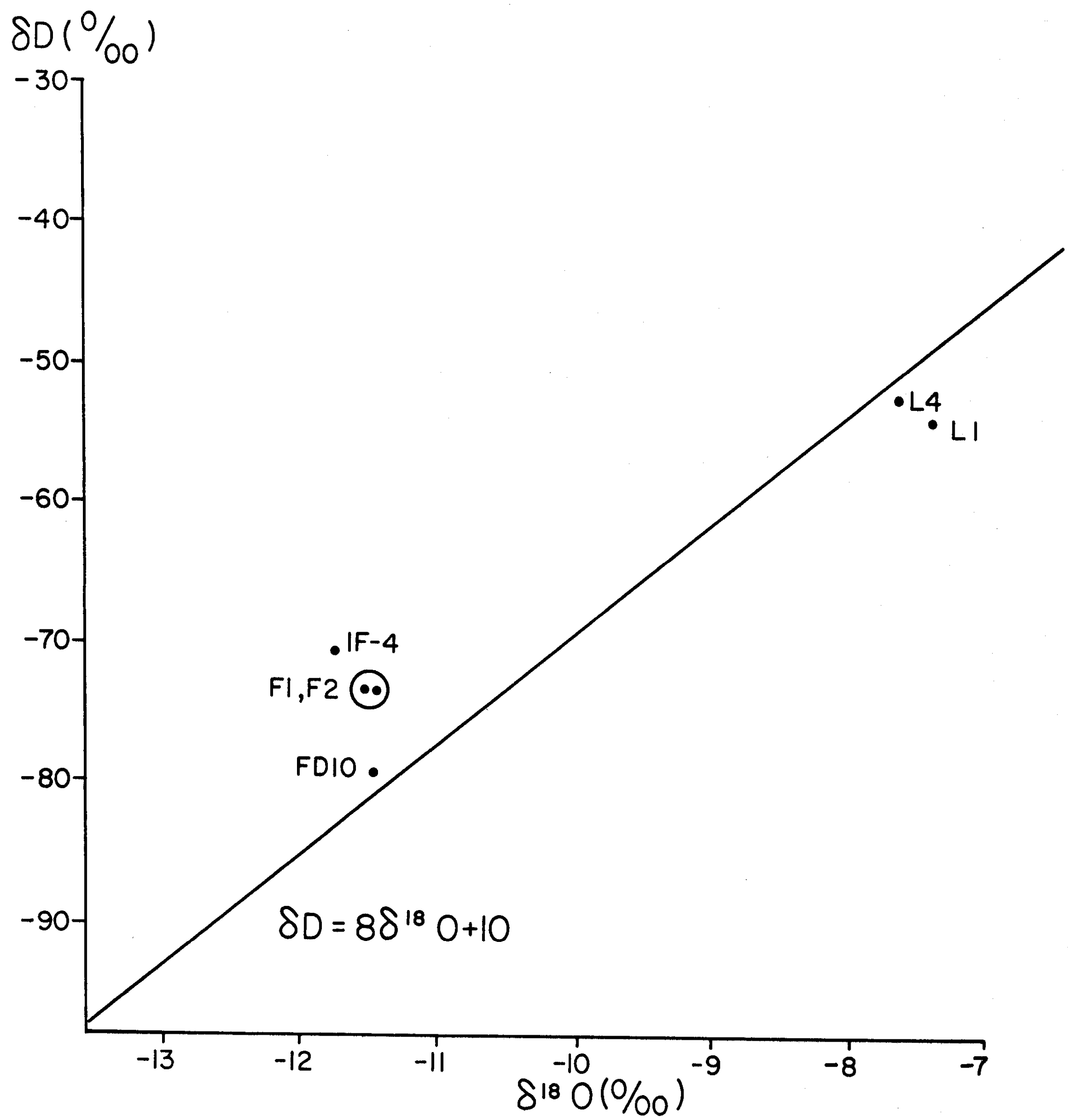


FIGURE 3 Isotopic compositions of the waters from PNPP. F1, F2, and IF-4 denote samples from the fault in the intake tunnel. FD10 denotes water from the fault in the discharge tunnel. L1 and L4 denote water from the top and bottom, respectively, of Lake Erie.

<APPENDIX 2D C>

GEOPHYSICAL METHODS

prepared by

WESTON GEOPHYSICAL CORPORATION

April 1979

APPENDIX 2D C

GEOPHYSICAL METHODS

1.0 INTRODUCTION

The following sections discuss the geophysical techniques employed during the investigation of the fault discovered in the intake and discharge tunnels at the Perry Nuclear Power Plant site. These techniques include magnetics, gamma radiation, logging, and in situ velocity measurements.

2.0 THE MAGNETIC METHOD

The magnetic method is a versatile, relatively inexpensive, geophysical exploration technique. Magnetic data can be acquired on land, over water, or in the air. Aeromagnetic surveys and deep water marine studies are commonly used as a reconnaissance tool for tracing large-scale geologic structure, especially basement depth. Land and coastal water marine data are more useful in tracing smaller, more localized geologic structures, such as mineral and ore deposits, and for detailed geologic structural modeling. Land and coastal water marine surveys yield more detail and higher resolution, since the measurements are taken closer to the anomaly source. Land magnetic data can also be used to locate buried, man-made structures such as pipelines and tunnels, and for archaeological prospecting.

2.1 EARTH MAGNETISM

Magnetics, like gravity, is a “potential field” method. For a given magnetic field, the magnetic force in a given direction is equal to the derivative of the magnetic potential in that direction. The source of the earth’s magnetic potential is its own magnetic field $(\vec{F})$ and the

inducing effect this field has on magnetic objects or bodies above and below the surface. The earth's field is a vector quantity having a unique magnitude and direction at every point on the earth's surface. This magnetic field is defined in three dimensions by angular quantities known as declination and inclination. Declination is defined as the angle between geographic north and magnetic north, and inclination is the angle between the direction of the earth's field and the horizontal. The earth's total magnetic field is measured in "gammas" (γ) (where 1 gamma = 10^{-5} Oersted) and varies from about 25,000 gammas near the equator to 70,000 gammas near the poles.

The earth's magnetic field is not completely stable. It undergoes long term (secular) variations over centuries; small, daily (diurnal) variations (less than 1% of the total field magnitude); and transient fluctuations called magnetic storms resulting from solar flare phenomena.

The earth's ambient magnetic field can be modified locally by both naturally-occurring and man-made magnetic materials. There are two types of magnetism involved: induced and remanent.

In the case of induced magnetization, the earth's ambient field is enhanced by materials which can behave like a magnet when an external magnetic field is applied.

Crustal rocks become "magnetic" due to the presence of magnetic particles, usually magnetite or related iron oxide minerals, in their compositional structure. These particles act as small dipoles, which can be uniformly oriented by an external magnetic field, making the host rock "susceptible" to magnetic induction by the earth's field.

These "susceptible" rocks (or any magnetic object) will thus receive an "induced" magnetic field $(\vec{H})$, which represents a local perturbation in the main earth field. The net field $(\vec{F}_t)$ in the vicinity of this

perturbation is simply the vector sum of the induced and earth fields. Although the induced field is not necessarily parallel to the ambient field, for cases where $|\vec{H}| \leq .25\,|\vec{F}|$, which is generally true for most geologic applications, the directional difference between the net field $(\vec{F}_t)$, and the ambient field $(\vec{F})$ is negligible. Thus, the induced field really serves to enhance the ambient field. The degree to which the ambient field is enhanced is a function of the "susceptibility" of the material, or its ability to act like a magnet.

Remanent magnetization is produced in materials which have been heated above the Curie point allowing magnetic minerals in the material to become aligned with the earth's field before cooling. The remanent field direction is not always parallel to the earth's present field, and can often be completely reversed. The remanent field combines vectorially with the ambient and induced field components. The contribution of the remanent components must be considered in magnetic interpretations.

2.2 INSTRUMENTATION

At present, the most widely used magnetometer is the "proton precession" type. This device utilizes the precession of spinning protons of the hydrogen atoms in a sample of fluid (kerosene, alcohol or water) to measure total magnetic field intensity.

Protons spinning in an atomic nucleus behave like tiny magnetic dipoles, which can be aligned (polarized) by a uniform magnetic field. The protons are initially aligned parallel to the earth's field. A second, much stronger magnetic field is produced approximately perpendicular to the earth's field by introducing current through a coil of wire. The protons become temporarily aligned with this stronger field. When this secondary field is removed, the protons tend to realign themselves parallel to the earth's field direction, causing them to precess about this direction at a frequency of about 2,000 Hertz. The precessing

protons will generate a small electric signal in the same coil used to polarize them with a frequency proportional to the total magnetic field intensity and independent of the coil orientation. By measuring the signal frequency, one can obtain the absolute value of the total earth field intensity to a 1 gamma accuracy. The total magnetic field value measured by the proton precession magnetometer is the net vector sum of the ambient earth's field and any local induced and/or remanent perturbations.

The total field proton precession magnetometer is portable and does not require orientation or leveling, as is required with vertical field instruments. There are a few limitations associated with the precession system, however; the precession signal can be severely degraded in the presence of large field gradients (greater than 200 gammas per foot) and near 60-cycle AC power lines; also, interpretation of total field data is somewhat more complicated than for vertical field data.

2.3 FIELD TECHNIQUES

In the field, the operator must avoid any sources of high magnetic gradients and alternating currents, such as power lines, buildings and any large iron or steel objects. The operator should also avoid carrying any metal articles. Readings are taken at a predetermined interval which depends on the nature of the survey, the accuracy required and the gradients encountered. Base station reading, if required, are usually made several times a day to check for diurnal variations and magnetic storms.

Depending on survey requirements, one should determine the magnetic susceptibility and remanent magnetism for the rock units in the survey area. If this information is not available, several representative rock samples should be collected and analyzed. One must properly mark the in situ orientation of these samples with respect to north direction and

horizontal plane. Susceptibility and remanent field measurements are obtained using standard laboratory techniques.

2.4 INTERPRETATION

Lateral variations in susceptibility and/or remanent magnetization in crustal rocks give rise to localized anomalies in the measured total magnetic field intensity. Geologic structural features (faults, contacts, intrusions, etc.) which correlate with susceptibility and/or remanent magnetization variations will cause magnetic anomalies, which can be measured and interpreted to quantitatively define the geometry of this causative structure.

After diurnal effects and regional gradients have been removed, magnetic anomalies can be studied in detail; derivative operations and frequency filtering can be employed.

Because it is a potential field method, there is an infinite number of possible source configurations for any given magnetic anomaly. There is also an inherent complexity in magnetic dipole behavior. Remnant field effects further add to the complexity. But if the various magnetic field parameters (inclination, declination and susceptibility) are well defined, and some reasonable assumptions can be made regarding the nature of the source, an accurate source model can generally be derived.

Magnetic anomalies can be analyzed both qualitatively and quantitatively. The physical dimensions of an anomaly (slope, wavelength, amplitude, etc.) often reveal enough to draw some general qualitative conclusions regarding the causative source.

Precise interpretation must be done quantitatively, however, and there are two basic approaches, each ideally requiring prior knowledge of earth and remanent magnetic field parameters. Modeling can be performed by various approximation methods, whereby one reduces the source to a

system of poles or dipoles, or assumes it to be one of several simple, geometric forms (vertical prism, horizontal slab, step, etc.). The magnetic properties for this simplified model can be rather easily defined mathematically. Simple formulas can be derived which relate readily measurable anomaly parameters, such as slope, width and amplitude ratios, to the general dimensions of the anomaly source, including depth to top, thickness, dip, and width normal to strike. Since these methods involve very limiting geometric assumptions, the results can only be treated as good approximations except for very simplified sources.

The second and more accurate quantitative method utilizes computer iteration techniques to directly calculate the resultant magnetic anomaly for a two- or three-dimensional geometric model constructed to fit the expected geologic source. This method allows one to develop by trial and error a model whose calculated magnetic field anomaly matches the observed anomaly as closely as possible.

In both two- and three-dimensional computer modeling, the source body is spatially defined by one or more n-sided polygons. In the two dimensional case, a vertical polygon of infinite length in a direction normal to the magnetic profile is used to define the source. Each polygonal segment then represents the vertical edge of a rectangular prism, which is infinitely long in the profile direction. The magnetic effect of each of these prisms is computed and summed with appropriate sign convention to give the net magnetic effect of the body circumscribed by the polygon, and thus, the magnetic anomaly.

In three dimensions, a series of horizontal polygons are stacked vertically to define the source. The net magnetic effect for the total volume is then obtained by computing the effect of each polygon, integrating it over the vertical extent of the body, and summing the results for all of the polygons used. The polygonal geometry allows a

great deal of flexibility in defining an anomaly source and can encompass a wide range of geologic forms.

3.0 GAMMA RADIATION LOGGING

3.1 PURPOSE AND BACKGROUND

Gamma radiation logging can provide an efficient method for correlating geologic units in uncored boreholes. The logging probe measures gamma radiation resulting from the natural radioactivity of the uranium (U), thorium (Th), and potassium (K^{40}) in nearby bedrock or soils. Although the radiation from either the U or Th series is much greater than that of K^{40}, the background radiation from each element is approximately equal because the potassium isotope is far more common.

The intensity of gamma radiation decreases rapidly as it passes through a material. This attenuation is exponential and dependent on the energy of the radiation and absorption coefficient of the particular material. For the average energy of natural radiation, the range of penetration in sediments is roughly 1 foot with about half the gamma rays detected in the borehole originating within 5 inches of the borehole wall.

The natural radioactivity in sedimentary rocks and metamorphosed sediments is generally higher than that in igneous and other metamorphic types, with the exception of potassium-rich granites. In sediments, the gamma ray log reflects mostly shale content because radioactive elements tend to concentrate in clays and shales; sands and carbonates usually have low radioactivity. Subtle changes in rock composition not readily apparent to the inspecting geologist may be revealed by the gamma ray log.

3.2 EQUIPMENT AND PROCEDURE

The logging system consists of a probe containing a scintillation crystal and photomultiplier tube, an electronic counting unit, a strip chart recorder with variable scale settings, and a power winch.

Gamma radiation incident on the scintillation crystal is converted to light through interaction with the crystal. This light enters a photomultiplier tube where it is converted to a pulse of electricity which is conditioned and transmitted through the cable to the counting unit. The average number of pulses per time unit (seconds or minutes) is plotted versus depth on the strip chart recorder.

In logging, the probe is lowered to the bottom of the borehole and measures the radiation as it is raised. Boreholes are generally logged twice to determine the "repeatability" of the data.

Statistical variations in radiation emission, significant at low counting rates, can generally be smoothed out by integration over a short time interval. If the hole is logged too quickly, however, the smoothing effect leads to erroneous results, and data are shifted in the direction of logging. The logging speed must be adjusted for the bed thicknesses and radiation levels. The length of the detector (the scintillation crystal) with respect to the bed thickness also affects the shape of the resulting log. Optimum resolution for thin beds is obtained with a short detector and a slow logging speed.

3.3 INTERPRETATION

The interpretation of gamma logs is relatively straightforward. The interface between beds of different natural radioactivity can be located with reasonable accuracy if it is assumed to occur halfway between the

two count levels for thick beds (<6 ft). For thinner zones, the location of the maximum count rate can be taken as the center of the zone.

In making correlations, all available geologic information is taken into consideration. This includes unit thickness and composition, and position in the geologic column. The gamma ray log displays this information in the form of the radiation level within a particular unit, as well as the gamma ray signature for that unit (the frequency of minor deviations from the average radiation level). If other geophysical information is available, it is also considered in the final interpretation.

4.0 IN SITU VELOCITY MEASUREMENTS

4.1 PURPOSE

In situ velocity measurements provide a reliable determination of material properties. The velocity measurements together with known or estimated densities are used to determine the dynamic elastic moduli of the material. It is necessary to obtain the data on material in place; velocity measurements made with laboratory samples may be strongly effected by alteration of the material in obtaining the sample, and by differences between the in situ and test-imposed stress conditions.

4.2 EQUIPMENT AND PROCEDURE

In situ velocity measurements are based on the determination of the time required for elastic waves, generated at a point source, to travel to a series of vibration-sensitive devices (geophones or seismometers). For in situ velocity measurements, usually the geophones contain three orthogonal seismometers, one vertical and two horizontal. These three components allow the seismologist to estimate the mode of vibration of the material in the vicinity of each geophone.

Seismograms are obtained using a portable 12- or 24-channel seismograph system which amplifies and filters the seismic signal detected by the individual geophones and provides a photographic record for each of the 12 channels (Figure 2D C-1). Timing lines are provided across the entire recording at two-millisecond intervals allowing direct reading to one millisecond. The seismograph is equipped so that the background noise level can be observed for all geophones simultaneously, enabling the operator to determine if the noise level is sufficiently low to minimize trace interference.

Depending on the requirements of the survey and specific site conditions, in situ velocity measurements are acquired in a number of ways, depending upon the deployment of source and geophones (Figure 2D C-2):

1. source and receivers in different boreholes (cross-hole);

2. source in borehole and receivers on the surface (up-hole);

3. source on the surface and receivers in borehole (down-hole);

4. high frequency source and receivers in the same hole (sonic logging);

5. source and receivers in tunnel; or,

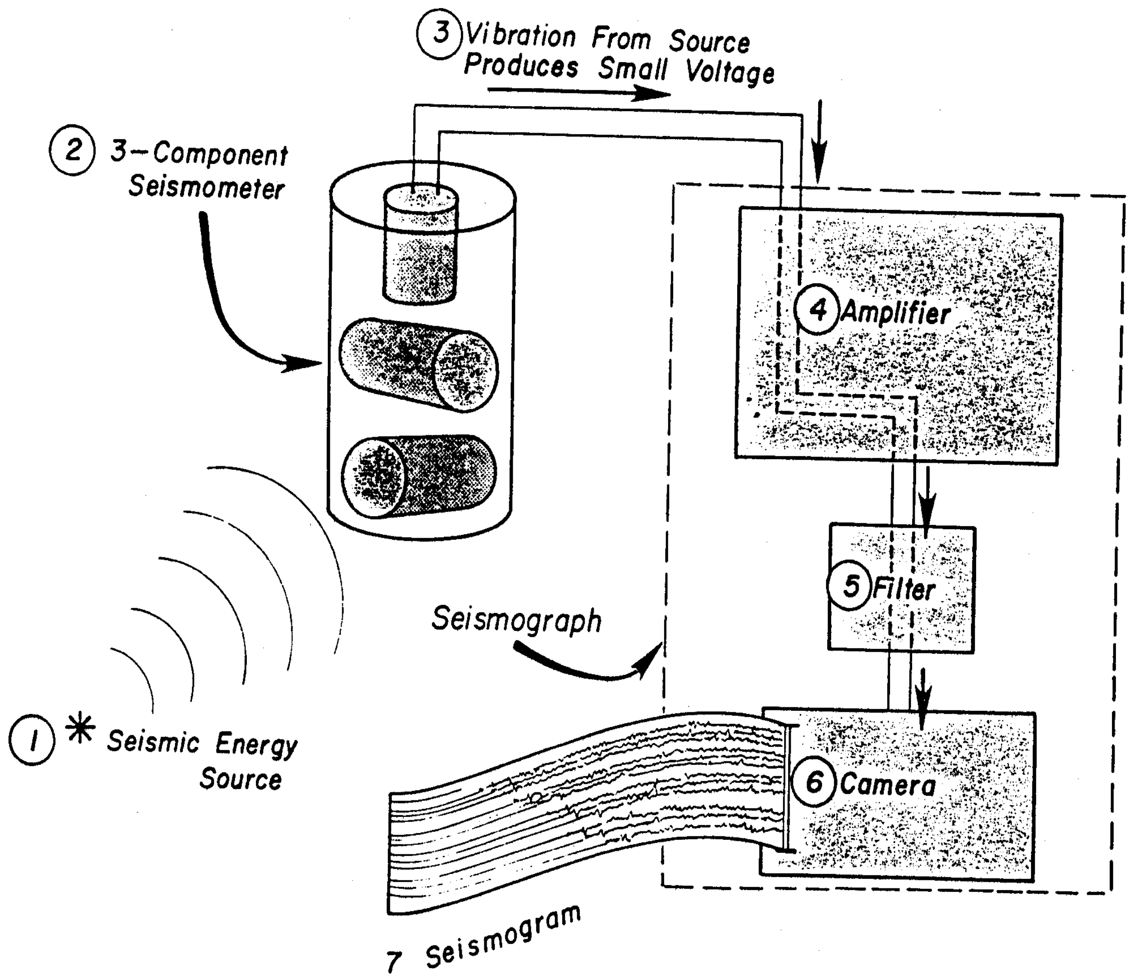
6. source and receivers on surface.

4.3 <u>INTERPRETATION</u>

The interpretation involves picking the arrival times of two forms of seismic waves at each geophone and determining the relationship between arrival times for each wave type. The two waves are the compressional ("P") wave and the shear ("S") wave. The "P" wave is transmitted as a

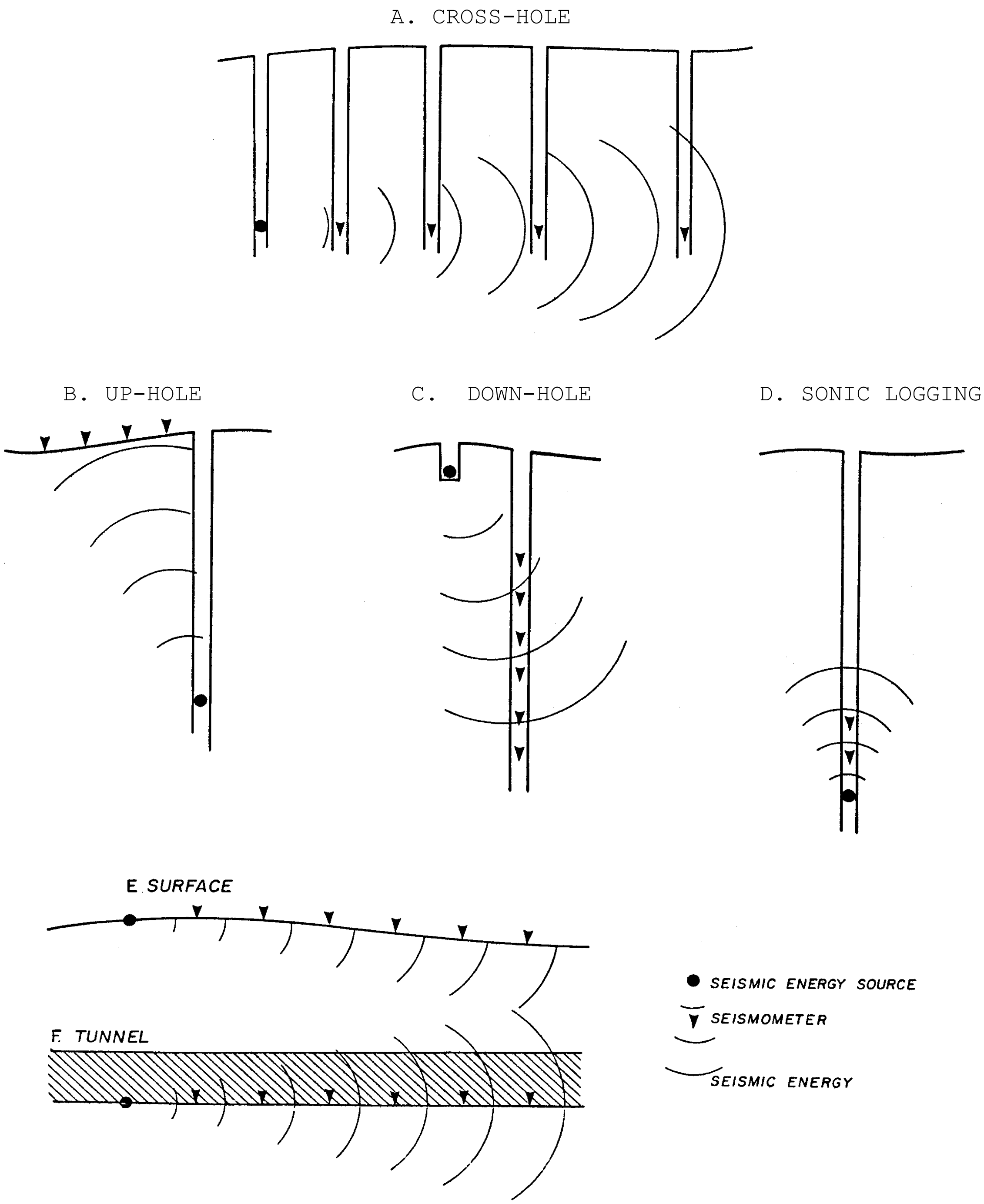
series of compressions and rarefactions, and the particle motion is parallel to the direction of propagation. The “S” wave, on the other hand, exhibits a particle motion perpendicular to the direction of propagation. Therefore, the information on particle motion given by the three-component seismometers can be used as an aid in determining the wave type of arrivals.

When the arrival times are plotted against distance from the source, the velocity of the material is determined by the inverse slope of the best linear fit to the data.



Seismic Instrumentation

Figure 2D C-1



In Situ Velocity Measurements

Figure 2D C-2

<APPENDIX 2D D>

EVALUATION OF LOCAL SEISMICITY

AROUND THE PERRY NUCLEAR POWER PLANT SITE

Prepared by

WESTON GEOPHYSICAL CORPORATION

September 21, 1979

LIST OF TABLES

EVALUATION OF LOCAL SEISMICITY AROUND THE PERRY NUCLEAR POWER PLANT SITE

INTRODUCTION

This Appendix presents additional information on the historical seismicity in the immediate vicinity of the site. The current guidelines for the Safety Analysis Report format suggest that all events with an intensity greater than IV(MM) or a magnitude greater than 3.0 be included. Such guidelines have been used in the USAR for the site region. Within the context of the fault studies, the Applicant has considered that it would be useful to go beyond the guidelines and examine all known events, regardless of size, within 50 miles or so from the site.

Smaller historical events, particularly those of the pre-instrumental era, are more likely to be inaccurately evaluated in terms of location and size. Felt reports, whether they were evaluated according to the Rossi-Forel or the Modified Mercalli scales, are always open to serious biases: population distribution, local construction practices and above all, local soil amplification. In the present case, because of the site location near Lake Erie, numerous reporting localities are close to the shorelines where soil effects can locally amplify ground vibrations. Local amplification of earthquake ground vibrations yield felt reports that can alter the true location and size of the event.

Richter (1956, P. 144) was very aware of these biases when he wrote: "The practice in the absence of seismographs, of drawing isoseismals and then locating an epicenter at the center of figure should be discontinued. In the majority of cases the instrumentally located epicenter proves to be at one side of the meizoseismal area." Clearly this strong statement should be kept in mind by anyone looking at epicentral maps where most of the events are purely historical, with coordinates obtained either from only few felt reports or from isoseismals that are poorly defined. Once an epicenter has been given

coordinates and is plotted for display purposes, the tendency is to accept it at face value. A spontaneous reaction of the analytic mind is to study the distribution of these points plotted on a map, and attempt to recognize patterns (e.g., clusters, alignments, etc.). After the above words of Richter, such a spontaneity cannot claim to be scientific unless an explicit effort is made to estimate the uncertainty attached both to individual epicenters and assumed patterns.

It is the objective of this Appendix to present the supporting evidence of epicentral locations and assignment of intensities, discuss some uncertainty estimates and draw some conclusions.

DATA BASE

The cumulative historical seismicity presented here is taken from Weston Geophysical's earthquake data base. This data base, which covers a much broader geographical region than the one investigated for the Perry site, has been developed through the last decade by incorporating many published sources and complementing these data with additional research. Through a parallel compilation of major catalogs and listings, typographical errors have been detected, duplications corrected, and significant discrepancies identified and noted for further investigation. Major sources included are United States Earthquakes, Earthquake History of the United States, the Publications of the Dominion Observatory, and the Seismological Series of the Earth Physics Branch (both of Canada), bulletins of major seismic networks such as those of Weston Observatory, the Lamont-Doherty Observatory, St. Louis University, and the New England Seismological Association. Important listings such as those by Mather and Godfrey (1927), Brigham (1871), Brooks (1960), Docekal (1970), Nuttli (1974), Nuttli and Herrmann (1978), Hopper and Bollinger (1971), Bollinger and Hopper (1972), Bollinger (1969, 1973), etc. are also included. Supplementary information for many historical events has also been collected from newspapers, town histories, private diaries, scientific papers,

technical reports, etc. Through a critical review and evaluation of the above material, a selected set of parameters was adopted for each event included in the data base.

Completeness and Reliability

In considering the cumulative seismicity of a region in terms of seismic risk assessment, it is necessary to examine the completeness and reliability of the data set. Because earthquakes are characterized either by their epicentral intensity or their magnitude, and are located by analyzing isoseismal contours and/or instrumental recordings, the spatial and temporal distributions of population and/or seismographic stations influence the number, size and location of reported events. It is almost impossible to get a homogeneous data set over a long period of time, as both factors, population and networks, constantly change. As long as proper thresholds and uncertainties are kept in mind, the data set is still most informative.

Even though major catalogs carry entries dating back to more than three centuries for some parts of eastern North America, in no way should one assume that completeness was achieved in these early years, except for a very high threshold, i.e., Intensity VIII or IX(MM). For the region presently under consideration, it is more realistic to assume that the seismic history is relatively complete over the last 160 to 200 years for events that would be significant in terms of structural design, i.e., with intensities equal to or greater than VII(MM). This period is long enough to provide an extremely useful insight on the local seismic regime.

The reliability of early historical data depends greatly on the population density and the construction practices in the area around the epicenters. A lack of population in the true epicentral area of an event, for example, can lead to that epicenter being mislocated in the populated region where the maximum intensity level was reported. Besides shifting true locations, a lack of an evenly distributed population can also result in underestimated epicentral intensities. The opposite bias can occur in cases where felt reports come only from

communities settled along river banks which characteristically experience enhanced ground motion due to the soil column, or where poor construction practices prevail. In cases of structural damages, one must remember that construction standards have substantially improved with centuries. A narrow application of the Mercalli scale to reports of fallen chimneys, for example, without due consideration for these basic differences in masonry can result in overestimated seismic events for the early period.

<Figure 2D D-1> and <Figure 2D D-2> show the progressive historical migration of the population, both in the eastern United States and Canada. Even though the westward migration with time is predominant, the regions around Lake Erie, in both countries, show relatively earlier settlements. By the early 1800's, the region in the immediate vicinity of the site was settled, even though not densely populated. It should be noted that the earliest reported events, within 50 miles of the site, occurred in 1823 and 1836, both of Intensity IV(MM). Taking into account the distance spread between settlements, events reported during the first half of the 19th Century must be given an uncertainty in location of the same order (several tens of miles). The assigned intensities may have been the actual epicentral intensities, but conceivably in some cases, they could have been maximum felt reports of slightly larger events located between settlements. Such population bias could not have resulted in an error larger than two intensity units. With the increasing population in the second half of the century, this uncertainty, both in location and intensity, can be safely reduced in half. In all likelihood, completeness above the Intensity VI(MM) threshold has been achieved for as long as 150 years in the immediate site area.

The instrumental era beginning around 1900 brought some improvements to the quality of seismological data, particularly with respect to epicentral location. Yet for the first half of the century, many epicenters continued to be located mostly on the basis of felt reports. Determination of magnitudes for regional events in California was initiated during the thirties, but not used for eastern earthquakes

until the forties and fifties. For the site region, from the start of the century and up to the sixties, only a few seismographs operated simultaneously, both in the United States and Canada. These few stations were part of regional networks operated by the Jesuit Seismological Association (JSA), the Canadian government, and some American colleges and universities. The closest seismographic station to the site was at John Carroll University in Cleveland. Even though this station was one of the first to operate in the east, it remained plaqued with shortcomings for many decades. The first seismograph purchased in 1910 was a Weichert, with a natural period of 7 seconds and a magnification of 80; it certainly was not suited to detecting and locating small local events. The history of the station by Macelwane (1950) refers to the fact that "during the latter half of the twenties, seismograms became less and less accurate due to the increase of traffic and industrial disturbances in the neighborhood." In the thirties, recordings were interrupted for some years, because of campus relocation and water seepage making the new vault unusable. After another relocation, the Weichert was operational from 1937 to 1947, when finally a short-period vertical and two long-period horizontal instruments were purchased. Two short-period horizontal instruments were obtained in the early fifties, finally making the station equipped for the recording of local earthquakes. In these early decades, numerous factors such as the type of instrumental response, lack of good time control, awkward geographic configuration, minimal exchange of data, use of graphical methods, and limited knowledge of crustal velocities remained potential sources of errors and uncertainties in the epicentral coordinates.

LOCAL SEISMICITY EVALUATION

Most seismic events located within 50 miles or so from the site, as reported in the standard earthquake catalogs, can be called "historical" in the strict sense, inasmuch as they occurred in the Nineteenth Century and the first half of the Twentieth Century, well before any adequate instrumental coverage of the region.

The historical evidence supporting some of the earlier cataloged events was found to be minimal, judging from the reference presented in standard catalogs. Because local seismicity patterns can reveal important elements of local tectonics, a special task was undertaken to examine the available evidence on each local seismic event, and a systematic effort was made to acquire additional pertinent information.

The initial phase of the research consisted in establishing what local newspapers were published in northeast Ohio, the exact period of their existence, and above all, where they might be available for consultation. A research matrix was prepared <Figure 2D D-3> where rows represent earthquakes to be investigated and columns indicate local newspapers.

The files of individual earthquakes were inventoried and the matrix elements filled, in order to prepare an effective onsite search at local libraries and archives for the missing elements. Table 1 lists all local repositories of newspaper collections that were visited in the survey. Newspapers determined to be pertinent to any one earthquake were researched commencing on the date that the earthquake occurred. This scanning continued though the following issues until datelines of dispatches reasonably indicated that further information pertaining to the earthquake would not be forthcoming. References to the event were xeroxed, whenever possible, or handcopied.

The second phase consisted in a careful review of assembled material. Individual files consist first in a parallel compilation of all available catalog entries and, secondly, in all additional references, newspapers, sources, etc. These additional references were individually evaluated according to the Modified Mercalli intensity scale. Whenever the felt reports covered a large enough area, maps were produced. Estimated epicentral locations are indicated by open circles on these maps. In other cases where only a few data points were available, approximate epicenters were associated with the location of the largest felt reports.

In some instances where local newspapers made reference to instrumental recordings from the John Carroll station, seismograms were

borrowed for examination. This review of the instrumental data turned out to be very enlighting, and will be discussed later within the individual earthquake evaluations.

The final phase consisted in the selection of a set of earthquake parameters and the writing of a brief synthetic evaluation for each event. These were used to produce the local seismicity map <Figure 2D D-4> and the corresponding local seismicity catalog (Table 2). In Table 3, some events with dubious origin and/or dubious coordinates are listed for sake of completeness. These events are not plotted on <Figure 2D D-4>.

The newspaper information collected for each event is presented in this Appendix, as it is needed to support certain changes in epicentral estimates and intensity reports. The information from standard catalogs has been transcribed in only a few cases, since it is assumed available to the reader.

Summary evaluations and compilations of accounts are now presented in chronological order. Revised parameters are flagged by the letter "R."

A general discussion of the seismicity and some brief conclusions will follow the individual evaluations.

EARTHQUAKE OF MAY 30, 1823

EPICENTRAL INTENSITY: II-III(MM) (R)

LOCATION: 42.5N, 81.0W (R)

EVALUATION:

The location and intensity of this event had been mysterious and uncertain. Smith was the first to assign coordinates (41.5N, 81.0W). The reasons for choosing those particular ones, in the Unites States, away from the shore, were not expressed. If one compares Smith's listing with that of Brigham, listed as a reference, it is not certain that Smith's interpretation is faithful. Brigham does not explicitly link the rise in water level to the occurrence of the "slight shock." Possibly, a sudden rise of the water level is normal in May. A rise in water level should not be confused with a tsunami or a seiche.

If another reference given by Smith, i.e., that of Dawson, is examined carefully, one finds that he considered the location to be in Canada, on the shore of Lake Erie. Such a location would be better approximated by 42.5N, 81.0W (near the Canadian shore). It seems that a typographical error must have been incorporated into Smith's listing, making it 41.5N, a location in the United States which is difficult to reconcile with his sources. It is thus suggested that the coordinates be revised to 42.5N, 81.0W.

Finally, it is not customary to translate "slight shock" into an Intensity IV (Smith, 1962). This event should be regarded as an Intensity II-III at the most. The uncertainty of location remains large; ±1/2° is suggested. Whenever Smith uses ".5°" or ".0°" for historical events, he does so in order to show an uncertainty of ±1/2°.

COMPILATION OF ACCOUNTS:

Brigham, W. T., 1871, "Volcanic Manifestation in New England," Memoirs of the Boston Society of Natural History, V. 2, pp. 1-28.

"In 1823, May 30, the water rose nine feet in Lake Erie; a slight shock."

Dawson, Sir J. W., 1864, Notes on the Earthquake of October, 1860, The Canadian Naturalist and Geologist, V. 5. pp. 363-372.

"In 1823, May 30, Canada, On shore of Lake Erie, slight but water of lake rose to height of 9 feet."

Smith, W. E. T., 1962, Earthquakes of Eastern Canada and Adjacent Areas 1534-1927, Publications of the Dominion Observatory, V. 26, No. 5.

"1823 May 30, IV. 41.5N, 81.0W. On the shore of Lake Erie. Slight shock but water rose to a height of nine feet."

EARTHQUAKE OF JULY 8, 1836

CA: 21:15 (LOCAL)

EPICENTRAL INTENSITY: IV(MM)

LOCATION: 41.5N, 81.7W

EVALUATION:

This event was clearly an earthquake; it was reported felt in Cleveland and vicinity with a maximum Intensity IV, according to the Cleveland Advertiser report. It was felt in Elyria with an Intensity III, and not reported in the Painesville and Ashtabula newspapers. The coordinates assigned are those of the city of Cleveland (41.5N, 81.7W). An uncertainty of ±15 miles is suggested here in view of the poor definition of the area where the Intensity IV was felt ("Cleveland and vicinity"). The correct date is assumed to be Friday, July 8, on the basis of the Cleveland Herald and Elyria Republican. Somehow, the text of the Cleveland Advertiser must have been written much prior to the day (14th July) of publication. July 14 was a Thursday.

COMPILATION OF ACCOUNTS:

Cleveland Advertiser, Cleveland, Ohio, July 14, 1836

> "Earthquake-Between the hours of 9 and 10 o'clock last evening a shock of an earthquake was experienced in this place and its vicinity which although of momentary duration was of such force and extent as to leave no doubt of its nature. The effect of it in the room where we were sitting was to jar the windows and furniture as if a heavy body had fallen in the room above. The shock was accompanied and succeeded by a dull rumbling sound."

Elyria Republican and Working Mens Advocate, Elyria, Ohio, July 13, 1836

> "Earthquake.-About 15 minutes past 9 o'clock on Friday evening last, our citizens felt a smart shock of an earthquake accompanied with a distant rumbling noise. The motion of the earth was quite perceptible."

Cleveland Herald, Cleveland, Ohio, July 9, 1836

> "A slight shock of an earthquake was experienced in this city last evening between the hours of 9 and 10."

EARTHQUAKE OF OCTOBER 1, 1850

CA: 10:25 (GMT)

EPICENTRAL INTENSITY: IV(MM)

LOCATION: 41.5N, 81.7W (R)

EVALUATION:

This event appears to have been incorrectly listed in the PSAR (41.4N, 82.3W), i.e., 30 miles west of Cleveland, it is now revised. Using additional newspaper documentation recently collected, the event is found to have been felt in various locations in and around Cleveland with an Intensity IV <Figure 2D D-5>. The Cleveland Daily Herald of October 1, 1850 substantiates an Intensity IV in Cleveland, Euclid (8 miles east of Cleveland) and Berea (12 miles southwest), thus suggesting that Cleveland coordinates would be an acceptable midpoint. The revised coordinates are those of Cleveland; 41.5N, 81.7W. It is suggested that an epicentral uncertainty of at least ±12 miles be attached to this event, since it is almost impossible to decide which of the three localities experienced the largest ground motion.

COMPILATION OF ACCOUNTS:

Cleveland Daily Herald, Cleveland, Ohio, October 1, 1850

"Earthquake in Cleveland.

"A very sensible shock of an earthquake was felt at this place this morning (Oct. 1) at about 5:25 o'clock. The morning was very clear with the exception of the horizon in the north and northwest.

“The night had also been quite clear with a beautiful display of Aurora Borealis which was most brilliant about 3 o’clock.

“The first indication of the phenomenon was a low rumbling sound somewhat like distant thunder apparently in a northwesterly direction. This sound increased in intensity for about 3 or 4 seconds, the deepest intonations being like very heavy distant thunder, the earth at the same instant exhibited a trembling motion which lasted nearly two seconds when it gradually died away with the sound in an easterly or southeasterly direction.

“The concussion was so violent that it produced a jarring and rattling of the windows, furniture and crockery and a very sensible trembling could be felt be one who stood up on the ground.

“In Euclid about 8 miles east of this city the shock was sufficiently violent to throw crockery from the shelf. We also learn by a gentleman from Berea (about 12 miles southwest) that the concussion were sufficient to awaken person from their sound sleep.

“Most of those with whom we have conversed who observed the phenomenon give very near the same description of the impressions and sensations produced as are stated above.”

Cleveland Daily True Democrat, Cleveland, Ohio, Oct. 2, 1850

“An Earthquake.

“About 5:20 yesterday morning the shock of an earthquake was felt distinctly by our citizens. It was accompanied by a rumbling noise similar to the roar of distant thunder and appeared to

vibrate from the west to the east. The houses in the city were jarred for several seconds. It was observed at Parma, Brecksville, Strongsville, Rockport, and Euclid."

Cleveland Plain Dealer, Cleveland, Ohio, October 1, 1850

"Was That Thunder?

"This inquired many of our citizens this morning on being awoke about five o'clock with a deep rumbling sound and a loud shake to all appearances a young earthquake. We expected this phenomenon about this time, and therefore was no alarm. It is the ground swell, or forerunner of an Ohio earthquake which is to come off on the 8th of October, and is not a ... to the Democratic thunder which will then be heard. We have already engaged "big-mouthed Jacques" to do our shouting, commencing on the third day after the election, as we expect this to be too ...to be understood"

EARTHQUAKE OF FEBRUARY 28, 1857 (R)

CA: 01:40 GMT

EPICENTRAL INTENSITY: IV-V(MM) (R)

LOCATION: 41.8N, 80.6W (R)

EVALUATION:

This event was felt with Intensity IV in many localities from Painesville, Ohio to Conneautville, Pennsylvania. There are also a few instances of IV-V reports, e.g., in Ashtabula and Conneaut, Ohio, and Hayfield, Pennsylvania <Figure 2D D-6>. The isolated mention from Concord referring to a cracked stone wall does not seem to support a higher intensity, since no other effects were reported. The epicenter was probably not south of Jefferson since the event was not reported at Warren.

Considering that the felt area borders on Painesville, it appears justified in view of the additional information to revise the original location given by Reid ("Painesville, V?"), based on the American Journal of Science, and shift it to the northeast: 41.8N, 80.6W. Clearly, a large uncertainty (±20 miles) should be attached to this revised location.

Considering that February 27, 1857 was a Friday, and the newspapers say "Friday evening," the date of the earthquake has been revised from March 1 to February 28, GMT (i.e., February 27, local time), in correction of Docekal.

COMPILATION OF ACCOUNTS:

Sentinel, Ashtabula, Ohio, March 5, 1857

"Earthquake.

"Between 8 and 9 o'clock on Friday evening of last week, there was a very sensible trembling of the Earth observed in these parts. The vibration lasted several seconds, jarring houses in such a manner as to alarm the inmates. It was felt in various parts of the county, and is of course the subject of much speculation."

Reid, H. F., Unpublished notebooks, scrapbooks and card files. Custodian: U.S. Coast and Geodetic Survey, Rockville, Md.

"Evening, 28 February 1857. Painesville, Ohio. V(?)"

West, C. E., 1858, On an Earthquake in Western New York, American Journal of Science, V. 26, pp. 177-182.

"Wm. L. Perkins, ESQ., of Painesville, Ohio, on the railroad from Erie to Cleveland, writes; '...We have, within about a year past, experienced two, and it seems to me, three earthquake shocks here. The first, and by far the most energetic, was on the last day of Feb., 1857, I think in the evening. The last was on the 16th of April, 1858, about 6 o'clock, a.m.'"

Western Reserve Chronicle, Warren, Ohio, March 18, 1857

"News of the Neighborhood.

"An Earthquake-The Conneaut Reporter of the 5th inst, says: The quiet of our citizens was disturbed on Friday evening last, by experiencing a shock of an earthquake at about 20 minutes

before 9 o'clock. The shock was so peculiar, so unlike anything before felt, that it attracted very general notice. Buildings trembled and furniture rocked. The shocks lasted about five or six seconds, and passed away with a hollow sound, like distant-very distant thunder.

"A correspondent of the same paper writing from Jefferson in the same county says:

"Friday night a slight shock of an earthquake was felt by many of our citizens at 8 1/2 o'clock-jarring houses, and trembling with considerable force. We are informed that the shock was sensibly felt at Farmington, in this county.

"More of the Earthquake-

"The Conneautville, Pa., Courier says, that a distinct and heavy shock of an earthquake was experienced in that place and various parts of the country around there, on Friday evening 28th ult. Various buildings swayed to and fro perceptibly; windows rattled, and the furniture creaked and jarred. The shock was accompanied by a sharp rumbling sound, likened by many to a wagon passing hastily over a bridge. A gentleman from Hayfield says the vibration caused his clock to keep up a constant striking for ten minutes; another, that the water in his well which was uncovered, at intervals during Friday, bubbled like a boiling kettle."

(same account appeared in Elyria Independent Democrat, March 11)

Painesville Telegraph, Painesville, Ohio, March 5, 1857

"An Earthquake.

"On Friday evening last, a few minutes before 9 o'clock, there was felt in this town a smart shock of an Earthquake. How extensively the shock may have been felt we know not. We see no mention of the affair in any of our exchanges. In the neighboring town of Concord, we learn that the swaying was sufficient to crack the walls of a stone house. A correspondent at Unionville makes the following report of the event in that locality:

"MR. FRENCH-Last evening about a quarter before nine o'clock, a shock of an earthquake was felt in this place. The rumbling was heard a moment or two before the jarring occurred,--and that was severe enough to give our dwellings considerable shaking. It continued some ten seconds, and seemed entirely different from an ordinary jar."

Yours truly, P. Terry.

Unionville, Saturday, 28

EARTHQUAKE OF APRIL 10, 1858 (R)

CA: 11:30 GMT

EPICENTRAL INTENSITY: IV(MM)

LOCATION: 41.67N, 81.25W

EVALUATION:

This event was originally cataloged by Docekal, following a reference in the American Journal of Sciences, where April 16, 1858 was given as date of occurrence. Docekal's comment was that "no details are known of an earthquake felt at Painesville, Ohio, on April 16." The research recently carried out uncovered numerous newspaper articles referring to the earthquake. Some confusion on the date arises from the fact that Cleveland newspapers carried on later dates, earlier dispatches from Painesville, Conneaut and Ashtabula. A careful examination of the cross-references suggests that the event occurred on April 10, since the Thursday, April 15, 1858, edition of the Conneaut Reporter and Painesville Telegram both refer to an event occurring on "last Saturday." Most likely, the American Journal of Science's reference to April 16 is a typographical error for April 10.

The event was reported at Painesville as an Intensity IV(MM), in Ashtabula as an Intensity III(MM), and in Conneaut as an Intensity II-III(MM). The fact that the Cleveland newspapers carried only dispatches from other localities suggest that the event was not felt in Cleveland itself <Figure 2D D-7>.

In the Cleveland Herald of April 19, there is a reference to a dispatch from Painesville in which a mention to a second event on that day is made. The fact that such an aftershock was not mentioned before, and that this second event is reported for 6 p.m., while all other references fixed the first shock at 6 a.m., suggests a possible

confusion. It is probably better to consider this second event as doubtful. There is no doubt that if two events are accepted, the first one was stronger, as it was never reported to Ashtabula and Conneaut.

When assigning Painesville coordinates to the epicenter, an uncertainty of ±15 miles seems appropriate.

COMPILATION OF ACCOUNTS:

Ashtabula Sentinel, Ashtabula, Ohio, April 22, 1858

> "Lake Co.-...A shock of an earthquake was very distinctly felt here on Saturday morning.

Cleveland Herald, Cleveland, Ohio, April 17, 1858

> "Earthquake.
>
> "A little after 6 o'clock on Saturday morning last, a sensible shock of an earthquake was felt in this place. The shock was of short duration, but sufficiently continued for anyone to settle in his own mind its distinctive character-" Ashtabula Telegraph, 17th.

Cleveland Herald, Cleveland, Ohio, April 19, 1858

> "From the Painesville Advertisor, of the 17th:
>
> "A shock of an earthquake was very distinctly felt here on Saturday morning last, at quarter past six. About the same hour in the evening another shock was also felt. In both instances, buildings shook, dishes rattled, and other evidences of the shock were made."

Conneaut Reporter, Conneaut, Ohio April 15, 1858

"'Earthquake'!-An earthquake was distinctly heard and felt in this village about 25 minutes past 6 o'clock on Saturday morning. Buildings tottered, the ground heaved and trembled, and the trees swayed and made obeisance like the sheaves in Joseph's dream, although not a breath of air was stirring. Many of our people were considerably shocked."

(the same account appeared as a dispatch from Conneaut in Cleveland Herald, April 16, and Cleveland Leader, April 19)

Painesville Telegraph, Painesville, Ohio, April 15, 1858

"An Earthquake.

"At 6 1/2 o'clock on Saturday morning last the shock of an earthquake was distinctly felt in this place, accompanied by a rumbling noise not unlike distant thunder. Buildings shook, windows rattled and light articles of furniture had their gravity very much disturbed by it. The course of the quake seemed to be from the south toward the north and was similar in character the shock felt here about a year ago."

(the same account appears in Cleveland Herald, April 16, as a dispatch from the Painesville Telegraph of April 15)

West C. E., 1858, On an Earthquake in Western New York, American Journal of Science, V. 26, pp. 177-182.

"Wm. L. Perkins, ESQ., of Painesville, Ohio, on the railroad from Erie Cleveland, writes; '...We have, within about a year past, experienced two, and it seems to me, three earthquake shocks here. The first, and by far the most energetic, was on the last day of Feb., 1857, I think in the evening. The last was on the 16th of April, 1858, about 6 o'clock, a.m.'"

EARTHQUAKE OF JANUARY 13, 1867

CA: 22:00 GMT

EPICENTRAL INTENSITY: III(MM)

LOCATION: 42.97N, 77.85W (R)

EVALUATION:

This event was mistakenly carried in the PSAR with the coordinates of Cleveland. The event occurred in New York state. Recent investigation shows that a dispatch from Rochester, New York appeared in the Cleveland Leader concerning an earthquake felt in Monroe and Livingston counties N.Y. A suggested relocation of the epicenter is Caledonia, New York, (42.97N, 77.85W), approximately 175 miles from the site. It should be noted that the dispatch refers to a possible aftershock three hours later.

COMPLETION OF ACCOUNTS:

Cleveland Leader, Cleveland, Ohio, January 15, 1967

"The Recent Earthquake in Monroe and Livingston Counties.

"The Rochester Union of Tuesday evening has the following in relation to the earthquake mentioned in our dispatches:

"On Sunday afternoon and evening two distinct shocks of an earthquake were experienced in the southwest corner of this county and in the adjoining county of Livingston. The first shock came about 5 p.m., attended by a rumbling sound, which appeared to come up from the southwest and pass away to the southeast. Buildings were shaken in the village of Mumford, and people sitting in their houses were startled by the sensation produced. Between 8 and

9 p.m., another and a lighter shock was experienced. The first shock was sensibly experienced in the village of Caledonia, Livingston County.

"The testimony to the statement above made is such that cannot be doubted that there was a convulsion of the earth in the localities named sufficient to startle and alarm the people. It can be explained upon no other hypothesis than that it was an earthquake. It was on Sunday evening, when all was quiet and the effect would be most readily noticed."

EARTHQUAKE OF APRIL 9, 1869

CA: 13:00 GMT

EPICENTRAL INTENSITY: III(MM)

LOCATION: 42.7N, 80.8W

EVALUATION:

This event was felt as an Intensity III in Vienna, Ontario, according to Smith and Lancaster. It has been given the coordinates of Vienna, Ontario. No mention was found in Ashtabula. Probably quite small and local.

COMPILATION OF ACCOUNTS:

Lancaster, A., 1873, "Note Additionnelle au Memoire de M.W.-T. Brigham, intitule: 'Volcanic Manifestations in New England (1638-1870),'" Memoirs of the Boston Society of Natural History, V. 2, pp. 241-247.

"1869 Avril. Le 9, entre 8 et 9h. du matin, a Vienna (Ontario, une legere secousse du N. au S. et de vingt secondes de duree."

Smith, W. E. T., 1962, Earthquakes in Eastern Canada and Adjacent Areas 1534-1927, Publications of the Dominion Observatory, V. 26, No. 5.

"1869 April 9, 8:00-9:00 a.m. III. Felt at Vienna, Ontario."

EARTHQUAKE OF JULY 23, 1872

CA: 11:00 GMT

EPICENTRAL INTENSITY: III(MM) (R)

LOCATION: 41.4N, 82.1W

EVALUATION:

This shock appears to have been felt very locally in Elyria, near the Red Mill. A revised Intensity III would seem adequate (as used by Bradley and Bennett and Docekal). The seismic origin of this event is somewhat doubtful as the two reports available emphasize the dullness of the sound. Residents found that a 4,000 ton overhanging rock had fallen along with 3,000 tons of other material. The Elyria report refers to a jar and a dull sound. One could consider the possibility that an earthquake was the cause of the rock fall; yet the fall of the rock, followed by the detritus, could also explain the report very simply.

The fact that the shock was not felt in any other locality makes the occurrence of an earthquake appear doubtful. Had an earthquake occurred, causing the rockfall, it should have been felt in Lorain, 8 miles northwest of Elyria, and in Cleveland, 20 miles to the east. This dubious event (Intensity III) is considered non-seismic, and will be listed in Table 3.

COMPILATION OF ACCOUNTS:

Cleveland Plain Dealer, Cleveland, Ohio, July 25, 1872

> "-The Elyria Democrat says that on Tuesday morning the citizens of Elyria were startled by the jarring of the earth, followed by a crashing dull sound, like that produced by the fall of a heavy body. Those living in the vicinity of the red mill soon discovered the cause. The immense overhanging rock over which the

road bed formerly passed to the lower mill, had fallen into the chasm below, with a crash that at once revealed the cause of the alarm. The rock that fell intact is about one hundred feet long by thirty feet in width and depth and weighs about 4,000 tons. The whole weight of rock that fell, including the detached portions, must have been 7,000 tons. A crevice is opened in the rock, extending around under the corner of the mill to the verge of the falls and there is danger of another fall of rock, which however will not endanger the mill property."

Elyria Independent, Elyria, Ohio July 24, 1872

"Great Fall of Rock.

"Grand Exhibition of the Force of Nature.

"This (Tuesday) morning, at a few minutes before six o'clock, the citizens of Elyria were startled by the jarring of the earth, followed by a crashing dull sound, like that produced by the fall of a heavy body. Those living in the vicinity of the Red Mill soon discovered the cause. The immense overhanging rock over which the road bed formerly passed to the lower mill, had fallen into the chasm below, with a crash that at once revealed the cause of the alarm.

"The rock that fell intact is about one hundred feet long by thirty feet in width and depth and weighs about 4,600 tons. The whole weight of rock that fell, including the detached portions, must have been 7,000 tons. A crevice is opened in the rock, extending around under the corner of the mill to the verge of the falls and there is danger of another fall of rock, which however will not endanger the mill property.

"Hundreds of our citizens visited the scene, and looked with wonder upon the change that had been wrought in a moment, by the rending asunder of what has always been regarded as a rock that could only be moved by the force of the most powerful explosive agencies. Sight-seers will do well to avoid the precipice immediately adjoining the part that fell, as the large crevice in the earth shows that it is liable to fall at any moment. The mill stands far enough back to be out of all danger."

Lorain Constitution, Lorain, Ohio, July 26, 1872

"A Rending of the Rocks.

"Falling of the Rocks at the East Falls.

"On last Tuesday morning, the attention of the entire population of the village was called to the East Falls by the report that a large portion of the rock which hung over the basin had split off and fallen into the chasm, and, though a slow, drizzling rain kept up for several hours, large crowds gathered there to look upon the scene. The fall occurred about seven o'clock in the morning, and the dull, but heavy rumbling report it made, startled many of these living in the vicinity of the Red Mill. The portion that fell was that which formed the table over which the road passed leading to the old mill, and it carried away surface equal to about ten square rods. The scene resembles very much what might be produced by a heavy blast of powder, as rocks, trees and earth are scattered in all directions. The main rock, which now lies at the brink of the basin, measured eighty-one feet long, and in the middle is about thirty-five feet thick, and about the same width. It is estimated to weigh 12,700 tons, and would be sufficient to construct several good-sized buildings. Nearly an equal amount of smaller rocks fell with or broke off from the main piece in the fall. By this breaking off the precipice is now

within a few feet of the west wall of the Red Mill, though the mill is not believed to be in danger, and the passage way from the mill to the river below the falls has been carried away. Mr. Stich, the artist, took sketches of the scene, and has sent them to a New York illustrated paper, and it may be that it will be published. The scenery below the falls was always regarded as very beautiful and romantic, and this last breaking away has given in a wildness almost startling to look upon."

EARTHQUAKE OF AUGUST 17, 1873 (R)

CA: 14:00 GMT

EPICENTRAL INTENSITY: III(MM) (R)

LOCATION: 41.25N, 80.50W

EVALUATION:

This event was felt in Sharon, Pennsylvania according to the American Journal of Science. It does not appear to have been felt in Ohio as no mention was found in Ashtabula, Warren, Cleveland, or Painesville. The coordinates assigned are those of Sharon (41.25N, 80.50W). This earthquake was mentioned originally by Reid, using the American Journal of Science as source. An Intensity III is more than adequate to describe "a shock." Docekal mistakenly carried this event one day later, and evaluated it as Intensity III-IV.

COMPILATION OF ACCOUNTS:

Rockwood, C. G., JR., Notices of Recent Earthquakes NO. 4, American Journal of Science, V. 107, No. 40, pp. 384-387.

"Aug. 17, 1873 - A shock about 9 A.M. in Sharon, Pa., lasting ten seconds."

EARTHQUAKE OF JANUARY 18, 1885

CA: 10:30 GMT

EPICENTRAL INTENSITY: IV(MM) (R)

LOCATION: 41.10N, 81.45W (R)

EVALUATION:

This event, on the basis of new information recently acquired, needs to be revised from the original PSAR location. The latter was based on the Monthly Weather Review, which put the event in Garrettsville. Rockwood assigned an Intensity II to this report. Numerous reports recently acquired from Summit and Portage counties suggest an Intensity IV in the vicinity of Akron and Kent (Figure 2D D-8). The new information suggests this area as the epicentral region. The somewhat isolated report of an Intensity IV in Painesville might be attributed to local amplification due to the proximity of the lake shore. The location is revised to 41.10N, 81.45W, with a suggested uncertainty of ±10 miles, and the intensity is increased from II-III to IV.

COMPILATION OF ACCOUNTS:

Cleveland Herald, Cleveland, Ohio, January 22, 1885

"An Earthquake in Summit County.

"Akron, Ohio, Jan. 21 - (Special) - Reports come from the northern townships of the county of a pronounced earthquake shock felt there early Sunday morning. A number of Arkonians who felt it, but would not speak of it for fear of ridicule, are now coming to the front."

Cleveland Herald, Cleveland, Ohio, January 23, 1885

"Man Killed at Chicago Junction - Earthquake.

"Plymouth, Jan. 22 - ... Since your correspondent at Akron opened up the subject we can add a little about that earthquake on late Sunday morning. It was felt here by several persons. In one house the dishes fell from cupboards and in some places a loud report as of an exploding gun was heard. The subject was not mentioned at first by the parties noticing it for fear of ridicule, thinking possibly they were mistaken."

Monthly Weather Review, Jan., 1885, United States Weather Bureau, Washington, D.C.

"Mr. S. M. Luther of Garrettsville, Portage County, Ohio, reports that during the early morning of the 18th a shock, supposed to have been due to an earthquake, occurred at that space. He also states that several persons in the vicinity of Garrettsville noticed the shock. The time at which it occurred was about 5:30 or 5:45 a.m."

Painesville Telegraph, Painesville, Ohio, January 22, 1885

"'Was it an earthquake.' Last Sunday morning between 4 and 5 o'clock several shocks, or explosions were heard and felt as though some heavy body had been thrown against the house; the last one a little before 5 o'clock was so violent as not only to jar the houses, but the furniture and to disturb those in bed. Even hanging lamps rattled and vibrated. The what it was has not been settled, some thinking it the action of the frost and others that a real earthquake was traveling about."

Rockwood, C. G., Jr., Notes on American Earthquakes, No. 15, American Journal of Science, V. 132, No. 187, pp. 7-13.

"Jan. 18, 1885 - About 5^h30^m or 5^h45^m, a very light shock (II) at Garrettsville, Portage County, Ohio.-U.S. Weath, Rev."

Summit County Beacon, Akron, Ohio, January 21, 1885

"Some citizens insist that Akron was severely shaken up by an earthquake or something like it about 2 o'clock Sunday morning. What's the evidence?"

Summit County Beacon, Akron, Ohio, January 28, 1885

"'A shock as of an earthquake was distinctly heard and felt on Sunday morning at 5 a.m., by a great many people, your correspondent included.' So says a Twinsburg letter. Kent had the 'earthquake', too. At least the Bulletin says: Last Sunday morning a heavy shock and sound resembling that of an earthquake was heard through this section of Portage County. Many persons were aroused from their beds by the noise, which in some instances resembled the sound of some heavy body falling upon the roof of the house. The shock was distinctly heard in Brimfield."

Summit County Beacon, Akron, Ohio, February 4, 1885

"'Orville Crescent:' Persons at Wooster, Akron and other parts of Summit County, report that they felt the shock of an earthquake on Sunday of last week. We understand that the shock was felt quite distinctly at Burton City."

Warren Daily Chronicle, Warren, Ohio, January 23, 1885

"Garrettsville people claim to have had a slight earthquake Sunday."

The Warren Tribune, Warren, Ohio, January 27, 1885

"LAKE COUNTY.

"Painesville thinks she experienced an earthquake on Sunday morning of last week."

EARTHQUAKE OF AUGUST 15, 1885

CA: 04:05 GMT

EPICENTRAL INTENSITY: II-III(MM)

LOCATION: 41.27N, 81.10W

EVALUATION:

This location and intensity of this event are somewhat uncertain. The Monthly Weather Review speaks of a "severe shock supposed to have been due to an earthquake," felt in Garrettsville, Ohio. Later, Rockwood, using MWR as his source, makes it "a very light shock (II), at Garrettsville." Then Reid simply assigns an Intensity II in Garrettsville. Because no mention of this shock was found in any of the eleven newspapers consulted (see matrix) in the area, the Garrettsville coordinates are retained, but with a large uncertainty (±20 miles is suggested). An intensity of II-III is assigned as a compromise, between "severe" and "very light."

COMPILATION OF ACCOUNTS:

Monthly Weather Review, August, 1885, United States Weather Bureau, Washington, D.C.

> "Garrettsville, Portage County, Ohio: a severe shock, which is supposed to have been due to an earthquake, was experienced at 11:05 p.m. on the 14th."

Rockwood, C. G., Jr., Notices of Recent Earthquakes, No. 15, American Journal of Science, V. 132, No. 187, pp. 7-13.

> "Aug. 14-23^h 5^m, a very light shock (II) at Garrettsville, Portage County, Ohio - U.S. Weath. Rev."

EARTHQUAKE OF OCTOBER 29, 1898 (R)

TIME UNCERTAIN

EPICENTRAL INTENSITY: III(MM)

LOCATION: 41.5N, 81.7W

EVALUATION:

Reid, following a report published in the Monthly Weather Review listed three shocks for October 23. This entry was subsequently accepted and listed by Docekal in his catalog. Nuttli later carried one event on October 24 (a.m.).

During the newspaper search for the three tremors reported in MWR, no accounts were found for October 23, but three accounts were found of three tremors on October 29.

A calendar verification revealed that "Friday October 23" as reported in Monthly Weather Review does not exist. Considering that accounts for October 29 were found, and that October 29 was a Saturday, it is inferred that the MWR entry must be a transcription error, e.g., Friday, the 28th, was mistaken as the 23rd. Thus, only the shocks for October 29 are retained. "Early today" (29) or during the night" (28) would account for all the reports.

For the "three shocks", an Intensity III is sufficient; not III-IV as in Docekal. The coordinates given are those of Cleveland (41.5 N, 81.7), with a suggested uncertainty of ±15 miles.

COMPILATION OF ACCOUNTS:

Berea Advertiser, Berea, Ohio, November 4, 1898

"Three slight but distinct earthquake shocks were felt in Cleveland Ohio."

Monthly Weather Review, October, 1898, United States Weather Bureau, Washington, D.C.

"Friday, October 23, at Cleveland, Ohio, three successive shocks are reported by the newspapers to have been felt during the night. Prof. E. W. Morley, of Adelbert College, Cleveland, reports several disturbances shown by the seismograph during October, caused by blasting at a point about 800 feet southwest of the instrument. Only the most powerful blasts made any record. The most vigorous movement occurred on October 29, and was probable due to some seismic disturbance. Prof. Morley further reports that the seismograph was not disturbed during November and December."

Youngstown Vindicator, Youngstown, Ohio, October 29, 1898

"Cleveland Shaken by Earthquakes.

"Cleveland, Oct. 29 - Three distinct earthquake shocks were felt in this city early today, each being about 10 seconds in length. The quake was not severe enough to be noticed generally except in tall buildings and on seismographs. The trend of the quakes were to the northerly and southerly direction."

(same account in Youngstown Telegram, Oct. 31)

EARTHQUAKE OF APRIL 9, 1900

CA: 13:00 GMT

EPICENTRAL INTENSITY: VI(MM)

LOCATION: 41.37N, 81.85W

EVALUATION:

This event was originally cataloged by Docekal, whom Nuttli later followed, as an Intensity VI at Berea on the basis of a dispatch from Berea to a Cleveland newspaper. A recently acquired article from a Berea newspaper states clearly that this shock was a blast "which felt like a miniature earthquake." This conclusion is accepted here since there are no reports of an earthquake being felt at any other surrounding localities. Had an earthquake of true Intensity VI occurred in Berea, it should at least have been felt at Cleveland, Elyria and Lorain, which are 11, 13 and 17 miles respectively from Berea. An extensive literature search (see matrix) failed to show any sign of this event elsewhere.

It seems that the Intensity VI was assigned not on the basis of effects on people and objects, but solely on the fact that two chimneys of a single house fell down. It is suggested that this event be removed from the earthquake catalog and put in Table 3 where events with dubious origin are listed.

COMPILATION OF ACCOUNTS:

Berea Advertiser, Berea, Ohio, April 13, 1900

"A Great Blast.

"Since Berea is a quarry town a blast, a gunpowder explosion, or a miniature earthquake is not all together a novelty. During

the quarry season these blasts may be heard at all hours of the day in different parts of the town where ever the quarries are located. Citizens have been startled not only these blasts but also of falling rocks as well, which are sometimes thrown to great distances unless proper precautions are taken.

"The quarry people have become somewhat adept in the use of gunpowder to loosen the rock and in late years very little has been heard of accidents or violent explosions.

"Monday morning however, about 8 o'clock a blast occurred which startled the whole village and in some localities it had the effect of a miniature earthquake. Buildings were shaken and 2 chimneys from Dr. Clarks Bridge Street residence were shaken to the ground. The effects was not entirely upon the surface but must have extended to a great depth as shown by the water in several deep wells in the vicinity."

Cleveland Leader, Cleveland, Ohio, April 10, 1900

"An Earthquake Felt at Berea.

"People Rushed into the Street In Great Fright.

"The Clark House Rocked and the Chimneys Loosened-Effect Upon a Well.

"Special Dispatch to the Leader.

"Berea, OH, April 9.-This village was visited by a miniature earthquake at about 8 o'clock this morning. The greatest force of the phenomenon was expended at the home of Dr. William Clark on Bridge street. The wave-like motion traveled from north to south for a distance of nearly a half mile, its path being about

1,000 yards wide. The Clark home, which is a large two-story frame structure, was rocked back and forth with such violence that both the large brick chimneys on the roof were loosened from their fastenings and came tumbling into the yard below.

"The vibrations lasted for about five seconds and were accompanied by a rumbling, thunder-like noise, which was distinctly heard throughout the northeastern part of the village.

"At the Clark home is a well which is seventy-three feet deep, and which is drilled into the rock. Before the occurrence of the phenomenon the water in the well was considered among the purest and clearest in the village. It is now of a milky color and has a peculiar taste.

"Several of the residents living within the section in which the vibrations were the greatest, rushed from their homes into the streets. At about 10 o'clock this morning the rumbling noises were heard again but no motion of the earth was discernible."

Cleveland Plain Dealer, Cleveland, Ohio, April 10, 1900

"Earth Quaked at Berea.

"Vibrations Were Sufficient to Shake the Chimneys from a House.

"Special to the Plain Dealer.

"Berea, April 9.-This village was visited by a miniature earthquake at about 8 o'clock this morning. The greatest force of the phenomenon was expended at the home of Dr. William Clark on Bridge street. The wave-like motion traveled from north to south for a distance of nearly a half mile, its path being more than a

half-mile wide. The Clark home, which is a large two-story frame structure, was rocked back and forth with such violence that both the large brick chimneys on the roof were loosened from their fastenings and came tumbling into the yard below."

EARTHQUAKE OF APRIL 20, 1906

CA: 17:30 GMT

EPICENTRAL INTENSITY: III(MM) (R)

LOCATION: 41.50N, 81.75W (R)

EVALUATION:

This event was reported felt in Cleveland, especially in the western section (see Cleveland Plain Dealer). An Intensity III appears to be adequate for these reports. There is no reason for following Docekal in assigning an Intensity IV to this event. No felt reports were found in any of the surrounding towns (see matrix). The former coordinates assigned to this event were those of Cleveland; it is now suggested that the coordinates of western Cleveland (41.50N, 81.75W) be used. Suggested uncertainty: ±10 miles.

It should be noted that the time of occurrence, right after noon, could indicate a blast as the source. The newspaper reports, e.g., "believed to be," "believed to have been a slight seismic disturbances," seem to cast doubt on the true seismic origin of the event. Nonetheless, the event is retained in the main catalogue.

COMPILATION OF ACCOUNTS:

Cleveland Plain Dealer, Cleveland, Ohio, April 21, 1906

"'Distinct Shock was Felt Here'.

"'Seismic Disturbance is Believed to have Occurred Yesterday Noon'.

"'Police Search in Vain for Report of an Explosion'.

"A distinct shock believed to have been a slight seismic disturbance was felt in Cleveland shortly after noon, yesterday. The trembling of the earth was very brief, and not at all severe, but it was felt in all parts of the city.

"It was particularly noticeable on the west side of the city. Officials of the Austin Powder Co. say that Father Odenbach of St. Ignatius college informed them that his seismograph had without doubt responded to disturbances in the locality.

"It was about 12:30 o'clock in the afternoon that the disturbance was felt. The first supposition was that an explosion had occurred in one of the manufacturing plants. Careful investigation on the part of the police and others failed to reveal anything in the nature of an explosion.

"Every place where an explosion might have occurred was throughout the afternoon and early evening beseiged with telephone calls. Many residents of the west side claim to have heard peculiar unexplainable rumblings of the earth at about 12:20 o'clock in the afternoon. Others though fewer in number claim to have felt a distinct shock."

<u>New York Times</u>, New York, New York, April 21, 1906

"Cleveland has a Shock.

"No Explosion Found, so an Earthquake was the Next Guess.

"Special to the New York Times.

"Cleveland, Ohio, April 20.-A distant shock, believed by many to have been an earthquake, was felt in various parts of Cleveland

at 12:30 o'clock this afternoon. A few minutes later the telephone and newspaper offices were besieged with telephone queries as to where the explosion occurred.

"A report was circulated that there had been an explosion at the Austin Powder plant in Newburg, but this proved to be unfounded. Careful investigation failed to show that there had been any kind of an explosion in the city.

"Forecaster Kenealy felt the shock in the Weather Bureau in the Society for Savings, but could not tell whether it was due to earthquake shock."

EARTHQUAKE OF JUNE 22, 1906

TIME UNCERTAIN

EPICENTRAL INTENSITY: I-II(MM)

LOCATION: 41.37N, 81.87W

EVALUATION:

The research turned up one single account of a very small (Intensity I-II) event, which could be seismic, felt by one person in Berea. It is clear that the note from the Meteorological Observatory at St. Ignatious College in Cleveland to the observer cannot be interpreted as a confirmation. Berea coordinates (41.37N, 81.87W) should be assigned to this dubious event (listed in Table 3).

COMPILATION OF ACCOUNTS:

Berea Enterprise, Berea, Ohio, June 29, 1906

"Felt in Berea.

"Mr. E. M. Carrol felt the vibrations of Mother Earth on the night of June 22nd. The papers did not record the shock, and Mr. Carrol to satisfy himself wrote to the meteorological observatory, at St. Ignatius College, Cleveland to know if it had been indicated there. He received the following notice, June 25th, our instruments recorded extensive vibrations on the night of June 22, 23, from 11 p.m. to 2 a.m. They were from E.W; and were many, turning up in periods of about three minute duration and about that long apart."

EARTHQUAKE OF JUNE 27, 1906

CA: 21:10 GMT

EPICENTRAL INTENSITY: IV-V(MM) (R)

LOCATION: 41.4N, 81.6W

EVALUATION:

This event remains quite controversial, on the basis of the conflicting evidence made available through the literature search. There are, without doubt, felt reports that correspond to Intensity IV-V; the problem arises from the fact that these reports are distributed along the shore only, over a distance of about 100 miles <Figure 2D D-9>. Freeport Harbor and Put-in Bay constitute the extreme points of this thin band of poorly differentiated intensity reports. Only one report in the Cleveland News could support making Cleveland (Broadway Street and along the water front) the approximate epicenter, on the basis of an Intensity V report. But soil amplification along the water front could also explain the higher intensity.

There exists an alternate possible explanation that a large blast (20 tons) near Monroe, at the western end of the lake, and which caused similar effects (rattling windows, etc.) for miles around, was also responsible for the felt reports observed form Freeport to Put-in Bay. This theory was quickly dismissed by all the papers of the day. It was alleged that the earthquake (4:10 to 4:20 local) and the blast time (about 4:40) were sufficiently apart. The seismograph at St. Ignatius recorded numerous disturbances that afternoon, the largest about 4:10. Keeping in mind the poor suitability of the 1906 home-made seismograph to record local events, and the time keeping problem, one can truly wonder if the instrumental data are adequate to rule out entirely the sound wave from the blast as the true cause of the noise and vibration observed. It should be stressed that Fr. Odenbach never took a firm position. On that day, as on many others, he talked about seismic

disturbances on his instruments; never committing himself to the occurrence of either an earthquake or a blast.

A newspaper, the Elyria Reporter, mentions the event on June 28th and also the next day, on the 29th. On June 29th, the blast theory is firmly endorsed. It is not clear how much additional research in comparing blast and felt report times supported this later report of June 29th, but it certainly has the tone of a retraction. The damages caused by the explosion certainly indicate the amplitude of the shock. The front of the airwave hitting the south shore of Lake Erie could explain the extensive distribution of the felt reports.

In view of the extended length of the affected lake shore in the Cleveland area and very similar felt reports along the western end of the lake, near Toledo and Monroe, it is considered logical to accept the blast as the cause and explain with a single, well identified phenomenon, the felt reports obtained all along the shorelines. The seismographic evidence is considered too weak to support the discrimination of two separate events. The home-made seismograph recorded "steady seismic disturbances for forty-five minutes." These disturbances and similar recordings (see April 12, 1907) are of a suspicious nature; the "shock at 4:10" may have been part of these erratic seismic noises.

For this reason, the event is considered to have a dubious seismic origin and is listed in Table 3.

COMPILATION OF ACCOUNTS:

Akron Beacon Journal, Akron, Ohio, June 28, 1906

"Earthquake Felt Along Lake Shore.

"A Violent Shock Shook Up Northern Ohio Yesterday Afternoon.

"Cleveland, O., June 28,-A violent earthquake shock shook the southern shore line of Lake Erie for a distance of 100 miles yesterday afternoon, the eastern limit being Painesville and the western Marblehead.

"While no serious damage has been reported, the shock was so violent in may places as to throw pictures from the walls of houses and shatter bric-a-brac. In other cities and towns, especially in Cleveland's suburbs, windows and transoms were shaken violently, and open doors were slammed shut.

"In many instances temporary panic was caused by the disturbance. The memory of the San Francisco horror is so vividly before the public that the timorous ones feared the worst. So brief was the duration of the shock, however, that calm was soon restored.

"Scientist in Cleveland explain that the seat of the seismic disturbance was probably beneath the bed of Lake Erie. The fact that no serious wave movement accompanied the shock they add, proves that in spite of its apparent violence it was of minor importance.

"None of these scientists, however, felt the shock, and those who did dispute its being of merely minor importance. When windows rattle and doors tremble, residents of Cleveland aver, there must be "something doing" in the stomach of Mother Earth."

"It was learned last night that there was a severe powder explosion near Detroit. For a time this gave rise to the theory that it might account for the disturbances on this side of the lake, but a comparison of the time seemed to make this impossible. According to seismographic registration the shock occurred at 4:10 o'clock, while the explosion was at 4:40. Even the average

time of 4:20 o'clock set by the general public as when the shock was felt, would leave 20 minutes to be accounted for.

"That there was only one shock, but that of violent character is the testimony from all quarters. The seismograph of Father Odenbach at St. Ignatius' College tells a different story, however. Its delicate mechanism affords unerring proof of three separate visitations during the afternoon the second one being most generally felt."

Cleveland Leader, Cleveland, Ohio, June 28, 1906

"A violent earthquake shock shook the southern shore line of Lake Erie for a distance of one hundred miles yesterday afternoon, the eastern limit being Painesville and the western Marblehead.

"While no serious damage has been reported, the shock was so violent in many places as to throw pictures from the walls of houses and shatter bric-a-brac. In other cities and towns, especially in Cleveland's suburbs, windows and transoms were shaken violently; and open doors were slammed shut.

"In many instances temporary panic was caused by the disturbance. The memory of the San Francisco horror is so vividly before the public that the timorous ones feared the worst. So brief was the duration of the shock, however, that calm was soon restored.

"Disturbance in Bed of Lakes.

"Scientist in Cleveland explain that the seat of the seismic disturbance was probably beneath the bed of Lake Erie. The fact

that no serious wave movement accompanied the shock, they add, proves that in spite of its apparent violence it was of minor importance.

“None of these scientists, however, felt the shock, and those who did dispute its being of merely minor importance. When windows rattle and doors tremble, residents of Cleveland aver, there must be “something doing” in the stomach of Mother Earth.

“It was learned last night that there was a severe powder explosion near Detroit. For a time this gave rise to the theory that it might account for the disturbances on this side of the lake, but a comparison of the time seemed to make this impossible. According to seismographic registration the shock occurred at 4:10 o’clock, while the explosion was at 4:40.

Even the average time of 4:20 o’clock set by the general public as when the shock was felt, would leave twenty minutes to be accounted for.

“That there was only one shock, but that of violent character, is the testimony from all quarters. The seismograph of Father Odenbach, at St. Ignatius College, tells a different story, however. Its delicate mechanism affords unerring proof of three separate visitations during the afternoon, the second one being most generally felt.”

“Seismograph Shows Several Shocks.

“‘Steady seismic disturbances between 1:15 and 2 o’clock are recorded by the seismograph,’ said Father Odenbach last night. ‘At 4:10 o’clock there was a violent disturbance-so violent that one of the pins was wrested from the instrument’s paper. This lasted

possibly eight seconds. At 5:59 o'clock there was a third tremble, but this was almost imperceptible and of slight duration'.

"'Until comparisons are made with observations taken at other points, it is impossible for me to say where the seat of the disturbance was located. I should judge, though, from the reports I have received from along the shore, that it was somewhere beneath Lake Erie and close to the southern shore line. No, such a disturbance would not necessarily cause a tidal wave or even any appreciable wave movement. Conditions on Lake Erie are different from those along the oceans'.

"'The fact that such a disturbance has occurred is most interesting,' said Professor Cushing, head of Western Reserve University's geological department. 'Until the necessary technical facts are at hand it is impossible even approximately to locate the center. I should say, though, that the theory that it was under Lake Erie's waters is the most tenable one.'

"Rocky River and Lakewood felt the shock more severely than any other sections of this county. At first, so violent was the disturbance, the general belief was that there had been a terrific explosion, and the Leader's telephones were kept busy by anxious inquirers. Investigation developed that the scene of visitation was so great in extent and of such narrow width that nothing but an earthquake would be likely to cause it.

"Among those who told of having experienced the shock were Captain J. C. Gilchrist, the veteran vessel owner, who was at his summer home at West Park; A. W. Van Denschoten, Rocky River; Mrs. Jay E. Andrews, Lakewood; and the family of M. F. Bramley, just inside the western city limits.

"Painesville Feels Shock.

"At Painesville County Clerk John T. Barto told of the rattling of the windows in the court house. Nothing of the kind was experienced, though, at Fairport, only a few miles away.

"Sandusky reports that a severe shock, as of an explosion or earthquake, shook that city. The shock was also felt at Put-in-Bay, Marblehead and other points in that vicinity.

"A dispatch from Lorain says that at about 4 o'clock a loud rumbling noise was heard and buildings were shaken in all parts of that city. Women and children were thoroughly frightened. Pictures were shaken from the walls and bric-a-brac was rattled."

Cleveland News, Cleveland, Ohio, June 28, 1906

"Earthquake All Along Lake Erie-

"Sharp Shock That Shook Houses was Accompanied by Deep Rumbling Noise-

"A perceptible earthquake shock was felt shortly after 4 o'clock Wednesday afternoon by residents along the south shore of Lake Erie from Painesville to Sandusky. The shock was accompanied by a deep rumbling noise which was mistaken as thunder, but at the time the sky was clear. The shock was more noticeable immediately along the lake shore. In Lakewood, Lorain and Painesville houses were shaken by the seismic disturbance while in many houses the windows rattled and bric-a-brac was overturned.

"People living in the big blocks on Broadway and along the water front were jarred to such an extent that several women ran down into the street. On woman was thrown from a chair in Duane

Block, and slightly hurt. Dishes were broken in the upper stories and pictures were disarranged on the walls. The seismograph at St. Ignatius College recorded earthquake shocks. Father Odenbach stated that steady seismic disturbances were recorded from 1:15 to 2:00 o'clock while a violent shock occurred at 4:10 lasting about 8 seconds. He believes that disturbance was under the bed of Lake Erie."

Elyria Reporter, Elyria, Ohio, June 28, 1906

"The Earth Trembled Wednesday Afternoon.

"Earthquake Shock Felt at Lorain and Sandusky. Buildings Rocked and Goods were Strewn About.

"A violent earthquake shock shook the southern shore line of Lake Erie for a distance of one hundred miles on Wednesday afternoon, the eastern limit being Painesville and the western Marblehead.

"While no serious damage has been reported the shock was so violent in many places as to throw pictures from the walls of houses and shatter bric-a-brac.

"Sandusky reports that a severe shock, as of an explosion or earthquake, shook that city. The shock was also felt at Put-in-Bay, Marblehead and other points in that vicinity. The shock was also felt at Lorain about four o'clock. A loud rumbling noise was heard and buildings were shaken in all parts of the city. Women and children were thoroughly frightened. Pictures were shaken from the wall and bric-a-brac was rattled."

Elyria Reporter, Elyria, Ohio, June 28, 1906

"Earthquake Shock was Felt Here.

"The earthquake shock which occurred on Wednesday afternoon between four and five o'clock along the southern line of Lake Erie, was felt in Elyria. People living on Fifth Street, felt the shock and say their houses trembled like a leaf in a gale. The buildings rocked for a few seconds.

"Shock was Felt in Amherst.

"The earthquake shock which occurred on Wednesday afternoon was felt in North Amherst. One woman writing to a friend to-day from North Amherst said that she was considerable frightened by the rocking of the house for a few seconds. The articles in her cupboards danced on the shelves. She said she never felt an earthquake shock as clearly (sic) as she felt the one of Wednesday."

Elyria Reporter, Elyria, Ohio, June 29, 1906

"Twenty Tons Dynamite Exploded in a Scow.

"This was the Cause of the Shocks, supposed to be the effect of an Earthquakes Sailors Fired into the Dynamite.

"The supposed earthquake shocks felt here and in other places turns out to be the effect of a dynamite explosion. A dispatch from Monroe, Mich., says that the shock was felt there, and was caused by the explosion of twenty tons of dynamite stored in a scow at the mouth of the Detroit River. The dynamite was the property of contractors engaged in deepening the channel at the Limekiln crossing near Amherstburg, Ont. and was exploded by some

sailors on a yacht shooting into the scow. Many windows for miles around were broken, and the foundations of several buildings were cracked.”

Lorain Daily News, Lorain, Ohio, June 28, 1906

“Buildings Shook; City Felt Earthquake.

“South Shore of Lake Erie from Toledo to Cleveland Shaken Mysteriously Yesterday Afternoon-Seismographs in Cleveland Register Quake-Women Scared in Lorain.

“A severe earth tremor which is variously ascribed to earthquake or explosion or thunder causes was felt in this city about 4 o’clock yesterday afternoon. Buildings trembled, windows rattled, pictures swayed and dishes bounced upon the shelves of pantries.

“Reports from other towns along the lake for a distance of 100 miles give practically the same story.

“While no serious damage has been reported, the shock was so violent in many places as to throw pictures from the walls of houses and shatter bric-a-brac. In other cities and towns windows and transoms were shaken violently, and open doors were slammed shut.

“In this city many buildings were shaken. Women and children were alarmed. In the big Duane building a chair was almost shaken from under a woman, while the sewing machine at which she was working swayed and danced under her hands.

“Scientists in Cleveland explain that the seat of the seismic disturbance was probably beneath the bed of Lake Erie.

"None of these scientists, however, felt the shock."

"It was learned last night that there was a powder explosion near Detroit. For a time this gave rise to the theory that it might account for the disturbances on this side of the lake, but a comparison of the time seemed to make this impossible. According to seismographic registration the shock occurred at 4:30 (sic) o'clock, while the explosion was at 4:40. Even the average time of 4:20 o'clock set by the general public as when the shock was felt would leave twenty minutes to be accounted for.

"That there was only one shock, but that of violent character, is the testimony from all quarters. The seismograph of Father Odenbach, at St. Ignatius' college, Cleveland, tells a different story, however. Its delicate mechanism affords unerring proof of three separate visitations during the afternoon, the second one being most generally felt.

"'Steady seismic disturbances between 1:15 and 2 o'clock are recorded by the seismograph,' said Father Odenbach last night. 'At 4:10 o'clock there was a violent disturbance-so violent that one of the pins was wrested from the instrument's paper. This lasted possibly eight seconds. At 5:59 o'clock there was a third tremble, but this was almost imperceptible and of slight duration.

"Sandusky reports that a severe shock, as of an explosion or earthquake, shook that city. The shock was also felt at Put-in-Bay, Marblehead and other points in that vicinity.

"Detroit, June 28.-'Theodore H. Perry and Harry Rogers, two Detroit men, had a marvelous escape from death yesterday, being blown out of their sailboat by a terrific explosion while sailing near Fox island at the mouth of the Detroit River. The young men were passing a small island at the head of Fox island, the smaller

island being used by a contracting firm for the storage of explosives used in dredging and blasting operations. The powder house was wrecked and windows were broken as far away as the Canadian city of Amherstburg."

Painesville Evening Telegraph, Painesville, Ohio, June 28, 1906

"Painesville People Feel Jars of Earthquake.

"A violent earthquake shock shook the southern shore line of Lake Erie for a distance of 100 miles Wednesday afternoon, the eastern limit being Painesville and western Marblehead.

"While no serious damage has been reported, the shock was so violent in many places as to throw pictures from the walls of houses and shatter bric-a-brac. In other cities and towns, especially in Cleveland's suburbs, windows and transoms were shaken violently, and open doors were slammed shut.

"County clerk J. C. Barto noticed the shock shortly after 4 o'clock. The windows in his office at the court house shook violently and Mr. Barto jestly remarked to his deputy, Mrs. Downee, that it was an earthquake, not thinking that it was such a disturbance. At the home of E. G. Hardy, near the lake, the shock was quite perceptibly felt, his daughters feeling the house shake beneath them. Quite a number of others observed the disturbance.

"In many instances temporary panic was caused by the disturbance. The memory of the San Francisco horror is so vividly before the public that the timorous ones feared the worst. So brief was the duration of the shock, however, that calm was soon restored.

"Scientist in Cleveland explain that the seat of the seismic disturbance was probably beneath the bed of Lake Erie. The fact that no serious wave movement accompanied the shock, proves that in spite of its apparent violence it was of minor importance.

"None of these scientists, however felt the shock, and those who did dispute its being of merely minor importance.

"It was learned Wednesday night that there was a severe powder explosion near Detroit. For a time this gave rise to a theory that it might account for the disturbances on this side of the lake, but a comparison of the times seemed to make this impossible. According to seismographic registration the shock occurred at 4:10 o'clock while the explosion was at 4:40. Even the average time of 4:20 set by the general public as when the shock was felt would leave 20 minutes to be accounted for.

"That there was only one shock, but of violent character, is the testimony from all quarters. The seismograph of Father Odenbach, at St. Ignatius College, tells a different story, however. Its delicate mechanism affords unerring proof of three separate visitations during the afternoon, the second one being most generally felt."

EARTHQUAKE OF APRIL 12, 1907

CA: 18:28 GMT

EPICENTRAL INTENSITY: I(MM)

LOCATION: 41.5N, 81.7W

EVALUATION:

The newspaper search (see matrix) failed to turn up any report of this supposed event which was originally listed by Docekal and later carried by Nuttli. Docekal's main reference is Reid. Reid's handwritten note is extremely hard to decipher, but, on a close examination, the text states clearly that this event was not an earthquake. One can also see that the seismograph was not performing too well on that day. This event has been removed from the catalog and placed with the dubious events (Table 3).

COMPILATION OF ACCOUNTS:

Reid, H. F., Unpublished notebooks, scrapbooks, and card files. Custodian: U.S. Coast and Geod. Survey, Rockville, Md.

"C.S.T. 1:28 p.m. 12 April 1907. Cleveland, Ohio. I. Father Odenbachs' seismogram shows a sudden fling of pendulum to N.W. at 1:28 p.m. with a gradual but irregular recovery in 1^m in the N. comp. and more rapid recovery... in the W. comp. The displacements are somewhat like smaller displacements which characterize the whole record. This is especially true of the N-S comp. the trace of which is made up of sudden displacements to N. and slow recoveries. The meteorological condition do not explain this displacement,... was complete recovery: the disturbance was probably not an E.Q."

EARTHQUAKE OF SEPTEMBER 27, 1921

CA: 04:32 GMT

EPICENTRAL INTENSITY: III(MM)

LOCATION: 42.1N, 80.2W

EVALUATION:

This event was felt by two persons in Erie, Pa. (42.1N, 80.2W) according to Monthly Weather Review, where an Intensity III Rossi Forel was assigned. It was later given an Intensity III (MM) by Smith. It seems that the evidence presented would have been adequately covered by an Intensity II (MM). However, the Intensity III will be retained.

COMPILATION OF ACCOUNTS:

Monthly Weather Review, September, 1921, United States Weather Bureau, Washington, D.C.

"September 27, 1921. 4:32. Erie, Pennsylvania, 42°05'N. 80°10' W. III(RF). Felt by two."

Smith, W. E. T., 1962, Earthquakes of Eastern Canada and Adjacent Areas 1534-1927, Publications of the Dominion Observatory, V. 26, No. 5.

"September 26, 1921, 11:32 p.m. III. 42.1°N, 80.2°W. Felt at Erie, Pa."

EARTHQUAKE OF SEPTEMBER 9, 1928

CA: 20:00 GMT

EPICENTRAL INTENSITY: V(MM)

LOCATION: 41.5N, 82.0W

EVALUATION:

The location, intensity and nature of the seismic activity observed on this day all remain somewhat mysterious. Three district tremors were observed over a rather large area along the lake from East Cleveland to Port Clinton <Figure 2D D-10>. Some of the felt reports can be evaluated in the IV-V intensity range, but it is never clear how the intensities of the three events compared with each other.

One source of confusion arises from the fact that a bombing exercise took place just about the same time (≈3:00) at Camp Perry (7 miles from Port Clinton). Some reports, e.g., "distant thunder," "earthquake appeared remote," "three distinct rumblings," could be interpreted in support of the theory that the bombing exercise was indeed the cause of the felt reports. But this interpretation was not accepted in United States Earthquakes: "it is not thought that the tremors were a result of these operations." Unfortunately, the reasons for this rejection are not given. One disturbing question comes from the fact that the seismograph at John Carroll did not record any earthquake signals that afternoon. This is hard to reconcile with the true occurrence of a seismic event (Intensity V) located near Lorain and West Cleveland. The absence of a signal on the seismograph could indicate that the observed noise and vibrations were not related to seismic waves, but simply noise (air waves) generated by bombs exploding with a poor coupling to the ground.

If one insists on maintaining the occurrence of a true seismic event (with aftershocks), the epicenter should remain west of Cleveland, as

more localities reported the rattling there than east of Cleveland. A suggested epicentral uncertainty of ±20 miles would be a fair estimate.

The event was not reported felt in Painesville, and was most likely not felt at the site. The originally assigned V is maintained to account for some fright, but it is considered quite conservative since no damage was reported.

COMPILATION OF ACCOUNTS:

Ashtabula Star Beacon, Ashtabula, Ohio, September 10, 1928

> "Earth Shocks Cause Scare.
>
> "Cleveland is Shaken by Strange Tremors.
>
> "Cleveland, Sept. 10-Explanations for three sharp earth tremors which shook downtown office buildings and the lake shore from Port Clinton to the city's eastern limits, frightening thousands Sunday, were varied Monday. No appreciable damage was reported.
>
> "Some observers accredited the abrupt shocks, which were felt throughout the entire Cleveland area, to an aerial bombing demonstration at Camp Perry while others believed them caused by the shifting of salt mines said by Father F. L. Odenbach of John Carroll University on former disturbances, to underlie the upper earth strata. (sic)
>
> "The tremors were not recorded on the seismograph at the local university."

Cleveland Plain Dealer, Cleveland, Ohio, September 10, 1928

"'Earthquakes Shake City and Lake Shore'.

"'Rattle Windows in Downtown Skyscrapers and Send Scores into Streets on East Side.'

"Three abrupt earth tremors which shook the lake shore from Port Clinton to Cleveland's eastern limits at East 185th St. mystified residents throughout the entire area late yesterday afternoon as their houses rocked to the creaking of window frames.

"One hundred families in the area between Euclid Beach Park and E. 185th St. flocked to the street shortly after 3 p.m. as two temblors rattled windows and set floors to rolling. One half were frightened and the other merely curious.

"E. L. Gove, engineer of WHK on the top floor of the Engineers Bank Building, was in the broadcasting station's battery room when the shocks came. He said that they caused a marked rumbling throughout the offices.

"Windows in the lower floors of the Terminal Tower Building rattled loudly from the tremors, custodians there said.

"Although no explanation for the shocks could be obtained last night, Toledo observers accredited them to an aerial bombing demonstration at Camp Perry. Occasional similar disturbances in the Cleveland area have been accredited to the shifting of salt mines said by Father F. L. Odenbach of John Carroll University to underlie the upper earth strata.

"Although no tremors were recorded on the seismograph at John Carroll University, it was generally believed that the shocks were

of subterranean origin and had nothing to do with the Camp Perry exhibition where three 300-pound bombs were dropped upon targets near the shore during the hour between 3:30 to 4:30 p.m.

"At Port Clinton, seven miles from the camp, shocks were felt almost simultaneously with the bomb explosion, however.

"Buildings shook and windows rattled at Cedar Point as the earth trembled from the shocks.

"Residents of the shore east of Lorain felt the shocks distinctly and reported a third disturbance at 3:45 p.m.

"Lorain police telegraphed Cleveland, Toledo, and Detroit after the shocks were reported fearing an earthquake in this vicinity.

"The three shocks were felt distinctly at Loch Doon, summer home of E. N. Newberry, on the lake shore at E. 185th Street.

"No damage was reported from any source. The last pronounced quake here was in February."

Elyria Chronicle Telegram, Elyria, Ohio, September 10, 1928

"Feel Tremors along the Lake Shore.

"Cleveland, O., Sept. 10.-Residents along the lake shore from Cleveland to Port Clinton were speculating today upon the origin of a series of tremors which shook the earth at intervals Sunday.

"Some persons believed the tremors were the offshoot of an earthquake but no disturbances were recorded by the seismograph at John Carroll university here.

"Others attributed the disturbances to an aerial sham battle at Camp Perry where 300-pound bombs were dropped from maneuvering airplanes.

"No damage was reported from any of the affected areas.

"Port Clinton residents reported the tremors came simultaneously with the explosion of the practice bombs."

Lorain Journal, Lorain, Ohio, September 10, 1928

"Tremors Shake City but Cause's Mystery.

"The cause of the series of earth tremors which shook the Lake shore from Cleveland to Port Clinton Sunday afternoon, still remained a mystery today.

"Hundreds in Lorain reported that they distinctly felt the shocks which shook houses and rattled windows here. Some declared there were three tremors here at intervals of a few seconds, while others said they felt only one or two.

"Lorain police received a lot of telephone calls immediately following the tremors and wired Cleveland, Toledo and Detroit, fearing there had been an earthquake in the vicinity.

"The earthquake possibly (sic) appeared remote as no disturbances were recorded by the seismograph at John Carroll university at Cleveland.

"The most logical cause seemed the aerial sham battle at Camp Perry where 300-pound bombs were dropped from maneuvering airplanes. Port Clinton residents reported the tremors came simultaneously with the explosion of the practice bombs.

"No damage was reported from any of the affected areas.

"Lorain observers varied as to the time they felt the shocks. The time they reported varied from 3:12 p.m. until 3:45."

Painesville Telegraph, Painesville, Ohio, September 10, 1928

"-Earth Shocks on Lake Shore Cause Alarm-.

"-Tremors are Felt from Cleveland on Sunday-.

"Cleveland, Ohio, Sept. 10-Explainations for 3 sharp earth tremors which shook downtown office buildings and the lake shore from Port Clinton to the city's eastern limits frightening thousands Sunday afternoon were varied Monday, No appreciable damage was reported.

"Some observers accredited the abrupt shocks which were felt throughout the entire Cleveland area to an aerial bombing demonstration at Camp Perry while others believed them caused by the shifting of salt mines, said Father Odenbach of John Carroll University on former disturbances to underlie the earths strata.

"The tremors were not recorded on the seismograph at the local university. Although 300 pound bombs were dropped upon targets at Camp Perry at the approximate time of the shock here it was generally believed the shocks were of subterranean origin and had nothing to do with the Camp Perry demonstration.

"Windows were rattled and floors set to rolling in 100 homes in the area between Euclid and E. 185 St. Many of the residents were frightened while others appeared merely curious at the shocks.

"Windows in the lower floors of the Terminal Tower Building rattled loudly, according to custodians. Similar rumblings were heard in other downtown buildings. It is believed that the shocks were not severe enough to cause an appreciable damage anywhere in the affected area.

"Reports from Port Clinton, Cedar Point, Lorain and other cities on the lake shore west of Cleveland declared the tremors were distinctly felt as the earth shook. Lorain police telegraphed Cleveland, Toledo and Detroit fearing an earthquake in the vicinity.

"The last pronounced earthquake in Cleveland was in February 1925 when the shock was severe enough to shake pictures from walls."

EARTHQUAKE OF SEPTEMBER 17, 1929

CA: 19:16 GMT

EPICENTRAL INTENSITY: II(MM)

LOCATION: 41.50N, 81.55W

EVALUATION:

This event had been incorrectly listed in the PSAR as having occurred on September 27. Bradley and Bennett assigned an Intensity II to this event with the coordinates of Euclid (41.50N, 81.55W). No other reports of this small, local event were found in the nearby localities during our newspaper search.

It is suggested that this event be included among these of dubious origin (Table 3). A single report from an individual speaking for himself does not seem sufficient to support the true seismic origin of the felt vibrations. An earthquake strong enough to "shake a house violently" would have been felt by more than one person and would deserve an intensity higher than II(MM).

COMPILATION OF ACCOUNTS:

Bradley, Edward A., S. J. and Theron J. Bennett, 1965, Earthquake History of Ohio, B.S.S.A., V. 55, No. 4, pp. 745-752.

"1929 September 17: 19^h16^m; II. In Cleveland suburb of Euclid; man reported house violently shaken."

EARTHQUAKE OF FEBRUARY 16, 1930

CA: 12:17 GMT

EPICENTRAL INTENSITY: III(MM)

LOCATION: 42.83N, 80.25W

EVALUATION:

This event was felt in Ontario, at Simcoe and Tillsonburg, according to Smith. His Intensity III and coordinates of 42.83N, 80.25W are accepted with no further research.

COMPILATION OF ACCOUNTS:

Smith. W. E. T., Earthquakes of Eastern Canada and Adjacent Areas 1928-1959, Publications of the Dominion Observatory, V. 32, No. 3.

"1930 February 16. 12:17.III. 42°50'N, 80°31'W. Felt in Ontario, at Simcoe and Tillsonburg, where it rattled windows and dishes."

EARTHQUAKE OF JANUARY 21, 1932

EPICENTRAL INTENSITY: IV(MM)

LOCATION: 41.08N, 81.50W

EVALUATION:

An Intensity IV, as chosen by Bradley and Bennett, appears to be characteristic of this event, even though a few windows were cracked. The tremor was felt only on the west shore of Summit Lake, which is within the city limits of Akron. As explicitly mentioned in reports, the shore sediments had a very localized amplification effect. The rest of Akron remained unaffected by the event. Coordinates are those of the lake as given by Docekal.

COMPILATION OF ACCOUNTS:

Akron Beacon Journal, Akron, Ohio, January 22, 1932

"Quake? Here's Evidence!.

"Earthquake in South Akron? "'Here's evidence,' says Miss Mary Jane Brady, 530 Indian Trail, as she pointed to a cracked kitchen window. And there were not small boys playing baseball nearby.

"Other residents in the area around Summit Lake, today still were trying to puzzle out source of earth tremors Thursday afternoon which broke windows in their homes, rattled dishes, caused furniture to hop around crazily and otherwise created consternation. No official inquiry has been undertaken, but offhand opinion is that earth caverns bordering the lake may have collapsed, producing the shock."

Akron Times Press, Akron, Ohio, January 22, 1932

"Quake of Summit Lake is Mystery to 'Victims'.

"Seismograph Packed up as Pictures Sway, Furniture Dances.

"Cause of earth tremors that shook a small area on the west shore of Summit Lake late Thursday remained a mystery Friday as amateur geologists sought an explanation.

"Whether it was an honest-to-goodness earthquake could not be proved scientifically Friday since the seismograph at John Carroll University in Cleveland was packed up for removal to new quarters.

"But residents of Summit Lake Blvd. and streets off Manchester Road near the lake saw furniture move, pictures sway and a few windows broken.

"Francis Lavery, 19, of 1742 Summit Lake-blvd. saw dresser dance sway as he combed his hair. He found 15 other families in the neighborhood felt the shock.

"Lavery advanced the theory that the tremors were caused by earth filling into underground caverns from which salt had been washed thru Kenmore district wells.

"Colonial Salt Works officials refused to comment on the possibility, but said no tremors had been felt at their plant at 2065 Manchester road.

"J. H. Vance, chairman of the Chamber of Commerce Waterways Committee, explained that Summit Lake and its shore rest on a deep bed of springy, jelly-like muck, that would reflect the slightest disturbance in tremors."

BSSA, V. 22, No. 1, pp. 68-72

"Akron, Ohio, January 21, 1932.-Residents near Summit Lake, which is within the city limits of Akron, felt a slight earthquake, which broke windows in three houses and rattled dishes furniture in several others, on the afternoon of January 21st." SDGU

Cleveland Plain Dealer, Cleveland, Ohio, January 22, 1932

"'Quakes' at Akron Remain a Mystery; Caverns Blamed.

"(From Plain Dealer Bureau).

"Akron, O., Jan. 21.-The origin of earth tremors which this afternoon broke windows, turned pictures on walls and caused chandeliers to sway like pendulums, on the west shore of Summit Lake remained a mystery tonight.

"Francis Lavery, 19, of Summit Lake Boulevard was slicking up his hair before a mirror when he was surprised to have the glass move out of range. Investigation disclosed that pictures and chandeliers in other parts of the house were swaying, too.

"His curiosity aroused, the youth called at fifteen homes in the vicinity and found their occupants had all noticed the tremors and that some of the houses had windows broken by the 'quakes.'

"Lavery believes the tremors were due to the earth settling into underground caverns formed by drawing salt through the salt wells in Kenmore.

"Ralph C. Durst, who teaches geology at Akron University, said tonight he had not heard of the tremors. He admitted, it might have been an earthquake and said the salt cavern theory was plausible but not probable."

EARTHQUAKE OF OCTOBER 29, 1934

CA: 20:07 GMT

EPICENTRAL INTENSITY: V(MM)

LOCATION: 42.0N, 80.2W

EVALUATION:

This event was reported felt with Intensity IV-V in Erie, Pa. (42.0N, 80.2W). It was felt over an area of about 700 square miles. The earthquake was apparently very local in nature, since no felt reports were found for eastern Ohio. The Painesville, Cleveland, Youngstown, Ashtabula, and Niles newspapers all carried similar reports about the event felt in Erie, but no reference was made to local felt reports.

The Intensity V(MM) is retained because of the fright and slight damage reported in Erie, by Coffman and von Hake (1973). The current search was extended to Pennsylvania.

COMPILATION OF ACCOUNTS:

Ashtabula Star Beacon, Ashtabula, Ohio, October 30, 1934

"'Quake Jars Buildings in Erie Business Area'.

"Nature was resting quietly today after two sprees along Lake Erie. She gave Buffalo a view of some of the tricks she can do with air currents, sending water spouts high in the air along the shore of the lake. In Erie, Pa., she caused a mild earthquake. In Ashtabula, she sent a heavy snowfall.

"Downtown and residential Erie was shaken from end to end by the earthquake. Buildings swayed, housewives reported dishes fell

from cupboard shelves and there was intense excitement, but no serious damage occurred. One woman said she was thrown from her bed while asleep.

"The shock occurred shortly after 3 p.m., and was felt only for an instant. The seismograph observer at the University of Pittsburgh reported a very slight shock had been registered within close proximity at 3:08 p.m.

"Many residents thought the shock might have been caused by an explosion, but a check did not disclosed any had occurred.

"'Shakes Buildings'.

"Office workers in the heart of Erie and residents of the suburbs reported the shock was distinctly felt. It was also felt at the Coast Guard station and for an area of more than 10 miles along the lake front.

"Apparatus used by a gas company to blend natural gas for use in the city was thrown out of commission. Erie last experienced an earthquake eight years ago, of about similar proportions of Monday's."

(same account in Youngstown Vindicator, Oct. 30, and Painesville Telegraph, Oct. 30)

Cleveland Plain Dealer, Cleveland, Ohio, October 30, 1934

"Erie is Startled by Baby Quake.

"Five Water Spouts March in on Buffalo from Lake, Drenching Many.

"Loose on an orgy of Halloween pranks, Dame Nature raced eastward along the shores of Lake Erie yesterday to administer a shaking up to residents of Erie, Pa., who felt a sharp earth tremor at 3:08 p.m., and then moved on to Buffalo, where she sent five roaring water spouts whirling into the harbor.

"While Clevelanders stared at the freak skyline over the lake, the terrestrial shock at Erie set buildings swaying and shook pictures from the walls and dishes from shelves and tables.

"At Buffalo, a little later, the water spouts sped across the harbor from the southwest, tossing sea gulls into the air and then crashing against the stout sea wall and docks.

"The tremor at Erie was felt downtown as well as in residential and industrial areas. In the excitement hundreds of householders were in a panic momentarily, but no serious damage resulted.

"One woman was reported thrown from her bed by the shock.

"The baby quake was recorded on seismographs at the University of Pittsburgh and at Canisius College, Buffalo, at 3:08 p.m.

"The quake at Erie was not noted more than ten miles from the city's center, except by the seismologists. It was the second earth disturbance there in eight years."

Niles Daily Times, Niles, Ohio, October 30, 1934

"'Baby Earthquake Felt at Erie, PA'.

"Erie, Pa.-Foundations of down town buildings were shaken and gas lines broken here by an earthquake shock which rocked the city.

"The tremor was felt late yesterday following a heavy snow storm. A seismograph of St. Canisius college in Buffalo recorded the shock.

"At least one gas line was shattered in the western section of the city. Occupants of the citys' two tallest buildings said the structures rocked for several seconds.

"Hundreds of persons reported dishes rattled on tables in their homes. One woman at Westville, near here, said she saw a building move slightly."

Youngstown Telegram, Youngstown, Ohio, October 30, 1934

"Erie Shaken by Quake; Ohio may Feel Temblors.

"Special to the Telegram.

"Cleveland, Oct. 30.-Eastern Ohio may be subject to quakes such as shook Erie, Pa., last night, according to Dr. J. E. Hyde, professor of geology at Western Reserve University.

"Foundations of downtown buildings in Erie were shaken and gas lines broken.

"The tremor was felt late yesterday following a heavy snow storm. Occupants of the city's two tallest buildings said the structures rocked for several seconds.

"Hundreds of persons reported dishes rattled on tables in their homes.

"The earthquake probably occurred a mile or more underground, Dr. Hyde said. Erie probably experienced the surface manifestations of a readjustment in the 'basement complex,' he explained.

"The oldest rocks known to geologists, rocks more than a billion years old, are called technically the 'basement complex.' They are granites and marbles and schists, bent and twisted and tangled in wild confusion.

"'The basement complex comes to the surface in northeastern Canada and again in the south in the Ozarks and Texas,' Dr. Hyde said 'In Ohio, the basement complex is beneath layers of stratified rock ranging to a mile in thickness.'"

EARTHQUAKE OF NOVEMBER 5, 1934

CA: 20:00 GMT

EPICENTRAL INTENSITY: III(MM)

LOCATION: 41.88N, 80.37W

EVALUATION:

United States Earthquakes assigned this event an Intensity III and the coordinates of Albion, Pa. (41.88N, 80.37W). No further report was found in nearby Ohio newspapers. An Intensity III is more than adequate for "trembling motion."

COMPILATION OF ACCOUNTS:

Neumann, Frank, 1936, United States Earthquakes, 1934, U.S. Dept. of Commerce, Coast and Geodetic Survey, Washington, D.C.

> "November 5: 15:00. Albion, Pa., III. Trembling motion."

EARTHQUAKE OF AUGUST 26, 1936

CA: 08:55 GMT

EPICENTRAL INTENSITY: II(MM) (R)

LOCATION: 41.4N, 80.4W

EVALUATION:

This small event was assigned an Intensity III and the coordinates of Greenville, Pa. (41.4N, 80.4W) by Smith. United States Earthquakes had simply reported "a weak" event at the same place. The research found no reports of this earthquake in nearby Ohio localities (see matrix). It is suggested that the intensity could be lower (II), since the event appears to be very local.

COMPILATION OF ACCOUNTS:

Neumann, Frank, 1938, United States Earthquakes 1936, U.S. Department of Commerce, Coast and Geodetic Survey, Washington, D.C.

"August 26: about 3:55 to 4:05. Greenville, Pa. Weak."

EARTHQUAKE OF MAY 31, 1940

CA: 16:00 GMT

EPICENTRAL INTENSITY: II(MM)

LOCATION: 41.10N, 81.52W

EVALUATION:

United States Earthquakes states that this event was a "slight tremor felt by a few" at Akron. The investigation found no report of this event in the Akron Beacon Journal. Bradley and Bennett will be followed: Intensity II with the coordinates of Akron: 41.10N, 81.52W.

COMPILATION OF ACCOUNTS:

Neumann, Frank, 1942, United States Earthquakes 1940, U.S. Department of Commerce, Coast and Geodetic Survey, Washington, D.C.

May 31: 11:00-11:30, Akron, Ohio. Slight tremor felt by few."

EARTHQUAKE OF MARCH 9, 1943

CA: 04:25:34 GMT

EPICENTRAL INTENSITY: V(MM)

LOCATION: 41.61N, 81.33W (R)

EVALUATION:

The epicentral location and estimated epicentral intensity of this event have been the object of great confusion for some years. Because this event is, in all appearances, the largest to have occurred in the vicinity of the site, it is important to clarify the problem. The earthquake was felt over a relatively large area, 220,000 square kilometers <Figure 2D D-11>. Heck and Eppley (1958) originally assigned the following coordinates: 42.2N, 80.9W, and an Intensity IV-V(MM) (see their commentary below). Eppley (1965) did not change anything to the location, intensity and commentary. Smith (1966) kept the same coordinates; no mention of intensity; the only new element: an instrumental magnitude M_L=5.5 was listed. Coffman and von Hake (1973), changed the location, from Lake Erie to Lake Erie area, and assigned new coordinates without any further explanation: 41.6N, 81.3W, preserving the same Intensity IV-V(MM). Their commentary (see below) was taken integrally from Eppley. Other catalogs, Bradley and Bennett (1965), Docekal (1972), Nuttli and Herrmann (1978) have retained the original location in the middle of the lake, probably because they simply followed Eppley's versions.

Recently, Gordon, Dewey and Jones (1978), of the USGS, in a revision of approximately 100 hypocenters, have noticed the mislocation of the 1943 Lake Erie event. Their revised coordinates, 41.61N, 81.33W, are in perfect agreement with the Coffman and von Hake unexplained relocation.

The additional research carried out by Weston Geophysical for the present appendix has uncovered numerous references from local

newspapers. Felt reports from Cleveland and vicinity do not exceed Intensity V. Most of them suggest that the original assignment of IV-V, by Heck and Eppley was correct.

The assumed relation between the earthquake and the breakage of the water main in Willoughby does not justify the raising of the epicentral intensity. Even if the causal relationship is accepted, such a breakage should be discussed in connection with age and corrosion of the water main, frost action, soil amplification, etc.

Some local newspapers refer to the seismographic recording obtained at John Carroll University, and some interesting comments of Rev. Joseph Joliat, S.J., seismologist in charge. Weston Geophysical has obtained a copy of the seismogram <Figure 2D D-12> and interpreted the data. On this basis, Father Joliat's comments can now be discussed.

1. Father Joliat "thought that the epicentral distance was 20 or 30 miles." Considering the irregularity of the drum speed, the poor knowledge of velocity model and the reading uncertainty of P and S phases due to slow drum speed, the suggested distance range was certainly correct. Reinterpretation of the seismogram, suggests a range of 16 to 24 miles, which would account for most of the uncertainties. It is interesting to note that the average of 20 miles is in agreement with the relocated epicenter, (Gordon et al, 1978) and very similar to the 1951 Willoughby epicentral distance.

2. Father Joliat stated that he could not ascertain the "direction of the quake," but ventured to say "to the southwest." Without a vertical instrument, first horizontal motions cannot give the direction of approach. The low magnification of the Weichert instrument (80), the long period (7 sec) and the slow drum speed, did not even give readable first motions <Figure 2D D-12>. Father Joliat had a 50/50

chance to be right. The event was most likely located to the northeast. The interesting fact is that the azimuth NE-SW had been correctly inferred.

3. Father Joliat suggested focal depth estimates (10 to 20 miles, depending on the reporting newspapers) are merely reflective of contemporaneous geological thoughts, and are not dependent on instrumental data. The current average focal depth of 15 km. for eastern North American events is probably applicable here in view of the observed felt area and epicentral intensity.

4. It is interesting that Fr. Birkenhauser, successor of Fr. Joliat, commenting on the location of the December 3, 1951 earthquake, suggests a similarity between the two epicenters. First, the 1951 event distance is 20 miles, "in the vicinity of Willoughby," and "felt at almost the identical place in March 1943." The epicentral distance obtained from the December 3, 1951, seismograms (three components) ranges between 19 to 21 miles. It is possible that Fr. Birkenhauser did compare the seismograms before making his statement.

Final point needs to be addressed: that of the probable magnitude of the event. When Smith (1966) decided to characterize the event in terms of magnitude, he used three Canadian stations that had recorded the shock. In his computations of M_L Richter magnitude estimates, Smith was already aware that attenuation in California was higher than in eastern Canada. Short of something more applicable, he did calculate an average M_L=5.5. Within the following decade, almost everyone recognized that the use of Richter's formula led to overestimated values for eastern magnitudes. Nuttli (1973) did provide a more applicable scale. A. Stevens from Ottawa, using the same ground motions measured by Smith, calculated an average m_{bLg}=4.7 for the event, identical to the estimate provided by Nuttli and Herrman (1978) on the basis of felt area versus

magnitude relationship. It could be noted that such a magnitude appears compatible with an epicentral Intensity V(MM).

COMPILATION OF ACCOUNTS:

Akron Beacon Journal, Akron, Ohio, March 9, 1943

"Did you feel it too?

"Akron Jarred By Earthquake.

"Dishes rattled in cupboards, homes quivered slightly and the curiosity of citizens was fired but those were the only effects reported in Akron Monday night in the wake of a slight earth tremor, the first experienced in northern Ohio for six years.

"Curious citizens thought of nearly every possibility in the books when they felt their homes quiver about 11:27 p.m. but few even thought they were feeling a bona fide earthquake, judging from telephone calls received by the police and fire departments. There were no reports of any damage-not even as much as a broken window.

"Some thought there had been an explosion in one of the war plants and made anxious inquiries. Others rushed to their basements because they thought there had been an explosion there, according to reports.

"And thousands of other citizens didn't know anything about it, sleeping blissfully through the earthquake. Neither was the tremor felt above the din and roar of machinery in local war plants.

"The worst shock was experienced in Cleveland area where the quake officially was recorded on the seismograph at John Carroll

University, according to Rev. J. S. Joliat, S. J., seismologist. It lasted for about two and one-half seconds. Reports of the tremor were also made from other cities between Detroit and Pittsburgh.

"Father Joliat said he could not locate the direction of the quake, but estimated its origin at about 20 to 30 miles southwest of Cleveland. It was caused, he said, by dislocation of strata resulting from strain in the earth's crust, probably about 10 miles under the surface.

"The last earth shock felt here came almost six years to the hour before the one that jolted the district last night. It occurred at 12:44 a.m. on March 9, 1937.

"The quake that really shook this area occurred 18 years ago on February 28, 1925. It centered in Cleveland area."

Akron Beacon Journal, Akron, Ohio, March 10, 1943

"'Quake Really Fooled Frank'.

"When the earth did a Gilda Grey Monday night, many Akron residents reacted in just as many different ways but none of them could hardly surpass the experience of Frank Yacobucci, assignment clerk of the municipal court.

"Frank had just returned from a meeting to his home at 891 N. Howard St. and sat down to eat a midnight snack of rolls and coffee when the earth tremor occurred. The coffee cup started to dance a jig on the saucer and the electric refrigerator began to hum.

"Thinking it was caused by vibrations from the refrigerator, Frank found some adhesive tape and wood chips and secured the

kitchen window so it would stop rattling. Then to stop what he thought were vibrations in the refrigerator, he shoved wooden blocks beneath its legs to set it 'more level'. Not until the next day did he learn that the shimmy was caused by Mother Nature."

Ashtabula Star Beacon, Ashtabula, Ohio, March 9, 1943

"'Northern Ohio Escapes Damage in Earthquake'.

"'City and County Shaken by Tremors at 11:26 P.M. Monday; Wide Area Affected'.

"Ashtabulans shook in their beds for three seconds last night at 11:26, when the most severe earthquake in this territory for 20 years rattled windows and teetered furniture. The widely felt tremors extended as far south as Zanesville and Columbus, shook Toronto to the north, Buffalo to the east and Detroit to the west.

"It is believed that the quake originated 20 or 30 miles southeast of Cleveland, caused by a strain in the earth's crust, which broke about 20 miles under the surface. The last recorded tremors in this area were in 1937.

"Little or no damage was caused by March's contribution of surprise to northern Ohioans. Telephone calls flooded the city central police station as Ashtabulans called to find out if there had been an explosion. The sheriffs' office was beseiged with calls from all over the county from people many of whom thought the Ravenna arsenal had blown up.

"The shock was felt in Jefferson, but no damage was reported. Telephone lines were unaffected and greenhouses have noticed no particular damage as yet. Conneaut, Geneva, Rock Creek, Andover and other county areas report feeling the quake."

"'Knocked Across Floor'.

"Petty officer, Daniel A. Mock of the Ashtabula Navy Recruiting Sub-Station, was standing on one leg taking off his shoes to go to bed, when he suddenly found himself reeling across the floor from the impact of the jolts.

"A radio was reported out of order by one Ashtabulan and a North Ridge East resident reports that the door of his bookcase on the third floor set up a loud rattling. He said he noticed a similar rattling two or three days ago.

"'I never heard such a concert in my life', exclaimed Mr. A. O. Keinberg, 106 W. 44th Street referring to the noise made by the brass handles on her dresser clanging against the wood from the reverberations.

"Mrs. Margaret Lundegard of the Social Security office remarked that 'It sounded like a train running across our porch.'

"Many thought it was snow falling from roofs, an explosion or even a truck passing, as did Mrs. L. L. Sandie, 2004 E. 40th St. They soon realized, however, that it was too continuous and heavy for any of these things.

"Mrs. J. C. Abbey, 381 W. 35th Street was sitting at her desk writing when the impact came. The desk moved and made her writing noticeably crooked and wavery. At first she thought it was a train passing but the shaking was much worse than that caused by a train.

"Cuyahoga and Lake Counties apparently experienced the earthquake in about the same severity as Ashtabula County."

Berea Enterprise, Berea, Ohio, March 12, 1943

"'Quake Shock was no Fake'.

"Now we've been everywhere and seen everything.

"We've seen fire and flood, hard times and good times, most of the opposites of the world, but up to last Monday an earthquake had never hunted us up.

"Official earthquake observers, who have lived in hope and small fruition hereabouts for these many years, realized their fondest dreams at 11:26 Monday, when this section had a real quake.

"No buildings were shaken down, and most folks thought their furnaces had blown up for keeps. However, buildings received a good solid jar, windows rattled ominously and possessions that were on the brink took the plunge. It is estimated that the center of the disturbance was within 20 to 25 miles of here.

"Those who slept through it, and thus lost the impression that the Germans had gone to work on the Airport, really missed something to tell their grandchildren."

Cleveland News, Cleveland, Ohio, March 9, 1943

"What was that? Phone Calls ask as Quake Rocks all of Cleveland.

"An earthquake that had its center within 20 or 25 miles of Cleveland and that rocked the city for a few seconds last night was a forerunner to two severe earth shocks recorded today.

“The Cleveland temblor was recorded on the seismograph at John Carroll University at 11:26 p.m., and followed by two shocks recorded Fordham University in New York at 2:03 and 2:14 a.m.

“Those disturbances were estimated to have originated 5,500 miles from New York.

“The Rev. J. S. Joliat, seismologist at John Carroll University, said the first jolt was felt with unusual force here because the center of the disturbance was not more than 20 or 25 miles from Cleveland.

“The actual quake itself lasted a matter of perhaps two seconds, Father Joliat said, but the university seismograph recorded the oscillations of its aftermath over a period of between two and a half and three minutes. He said the two later quakes had no exact connection with the one felt here.

“‘To say that it was like pavement buckling under extreme heat would be a good comparison,’ Father Joliat said.

“Father Joliat was in bed when the quake sent him hurrying to his seismograph vault. He was attired in house slippers, trousers and a gray sweater when Hal Metzger, program director of WTAM, reached him by telephone. Previously WTAM had broadcast facts on the quake as reported by Dr. J. J. Nassua, professor of astronomy at Case School of Applied Science.

“Father Joliat went to WTAM’s downtown studio in a taxicab and said today ‘I was much surprised when I got in the light to discover how I looked.’

“He got back to bed shortly before 3 for not many more than 40 winks for today was his day to say a mass at 5 a.m.

"The earthquake was described by various persons in different parts of the city as 'a rumble,' 'a roar,' and 'the jolt of a distant explosion.'

"Pearl Schmear, night telephone operator at the News, said: 'I thought some machinery in the composing room over the switchboard had torn loose. It seemed for a second that the ceiling was going to fall in. Then the calls started, and I didn't get away from the board until after 12:30.

"'Many who called wanted to know if the city was being bombed. Others asked if there had been an explosion at the Ravenna arsenal.'

"Stirs Strange Reactions.

"Inquiries ranged from deadly serious to ridiculously absurd. The rumble, the roar and the vibrations were caused not only by bombs and an explosion of block busters, but, according to the imagination of the inquirer, by a truck running into the house across the street, by the explosion of a neighbor's furnace and by head-on street car collisions around the corner.

"Many Clevelanders admitted sheepishly as they rode to work this morning that the jar sent them at neck-break speed to their own basements to investigate the security of furnaces and oil and hot water tanks.

"Material damage was confined, however, to a few splintered picture frames. Somewhere in the vicinity, of course, Mother Earth feels the need today of a face-lifting treatment."

"The disturbance was felt as far away from Cleveland as Detroit, Pittsburgh and Dayton. At the East Cleveland police

station three telephone operators were kept busy answering inquiries until nearly 2 a.m. Common questions there were 'Did the Ravenna arsenal blow up?' and "Has there been an explosion at the TNT plant at Plum Brook near Sandusky?'

"Strangely enough, Sandusky police reported that the jolt was barely perceptible there.

"Telephone Company Swamped.

"The Ohio Bell Telephone Co. reported 'a terrific overload on personnel and equipment' as Greater Cleveland reached, in an apparent mass unified movement, for its telephones.

"The citizens lost no time about it either. Father Joliat timed the disturbance at 11:26 p.m., and the telephone service was swamped at 11:27.

"The bulk of the calls went in order to the fire department, police, newspapers and John Carroll University. Many patrons, hearing no dial tone because lines were already overloaded, tried to reach the operator, thus adding to the service jam.

"East Siders showed more curiosity than West Siders, according to telephone company officials who said the congestion in the Fairmount exchange continued for 40 minutes.

"Airport Towers Sway.

"At Cleveland Airport, the control towers 'swayed dangerously,' in the word of attendants on duty. Weatherman George Andrus was shaken out of sleep at home and then was kept awake by the incessant ringing of his telephone by persons who couldn't out-wait the busy signal on Airport lines.

"Downtown hotels reported different experiences.

"Attendants at Hotel Cleveland, said they didn't notice the disturbance and that if they had they probably would have attributed it to the roar of a train with brakes applied as it slid into the terminal."

No Reports of Commotion

The night telephone operator at Hotel Allerton said she felt as though she were "standing close to the curb and feeling the vibrations caused by the passing of a heavy truck."

Nowhere were there any reports of commotion or disorder. Hotel guests and householders who were momentarily disturbed by the clatter of pictures, dishes and furniture used the telephone to confirm their own guesses that there had been an earthquake.

Cleveland Plain Dealer, Cleveland, Ohio, March 9, 1943

"Mather Girls Gun for Quake Joker.

"Some 600 girls from Flora Stone Mather Dormitory are looking for a man.

"The students were aroused from their slumber Monday night and ordered to dress and come downstairs as quickly as possible. Hurriedly they filed down to the living room. Some thought there had been an earthquake, a blonde, she made Phi Beta Kappa this year called the Plain Dealer. 'Yes it was an earthquake' she was told, 'No it is all over now'.

"They all filed back to bed. A practical joker, presumably a fraternity house had identified himself as a police officer. He

called the dormitory, shortly after the quake ordering the girls to be prepared to evacuate the building. Wait until they find him."

Elyria Chronicle-Telegram, Elyria, Ohio, March 9, 1943

"'Quake Shakes Homes but no Damage is Done.'

"Elyria and Lorain County, along with the rest of northern Ohio, were shaken by a two and one-half minute earthquake shortly before midnight last night.

"The temblor was described as the most severe in this section in nearly 20 years.

"This news today explained to thousands of mystified Lorain County residents why their homes were shaken and windows and dishes rattled. Although many noted these evidences of the earthquake, reports indicated that few realized the cause of the shaking until they learned today that it was an earthquake.

"Probability that the quake originated in or near Lorain County was indicated in a report by the Rev. J. S. Joliat, S. J., seismologist at John Carroll University in Cleveland. Although he could not determine the quake's location, he said that he thought it originated southwest of Cleveland, within 20 or 30 miles.

"It was recorded on a seismograph at John Carroll University at 11:26 p.m. It was felt throughout northern Ohio and western Pennsylvania and was noted as far south as Columbus and Dayton.

"Doors are Opened.

"No damage had been reported in this section at noon today, but many residents reported their homes shaken.

Mrs. Alice Platner, 149 Columbus Street, reported that the shock was so pronounced at her home that three doors of the furnace were opened and she found that the furnace fire had gone out.

"Many Lorain Countians who were asleep at the time of the shock were not even awakened by the shaking and rattling which resulted from the quake, however. Many of those who felt the shaking or heard the rattling of windows and dishes believed them due to the passing of heavy trucks nearby and felt no anxiety."

"In Cleveland, however, the central police station was swamped with hundreds of calls shortly after the earthquake was felt and telephone operators just pulled down the keys and told all callers: 'There has been an earthquake; there is no more danger.'

"A Buffalo dispatch reported that the tremor was felt in that area and that in North Buffalo the shaking was pronounced. Dishes and windows rattled in Dunkirk, New York, but other lake shore communities in New York reportedly were unaffected.

"The earthquake last night came almost six years to the day after the last previous recorded quake in this region. That one occurred at 44 minutes and 55 seconds after midnight on March 9, 1937, and endured eight minutes.

"This area also was shaken for a full minute on February 28, 1925, by a quake believed to have originated about 500 miles to the northeast. Tall buildings in downtown Cleveland swayed perceptibly in that quake."

Lake County News Herald, Willoughby, Ohio, March 12, 1943

"Water Main Broken by Quake - 500,000 Gallons of Water Leaking Daily from Lines.

"Because Willoughby Village is having to pump a half million gallons of water more than normal requirements as the earthquake rocked community Monday night - fears expressed by village officials Monday as the quake broke the village water main, George Thomas, Village Clerk, revealed Thursday. Efforts are being made to determine where the half million gallons can be leaking from the Village main. The Lake County Water Department is searching for the leak in those mains in this section which are supplied by the Village water Department. To meet normal needs, the Village water department pumps only 1 million gallons of water daily, this Mr. Thomas reports. Since the earthquake Monday night, the department has had to pump 1-1/2 million gallons to keep the supply tanks at a normal level... Since the ground shaken here was so violently shaken during the quake, Officials are convinced that the earth shock must have loosened one of the large watermains. Reports from John Carroll University where the only seismograph in this area is located, indicate the center of the earthquake could have been somewhere near Willoughby.

Experience of local people indicates also that the effect here was most severe. Such a shock could damage the water main here, officials report. It is proven that the watermains were damaged from the quake and... this is the only extent of damage yet to be discovered as a result of the current... throughout the whole area by the earth shock."

Lorain Journal, Lorain, Ohio, March 9, 1943

"Shock Felt in Parts of 4 States.

"People Roused by Jolts, but Quake Passes with no Damage Reported.

"Many Awakened.

"Heaviest in 20 years to hit Ohio Area, Say Scientist.

"The first earth tremor experienced here in six years bounced Lorainites in their beds, shook furniture and rattled windows last night but caused no damage or injuries.

"The shock was felt thruout most of northern Ohio, parts of New York state, Pennsylvania and northern W. Virginia and as far south as Dayton and Zanesville, according to Associated Press dispatches.

"Rev. J. S. Joliat, S. J., seismologist at John Carroll university, said the quake was recorded on his seismograph at 11:26 p.m. eastern war time, and that it lasted about two and one-half seconds.

"Last One Six Years Ago.

"He said he thought it originated within 20 to 30 miles southwest of Cleveland.

"Last night's tremor happened six years almost to the hour of a similar quake which shook northern Ohio March 9, 1937.

"Lorain police and men on duty at the Lorain Coastguard station reported numerous phone calls from citizens who thought the trembling was caused from an explosion."

"Feared Explosions.

"'Coastguardsmen said they did not know for sure it was an earthquake but that they "had a good idea it was.'

"Guy A. Wells, 114 W. 29th St. who lived in California for more than seven years and who experienced several earthquakes while there, said the tremor felt like it might have been caused by 'a large truck going down Broadway with a flat tire.'

"But he said he realized it was an earthquake after he looked out and was unable to see any trucks in sight.

"Numerous Lorainites thought the disturbance was caused by their furnaces 'blowing out' from an accumulation of gas, police reported.

"Homes and buildings in Elyria were also shaken by the tremor and Deputy Sheriff James Elemes, at home at the time, reported he thought an explosion had occurred at an Elyria war plant and called the sheriff's office for a check, expecting to be called out on duty.

"The last recorded quake in this region in 1937 originated much farther away, Rev. Joliat reported, according to the Associated Press. He declared the tremor originated because a strain in the earth's crust broke, probably about 20 miles under the surface.

"Strongest in 20 Years.

"Dr. J. J. Nassau, director of Case School of Applied Science observatory, said the tremor was 'unusually strong for this area.' He explained that northern Ohio is comparatively free from earth shocks and described the occurrence as 'perhaps the strongest in this region for the last 20 years.'

"The last earth shock felt here came almost six years to the hour before the one that jolted the city last night, Associated

Press said. It occurred at 12:44 a.m. on March 9, 1937, and was clearly noticeable by residents of Lorain, Cleveland and surrounding areas.

"Police in several cities from Detroit on the west to Pittsburgh on the east reported 'floods' of telephone calls from anxious residents asking information after their homes had been jarred in shocks lasting as long as 40 seconds."

Painesville Telegraph, Painesville, Ohio, March 9, 1943

"Thousands Alarmed by Quake.

"A broken strain in the earth's crust probably 20 miles beneath the surface at a point 20 to 30 miles southwest of Cleveland was advanced as the probable cause of the earthquake.

"Hundreds of Painesville residents alarmed at the severe tremor which rocked homes and business places at 11:26 p. m. Father Joliat, seismologist at John Carroll University said the seismograph recorded a definite tremor and that it had it's center some where in the greater Cleveland area. Father Joliat described the shock as a light one.

"The last recorded quake was in 1937, many Painesville residents remember that one because it rocked at least one building downtown. The building on S. State St. was wrenched at the time and a beam in the structure was moved out of place by a few inches. No incidents of that kind were reported last night.

"Many suspected their furnaces in their homes had exploded or that some industrial plant had undergone a disaster such as a blast.

"United Press in Cleveland received reports from Elyria, Columbus, Zanesville, Western Pennsylvania, Detroit, and Toronto. Cary Ritterrath, 19, a student at Lake Erie College from Altadena, California said she immediately knew it was a quake baring her experience she said it was a 'medium strong quake.'"

Warren Tribune Chronicle, Warren, Ohio, March 9, 1943

"Quake Jars City, Large Ohio Area.

"2 1/2-Second Tremor Shakes Homes, Buildings; No Damage Reported.

"Warren and vicinity felt an earth tremor Monday night about 11:30 o'clock which was the first to be experienced in six years. The shock was felt through much of northern Ohio and as far south as Zanesville and Dayton.

"Houses and buildings shook, chairs trembled, pictures and bric-a-brac were tossed around and hundreds of persons were bounced in their beds but no damage was reported.

"The shock felt here was recorded as having reached New York several hours later, according to the recording at the Fordham University.

"Many Sleep Undisturbed.

"While nine out of every ten persons in Warren and vicinity slept, the tremor bounced hundred of residents in their beds, moved pictures and vases, making people believe they were seeing things.

"Large apartment buildings and homes were shaken, chairs trembled and dishes were hurled from cupboards in the homes of a number of citizens who had no idea of the cause.

"The police department, county jail and fire department received call after call from persons wanting to ascertain the trouble.

"Recorded at John Carroll.

"The Rev. J. S. Joliat, S. J., seismologist at John Carroll University, Cleveland, said today the quake was recorded on his seismograph just before 11:26 o'clock (EWT) Monday night and lasted for about two and a half seconds.

"Several persons in Warren said they felt their homes rock a minute or so after that time and in some cases it lasted longer than five or six seconds.

"The last recorded quake in this region in 1937 originated much farther away, Father Joliat reported. He said he could not locate the direction of last night's quake but thought it originated southwest of Cleveland within 20 to 30 miles.
Farther Joliat declared the 1937 tremor originated because a strain in the earth's crust broke, probably about 20 miles under the surface."

"Police in several cities from Detroit on the west to Pittsburgh on the east reported 'floods' of telephone calls from anxious residents asking information after their homes had been jarred in shocks lasting as long as 40 seconds.

“A tour of Warren’s stores and downtown business places this morning revealed that more persons had no knowledge of the tremor than those who actually felt it.

“A Tribune reporter discovered that Warrenites retire early because most of them said they were in bed and sound asleep about the time the earth trembled.

“Many said they had the impression that heavy trucks had stopped suddenly in front of their homes, causing a vibration.

“Dr. J. J. Nassau, director of the School of Applied Science, said the tremor was unusually strong for this area. He explained that northern Ohio is comparatively free from earth shocks and described the occurrence as ‘perhaps the strongest in this region in the last 20 years.’

“Person residing on the outskirts of Warren felt the tremor more than those residing in Warren proper.

“Two severe earth shocks approximately 5500 miles from New York are were recorded today on the Fordham University seismograph. The tremors were timed several ... later than here.

“Mrs. Lyle Warren, Rt. 3, Warren told the Tribune today that the door between her living and dining room shook and rattled and the dog ran excitedly thru the house barking. Persons living out in Champion Heights where Mrs. Warren resides also felt the tremor.

“Sounded Like Distant Blast.

“The sound was like a distant rumbling explosion in some parts of the county, according to information received.

“A local husband was awakened when his bed shook and half asleep he said to his wife, ‘This is a ...time to be moving furniture around.’”

Mrs. Katherine Leach, 248 Mon... NW, was reading when she heard a plate fall in her china cupboard. She ran to the window to look out to see what was happening.

A prominent woman was writing a letter when she noticed the small sturdy lamp on her desk swaying from one side to the other. “I thought I was seeing things and couldn’t imagine what in the world was happening.”

Mr. Kenneth McNair, county secret service officer; Sheriff Russ Stein, and Postmaster Dixon slept thru the event.

According to waitresses in downtown restaurants, the main topic of conversation over the coffee cups this morning was “Did you feel the earthquake?” Those who hadn’t thought they were being...

Assistant Prosecutor William ... who resides on Fairway Drive said he felt the house shake for about five seconds, the lamps and vases moved around and the chair he was sitting in trembled. Bernard Roseberg said, “I was just going to do some reading when the house shook and I thought a terrific wind had started up.”

Mrs. Leroy G. Stevenson, 583 ... NE, felt her bed sway and said she thought she was imagining these things so she went back to sleep.

W. B. Sweet, 385 Homewood, SE, said he was just going to bed when he felt the house rock, “I thought an immense truck had

stopped suddenly outside causing a vibration, but when I looked out there was nothing but darkness."

An occupant of the Reeves Apartments said, "The entire building shook."

Youngstown Vindicator, Youngstown, Ohio, March 9, 1943

"Night Shock is Strongest in 20 Years.

"Residents here report that Furniture moved and Dishes Rattled.

"Came at 11:26.

"Ohio, Pennsylvania, W. Virginia, Michigan, New York, Feel Temblor.

"An earthquake described as 'unusually strong for this district' was felt over wide areas of Ohio, Pennsylvania, New York, West Virginia, and Michigan at 11:26 p.m. Monday, but it went unnoticed by the great majority of persons in the Youngstown area.

"The shock was felt through northern Ohio and as far south as Zanesville and Dayton. There were reports from Pittsburgh and many Pennsylvania and West Virginia cities, Buffalo and Dunkirk, N. Y. and Detroit and Ontario.

"Dr. J. J. Nassau, director of Case School of Applied Science Observatory at Cleveland, said the tremor was 'unusually strong for this area.' He said that this section of Ohio is comparatively free of earth shocks and described the occurrence as 'perhaps the strongest in this region in the last 20 years.'

"Mrs. John H. Chase of 69 Benita Ave., who is familiar with Californian earthquakes, noticed furniture moving.

"Mrs. Thomas Martin, who lives north of Coalburg, reported that dishes rattled. Several others reported thinking they heard something the matter with their coal furnaces about that time and going down to see about it."

"Mrs. Joseph O'Brien of 212 Broadway was about to go to bed when she felt the tremor shake the house.

"Police get three calls.

"The Youngstown police department reported only three calls, but this morning after reports became current, many recalled some unusual incident at the earthquake time. Several persons reported hearing beds move, going upstairs to see about babies sleeping, etc.

"Youngstown's war industries reported no trouble resulting from the earthquake. Few workers in the local plants were aware of the tremors until they read about them.

"While recorded earthquakes here have been minor John H. Chase in 1938 discovered evidence of severe quakes at Brier Hill quarry, while making geological studies. Other geologists have confirmed his finding.

"The discovery consists of a 'horst fault,' an upthrust of lower strata about 20 feet high and 15 feet wide, about 50 yards from the southern tip of the quarry.

"The temblor was recorded on a seismograph at John Carroll University, Cleveland at 11:26, Rev. S. Joliat, S. J., the

university seismograph, said he could not determine the quake's location, but said he thought it originated southwest of Cleveland, within 20 or 30 miles.

"The last recorded quake in this region was almost six years ago to the day. It occurred at 12:45 a.m. March 9, 1937, and lasted eight seconds.

"February 28, 1925 an earthquake shook this area for a full minute, tall buildings in downtown Cleveland swaying perceptibly.

"The tremor last night was more noticeable in Cleveland than in other cities, causing observers to speculate that the center of the earthquake was near that city.

"Mayor Frank J. Lausche of Cleveland, who had dropped off to sleep, said he thought the house was caving in, 'The bed shook and the wall shook' Lausche said 'I jumped out of bed and ran into the basement to see if there had been an explosion.'

"Police in several cities from Detroit on the west to Pittsburgh on the east reported 'floods' of telephone calls from anxious residents asking information after their homes had been jarred in shocks lasting as long as 40 seconds.

"An Erie, Pa., man said the shock was so hard he fell out of his chair.

"The University of Michigan at Ann Arbor reported a distinct shock recorded on its seismograph at 11:27 p.m. (EWT) and shocks of diminishing intensity continued about 40 seconds. Canisius (N. Y.) College said it recorded a light tremor at 11:26 1/2 p.m. and that the epicenter was about 50 miles from Buffalo."

Heck, N. H., and R. A. Eppley, 1958, Earthquake History of the United States, United States Department of Commerce, Coast and Geodetic Survey, Washington, D.C.

"1943, March 8. Epicenter in Lake Erie and sixty miles northeast of Cleveland, Ohio. This area was not previously recognized as seismic. No damage was reported though the shock was widely felt in the United States and Canada. It was noted over a large part of Ohio and in parts of Michigan, Pennsylvania, and New York."

Coffman, Jerry L. and Carl A. von Hake, 1973, Earthquake History of the United States, United States Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, Boulder, Colorado.

"1943. March 8. Lake Erie area, 60 miles northeast of Cleveland, Ohio. This area was not previously recognized as seismic. No damage was reported, though the shock was widely felt in the United States and Canada. It was noted over a large part of Ohio and in parts of Michigan, Pennsylvania, and New York."

EARTHQUAKE OF DECEMBER 3, 1951

CA: 07:02 GMT

EPICENTRAL INTENSITY: IV(MM)

LOCATION: 41.65N, 81.41W

EVALUATION:

This event was felt with an Intensity IV(MM) in a rather restricted area (less than 10 mile radius) around Willoughby, a suburb northeast of Cleveland. The Painesville and Cleveland newspapers have no local felt reports and only refer to Willoughby and immediate vicinity, from Mentor to Wickliffe, as the affected zone.

The coordinates of Willoughby (41.65N, 81.41W) have been selected for the epicenter; an uncertainty of ±5 miles appears to be adequate in this case. A shallow focal depth can explain the Intensity IV(MM) associated with such a restricted felt area. Even though in the newspapers the epicentral area is suggested to be similar to that of the March 9, 1943 event, this event is certainly much smaller in magnitude than the 1943 event. The three seismograms of John Carroll <Figure 2D D-13> certainly indicate a very small event. An epicentral distance is estimated at about 20 miles.

Bradley and Bennett (1965) have listed two small shocks, with Intensity II, as having occurred on December 7 and 21 in Willoughby. The search of local newspapers failed to confirm the occurrence of these events. Moreover, an examination of the seismograms at the times suggested by Bradley and Bennett failed to confirm the occurrence of any local event that could be interpreted as a Willoughby tremor. For this reason, these two events are herein considered dubious and listed in Table 3.

COMPILATION OF ACCOUNTS:

Cleveland News, Cleveland, Ohio, December 3, 1951

"Light Tremors Hit City's East Suburbs.

"A light earthquake shook houses and frightened residents over a wide area of eastern Cuyahoga County and the western portion of Lake County early today but apparently caused no damage.

"The tremor, which was recorded at 2:02 a.m. centered around Willoughby but was felt throughout an area 10 to 15 miles in diameter on Lake Erie's south shore, according to police and the Rev. Henry F. Birkenhauer, seismologist at John Carroll University.

"Fr. Birkenhauer said a fracture in rocks two or three miles underground caused an 'elastic wave' which resulted in a slight quivering of the earth's surface. A similar mild quake was felt in the same area in March, 1943, he added.

"Hundreds of calls from residents in Kirtland, Wickliffe, Willowick and Bratenahl awakened as their homes shook and dishes and windows rattled were received by police. Within an hour after the tremor Willoughby police received 100 calls. Eastlake and Euclid police said the tremor seemed to miss their communities."

Akron Beacon Journal, Akron, Ohio, December 3, 1951

"Quake Rattles Willoughby.

"Cleveland (AP) - A slight earthquake rattled windows early today in the vicinity of Willoughby, 20 miles east of here.

"Fr. Henry F. Birkenhauer, seismologist at John Carroll University, said the quake occurred at 2:02 a.m. and was so mild there probably was no damage at all.

"He said a fracture in rocks two or three miles underground caused an 'elastic wave' which resulted in a slight quivering felt at the earth's surface over an area perhaps 10 to 15 miles in diameter.

"A similar quake was felt at almost the identical place in March, 1943, Fr. Birkenhauer said."

(same account in Warren Tribune Chronicle, Dec. 3, and Youngstown Vindicator, Dec. 3)

BSSA, Vol. 42, No. 1, pp. 95-108

"Willoughby, Ohio, December 3, 1951 - The John Carroll University Seismological Observatory reports an earthquake at 2:02 a.m., nineteen miles northeast of the station, which was felt at Willoughby, Ohio, and near-by villages. No damage was caused."

Painesville Telegraph, The, Painesville, Ohio, December 3, 1951

"Willoughby and Nearby Area are Shaken by Mild Earthquake.

"Willoughby - The sleep of several hundred persons in the Western Lake County area apparently was the only thing damaged by an earth tremor early this morning.

"Lieut. John Hayer of the Willoughby Police Department noted on the daily report at 2:03 a.m. that he 'felt the station tremble.'

"Rev. Fr. Henry Birkenhauer, director of the seismological dept. at the John Carroll University, Cleveland, said the disturbance was caused by a sliding rock formation far below the surface of the earth.

"The seismograph recorded the disturbance at 2:02:39 a.m. he said, about 19 miles northeast of the university.
Rev. Fr. Birkenhauer said there was no record of a 'fault' under the area which might cause major earthquakes. 'but it is obvious there is a weakness of some sort below Willoughby.'

"It was reported that the quake was 'very localized' and similar to the one that occurred in Willoughby on March 8, 1943.

"Police officials in nearby communities from Mentor on the lake to Wickliffe reported noting the tremor this morning and received a number of calls from residents, who felt their homes shake and heard their furnace pipes rattle."

<u>Painesville Telegraph, The</u>, Painesville, Ohio, December 7, 1951

"Earthquake is put on Record.

"Willoughby - This area's 'shocking' experience of undergoing an earthquake early this week may have been forgotten by most, however, the incident will be on the records of the John Carroll University's seismological observatory in Cleveland.

"Chief James G. Billson of the Willoughby Police Department was requested by the university's director, Henry F. Birkenhauer, S.J., to submit data on the effects of the quake here.

"A questionnaire to be returned to the director...
Chief Billson designates which of the following incidents resulted

from the tremor: Rattling of windows, doors, dishes; creaking of frame walls; felt indoors by many; shifted small objects or furnishings; cracked plaster, broke dishes; awakened many, frightened some; overturned furniture, shook trees, bushes; caused books, pictures to fall; caused general excitement.

"In addition, Chief Billson was requested to note any other particulars of the quake and he reported that 'a man fell out of bed' in the lake front section."

<u>Willoughby News Herald</u>, Willoughby, Ohio, December 3, 1951

"Mild Earthquake Hits West Lake County"

"No Damage Reported After 35 Second Tremor - Last Earthquake Felt Here in 1943"

"A mild earthquake of about 30 second duration shook Western Lake County homes early this morning but no damage was reported. The tremor was felt about 2 a.m. by most local residents many of whom though their furnaces had exploded. The quake rumblings vibrated homes and rattled windows. Rev. Henry F. Birkenhauer, Seismologist at John Carroll University, said the quake occurred about 30 seconds beginning at 2:02 a.m. EST today. He said, however, that the tremors only lasted probably about 15 seconds at the source. The seismologist said the quakes occurred about 2 or 3 miles below the surface in a rock strata. A similar quake was recorded on the university seismograph in 1943; the only other known quake to occur in the Lake County area. He added that the cause of the quake had not been determined. At Willoughby the police station was felt to tremble at 2:03 a.m. and several calls were received from residents who felt the tremor according to Lt. George Hager, who was on duty at the time. Wickliffe police also reported receiving a number of calls from residents who felt

the shake. Eastlake, Mentor and Mentor on the Lake were other communities where persons were awakened from their sleep and called police to inquire about the cause of the tremor..."

EARTHQUAKE OF MAY 26, 1955

CA: 18:09:23 GMT

EPICENTRAL INTENSITY: IV-V(MM) (R)

LOCATION: 41.33N, 81.40W (R)

EVALUATION:

In United States Earthquakes, 1955, this earthquake was included among the noninstrumental events, with no specific epicentral coordinates. It was given only a general location, "southeastern suburbs of Cleveland." Later, the Earthquake History of the United States (1958, 1965, 1973) assigned the coordinates of downtown Cleveland (41.5N, 81.7W) to the epicenter, and retained the same intensity. This is slightly incorrect. First, all newspaper reports emphasize that the shock affected mostly the southeastern suburbs of Cleveland, and suggest a point where four counties meet as the epicentral area. This location is in good agreement with Dr. Walter's estimated epicentral distance (13 miles to the southeast) on the basis of John Carroll seismograms <Figure 2D D-14>. Secondly, the felt reports for the epicentral area are more of an Intensity IV or IV-V level than an Intensity V. The fact that newspaper and police headquarters were "flooded" with calls does not support the upgrading of the reported intensities. There was no local felt report for Willoughby, Painesville, Cleveland proper, and Akron. The felt report map <Figure 2D D-15> shows a concentration of reporting localities near Aurora, particularly to the northwest. It is suggested that the epicenter be revised to 41.33N, 81.40W just northwest of Aurora, with an uncertainty of 10 miles. The epicentral intensity is also revised to a IV-V(MM), as in Docekal. This revision is in better agreement with the local seismologist's report, i.e., "very mild," "no cause for alarm."

COMPILATION OF ACCOUNTS:

BSSA, V. 45, No. 4, pp. 327-345

"Cleveland, Ohio, May 26, 1955. - A slight earthquake was felt by residents of Aurora, Bedford, Chagrin Falls, Geauga Lake, and Solon (all suburbs of Cleveland) and recorded on the John Carroll University seismographs at 18^h 09^m $26^s.9$ G.C.T."

Cleveland News, Cleveland, Ohio, May 26, 1955

"Nine Suburbs Here Rocked by Quake.

"A slight earthquake was felt in nine southeast suburbs this afternoon. No damage was reported.

"Dr. E. J. Walter, assistant director of the seismological conservatory at John Carroll University, said his instruments had recorded a mild shock at 9 minutes and 23 seconds after 2 p.m. The tremor was approximately 13 miles south of John Carroll and lasted a full minute.

"Residents in the eight suburbs reported to their police departments they felt 'explosions,' 'rumbles,' or that their houses were mysteriously shaking. The suburbs affected were Garfield Heights, Solon, Pepper Pike, Mayfield, Maple Heights, Shaker Heights, Bedford, Warrensville and Richmond Heights.

"A woman in Richmond Heights said she thought a truck had hit her house. Officials of the Austin Powder Co., Pettibone Rd., Bedford, said the quake sounded like a 'subdued rumble.'
Dr. Walter said the shock was not strong enough to have been recorded on seismographs outside of the Cleveland area."

Cleveland Plain Dealer, Cleveland, Ohio, May 27, 1955

"Quake Shakes 4-County Area.

"Dogs Bark, Babies Yell After Mild Tremor.

"The earth quaked yesterday afternoon deep underneath the point where Cuyahoga, Geauga, Portage and Summit Counties meet.

"It jolted and rocked houses all the way from Aurora in Portage County through the southeast suburbs and in Cleveland as far as E. 101st Street near Union Avenue S.E.

"Dogs barked and babies yelled. An avalanche of telephone calls came from householders - 'What was it?' But it did no damage.

"'It was very mild. There is no cause for alarm. Mild quakes like this happen here in two or three-year cycles.'

"This was the sumup of Dr. Edward J. Walter, assistant director of the seismograph observatory at John Carroll University in University Heights.

"He said the quake began at 2:09:23 3/10 p.m. It lasted about one minute. It occurred about 13 miles from the seismograph, which is at North Park and Miramar Boulevards.

"Duration Two Seconds.

"'It took 3 6/10 seconds for it to reach us here,' said Dr. Walter. 'It would have been sensible for local residents for two seconds only. That was the period between the primary and secondary shock waves.'

"The Plain Dealer switchboard lit up like a Broadway billboard.

"One call was from the Bainbridge Center (O) telephone operator. She was swamped with calls. For almost half an hour it was impossible to get a call through to Aurora police.

"By 2:40 Dr. Walter had his graph and its tracings of the tremor ready and he too was inundated with calls.

"'I thought a truck had bumped into the house' was one of most frequent reports from housewives in Bedford, Orange, Shaker Heights, Geauga Lake, Bainbridge, Chagrin Falls, and Aurora.

"Others thought their furnaces had blown up or first blamed the thump on youngsters jumping off the bookcase or dining room table.

"'It was a low rumbling noise that lasted about half a minute.' said Mr. Ernest Pocek, calling from West Woodcrest Drive, Orange.

"'The dog was barking like mad out in the garage. The baby (Donald, 17 months) was crying in his crib because it banged up against the wall. The furniture seemed to be sliding, and the refrigerator bounced against the wall a couple of times.'

"Pictures fell off the wall at the home of Mrs. Stanley Vliek on Wincell Road near Route 82 in Aurora Township, she said, and a window pane cracked.

"'The house swayed for about a half minute,' said Mrs. Vliek, '...his face off the front steps and started screaming.'

"The desk shook under the elbows of State Patrolman Jack Gilmartin, dispatcher at the highway patrol station a mile and a half north of Cuyahoga Falls on Route 8 in Summit County.

"'The building made a noise like the furnace starting up,' he said.

"He, like some others, speculated that it might be blasting on the nearby turnpike route.

"Bedford police said: 'Something seemed to hit the side of the building, one jolt.'

"'Nobody will ever know certainly what caused the quake,' said Dr. Walter, the seismologist. 'It happened too far down under the earth's outer skin.'

"'One theory is that it is due to the removal of the glacial load,' he said, 'Another is settling where there once were salt deposits.'

Painesville Telegraph, Painesville, Ohio, May 27, 1955

"Mild Earthquake Felt in Four Counties.

"Cleveland. Hundreds of residents here and in surrounding area of northeast Ohio were alarmed by a mild earthquake that shook their homes.

"The tremors were said to have been felt in Cuyahoga, Geauga, Portage, and Summit counties on Thursday afternoon.

"Chardon apparently was untouched by the earthquake reported in nearby areas. The Bainbridge, Geauga Lake, and Chagrin Falls sections were said to have felt the reverberations. The earth was said to have quaked slightly under the point where the counties meet."

EARTHQUAKE OF JUNE 29, 1955

CA: 01:16:33 GMT

EPICENTRAL INTENSITY: IV(MM) (R)

LOCATION: 41.33N, 81.40W (R)

EVALUATION:

In United States Earthquakes, 1955, this earthquake was presented among the noninstrumental events, with no epicentral coordinates. It was given the general location of "southeastern suburbs of Cleveland," and an Intensity V(MM). The Earthquake History of the United States (1958, 1965, 1973), besides retaining the intensity, assigned the downtown Cleveland coordinates (41.5N, 81.7W) to the epicenter. As in the case of the May 26, 1955 event, this location is somewhat incorrect, as the felt reports clearly suggest that the event was not in Cleveland itself, but to the southeast, probably around Aurora.

As in the case of the May 26, 1955 event, Dr. E. Walter, from John Carroll, estimated from the seismograms an epicentral distance of 13 miles. This location agrees with the distribution of the felt reports <Figure 2D D-16>. The June 29, 1955 event is somewhat similar in location to the May 26, 1955 event, if the distributions of reports are compared.

The intensity of this event appears to have been lower than that of May 26, 1955, as explicitly suggested in the newspapers. Nonetheless, because the event occurred just over one month after the other, it did cause some concern resulting in a large number of calls. A large number of phone calls reflects the interest of people, but does not necessarily indicate a state of fright or panic, which would support an Intensity V. Judging by the reports, and Dr. E. Walter's comment, the tremor was "mild", and "non cause for alarm."

The coordinates of the epicenter are revised to 41.33N, 81.40W, just northwest of Aurora, with an uncertainty of 10 miles. The intensity is also revised to IV(MM), as more representative of the reports.

COMPILATION OF ACCOUNTS:

Cleveland News, Cleveland, Ohio, June 29, 1955

"County Quake Cycle Broken, Nothing Else.

"The second earthquake to be felt in Cleveland's southeastern suburbs in little more than a month broke nothing but the regular cycle for quakes in this area, according to Dr. Edward J. Walter, assistant director of John Carroll University's seismological observatory.

"The mild tremor was felt from East Cleveland to Bentleyville at 9:15 p.m. yesterday. It lasted about a minute and a half. Dr. Walter said the only shock heavy enough to be felt lasted about two seconds.

"'The worst thing it could do would be to alarm the people who could feel it,' he said. 'The tremor is the result of simple adjustments in the earth's crust and they come along ordinarily, about two years apart. The only thing unusual about this one is that it doesn't fit into the established cycle.'

"The last earthquake, which was in the cycle, occurred May 26. Both originated in subterranean rock formation near Aurora in Geauga County with shock waves spreading north and west.

"Residents of East Cleveland, Shaker Heights, Maple Heights, Bedford, Solon, Bentleyville, Moreland Hills, Pepper Pike and

Aurora felt the quake. They described it variously as sounding like the house was settling, the furnace rumbling or something falling in the next room."

Cleveland Plain Dealer, Cleveland, Ohio, June 29, 1955

"Mild Quake Hits S.E. County Area, Alarms Hundreds.

"Second Tremor in 33 Days; Shock Waves, Originating Near Aurora, Move Floors of Homes; No Damage Reported; Citizens Calm.

"A mild earthquake, the second within 33 days, struck the southeastern end of Cuyahoga County at 9:15 last night and alarmed hundreds of persons.

"The shock waves, originating in the general area of Aurora in Portage County, brought subterranean rumblings and moved the floors of homes.

"Telephone calls to the Plain Dealer came from affected residents of Shaker Heights, Bentleyville, Solon, Bedford, Bedford Heights, Moreland Hills, Maple Heights, Pepper Pike, Aurora, Beachwood, Chagrin Falls, Cleveland Heights, Orange Village and Hunting Valley.

"No damage was reported. Most accounts were that home foundations were believed to be shifting or settling, that furnaces were rumbling or that someone in the home had fallen.

"Shock Waves 'Mild'.

"Dr. Edward J. Walter, assistant director of the seismological observatory at John Carroll University, said the quake began at

9:15:30:8 p.m. approximately 13 miles from the observatory in the general area of Aurora. The shock waves, 'very mild,' moved north and west.

"Dr. Walter said that the shock 'might have moved or disturbed people, moved homes, and caused subterranean noises which could be heard,' but that there was no cause for alarm.

"It took the waves 3.6 seconds to reach the university, just as did the waves from the last quake recorded from the same area, at 2:09:23:3 p.m. on May 26.

"Duration of the waves was the same, a minute and a half, although persons could feel the shock for only two seconds, Dr. Walter said.

"Two Shocks Possible.

"There was some chance two shocks were felt, the primary and secondary, but this is doubtful because of their closeness to each other, Dr. Walter reported.

"He said the disturbance could have been caused by either a settling or a rising of the earth's crust. One theory has it that the retreat of the glaciers some 25,000 years ago with the removal of much pressure on the earth's crust has caused stresses and strains which slowly are adjusting themselves, Dr. Walter said.

"Unlike the May 26 tremor, there were no reports of sliding furniture, crying babies and bouncing refrigerators.

"Mrs. Thurman Ireland, 5064 Richmond Road, Bedford Heights, was awakened from a couch 'when the house shook.' The children in bed upstairs believed a dresser had fallen over, Mrs. Ireland said.

"2 Tremors Felt.

"In Bedford, Mrs. Beatrice Hawkins, 85 Egbert Road, reported she believed the house was settling, while her daughter thought that someone downstairs had fallen. Mrs. Hawkins said she believed there were two tremors about two minutes apart.

"In Moreland Hills, Alden Jenkins of Jackson Road reported his house shook. At first he believed his furnace was rumbling. The rumble was 'brief,' he said.

"Thomas W. Christal, 3601 Glencairn Road, Shaker Heights, said he heard a 'rumble' and the floor of this home appeared to move.

"Thought House Shifted.

"'We thought the house was shifting on its foundation,' said Mrs. J. W. Koring of Bentleyville. 'There was a low, heavy rumble, quite a pronounced noise.'

"'I was sitting on the basement stairs and thought at first my father in the basement was dragging some heavy object across the floor.'

"Mrs. John A. Becker, 17427 Lomond Boulevard, Shaker Heights, reported her house was shaken.

"Sees Lamp 'Wiggle'.

"A lamp 'wiggled' on a table in the home of Mrs. Edward E. Frank at 17825 Scottsdale Road, Shaker Heights. Mrs. Frank reported she thought her home had moved on its foundation.

"'It was like 10 trucks driving by, or as streetcars used to shake houses along streetcar lines,' said William Sherbondy of Chatham Drive, Pepper Pike.

"'It was like a furnace blowing up or a truck ramming a wall,' said Harold Meadows of Baldwin Road, Solon.

"Felt Only Upstairs.

"Mrs. Ethel Reynolds, receptionist at the swank Ambassador apartments at 13700 Fairhill Road, Shaker Heights, felt nothing at her first-floor desk. Residents on upstairs floors began calling down that davenports and chairs were shaking.

"Persons reported from Aurora that 'it seemed as if a truck had hit a tree': from Orange that 'dishes rattled and the dog ran, barking.'

"A University Heights housewife said: 'Something seemed to go wrong with my legs and I was scared to death.'

"A Moreland Hills resident said his house shook so much that the dog 'jumped in the air about a foot,' and another person in the same village said 'the house felt as if it was sliding out from under us.

"At Novelty, O., seven miles east of Chagrin Falls, Mrs. Margaret Johnson reported the roof of her home shook so much she thought it was caving in."

<u>Elyria Chronicle-Telegram</u>, Elyria, Ohio, June 29, 1955

"Tremor Felt in Cleveland East Suburbs.

"CLEVELAND, O., (AP) - A mild earth tremor startled residents of Cleveland's eastern suburbs Tuesday evening. The quake was registered on the John Carroll University seismograph just after 9:15 p.m. and lasted 90 seconds.

"Another such earthquake could occur in the next 30 days or it could be a year or more, scientists said. Charles S. Bacon, Professor of Geology at Case Institute of Technology, said there is just no scientific way these things can be predicted except by judging what might be expected from the geology prevalent in a region.

"The seismograph indicated the tremor was centered in the area of Aurora in Portage County. A similar tremor was recorded 33 days ago in the same area and lasted the same length of time.

"The consensus was that Tuesday's quake was a 'minor readjustment' of the earth's crust."

Lorain Journal, Lorain, Ohio, June 29, 1955

"Cleveland Area Rocked.

"CLEVELAND (AP) - The second earthquake in 33 days mildly shook up the southeastern section of Cuyahoga county and part of Portage county Monday night.

"Subterranean rumbling and moving floors of homes alarmed hundreds of residents. No damage was reported.

"Dr. Edward J. Walter, assistant director of the seismological department at John Carroll University said the shock waves which came at 9:15 p.m. EDT were very mild.

"Reports of the quake came from the towns of Shaker Heights, Bentleyville, Solon, Bedford Heights, Moreland Hills, Maple Heights, Pepper Pike, Aurora, Beachwood, Chagrin Falls, Cleveland Heights, Orange Village and Hunting Valley.

"The same area was mildly shaken by another earthquake May 26."

EARTHQUAKE OF JUNE 29, 1957

CA: 11:25:09 GMT

MAGNITUDE: 3.8 m_{blg} (R)

LOCATION: 42.92N, 81.32W

EVALUATION:

Smith states that this earthquake occurred 9 miles south-southeast of London, Ontario (42.92N, 81.32W) with an M_L of 4.2. This M_L magnitude is possibly too high, and Nuttli has suggested, more appropriately, a magnitude of 3.8 m_{bLg}. No further research was considered necessary.

COMPILATION OF ACCOUNTS:

Smith, W.E.T., (1966) Earthquakes of Eastern Canada and Adjacent Areas 1928-1959, Publications of the Dominion Observatory, V. 32, No. 3.

"1957 June 29. 11:25:09. M_L=4.2. 42°55'±18', 81°19'W±18'. Depth 26 km. About 9 miles south-southeast of London, Ont. Felt at London, Ont."

EARTHQUAKE OF MAY 1, 1958

CA: 22:46:31 GMT

EPICENTRAL INTENSITY: IV(MM) (R)

LOCATION: 41.49N, 81.82W (R)

EVALUATION:

Recent investigations suggest that there are problems associated with this event, particularly with respect to its true seismic nature and its epicentral intensity. In United States Earthquakes 1958, this event was listed as "an Intensity V in Cleveland." Later, the United States Earthquakes History (1965) assigned 41.3N, 81.4W as epicentral coordinates, probably by error. The revised edition (1973) gave the downtown Cleveland coordinates (41.5N, 81.7W) as the epicenter. The origin time was given as 16:46:31 (local CST); the hour was most likely in error (16 instead of 18).

The problems arise from the fact that on that evening, John Carroll's seismographs recorded some kind of an event at "6:46 p.m.," according to Dr. E. Walter, station seismologist, and that half an hour later, around "7:15 p.m.," numerous felt reports of explosive noises, mostly on the lake shore, from Lorain to Lakewood were received. Dr. E. Walter confronted with two phenomena, was explicit in his press release to say that the 7:15 p.m. blast was unrelated to his 6:46 p.m. recorded signal. The newspaper accounts collected recently indicate that the reported noises, shaking, etc. were all associated with the 7:15 p.m. event, and not with the earlier one. Somehow, these reports appear to have been used by government agencies as the basis for assigning an Intensity V(MM) to the earlier event listed in the USGS catalogs at 16:46. Besides this apparent miscorrelation, the intensity appears overestimated. The collected reports would substantiate an Intensity IV(MM), not V. "Rattling, shaking, noises, but no damage" does not support more than an Intensity IV. It has already been noted

that a large number of telephone calls are often placed out of curiosity; they are not necessarily to be interpreted as a sign of fright.

The seismic nature of the 6:46 p.m. event is uncertain. The John Carroll seismograms have been reexamined by two seismologists, Rev. D. Linehan, S.J. and Dr. G. Leblanc. They concluded that it remains dubious that the 6:46 p.m. (local time) recordings were truly indicative of a local earthquake. Only one horizontal component shows good motion <Figure 2D D-17> and the three of four oscillations of the surface waves have a period much longer (1.5 sec) than what was recorded during the true local events of 1951 and 1955 <Figure 2D D-13> and <Figure 2D D-14>.

It is worth mentioning that the local press suggest jet activity (breaking the sound barrier) as possible source for the noises. A careful reading of the press accounts indicate that this theory was dismissed on the basis that a spokesman at Cleveland Hopkins Airport said "there was no activity in the area all evening." It is possible that such a statement was not well substantiated; military planes have their own independent flight plans. Another remark included in a press account to the effect that "jets have been active in the area for the past week" would give support to the theory of the noises being related to planes breaking the sound barrier. Dr. Walter, recently consulted on this problem, seems to agree with this hypothesis.

In summary, if this event is conservatively retained as truly seismic, it should be located near Lakewood (41.49N, 81.82W), with a revised Intensity IV. In doing so, one has to reject the theory of two separate events, and postulate that the 7:15 p.m. felt reports, although originating about a half hour later, were truly related to the recorded event of 6:45 p.m. The observers (see accounts) who attempted to give the time of the noises could have been in error.

Because there appears to be much confusion on the origin, time, intensity, and location, and because the seismic recordings are not fully convincing, this event is carried in Table 3 with revised parameters.

COMPILATION OF ACCOUNTS:

Cleveland Plain Dealer, Cleveland, Ohio, May 2, 1958

"Mystery Blasts Trail Quake Here

"West Suburbs Shaken Half Hour After Tremor is Recorded.

"A 'home-grown' earthquake was recorded on the seismograph at John Carroll University last night. The sensitive mechanism put the location at 12.7 miles from the University Heights school and the time at 6:46.

"But residents and police in the western suburbs insisted that explosions were heard and felt half an hour later."

The differences in time and other reasons led Dr. Edward J. Walter, S.J., assistant director of the seismological laboratory at John Carroll, to the theory that the mild quake and the reported explosions were unrelated.

"Ray W. Rieke, 50, of 4521 W. 148th Street, said he was fishing in Lake Erie off the stone pier at Huntington Park in Bay Village when he felt the pier shake.

"'I looked at my watch,' he said, 'and I saw it was exactly 7:15 p.m.'

Ricke said thousands of minnows rose about a foot above the lake surface for a second, then fell back. 'Like rain splattering the water.' He said there seemed to be no disturbance of the water surface.

"Two Explosions

"The self-employed trucker said fisherman on the pier agreed that there were two successive explosions which seemed to come from the west. Lorain police said the shocks were felt, but they could offer no explanation.

"Dr. Walter said the tremor was too weak for the seismograph to provide a definite direction for the source. But he did not think it could have come from the east. He estimated that it occurred from two to five miles below the earth's surface and that 'billions of tons of earth must have been moved.'

"Had the earthquake occurred near the earth's surface, the scientist added, 'the explosion would have been tremendous; something like the disaster that destroyed about a mile of W. 117th Street in 1953.'

"Local earthquakes are not unknown, Dr. Water said. He recalled tremors in Willoughby and Aurora in May and June, 1955.

"Bay Village police said that a concussion was felt and heard at 7:17 p.m. and that residents began calling three minutes later to report houses shaken. One policeman said he ran outside after the loud report to see if a plane had crashed. He found nothing.

"Lt. Norbert J. Roglin of Lakewood police said headquarters there got its first of nearly 30 calls from questioning residents

at 7:24 p.m. He believed that the tremor and blast had occurred along the lakefront area. No damage was reported.

"Rocky River authorities also told of getting a handful of calls about 7:20 p.m.

"Coast Guardsmen reported no unusual disturbances of the lake surface, but they speculated that the rumble and concussion felt at Huntington Park might have been the aftermath of the mild quake.

"Authorities at first thought an explosion had occurred at the Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics at Cleveland Hopkins Airport.

"NACA officials said that, coincidentally, a fire had occurred about 9 p.m. when a testing cell fuel line broke and was ignited, setting the wooden cell roof afire. The blaze was subdued by NACA firemen, who estimated $500 damage. But no explosion marked the accident, they added."

Elyria Chronicle-Telegram, Elyria, Ohio, May 2, 1958

"Mystery Blast Follows Quake.

"AVON LAKE - Windows rattled and houses trembled when a mysterious blast shook northeastern Lorain County and western Cleveland suburbs last night.

"The loud explosion occurred 25 minutes after an earthquake was recorded on the seismograph at John Carroll University, University Heights.

"Dr. Edward J. Walter, S.J., assistant seismologist at the university said, 'A mild quake or earth tremor was recorded by the

instrument at 6:46 p.m.' However, residents of the western suburbs reported hearing the blast at 7:15 p.m.

"The quake, according to Dr. Walter, occurred at a distance of 12.7 miles west of the university campus. 'We are not able to fix the location with any degree of certainty' he said, but estimated it was near the western border of Cleveland and within the eastern portion of Lakewood.

"No Damage Reported.

"There were no reports of damage, and Dr. Water said, while homes were shaken, the quake was not severe enough to shatter windows or knock dishes off shelves.

"He could give no explanation for the tremor experienced 25 minutes later in Lorain County, Bay Village and Rocky River. 'The seismograph recorded nothing later to indicate the 7:15 matter.' he said.

"The quake occurred in two phases, with the second stage 6.4 seconds after the first which was recorded at 6:46 and 26.9 seconds. Dr. Walter said, 'Both of the tremors were strong enough to be felt by people.'

"It was estimated the quake occurred two to five miles beneath the earth's surface and that possibly billions of tons of earth shifted.

"While no damage was reported, police of Lakewood, Rocky River, Bay Village and Avon Lake said calls of inquiry began coming into the stations immediately after 7:15 p.m.

"Emergency units were alerted and police and fire departments of the communities 'stood by' to answer possible calls for assistance.

"Avon Lake fireman William Varner said doors of the fire station at Lake Rd. were rattled by the blast. Patrolman George Anthony, on duty at the police desk in the municipal building on Center Rd. said the whole structure trembled. There were numerous reports from all areas of Avon Lake of dishes rattling, dishes shaking, and houses vibrating.

"Immediately after the mysterious..., residents rushed outdoors to scan the skies. It was theorized that a jet plane had crashed the sound barrier producing the unusually loud blast.

"Not Jet Activity.

"A spokesman for Flight Operations at Cleveland Hopkins Airport said there was no jet activity in the area all evening.

"The Lorain County Sheriff's Department made a check of all area police stations and the Bay Village department reported the blast had occurred directly over Bay Village. Bay police also credited the mysterious noise to a jet plane passing through the sound barrier.

"Jets have been active in the area for the past week.

"While no plausible explanation has been given for the 25-minute time lag, those who experienced the blast claim there were two distinct shock waves similar to that recorded by the seismograph."

Lorain Journal, Lorain, Ohio, May 2, 1958

"Reports Differ After Quake.

"Conflicting reports today followed a mild earthquake which hit the Cleveland area last night, causing rattling of doors and cupboards and hurried telephone calls to police in Avon Lake and Bay Village.

"No major damage has been reported. The shock waves were felt along the shore of Lake Erie as far west as Lorain.

"Dr. Edward J. Walter, assistant director of the Seismological Laboratory of John Carroll University, said the quake apparently was centered two miles beneath the bottom of Lake Erie.

"Walter said he believed the quake moved tons of rock beneath the lake bed. He said the shock was not strong enough to provide a clue to its direction.

"The tremor was registered at the John Carroll laboratory at 9 p.m., according to the United Press. The delicate seismograph indicated the shiver was about 12 miles from the laboratory.

"Worried citizens reported a big 'bang' about 45 minutes later, but Walter said the explosion was not connected with the quake.

"An Avon Lake resident said he was told last night the tremor was recorded on the seismograph at 6:46 p.m. It was the first shock felt in the area since 1955, when twin shock waves were reported.

"Several Avon Lake residents said they heard what sounded like a bang and an echo at about 7:15 p.m.

"Numerous residents in Avon Lake said that dishes jumped in their cupboards. Willard Varner, Avon Lake fireman, said he heard the doors on the fire station rattle and stood by in case of fire.

"Ernest Leonard, Avon Lake patrolman, 146 Beachdale Dr. was given reason for fright. He had just sent his son out with gasoline for the car when he heard what sounded like a blast. He said that for several moments he didn't expect the boy to return.

"The Bay Village police Department reported 25 to 30 calls from residents last night but no damage."

EARTHQUAKE OF FEBRUARY 9, 1959

CA: 19 and 20 HR GMT

MAGNITUDE: 2.4M_L

LOCATION: 43.0N, 81.0W

EVALUATION:

Smith states that this earthquake was felt by "a few persons in London and Charlotteville Township," in Ontario. M_L = 2.4 and coordinates of 43.N, 81.W. No further research was considered necessary.

COMPILATION OF ACCOUNTS:

Smith, W.E.T., Earthquakes of Eastern Canada and Adjacent Areas 1928-1959, Publications of the Dominion Observatory, V. 32, No. 3.

"1959 February 9, Between 2:00 and 3:30, M_L=2.4. 43.°N±?, 81.°W±?. East of London, Ont. This shock was not recorded. The epicenter and magnitude were estimated from reports supplied through the courtesy of the London Free Press. The earthquake was felt by a few persons in London and in Charlottesville Township, and by one person on a farm at Walsingham, Norfolk County, all in Ontario."

EARTHQUAKE OF FEBRUARY 2, 1976

CA: 21:14:02.0 GMT

MAGNITUDE: 2.4 m_{bLg}

LOCATION: 41.960N, 82.670W

EVALUATION:

This event is listed in Preliminary Determination of Epicenters (NOAA) at 41.96N, 82.67W (in Ontario), with a magnitude of 3.4 m_{blg}. No mention of it was found in the Cleveland or Painesville newspapers.

COMPILATION OF ACCOUNTS:

Preliminary Determination of Epicenters, U.S. Dept. of the Interior/Geological Survey, Washington, D.C.

"February 2, 1976. 41.960N, 82.670W. Southern Ontario. Felt sharply in the southern suburbs of Detroit. Felt mildly on the northern shore of Lake Erie from Kingsville to Leamington in Ontario and more strongly on the western shore of Lake Erie including New Boston, Flat Rock, and Grosse Ile, Michigan. Mag. 3.4 m_{blg}."

DISCUSSION

The close examination of the local seismicity, as described in Table 2 and Table 3 and <Figure 2D D-4>, confirms the original seismicity evaluation expressed in the PSAR. Only minor seismic activity is found in the immediate site region (50 mile radius). The low-level seismicity is indicated by the historical record which shows less than 25 events over the last 150 years, most of them with Intensities III and IV(MM), and only several with Intensity V(MM).

From the preceding summary evaluations, the following observations can be made and used as guidelines in the evaluation of the local seismicity and potential correlation with local tectonics.

1. Most of the events that have occurred between 1823 and 1976 must be classified as truly "historical," in opposition to a small number that can be considered "instrumental." The predominant source of data in the assignment of epicentral coordinates consists of "felt reports." Even in the few cases where a seismogram reading was obtained at John Carroll University in Cleveland, felt reports have strongly influenced the assumed location of the epicenters. Consequently, as Richter (1958) recommended, the proposed epicenters based on felt reports should always be accepted with caution, never at face value, but within some reasonable uncertainty. This uncertainty is often hard to estimate.

2. There is a tendency for many events to be reported mostly in towns and villages located along the lake shores. Even some of the larger events (Intensity IV or IV-V) have very few, if any, felt reports inland. Such poor distribution of felt reports is somewhat abnormal and might be indicative of a pronounced soil amplification along the shores. This effect would result in slightly higher felt reports than those

observed on average rock foundations. The areas containing felt reports are usually elongated, narrow and parallel to the shores. It has been observed that felt reports are sometimes distributed in an undifferentiated manner within these areas, seemingly showing no apparent attenuation with distance as normally expected. This is interpreted either as a result of local soil amplification differences or of population density.

3. It is evident, through reading the supporting data, that many epicenters must be given a rather large uncertainty (tens of miles). This is an implicit consequence of Observations 1 and 2. Some epicentral coordinates have been assigned on the basis of very few reports, often those of the towns where the local newspapers published the descriptive accounts. Some newspaper dispatches sometimes refer to a very limited number of observers. Because of the uncertainty of most epicenters, it is unrealistic to give a tectonic significance to any apparent alignment that a few epicenters might show, or attempt a correlation of epicenters with geological features or geophysical anomalies, unless these would be larger than the uncertainties.

4. In general, the cataloged intensities have been assigned rather conservatively. The largest intensity reported is often accepted as characteristic, even in the case of a single report. An instance of a single broken window should not be equated, for example, with an Intensity V(MM) unless some other characteristics of that intensity level are also observed. The fact that events occur infrequently, sometimes decades apart, might result in a tendency to conservative estimates. These overestimated epicentral intensities (e.g., Intensity IV instead of III), either because of soil amplification of conservative evaluation of single reports, might explain why a thorough search of the newspapers has

often failed to uncover the expected Intensity III reports at some distance inland. In reality, these would be lower, and thus more easily missed.

5. A final observation should be made on the temporal distribution of the cataloged events. The last definite event within 50 miles from the site occurred in May 1955; a rather dubious event occurred in May 1958. The fact that so few local events, if any, have been recorded instrumentally in the last two decades might suggest that some of the older historical events were indeed related to blasting noises. A WWNSS Station currently operated in Cleveland certainly offers an adequate surveillance.

CONCLUSIONS

An intensive search for additional source material on the historical seismicity reported for the immediate region of the Perry site was undertaken with the purpose of an overall evaluation. By comparing existing catalogs, evaluating local felt reports and by examining some instrumental data, historical events were reviewed individually. Some earthquake parameters, i.e., epicentral coordinates and intensities, were revised, but in general, these changes were minor. The local seismicity of the immediate area remains low.

This review suggests that the originally cataloged information is relatively conservative; some of the intensities are possibly over-estimated, and some events with dubious origin may have been included as tectonic. Most of the locations of historical events should in any case carry an uncertainty of tens of miles, since the supporting data are relatively meager. For this reason, it would be unwise to accept epicentral locations at face value and attempt to define possible alignments; attaching any tectonic significance to such an alignment of epicenters is unwarranted. Some the most recent events, within the last

50 years, are undoubtedly tectonic in origin. Their intensity never exceeded an Intensity V(MM), well below the selected safe shutdown earthquake.

In summary, the investigations of the immediate site region seismicity have not revealed new information that would affect the original estimate of the seismic hazard.

REFERENCES

Bollinger, G. A., 1969, "Seismicity of the Central Appalachian States of Virginia, West Virginia, and Maryland - 1758 through 1968," Bulletin of the Seismological Society of America, Vol. 59, No. 5, p. 2103-2111.

Bollinger, G. A., 1973, "Seismicity of the Southeastern United States," Bulletin of the Seismological Society of America, Vol. 63, No. 5, p. 1785-1808.

Bollinger, G. A. and M. G. Hopper, 1972, "The Earthquake History of Virginia, 1900-1970," Virginia Polytechnic Institute and State University, Department of Geological Sciences Publication, 85 pp.

Bradley, Edward A., S. J. and Theron J. Bennett, 1965, Earthquake History of Ohio, Bulletin of the Seismological Society of America, Vol. 55, No. 4, pp. 745-752.

Brigham, William T., 1871, "Volcanic Manifestations in New England: Being an Enumeration of the Principal Earthquakes from 1638 to 1869," Memoirs of the Boston Society of Natural History, 28 pp.

Brooks, John E., S.J., 1960, "A Study in Seismicity and Structural Geology (Parts I and II)," Bulletin de Geophysique, Observatoire de Geophysique, College, Jean-de-Brebeuf, Montreal, Quebec, No. 6 and 7.

Coffman, J. L. and C. A. von Hake, 1973, Earthquake History of the United States, Publication No. 41-1, United States Department of Commerce/N.O.A.A., Boulder, Colorado.

Docekal, Jerry, 1970, "Earthquakes of the Stable Interior, with Emphasis on the Midcontinent," Ph.D. Thesis, University of Nebraska, 332 pp.

Eppley, R. A., 1965, Earthquake History of the United States, United States Department of Commerce, Coast and Geodetic Survey, Washington, D.C.

Gordon, D. W., J. W. Dewey, M. Jones, 1978, "Revised Hypocenters in the Northeast United States and Adjacent Canada," Earthquake Notes, Eastern Section, Seismological Society of America, Vol. 49, No. 4, p. 22.

Heck, N. H., and R. A. Eppley, 1958, Earthquake History of the United States, United States Department of Commerce, Coast and Geodetic Survey, Washington, D.C.

Hopper, M. G. and G. A. Bollinger, 1971, "The Earthquake History of Virginia, 1744 to 1900," Virginia Polytechnic Institute and State University, Department of Geological Sciences Publication, 87 pp.

Macelwane, James Bernard, 1950, Jesuit Seismological Association, 1925-1950, Central Station, St. Louis University, 347 pp.

Mather, K. F. and H. Godfrey, assisted by K. Hampson, 1927, "The Record of Earthquakes Felt by Man in New England," Copy of the manuscripts of a paper presented to the Eastern Section of the Seismological Society of America.

Nuttli, Otto, W., 1973, "Seismic Wave Attenuation and Magnitude Relations for Eastern North America," Journal of Geophysical Research, p. 876-885, Vol. 78, No. 5.

Nuttli, Otto, W., 1974, "Magnitude-Recurrence Relation for Central Mississippi Valley Earthquakes," Bulletin of the Seismological Society of America, Vol. 64, No. 4, p. 1189-1207.

Nuttli, Otto W., and Robert Herrmann, 1978, "State of the Art for Assessing Earthquake Hazards in the United States," Report 12, Credible Earthquakes for the Central United States, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, 100 pp.

Richter, C. F., 1956, Elementary Seismology, W. H. Freeman and Company, San Francisco, California, 768 pp.

Smith, W.E.T., 1966, "Earthquakes of Eastern Canada and Adjacent Areas 1928-1959," Publications of the Dominion Observatory, Department of Mines and Technical Surveys, Ottawa, Canada, Vol. 32, No. 3, 121 pp.

TABLE 1

LIBRARIES AND ARCHIVES CONSULTED

Akron Public Library, Akron, Ohio

American Antiquarian Society, Worcester, Massachusetts

Ashtabula District County Library, Ashtabula, Ohio

Berea Public Library, Berea, Ohio

Boston Public Library, Boston, Massachusetts

Cleveland Public Library, Cleveland, Ohio

Elyria Public Library, Elyria, Ohio

Lorain Public Library, Lorain, Ohio

Morely Public Library, Painesville, Ohio

Ohio Historical Society, Columbus, Ohio

Warren Public Library, Warren, Ohio

Western Reserve Historical Society, Cleveland, Ohio

Youngstown Public Library, Youngstown, Ohio

TABLE 2

LOCAL SEISMICITY DATA

DATE	PRESENT LOCATION N	PRESENT LOCATION W	UNCERTAINTY	PREVIOUS LOCATION N	PREVIOUS LOCATION W	PRESENT INTENSITY OR MAGNITUDE	PREVIOUS INTENSITY OR MAGNITUDE	REMARKS
1823 May 30	42.5	81.0	±1/2°	(41.5	81.0)	II-III	(IV)	Probable error in Smith.
1836 July 08	41.5	81.7	±15 mi	--	--	IV	--	
1850 Oct. 01	41.5	81.7	±12 mi	(41.4	82.3)	IV	--	Previously mislocated. Relocated near Cleveland.
1857 Feb. 28	41.8	80.6	±20 mi	(41.67	81.25)	IV-V	(IV)	To the northeast of Painesville. Previously carried on March 1.
1858 Apr. 10	41.67	81.25	±15 mi	--	--	IV	--	Previously carried on April 16.
1867 Jan. 13	42.97	77.85		(41.5	81.7)	III	--	Previously mislocated. Moved to Caledonia, New York.
1869 Apr. 09	42.7	80.8		--	--	III	--	

TABLE 2 (Continued)

DATE	PRESENT LOCATION N	PRESENT LOCATION W	UNCERTAINTY	PREVIOUS LOCATION N	PREVIOUS LOCATION W	PRESENT INTENSITY OR MAGNITUDE	PREVIOUS INTENSITY OR MAGNITUDE	REMARKS
1873 Aug. 17	41.25	80.50		(41.5	81.7)	III	(III-IV)	Previously carried on August 18.
1885 Jan. 18	41.10	81.45	±10 mi	(41.3	81.5)	IV	(II-III)	Moved from Garrettsville to Akron/Kent.
1885 Aug. 15	41.27	81.10	±20 mi	(41.3	81.15)	II-III	(II)	
1898 Oct. 29	41.5	81.7	±15 mi	--	--	III	--	New listing.
1906 Apr. 20	41.50	81.75	±10 mi	(41.5	81.7)	III	(III-IV)	From Cleveland to W. Cleveland.
1921 Sep. 27	42.1	80.2		--	--	III	--	
1928 Sep. 09	41.5	82.0	±20 mi	--	--	V	--	
1930 Feb. 16	42.83	80.52		--	--	III	--	
1932 Jan. 21	41.08	81.50		--	--	IV	--	
1934 Oct. 29	42.0	80.2		--	--	V	--	
1934 Nov. 05	41.88	80.37		--	--	III	--	

TABLE 2 (Continued)

DATE	PRESENT LOCATION N	PRESENT LOCATION W	UNCERTAINTY	PREVIOUS LOCATION N	PREVIOUS LOCATION W	PRESENT INTENSITY OR MAGNITUDE	PREVIOUS INTENSITY OR MAGNITUDE	REMARKS
1936 Aug. 26	41.4	80.4		--	--	II	(III)	
1940 May 31	41.10	81.52		(41.5	81.7)	II	(III)	
1943 Mar. 09	41.61	81.33	±20 mi	(41.6	81.3)	V	--	
1951 Dec. 03	41.65	81.41	±5 mi	--	--	IV	--	
1955 May 26	41.33	81.40		(41.5	81.7)	IV-V	(V)	From Cleveland to northwest of Aurora, Ohio.
1955 June 29	41.33	81.40		--	--	IV	(V)	From Cleveland to northwest of Aurora, Ohio.
1957 June 29	42.92	81.32		--	--	$3.8m_{bLg}$	$4.2M_L$	
1959 Feb. 09	43.0	81.0		--	--	$2.4M_L$	--	
1976 Feb. 02	41.96	82.67		--	--	$3.4m_{bLg}$	--	

TABLE 3

EVENTS WITH DUBIOUS LOCATION OR ORIGIN

DATE	LOCATION	INTENSITY	REMARKS
1872 July 23	41.4N 82.1W	III	Dubious origin. Most likely rock fall. (7,000 tons)
1900 Apr. 09	41.37 81.85	VI	Most likely blast.
1906 June 23	41.37 81.87	I-II	Felt by one person only.
1906 June 27	41.4 81.6	IV-V	Probably blast.
1907 Apr. 12	41.5 81.7	I	Reid says, "not an earthquake"
1929 June 10	41.5 81.7	III	Possibly blast. (Bennett and Bradley, 1965).
1929 Sep. 17	41.50 81.55	II	Dubious origin. Reported by one person only.
1951 Dec. 07	41.65 81.41	II	Dubious occurrence.
1951 Dec. 21	41.65 81.41	II	Dubious occurrence. Around Lakewood.
1958 May 01	41.49 81.82	IV	Dubious origin. Possibly jet activity.

<APPENDIX 2D E>

STRESS MEASUREMENTS HYDROFRACTURING TECHNIQUE

PERRY NUCLEAR POWER PLANT

Program Director and Coordinator

Dr. J. C. Roegiers

STRESS MEASUREMENTS

HYDROFRACTURING TECHNIQUE

PNPP - Cleveland Electric Illuminating Company

A report prepared by:

Professor J.-C. Roegiers and J.D. McLennan
Department of Civil Engineering
University of Toronto
35 St. George Street
Toronto, Ontario. M5S 1A4

for

Dr. Lane D. Schultz
Gilbert Associates, Inc.
P.O. Box 1498
Reading, Pennsylvania. 19603.

September 1979.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Dr. L. Schultz and R. Wardrop of Gilbert Associates Inc.; R.N.M. Urash, B.E. Hill and K.A. Holder of Dikor; D. Wallace and D. Remmington of Halliburton Services; and Pennsylvania Drilling Company (J. Adams, Driller).

Particular acknowledgement is due D. Bartolini and T. Wiles of the Department of Civil Engineering, University of Toronto, for their assistance during the field operations.

TABLE OF CONTENTS

SUMMARY

(1) ORIENTATIONS

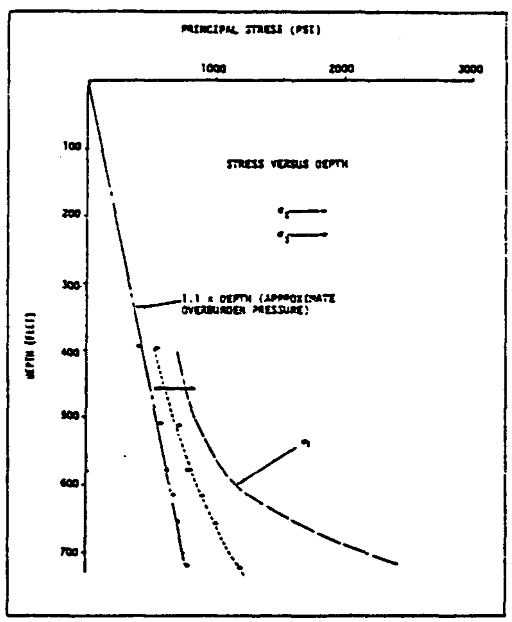
The direction of σ_1 was measured to vary between N67E and E10S. This fits in well with orientations of stress over a regional basis.

(2) MAGNITUDES OF THE HORIZONTAL STRESS

The stress measured (the horizontal stresses are the maximum and intermediate principal stresses) fall within the limits of stresses measured in other parts of northeastern and northcentral United States and in southern parts of Canada.

(3) COMPLETE STRESS TENSOR

In all cases, except possibly the uppermost interval, the complete stress tensor was defined.



(4) GRADIENTS

Below a depth of approximately 600 feet, both σ_{Hmax} and σ_{Hmin} show an increase in gradient with the gradient for σ_{Hmax} being larger. Above this depth, there is a tendency for more uniform stress conditions.

I. INTRODUCTION

Hydraulic fracturing at the North Perry Nuclear Power Plant site was performed during April and May 1979 in order to determine the magnitude and orientation of the *in situ* principal stresses.

The borehole in which measurements were made was 3.65 inches in diameter (0.093 m) and was drilled in the NE parking lot (N781,586.77; E2,369,806.12) to a depth of 730 feet. The hole passed through approximately 60 feet (18.3 m) of glacial till and extended through shaley material to the bottom.

Six intervals were fractured between a depth of 394 feet (120.1 m) and a depth of 718 feet (218.8 m).

The inclination of the hole was unknown prior to hydrofracturing. The horizons fractured were selected in order to:

(i) Provide an adequate representation of the variation of stresses and orientations with depth and to check for the existence of any anomalies in the neighbourhood of a suspected fault.

(ii) Attempt to induce fractures at depths where pre-existing discontinuities did not exist or where the laminations in the shale were not strong enough to govern fracture initiation direction.

II. STRATIGRAPHY

The sequence fractured was interbedded grey and bituminous shales (reference Gilbert Associates Inc. Drilling Logs for borehole in the NE Parking Lot). The lithology at the horizons tested, in the order of fracturing was:

FRACTURE NUMBER	DEPTH (ft.)	DEPTH (m)	DESCRIPTION	RQD
1	718	218.8	Brown bituminous shale with thin pyritic seams (715.5’ - 720’) and traces of light green, grey laminations (minimal gas)	100%
2	704	214.6	700’-710’ is predominantly light greenish-grey shale with some bands of brown shale (minimal gas)	96%
3	654	199.3	650’-660’ is hard, brown shale to siltstone with traces of thin grey shale laminae and traces of light grey siltstone laminae	100%
4	614	187.1	610’-620’ is hard, brown, oil shale to siltstone with traces of grey siltstone areas, traces of pyritic, micro-crystalline mineralization	100%
5	574	175.0	570’-580’ is medium, hard grey shale and brown shale with some very thin siltstone laminae (no gas)	98%
6	511	155.8	510’-520’ is medium, hard, brown shale (trace oil) with some grey shale laminations	98%

FRACTURE NUMBER	DEPTH (ft.)	(m)	DESCRIPTION	RQD
7	454	138.4	450'-460' is medium hard grey shale interlaminated with small amounts of light grey siltstone and dark brown shale - There is a 1/4" wide fissile zone immediately beneath (covered by) the upper packer[1].	450-455 92% 455-460 83%
8	394	120.1	This interval was interbedded brown and grey shale	

NOTE:

[1] This interval had to be fractured in this position because:

(i) hose for drill rig required direct wellhead Halliburton hook up, and

(ii) no shorter pipe lengths could be used in line because the available shorter lengths could not withstand the expected breakdown pressure.

III. HYDRAULIC FRACTURING AS A TECHNIQUE FOR STRESS DETERMINATION: AN OVERVIEW

PART A: CLASSICAL APPROACH

Conceptually, hydraulic fracturing involves pressurization of a sealed-off interval in a borehole until rupture of the rock formation, at the pressurized horizon, occurs. The pressure at which this rupture occurs is known as the *breakdown pressure* P_b. After "breakdown", further pumping propagates the fracture away from the borehole wall in a controlled manner. If pumping is discontinued, with the hydraulic circuit maintained closed, an instantaneous *shut-in pressure* is recorded. From equilibrium considerations prevailing at that time, this pressure is approximately equal to or slightly above the pressure necessary to keep the fracture open. The two characteristic parameters, breakdown pressure P_b and instantaneous shut-in pressure P_{isip}, are related to the pre-existing stress field provided certain assumptions are made:

(i) Linear elasticity and isotropic conditions prevail[1].

(ii) The borehole axis is parallel to the one of the principal stress components.

The two limiting situations are that:

(i) The vertical stress (σ_v) - or overburden stress - is the least principal stress component.

(ii) The vertical stress (σ_v) is either the intermediate or the largest principal stress.

NOTE:

[1] It should be pointed out, however, that the conventional interpretation of hydraulic fracturing data does not require the knowledge of any elastic rock mass parameters; and as such, anisotropic conditions do not play a role in the interpretation other than influencing the anisotropy in the apparent tensile strength.

(i) Vertical Stress as the Maximum or Intermediate Principal Stress

In this case, occurring usually at depths in excess of 1000 feet (300 metres), the shut-in pressure (P_{isip}) is taken equal to the in situ compressive stress component acting perpendicular to the fracture plane. Provided leakage into the formation is negligible, this shut-in pressure will remain constant and,

$$\sigma_{H\,min} \geq P_{isip}$$

$$\sigma_v = \gamma \cdot H$$

where:

$$\begin{cases} \gamma - \text{rock weight gradient} \\ H - \text{depth to the fracturing horizon.} \end{cases}$$

(ii) Vertical Stress as the Minimum Principal Stress

This situation generally occurs at shallow depths. A vertical fracture will probably be initiated regardless of the value of σ_v due to the use of rubber packers which influence the induced stress distribution at the borehole wall. However, the fracture will “rotate” to become horizontal as it propagates away from the borehole and from its local influence.

Consequently, two shut-in pressures may be detected if the hydraulic fracturing tests are conducted with great care. The first shut-in pressure is associated with a vertical fracture while the second one corresponds to an horizontal fracture.

$$\left.\begin{aligned} P_{s1} &\geq P_{s2} \\ P_{s1} &= \sigma_{Hmin} \\ P_{s2} &= \sigma_v \end{aligned}\right\} \qquad (1)$$

In this case, where fluid penetration into the formation is negligible,

$$P_b = 3\sigma_{Hmin} - \sigma_{Hmax} + T_o - P_o \qquad (2)$$

where (compression is taken positive):

P_b -- breakdown pressure

$\sigma_{Hmin} = P_{isip_1}$ -- minimum horizontal principal stress component

σ_{Hmax} -- maximum horizontal principal stress component

T_o -- apparent tensile strength

P_{isip_1} -- instantaneous shut-in pressure

P_o -- formation pore pressure

The stresses calculated are total stresses.

PART B: FRACTURE MECHANICS APPROACH

In recent years, consideration of the hydraulic fracturing process in terms of classical elasticity, particularly the propagation phase, has been extended to include the presence of the fracture itself. Conventional analysis is probably incorrect for the determination of σ_{HMAX} because it ignores the mechanics of fracture initiation and fracture extension.

For example, growth of a crack inclined to the directions of the farfield *in situ* stresses and subjected to pressure on its faces can be analyzed by using fracture mechanics concepts where linear elasticity is assumed and consideration is devoted to the elevation of stresses near the crack tip.

A prerequisite is the assumption that plastic deformation and other non-linear effects near the crack tip are confined to a small region within a linear elastic field. In such a circumstance, the state of stress near the fracture tip can be characterized by the stress intensity factor K, or alternatively by the strain energy release rate, G. Cracks are expected to advance if the values of these parameters reach critical values characteristic of the material considered.

An Introduction to Fracture Mechanics

The presence of a crack (or a notch) in a body causes a redistribution of stress which may be estimated by methods of linear elastic stress analysis.

The surfaces of the crack are the dominating influence on the distribution of stresses near and around the tip. Other remote boundaries and loading forces affect only the intensity of the local stress field at the tip. Equations in terms of stress intensity factors have been formulated for stresses and displacements at crack tips. These stresses depend on stress intensity factors K_I, K_{II} and K_{III} which reflect the elevation of stress due to crack opening, sliding and tearing respectively.

One philosophy is that failure occurs when stress intensity factors reach critical values (i.e. K_{IC}) appropriate for a particular material. Other failure criteria are based on attainment of a maximum circumferential tensile stress, $\sigma_{\theta MAX}$, near the crack tip, attainment of a critical strain energy release rate or attainment of a critical strain energy density.

Various authors have considered the application of fracture mechanics to hydraulic fracturing analysis. Several approaches are outlined in Appendix C which is an excerpt from Numerical Modeling of Pressurized Fractures by J.-C. Roegiers and J.D. McLennan, October 1978.

Discussion of this topic by Abou Sayed et al, 1977[1] is possibly the most relevant. Summarizing these authors' analysis ... Consider a pressurized crack which is oriented at an arbitrary angle α with respect to the direction of the horizontal stress σ_H of the far field system[2]. Extension of this existing crack at an arbitrary angle γ from the original inclination is associated with an energy-release rate $G(\gamma)$.

$$G(\gamma) = \frac{4\left(1-\upsilon^2\right)}{E} \left\{\frac{1}{3+\cos^2\gamma}\right\} \left(\frac{\pi-\gamma}{\pi+\gamma}\right)^{\gamma/\pi} \left[\left(1 + 3\cos^2\gamma\right)K_I^2 + 8 \sin\gamma \cos\gamma \; K_I \; K_{II} + \left(9 - 5\cos^2\gamma\right) K_{II}^2 \right] \qquad (3)$$

where $G(\gamma)$ - Strain energy release rate at an angle γ

υ - Poisson's ratio

E - Young's Modulus

NOTES:

(1) Abou-Sayed, A.S., Brechtel, C.E., Clifton, R.J., In Situ Stress Determination by Hydrofracturing - A Fracture Mechanics Approach; Terra Tek Report, TR77-60, July 1977.

(2) At the present time, mathematical complications encourage consideration of two dimensional situations.

K_I - Opening mode stress intensity factor

K_{II} - Sliding (shearing) mode stress intensity factor

Abou-Sayed et al. provided the relationship between orientation of crack advance in a direction γ_{max} (in a direction where $G(\gamma)$ is a maximum) and the ratio of stress intensity factors K_{II}/K_I. The theory basically predicts that for $(\sigma_H - \sigma_V) \neq 0$ the crack tends to extend in a direction which is more nearly perpendicular to the direction of minimum compressive stress rather than along an existing crack.

This theory is based on isotropic assumptions. If anisotropy prevails, numerical analysis is required (e.g. finite element analysis). If failure anisotropy is included, Abou-Sayed et al. proposed the following failure criterion:

If $G(\alpha)$ - G_{HC} and $G(\gamma_{max}) < G_{VC}$, the inclined fracture will take a sharp turn and propagate along the bedding planes. On the other hand, if $G(\gamma_{max}) = G_{VC}$ and $G(\alpha) < G_{HC}$, then the crack extension will be in a direction inclined at angle γ_{max} to its original direction.

where	$G(\alpha)$	-	strain energy rate in original direction
	$G(\gamma_{max})$	-	strain energy release rate in direction of additional extension
	G_{HC}	-	critical strain energy release rate for horizontal extension
	G_{VC}	-	critical strain energy release rate for vertical extension

Abou-Sayed et al, also offered a comparison between classical analysis and a fracture mechanics formulation:

$$\sigma^{t}_{Hmax} = 3P_s - P_b + \left(\frac{w^2 + 1}{w^2 - 1}\right)P_i - P_o \ (\text{CLASSICAL}) \quad (4)$$

$$\sigma^{f}_{Hmax} = \frac{G}{(G - F)} P_s - \frac{F}{(G - F)} P_b + \frac{K_{IC}}{0.6\,(G - F)\sqrt{\pi L}} \quad (\text{FRACTURE MECHANICS}) \quad (5)$$

where: w - ratio of outer radius to inner radius in a laboratory burst test

P_i - burst pressure in laboratory test

G,F - tabulated parameters depending on the ratio of fracture length to borehole radius

L - fracture length

Clearly, 1979 suggested an alternative.

$$p^F_o + p_T \approx 3\sigma_M - \sigma_H - \zeta p_T + K_C / \left(0.56\sqrt{\pi \ell}\right) \quad (6)$$

where: p^F_o - the breakdown pressure for fast fracture (or jacketed borehole walls).

P_T - the ambient pore-fluid pressure

σ_M - the minimum in situ horizontal stress (total)

σ_H - the maximum in situ horizontal stress (total)

ζ - an effective stress parameter where $\sigma' = \sigma + \zeta p$, the prime denoting effective stress and p being a pore pressure. Tension is taken as positive

K_C - critical opening mode stress intensity factor

ℓ - length of a pre-existing radial fracture

IV. FIELD PROCEDURES

4.1 Fractured Horizons

It was desired to fracture a complete depth range in order to evaluate variation of stress with depth. This initially entailed examination of the core in order to avoid pressurizing discontinuities. However, during actual fracture operations the hose on the drill rig burst at pressures low enough to necessitate coupling the wellhead with steel pipe directly to the pumping system. This, in conjunction with the low working pressures of the available subs, to some extent reduced flexibility in positioning the packers and necessitated some last minute changes. Regardless, based on the cores and logs, it seemed there were no predominant discontinuities in the pressurized intervals.

On the basis of the above considerations the following horizons were tested:

FRACTURE NUMBER	DEPTH BELOW GRADE (ft.)	(m)	COMMENTS
1	718	218.8	
2	704	214.6	steel sub bursts at the surface; interval not fractured
3	654	199.3	
4	614	187.1	
5	574	175.0	
6	511	155.8	
7	454	138.4	
8	394	120.1	

4.2 Field Instrumentation and Equipment

4.2.1 Straddle Packer

A straddle packer consists of two rubber sealing elements mounted a set distance apart on a steel mandrel. These elements “straddle” the zones to be fractured. The zone is isolated from the rest of the hole by inflating these sealing elements, forcing them against the borehole wall. This sealed-off zone can then be pressurized until hydraulically induced fractures occur and/or pre-existing discontinuities open up.

The elements used were commercially available units from Lynes Inc. The diameter of the tool was 2 5/8 inches (66.7 mm) and the sealing elements were separated by 58 1/2 inches (1.49 m) (minimum possible).

The elements were lowered in order to “straddle” the fracturing interval, were inflated and then sealed by twisting the tubing string at the surface. After several revolutions, a left-hand threaded split nut released, which in turn released the inner mandrel. The tubing was then raised two feet, moving the injection ports of the inner mandrel in line with the ports of the outer mandrel, located between the sealing elements. The system was then open to the formation. After the fracturing sequence was completed, the tubing was lowered two feet, moving the injection ports of the inner mandrel in line with the sealing elements and allowing for their deflation. The split nut was again engaged by this movement and the packer was ready to be moved to the next horizon.

4.2.2 Downhole Pressure Transducer

The downhole pressures were measured with a Kuster recording pressure transducer placed inside the tubing itself and located directly above the straddle packer. The pressure transducer consisted of three main components: a Bourdon-type pressure sensing element, a clock and a miniature recorder.

Pressure changes cause the Bourdon tube to expand or contract. These movements cause the attached recorder stylus to move. A coated brass chart records these stylus motions as etches in the chart coating. The chart moves past the stylus at a constant rate which is controlled by the spring driven clock. Pressures are then determined by measuring the displacement of the etched line from the baseline of the chart.

4.2.3 The Pumping System

In order to be capable of pumping at two vastly different flow rates, a multi-stage pumping programme was implemented. The first stage involved pressurization using a high pressure - low volume pump (referred to later as University of Toronto pump). This was an air-driven hydraulic pump manufactured by Teledyne Sprague. This pump operates on air pressure (100 psi ... 0.69 MPa) and can discharge fluid at up to 16000 psi (110.3 MPa). The pressure-flow characteristics are shown on the next page. This unit was used to initiate a first fracture or to inflate pre-existing discontinuities. When severe leakage was present in the overall system, the pressure could only be stabilized to a certain value and the larger pumping unit (referred to as Halliburton pump) had to be engaged. This unit is capable of flow rates of approximately 1000 gal/min (3.79 m^3/min) at a maximum pressure of 14000 psi (96.6 MPa).

TABLE 1

FLOW RATES FOR
UNIVERSITY OF TORONTO PUMP

Liquid Discharge Pressure		Flow	
(psi)	(Mpa)	(in^3/min)	(m^3/minx10^{-3})
0	0	78	1.28
250	1.72	77	1.26
500	3.45	76	1.24
750	5.17	74	1.21
1000	6.90	72	1.18
1500	10.34	68	1.11
2000	13.70	66	1.08
2500	17.24	63	1.03
3000	20.19	60	.98
4000	27.59	56	.92
5000	34.48	53	.87

4.2.4 Surface Recording Equipment

All pressurization procedures (University of Toronto pump and Halliburton pump)were monitored using an X-Y recorder (surface pressure versus time) and a strip chart recorder in parallel as a backup unit. These recorders responded to pressure sensed by a pressure transducer mounted on the surface iron. In addition, all pressurization was monitored (and systematically recorded) from output of a Bourdon type pressure gauge. Furthermore, the Halliburton pumping unit was equipped with a recording pressure gauge. Flow rates and total volume pumped were measured with an impellor type flow monitor.

4.2.5 Impression Packer

The impression packer was manufactured by Lynes, Inc., and consisted of a thick-walled rubber tube, which was wrapped with a soft semi-cured rubber sleeve.

The impression packer is lowered on tubing to the fractured horizon. The element is then inflated, forcing the soft rubber into all irregularities existing at the horizon, on the borehole wall. The impression packer is then deflated and allowed to return to its original shape. The impression of the borehole is retained on the soft rubber wrap.

The element is 3.5 feet (1.07 m) long and has an outside diameter of 2 inches (51 mm). This large diametral clearance allows the impression packer to be removed without marring the impression.

4.2.6 Single Shot Survey Instrument

A Kuster single shot survey instrument was used to orient the fracture traces recorded on the impression packer. This instrument photographically recorded the azimuth and inclination of the borehole by photographing a clinometer-compass unit, giving the azimuth and inclination of a line scribed on the housing of the device.

The instrument consists of three basic units: a 20° clinometer-compass, a controlled light source with batteries and a six hour clock, and the main frame containing the photographic mechanism.

4.3 Test Procedure

The tool string was lowered to the deepest horizon. Then using the Halliburton pump, the sealing elements of the straddle packer were inflated to approximately 500 psi (3.45 MPa). This pressure was held for several minutes in order to check the integrity of the O-rings in the straddle packer. The sealing elements were then inflated to approximately 1000 psi (6.9 MPa), thus packing off the 58 inch (1.49 m) interval to be pressurized.

The formation was then pressurized using the University of Toronto air operated pump. When breakdown appeared to occur[1], the well was "shut-in", i.e. pumping was discontinued but the pressure was not released. The well remained shut-in for several minutes and then the cycle of pressurization was repeated. At this point, the system pressure was bled and a series of breakdown-propagation-shut-in cycles was performed using Halliburton pumps pumping at a rate of 1/4 bbl per minute (.040 m^3/min). After the last cycle the system was shut-in for a longer period of time in order to study the pressure-decay behaviour.

During all phases, pressures were continuously recorded.

Ideally the packers are now deflated, the tool string raised to the next horizon and the same pressurization and repressurization procedures are performed. Unfortunately, problems with seals and packer deflation generally made it necessary to pull the entire tool string and "re-dress" the tool after each fracture.

The impressions of the fractures were taken by running the impression packer and single shot survey instrument down the hole on the tubing to one of the previously fractured horizons. The impression packer was then inflated to 1500 psi (measured at the surface). The impression packer was then left inflated for up to 90 minutes, after which time the packer was deflated and removed from the hole.

The orientation of the fracture trace was determined by measuring the relative angle between the fracture trace and the scribe line on the housing and from the film record determining the orientation of the scribe line (taking into account magnetic declination at the site).

<u>NOTE</u>:

[1] As the flow rate is very small, breakdown did not always occur due to leakages through pipe joints and into the formations.

V. LABORATORY TESTING AND RESULTS

5.1 Procedure for Determining Tensile Strength (T_o)

In order to estimate values of the tensile strength necessary for the calculation of σ_{Hmax}, laboratory hydraulic burst tests were performed on cores from the borehole. The cores, where possible, were machined to a length/diameter ratio of 2. The facility of bedding plane parting sometimes made it necessary to use smaller L/D ratios.

A 0.25 inch (6.4 mm) borehole was drilled through the sample (concentrically). The sample was then loaded axially, confined radially and the borehole was pressurized internally until breakdown. The borehole was lined with a latex membrane in order to prevent penetration of borehole fluid into the sample (i.e. P_o did not increase due to the fracturing fluid). Based on the burst pressure measured in these simulated hydraulic fracturing tests, the tensile strength was estimated.

Thirty-five burst tests were performed. Of these, a percentage was done with no confining pressure (i.e. axial and borehole pressure only). The others were done using a confining pressure (some with the confining pressure equal to the σ_{Hmin} and the remainder with higher confining pressures). Despite the statistical scatter associated with any form of tensile test, the calculated tensile strength did not seem to be strongly dependent on the confining pressure.

Due to the highly anisotropic character and the occurrence of minute or incipient horizontal discontinuities (whose presence was exaggerated by stress relief on sampling and by the unavoidable “distress” due to sample transportation) it was generally necessary to keep the axial pressure slightly above the confining pressure in order to create vertical fractures.

The average tensile strengths for the various horizons, as calculated from laboratory testing are listed below:

FRACTURE NUMBER	DEPTH BELOW GRADE		TENSILE STRENGTH T_o	
	(ft)	(m)	(psi)	(MPa)
1	718	218.8	1040	7.17
2	704	214.6	--	--
3	654	199.3	1300	8.96
4	614	187.1	--(1)	--(1)
5	574	175.0	1900	13.10
6	511	155.8	420	2.90
7	454	138.4	1040	7.17
8	394	120.1	785	5.41

NOTE:

(1) Samples of adequate length could not be prepared.

5.2 Procedure for Determining Critical Stress Intensity Factor (K_{IC})

Two separate testing procedures were used to estimate the critical stress intensity factors. These were:

(i) Hydraulic burst tests on prenotched specimens.

(ii) Short rod technique

Hydraulic Burst Tests

The test specimens were thick-walled cylinders with the outer radius 2.375 in. (60.3 mm) and the radius of the internal concentric borehole being .25 in. (6.35 mm). Two radially opposed prenotches were

cut along the entire length of the borehole. The borehole wall was lined with a thin tygon sheath to prevent penetration of fluid into the specimen during testing.

Specimens were loaded axially and confining pressure was applied by pressurization behind a urethane membrane. The applied loading was designed to simulate anticipated in situ stress conditions. Unconfined tests were also performed. The internal borehole was pressurized until breakdown occurred. Fracture toughness was calculated from available formulae (Tada et al, 1973).

The Short Rod Technique

(Refer to Figure 15)

This method allows measurement of the plane strain critical stress intensity factor K_{IC}. Advantages of this technique are that:

(i) The specimen has geometry favouring plane strain conditions.

(ii) The need for pre-cracking is reduced.

(iii) Sample size is small enough that measurements of anisotropic behaviour are possible.

The load F is increased slowly until a crack initiates at the point of the “V”. Initial crack growth is stable such that the load must be increased for continued propagation. When the crack attains a critical length, the load decreases with increasing crack length. The peak load, occurring at the critical crack length, is used to calculate the fracture toughness (K_{IC})[1],

NOTE:

[1] Barker, L.M.; A Simplified Method for Measuring Plane Strain Fracture Toughness; Engineering Fracture Mechanics, 1977, Vol. 9, pp. 361-369.

The formulation, with suitable approximations is:

$$K_{IC} = \frac{AF_c}{B^{3/2}} \qquad (7)$$

where: K_{IC} - critical stress intensity factor

A - a material independent parameter, found to be approximately 20.8 for the specimen proportions used

B - specimen diameter

Results

The critical stress intensity factors, using both tests are tabulated below. There is surprising good agreement between the results from the different tests.

DEPTH		DIRECTION[1]	K_{IC} (psi-in$^{-3/2}$)	
(ft)	(m)		BURST TEST	SHORT ROD TEST
718	218.8	H		1093
		H		660
		V	914	1200
691	210.1	H		406
		V	401	
654	199.3	H		589
		H		1048
		V	801	
614	187.1	-	-	-
574	175.0	V		641
511	155.8	H		519
454	138.4	-	-	-
394	120.1	V	457	562

<u>NOTE</u>:

(1) H - indicates a horizontal (parallel to bedding) fracture

V - indicates a vertical (perpendicular to bedding) fracture

Based on the values measured, the following fracture toughness values were adopted.

DEPTH (ft)	DEPTH (m)	DIRECTION	K_{IC} (psi-in$^{-3/2}$)
718	218.8	H	875
		V	1060
691[1]	210.1	H	400
		V	400
654	199.3	H	820
		V	800
614	187.1	H	720
		V	720[2]
574	175.0	H	640
		V	640
511	155.8	H	520
		V	520
454	138.4	H	515[2]
		V	515[2]
394	120.1	H	
		V	510

NOTES:

[1] This horizon was not hydrofractured.

[2] Average of adjacent formations

The general tendency is a decrease in fracture toughness with decreasing depth. There appears to be surprisingly little anisotropy despite the laminations and the ease with which bedding plane parting occurred. The underlying reason for this may be that the samples tested were necessarily from the stronger part of the core samples. Weaker samples often failed prior to testing during the preparation process. Consequently, especially for the "grey" shale specimens, the toughness values cited are upper limits.

VI. DATA ANALYSIS

6.1 Introduction

In order to reduce the probability of formation damage and borehole instability, fracturing was performed first at the deepest horizon with subsequent fractures at progressively shallower depths. The fractures were not propped.

6.2 *In situ* Stresses[1]

Table 2 synthesizes the results of the downhole and the surface recordings. Pressure-time diagrams are presented in Appendix A. Appendix B contains reproductions of the downhole pressure-time plots.

Table 3 indicates the calculated *in situ* stresses, based on the assumption of a tensile strength of 1000 psi in the plane of the laminations and 100 psi perpendicular to the laminations. These are approximate values typically representative of shales.

Table 4 is similar to the previous tabulation, with the primary difference being that tensile strengths are based on the difference between the initial and subsequent breakdown pressures (where such interpretation was possible). This assumes that after the initial breakdown, the second breakdown pressure largely reflected a reopening of the fracture.

Table 5 tabulates *in situ* stresses based on tensile strengths derived from the laboratory testing programme.

Finally, Tables 6-8 outline *in situ* stresses based on measured (laboratory) values of fracture toughness using fracture mechanics considerations.

NOTE:

(1) The stresses tabulated are total stresses.

TABLE 2

RECORDED HYDROFRACTURING PRESSURES AND DIRECTIONS

FRACTURE NUMBER	DEPTH (ft)	FORMATION PRESSURE P_o (psi)		INITIAL BREAKDOWN P_{b1} (psi)		SECONDARY BREAKDOWN P_{b2} (psi)	INSTANTANEOUS SHUT-IN PRESSURE P_{isip} (psi)	INSTANTANEOUS SHUT-IN PRESSURE AFTER SEVERAL CYCLES (psi)
		ESTIMATED	DOWNHOLE	SURFACE PLUS FORMATION PRESSURE	DOWNHOLE	SURFACE PLUS FORMATION PRESSURE	SURFACE PLUS FORMATION PRESSURE	SURFACE PLUS FORMATION PRESSURE
1	718	311	300	1941	1933	-	1211	796
2	704	-	-	-	-	-	-	-
3	654	283	270	2143	2187	1373	1023	733
4	614	266	-	2806	2920	1171	905	686
5	574	249	260	3269	3496	1265	809	634
6	511	221	230	1716	1770	-	721	586
7	454	197	200	2267	2271	1297	557-837	577
8	394	171	170	1646	1720	-	551	411

TABLE 3

IN SITU STRESSES (BASED ON T_o=1000 psi)[1]

FRACTURE NUMBER	DEPTH (ft)	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	ORIENTATION
1	718	2381	1211	796	-
2	704	-	-	-	-
3	654	1643	1023	733	N80E
4	614	646	906	686	N67E
5	574	-	809	634	E10S
6	511	1226	721	586	E04S
7	454	207 - 1047	557-837	577	N37E
8	394	836	551	441	-

TABLE 4

IN SITU STRESSES (TENSILE STRENGTH BASED ON DIFFERENT BREAKDOWN PRESSURES)

FRACTURE NUMBER	DEPTH (ft)	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	ORIENTATION
1	718	2261	1211	796	-
2	704	-	-	-	-
3	654	1413	1023	733	N80E
4	614	1281	906	686	N67E
5	574	809	809	634	E10S
6	511	-	721	586	E04S
7	454	177 - 1017	577-837	577	N37E
8	394	-	-	-	-

NOTE:

(1) Inherent inaccuracies in the fracturing procedure do not justify calculation of principal stresses to as many significant figures as shown.

TABLE 5

IN SITU STRESSES (TENSILE STRENGTH BASED ON LABORATORY MEASUREMENTS)

FRACTURE NUMBER	DEPTH (ft)	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	ORIENTATION
1	718	2421	1211	796	-
2	704	-	-	-	-
3	654	1943	1023	733	N80E
4	614	-	906	686	N67E
5	574	1058	809	634	E10S
6	511	806	721	586	E04S
7	454	247 - 1087	557-837	577	N37E
8	394	721	551	411	-

TABLE 6 (REFER TO FIGURE 12)

IN SITU STRESSES (FRACTURE MECHANICS APPROACH)

FRACTURE NUMBER	DEPTH (ft)	σ_1 (psi) [1]				σ_2 (psi)	σ_3 (psi)	ORIENTATION
		ℓ = .01 in	ℓ = .05 in	ℓ = .1 in	ℓ = 1 in			
1	718	9348	3793	2476	303	1211	796	-
2	704	-	-	-	-	-	-	-
3	654	6377	2181	1187	-454	1023	733	N80E
4	614	3933	157	-737	-2214	906	686	N67E
5	574	1956	-139	-2192	-3504	809	634	E10S
6	511	3661	936	290	-776	721	586	E04S
7	454	2017 → 2913	−681 → 215	−1320 → −424	−2375 → −1479	557-837	577	N37E
8	394	3187	517	-116	-2126	551	411	-

NOTE:

[1] Abou-Sayed proposed that, for a pressurized borehole intersected by a pre-existing fracture of preferred orientation, a more representative formulation for σ_1 is:

$$\sigma_1 \approx 3P_{isip} - 2Pb = \frac{K_{IC}}{\sqrt{\pi\ell}(0.6)}$$

where: ℓ - crack length for one arm of a diametrically opposed crack

K_{IC} - critical stress intensity factor

The predominant difficulty is in estimating the length of pre-existing fractures. A range of fracture lengths has been evaluated.

TABLE 7 (REFER TO FIGURE 13)
IN SITU STRESSES (FRACTURE MECHANICS APPROACH)

FRACTURE NUMBER	DEPTH (ft)	σ_1 (psi)[1]				σ_2 (psi)	σ_3 (psi)	ORIENTATION
		ℓ = .01 in	ℓ = .05 in	ℓ = .1 in	ℓ = 1 in			
1	718	12326	6446	4743	2445	1211	796	-
2	704	-	-	-	-	-	-	-
3	654	9667	4231	3181	2253	1023	783	N80E
4	614	6263	2873	1927	383	906	686	N67E
5	574	5327	1781	939	-449	809	634	E10S
6	511	5440	2560	1875	748	721	586	E04S
7	454	4371-5211	1519-2359	941-1681	-277-563	557-837	577	N37E
8	394	4960	2130	1458	348	551	411	-

NOTE:

[1] Cleary proposed that, for a pressurized borehole intersected by a pre-existing fracture, a formulation (where total stress is equal to effective stress) is:

$$\sigma_1 \approx 3P_{isip} - P_b - P_o + \frac{K_{IC}}{\sqrt{\pi \ell}\ .56}$$

where: ℓ - crack length for one arm of a diametrically opposed crack

K_{IC} - critical stress intensity factor

The predominant difficulty is in estimating the length of pre-existing fractures. A range of fracture lengths has been evaluated.

TABLE 8 (REFER TO FIGURE 14)

IN SITU STRESSES (FRACTURE MECHANICS APPROACH)

FRACTURE NUMBER	DEPTH (ft)	σ_1 (psi)[1]				σ_2 (psi)	σ_3 (psi)	ORIENTATION
		ℓ = .01 in	ℓ = .05 in	ℓ = .1 in	ℓ = 1 in			
1	718	11704	4924	4432	2134	1211	796	-
2	704	-	-	-	-	-	-	-
3	654	8384	3948	2898	1970	1023	733	N80E
4	614	6240	2250	1661	117	906	686	N67E
5	574	5078	1532	690	-698	809	634	E10S
6	511	5219	2339	1655	527	721	586	E04S
7	454	4174-5014	1322-2162	644-1484	-474-366	557-837	577	N37E
8	394	4789	1959	1287	177	551	411	-

NOTE:

[1] Cleary proposed that for a pressurized borehole intersected by a pre-existing fracture, a formation (where $\sigma^1 = \sigma - p$):

$$\sigma_1 \approx 3P_{isip} - P_b - 2P_o + \frac{K_{IC}}{\sqrt{\pi \ell}\ .56}$$

where: ℓ - crack length for one arm of a diametrically opposed crack

K_{IC} - critical stress intensity factor

The predominant difficulty is in estimating the length of pre-existing fractures. A range of fracture lengths has been evaluated.

Difficulties in determining instantaneous shut-in pressures have led to alternate interpretation of the data (B. Voight, personal communication). The proposed stress regime for the alternate interpretation is shown in Table 9.

TABLE 9

IN SITU STRESS REGIME (TENSILE STRENGTH BASED ON LABORATORY MEASUREMENTS

FRACTURE NUMBER	DEPTH (ft)	σ_1(psi)	σ_2(psi)	σ_3(psi)	ORIENTATION
1	718	1971	1061	796	-
2	704	-	-	-	-
3	654	1343-1943	823-1023	733	N80E
4	614	1281[(1)]	906	686	N67E
5	574	1178	849	634	E10S
6	511	806-1406	721-921	586	E04S
7	454	247-1087,1987	557-837,1137	577	N37E
8	394	721-1981	551-971	411	-

NOTE:

(1) T_o based on field measurements.

Figure 11 is a comparison of the two interpretations.

As a criterion for shut-in values, the authors have used pressure values where there was initial inflection on the pressure decay curve after the well was shut-in for the first time. The major discrepancy between the two interpretations is for Fracture 7 at a depth of 454 ft. The value suggested by Voight corresponds to a slight spike in the pressure time curve. It appears that this occurred just after breakdown and before the well was shut-in. Since pumping had not stopped this

value may be too high. Differences in interpretation for the other depths are not as significant. Consequently, the original interpretation (Roegiers and McLennan) has been adopted.

6.3 Fracture Orientations

Ideally, a fracture can be categorized as being vertical or horizontal by comparing the instantaneous shut-in pressure with the anticipated value of the overburden stress (gradient of approximately 1.1 psi/ft. depth). If this pressure is less than the weight of the overburden, then the fracture is vertical. This interpretation is complicated by two features:

(i) There is a general tendency for fractures to initially be vertical, due to the influence of the packers. However, if anisotropy is strong enough, this may not always be the case.

(ii) Interpretation is more complicated if the minimum horizontal stress has approximately the same value as the sum of the vertical stress and the tensile strength in the horizontal direction.

The final column in each of the foregoing tables summarizes the fracture orientations as determined from the impression packers and the downhole orientation surveys.

6.4 Discussion

(i) Variation of Horizontal Stress with Depth

Figures 1 and 2 indicate the variation of σ_1 and σ_2 (σ_{Hmax} and σ_{Hmin} in this case) with depth. It seems that the stress situation becomes more isotropic as the depth decreases.

(Figure 4). The gradient of σ_1 is larger than the gradient for σ_2, at the greater depths. The change in gradient may signify:

(a) The presence of a tectonically induced feature.

(b) Change in material characteristics.

(ii) Variation of Vertical Stress with Depth

σ_3, which is the vertical stress, corresponds closely to the anticipated overburden pressure. Table 10 indicates the ratio of σ_v/DEPTH. A standard rule of thumb is that σ_v(psi) is approximately equal to the DEPTH (feet) x 1.1.

TABLE 10

σ_V/DEPTH

FRACTURE NUMBER	DEPTH (ft)	σ_V(psi)	σ_V/DEPTH
1	718	796	1.11
2	704	-	-
3	654	733	1.12
4	614	686	1.12
5	574	634	1.10
6	511	586	1.15
7	454	577	1.27
8	394	411	1.04

The σ_v/DEPTH is close to what is expected. Fracture 7 gives an anomalously high value. No reason is offered for this at the present time.

(iii) Ratio of σ_{Hmin} to σ_V

Figure 8 is a plot of representative values of the ratio σ_{Hmin}/σ_V, indicating that the measured stresses are within the range of other measured values. Table 11 lists all the values for σ_{Hmin}/σ_V. Fracture 7 at a depth of 454 covers a range of values. This is due to the difficulty in determining with complete certainty a shut-in pressure at that particular horizon. However, based on the plot of σ_{Hmin} versus depth it seems highly likely that $\sigma_{Hmin} \approx 650$ psi. If this value is used and $T_o = 1040$ psi (laboratory) is used, σ_1 is calculated to be 596. This is inadmissible since $\sigma_1 < \sigma_2$ but probably stems from inherent inaccuracy (and statistical variation) in the laboratory measurements of T_o. Hence $\sigma_{Hmin} = 650$ psi and $\sigma_{Hmax} \approx 650$ psi at depth 454 would seem to be a reasonable prediction.

TABLE 11

σ_{Hmin}/σ_V

FRACTURE NUMBER	DEPTH (feet)	σ_{Hmin} (psi)	σ_V (psi)	σ_{Hmin}/σ_V
1	718	1211	796	1.52
2	704	-	-	-
3	654	1023	733	1.40
4	614	906	686	1.32
5	574	809	634	1.28
6	511	721	586	1.23
7	454	557-837	577	.97-1.45
8	394	551	411	1.34

It is to some extent unusual that the stress seems to become more isotropic as the depth decreases. However, measurements were made over a limited depth.

(iv) Change in Gradient With Depth

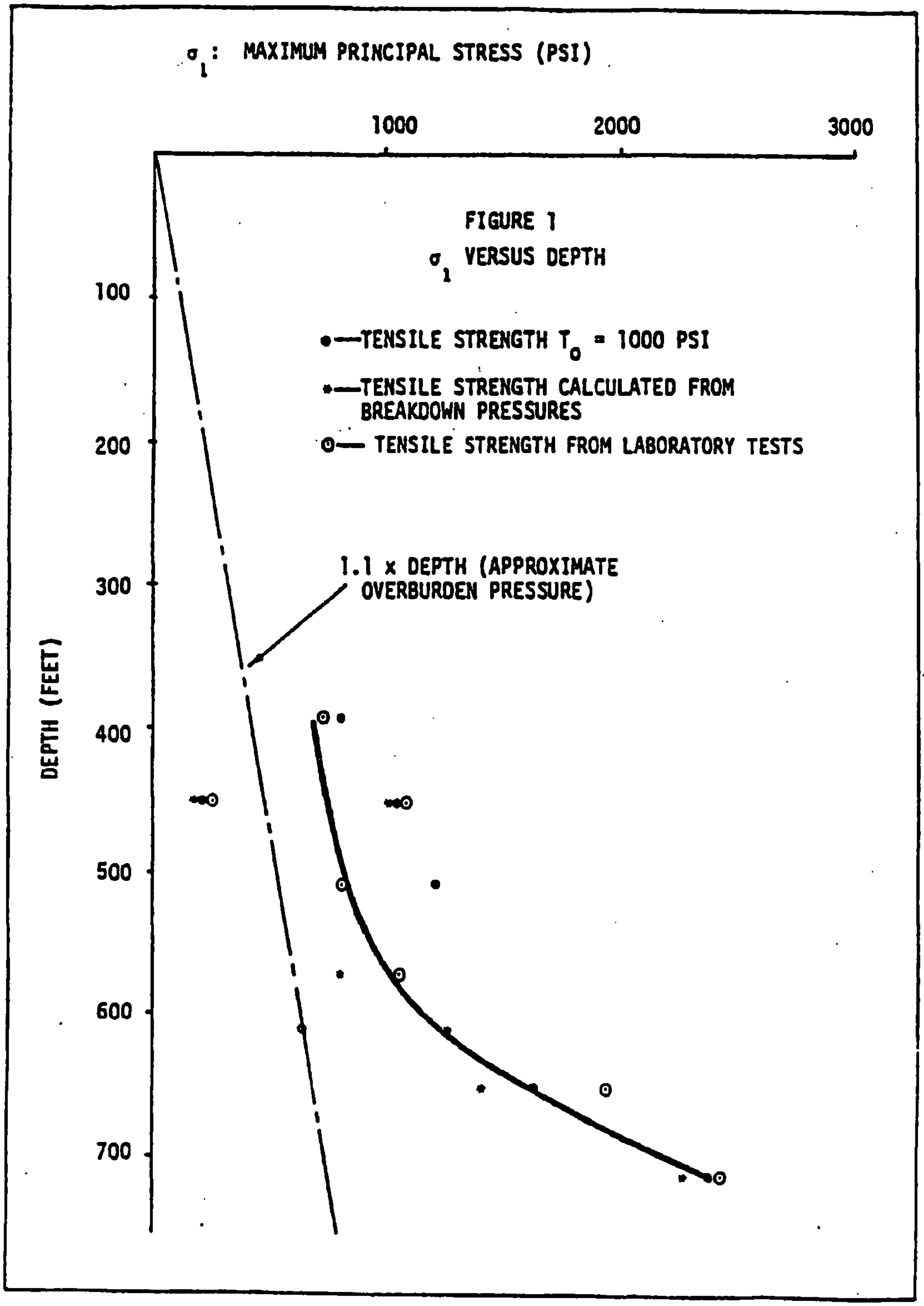
Below a depth of approximately 600 feet, both σ_{Hmax} and σ_{Hmin} exhibit an increase in gradient. To what depth below the measurement zone this trend continues is uncertain. At the shallower depths, the tendency for $\sigma_1 \approx \sigma_2 \approx \sigma_3$ is well defined and extrapolations of existing measurements to the surface would seem to be reasonable.

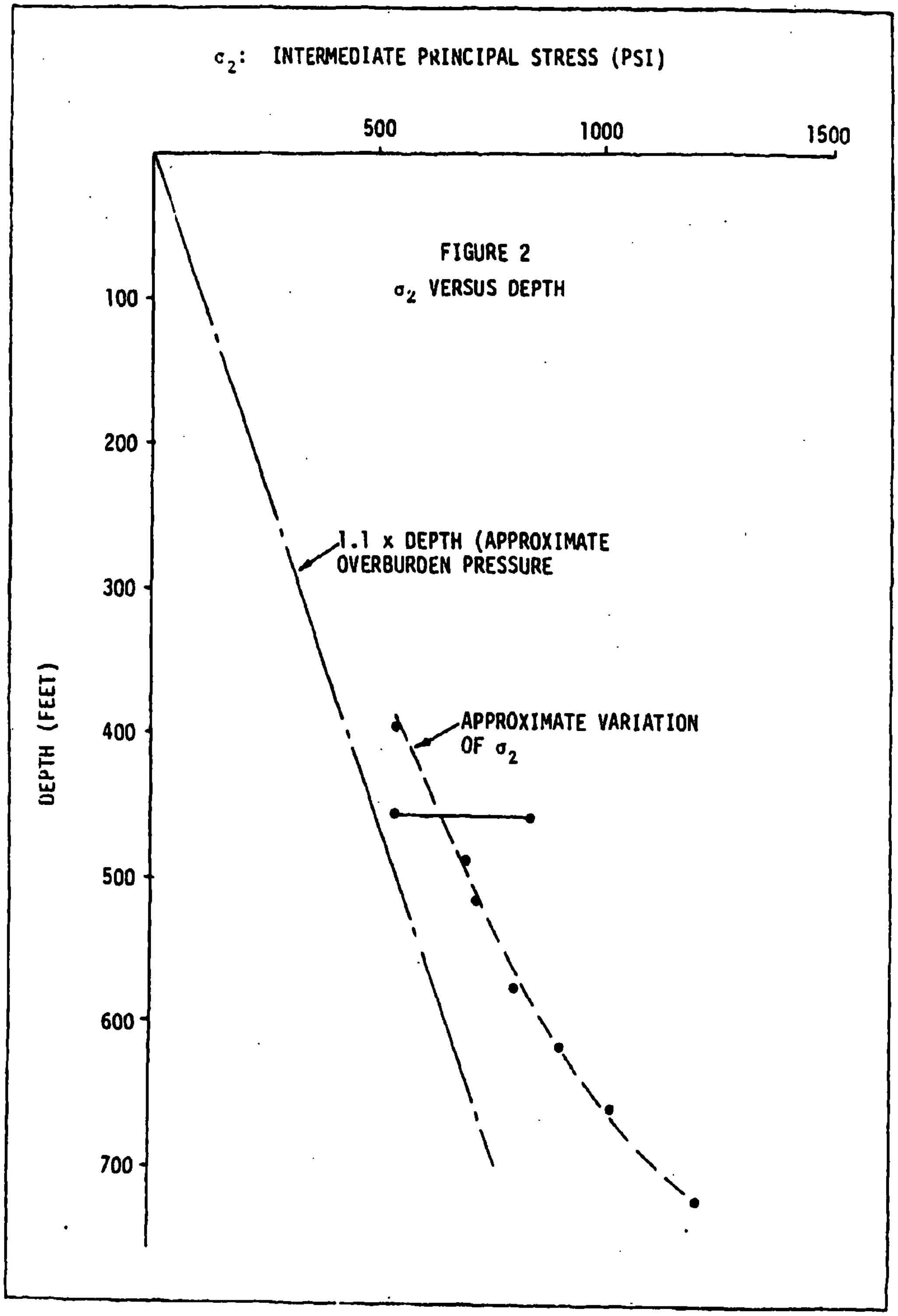
(v) Orientation and the Regional Stress "Picture"

The variation in orientation and magnitude with depth is shown in Figure 5. Orientation for the fracture at depth 454 feet is subject to some doubt due to the poor quality of the downhole photograph. It appears that σ_1 is approximately E-W and from Figures 9 and 10 it can be seen that this orientation is consistent with the regional stress picture (based on other field measurements).

(vi) Fracture Mechanics Considerations

Since no definite measurement of the length of influential pre-existing discontinuities is available, only a qualitative review of the data is possible. However, Figures 12-14 indicate that values calculated using conventional analysis are similar to values calculated using a fracture mechanics approach assuming feasible fracture lengths. This suggests a degree of reliability for values obtained using classical methods.


σ1: MAXIMUM PRINCIPAL STRESS (PSI)
1000
2000
3000
FIGURE 1
σ1 VERSUS DEPTH
•—TENSILE STRENGTH T0 = 1000 PSI
*—TENSILE STRENGTH CALCULATED FROM BREAKDOWN PRESSURES
⊙— TENSILE STRENGTH FROM LABORATORY TESTS
1.1 x DEPTH (APPROXIMATE OVERBURDEN PRESSURE)
DEPTH (FEET)
100
200
300
400
500
600
700


σ2: INTERMEDIATE PRINCIPAL STRESS (PSI)
500
1000
1500
FIGURE 2
σ2 VERSUS DEPTH
100
200
300
400
500
600
700
DEPTH (FEET)
1.1 x DEPTH (APPROXIMATE OVERBURDEN PRESSURE
APPROXIMATE VARIATION OF σ2

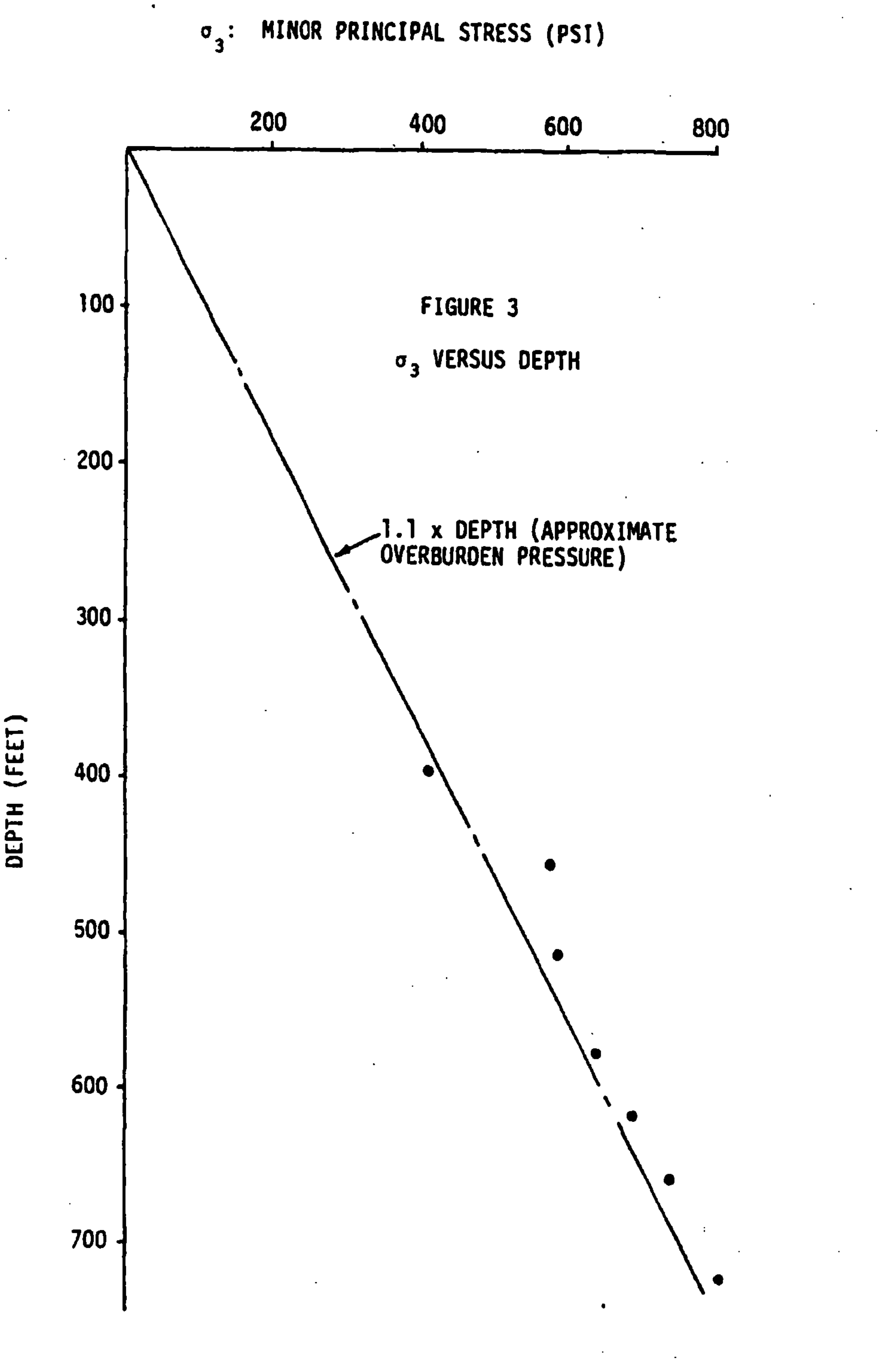


FIGURE 3

σ_3 VERSUS DEPTH

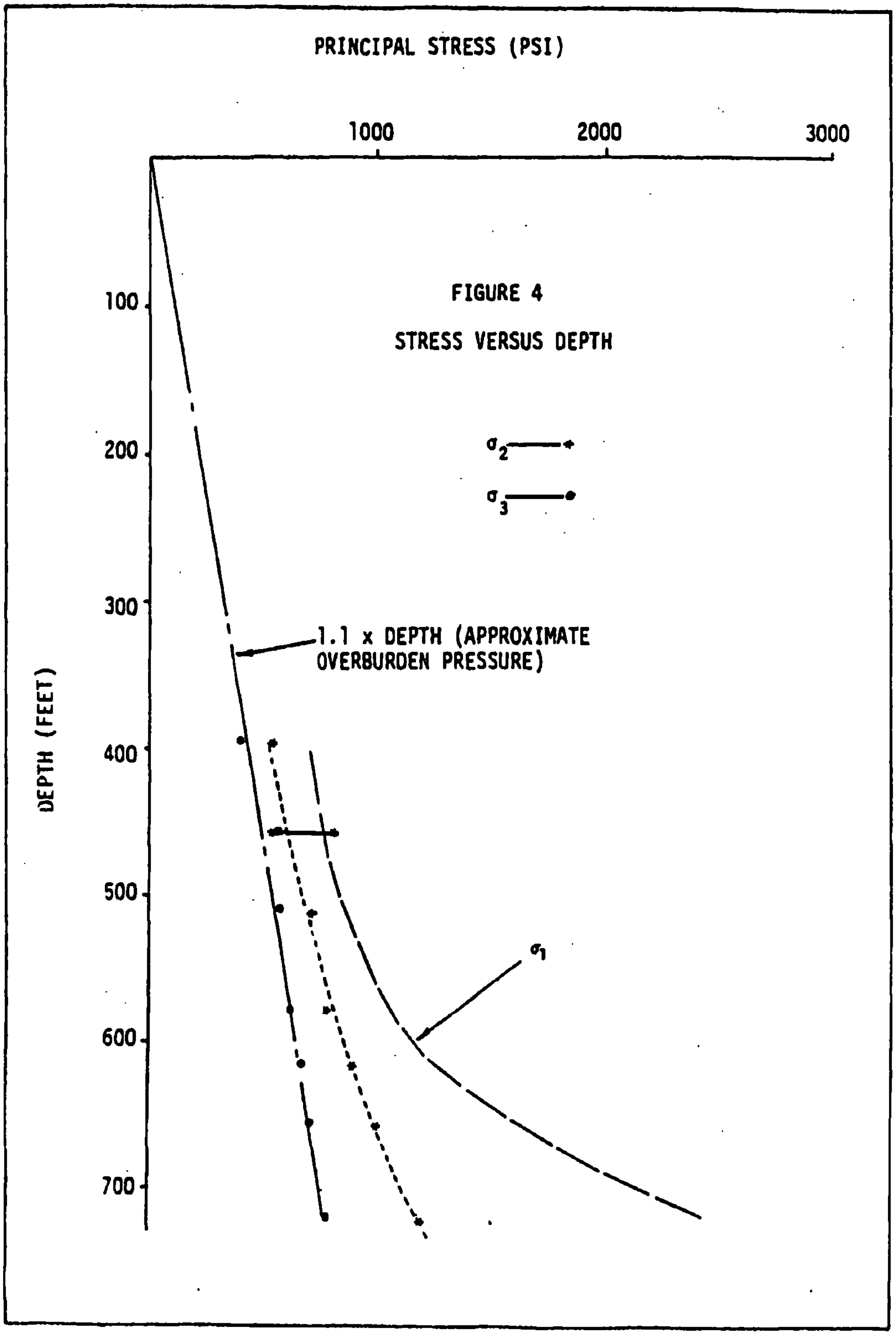


FIGURE 4

STRESS VERSUS DEPTH

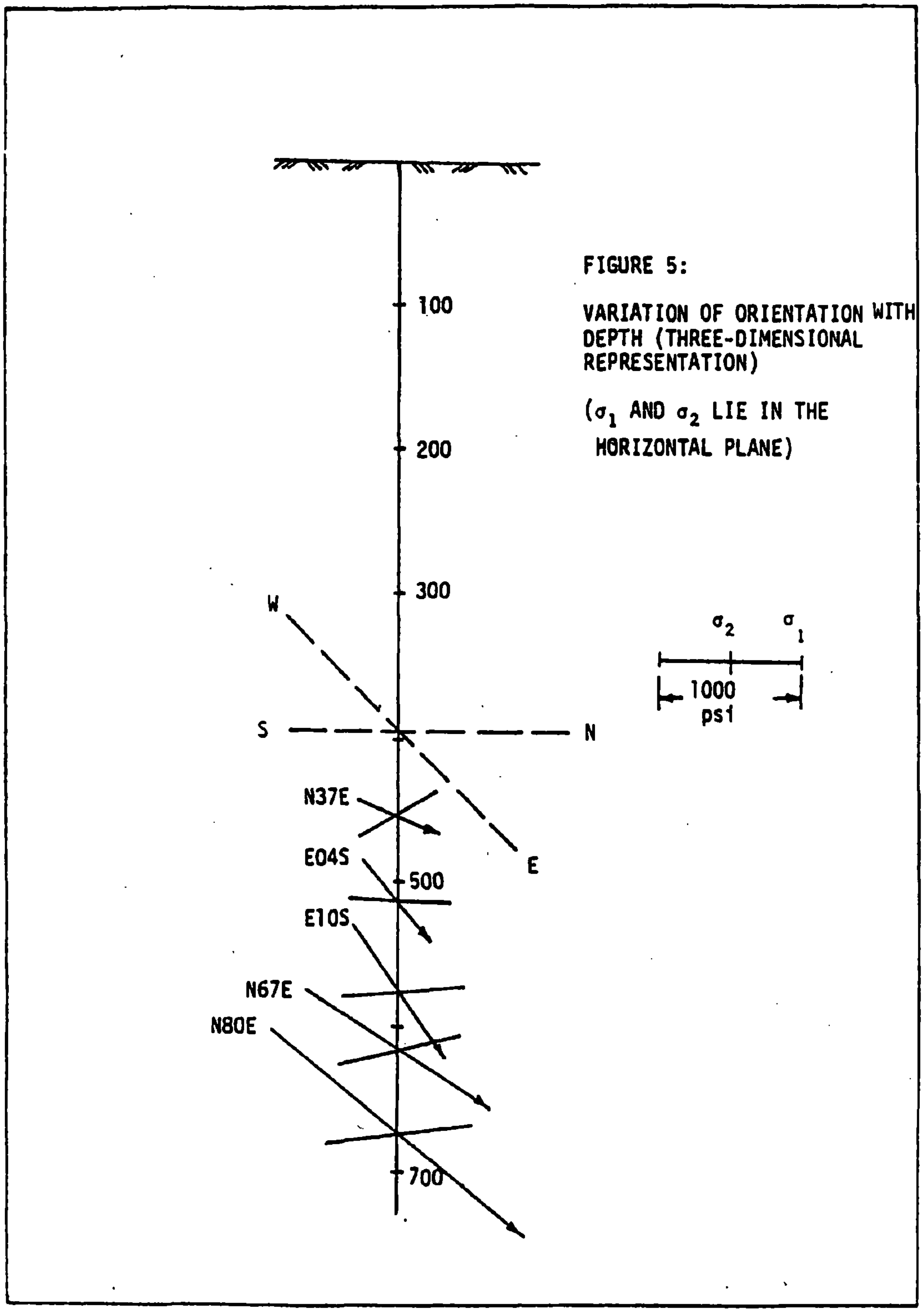
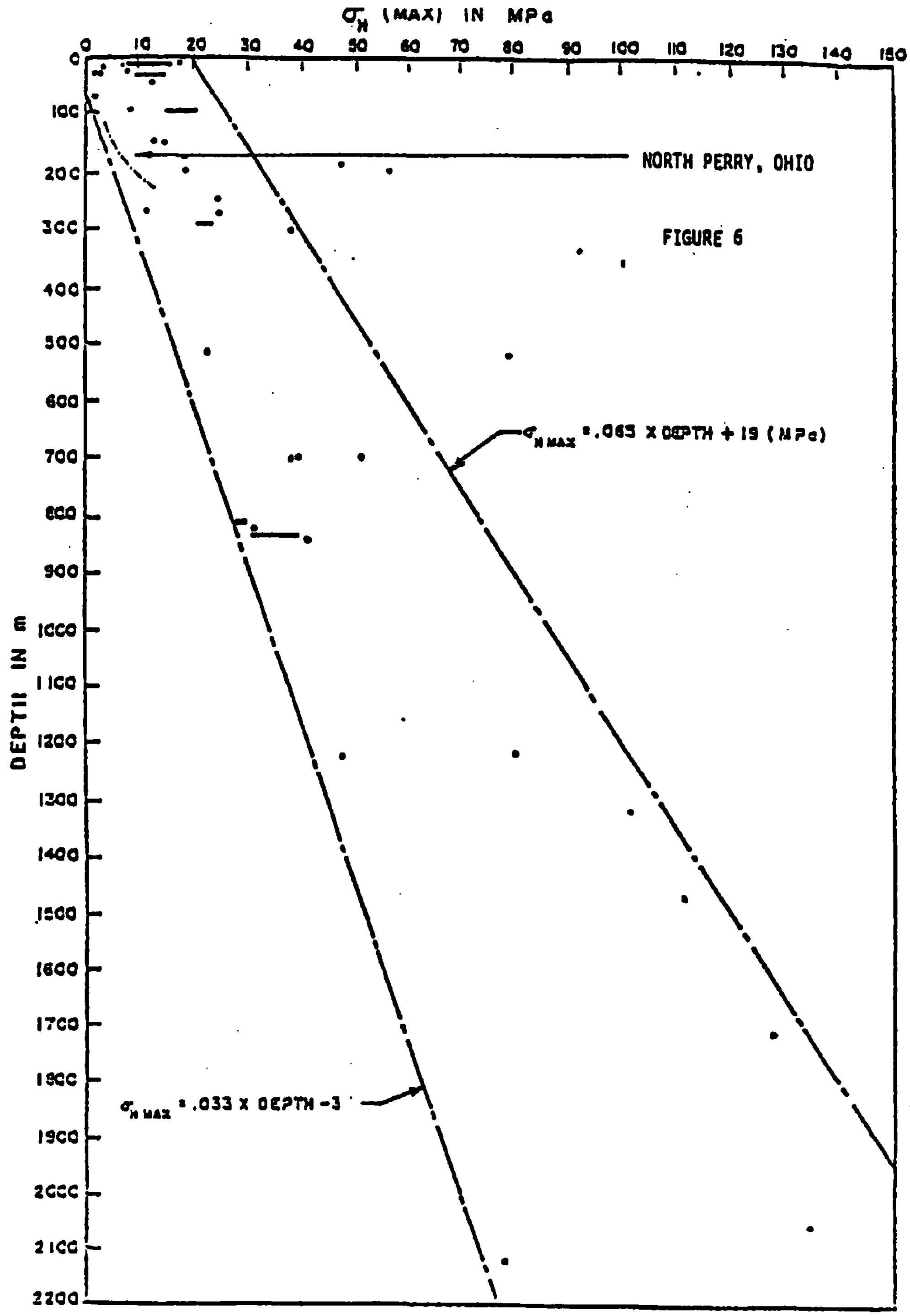
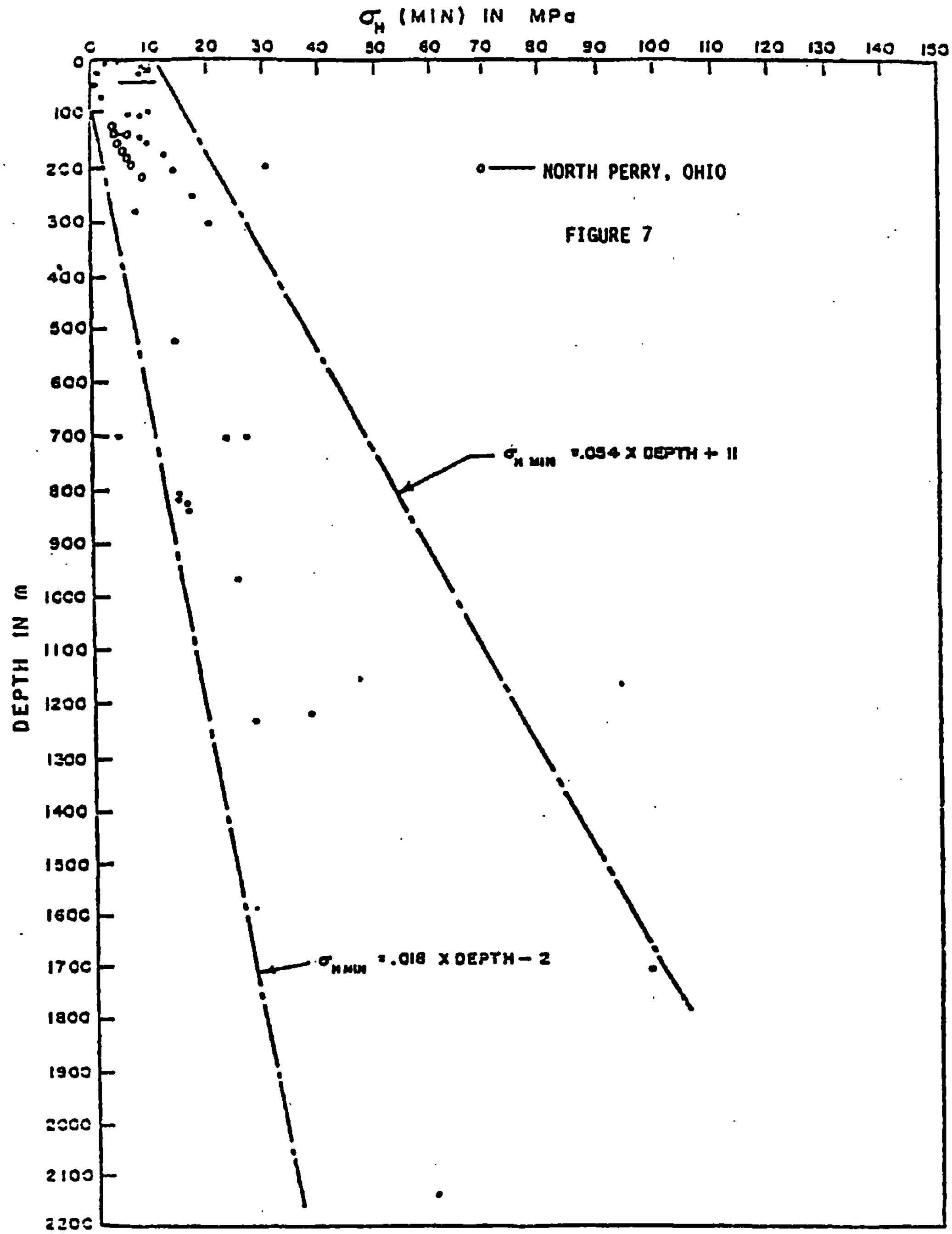


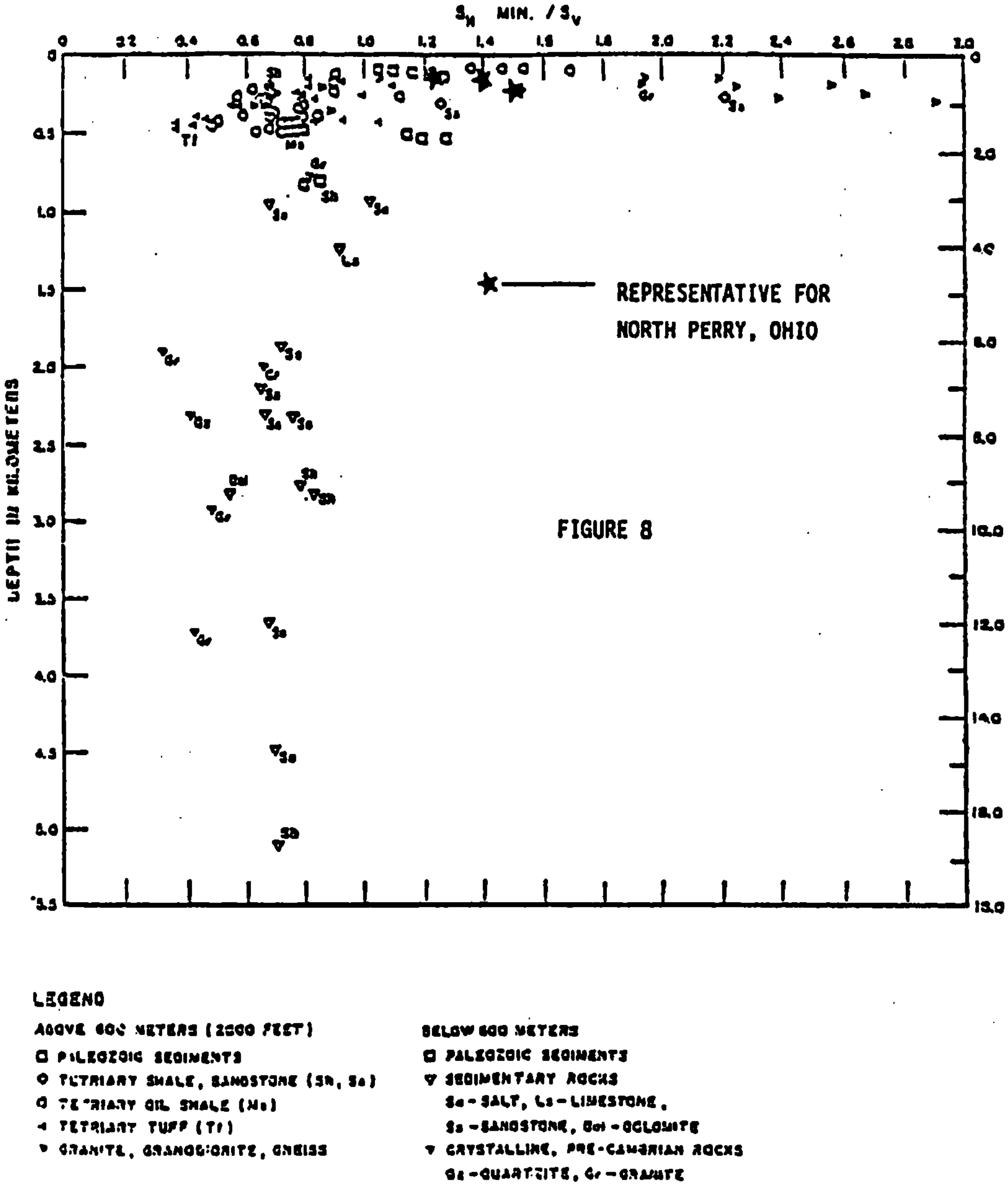
FIGURE 5:
VARIATION OF ORIENTATION WITH DEPTH (THREE-DIMENSIONAL REPRESENTATION)
(σ1 AND σ2 LIE IN THE HORIZONTAL PLANE)
100
200
300
500
700
W
E
S
N
N37E
E04S
E10S
N67E
N80E
σ2
σ1
1000 psi



Plot of measured values of $\sigma_{H\ max.}$ versus depth

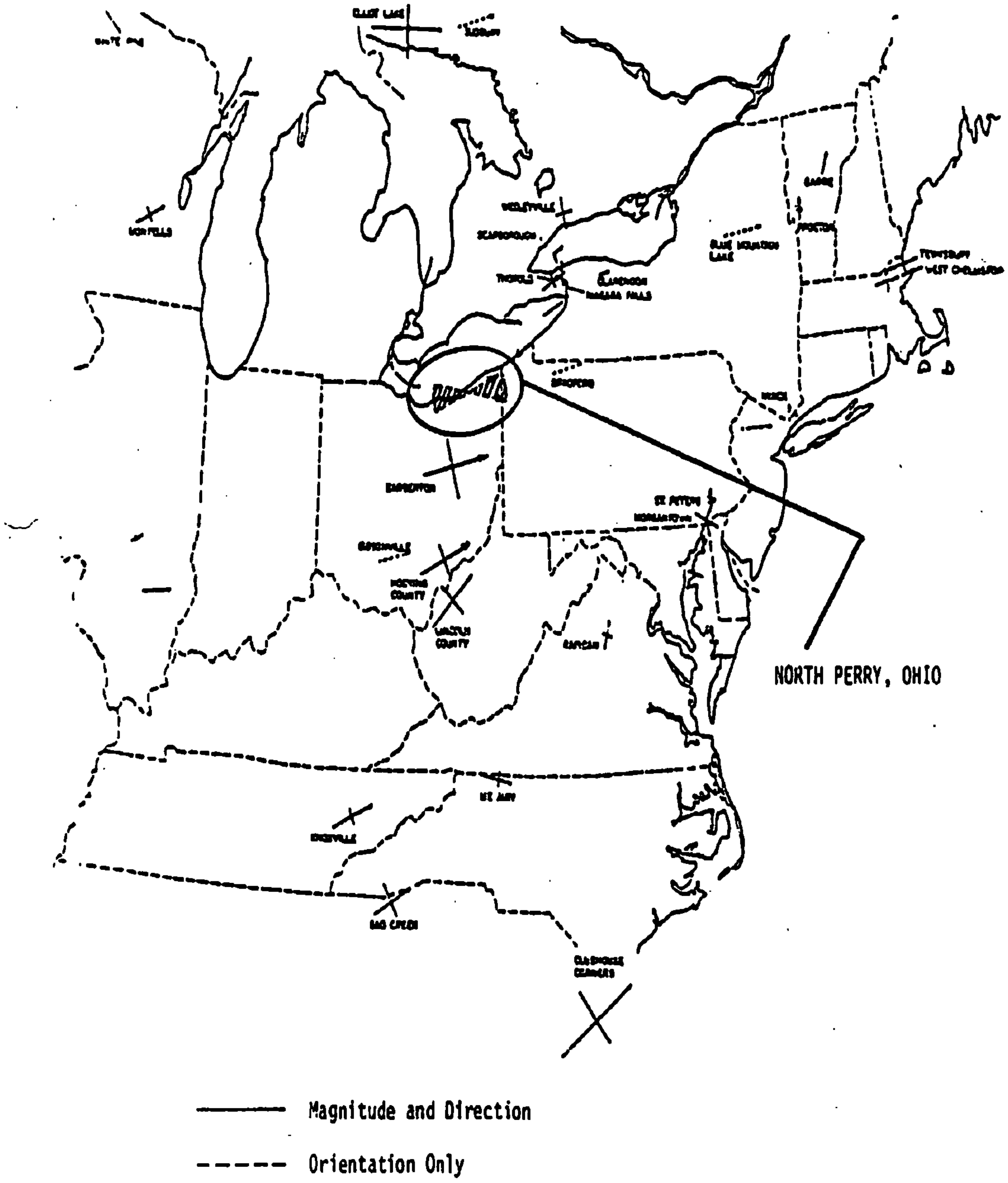


Plot of measured values of $\sigma_{H\ min.}$ versus depth



Ratio of $\sigma_{H\ min.}$ to σ_{OB} in sedimentary rock North America

Reference: Swolfs, H.S., 1977
Abou Sayed, A.S., 1977



LOCATION, DIRECTION AND MAGNITUDE OF MEASURED PRINCIPAL
HORIZONTAL STRESSES

FIGURE 9

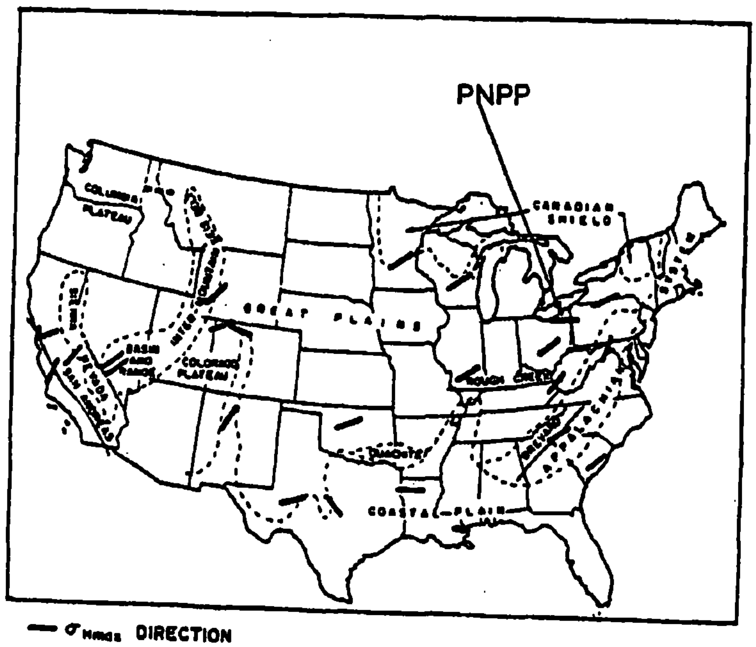
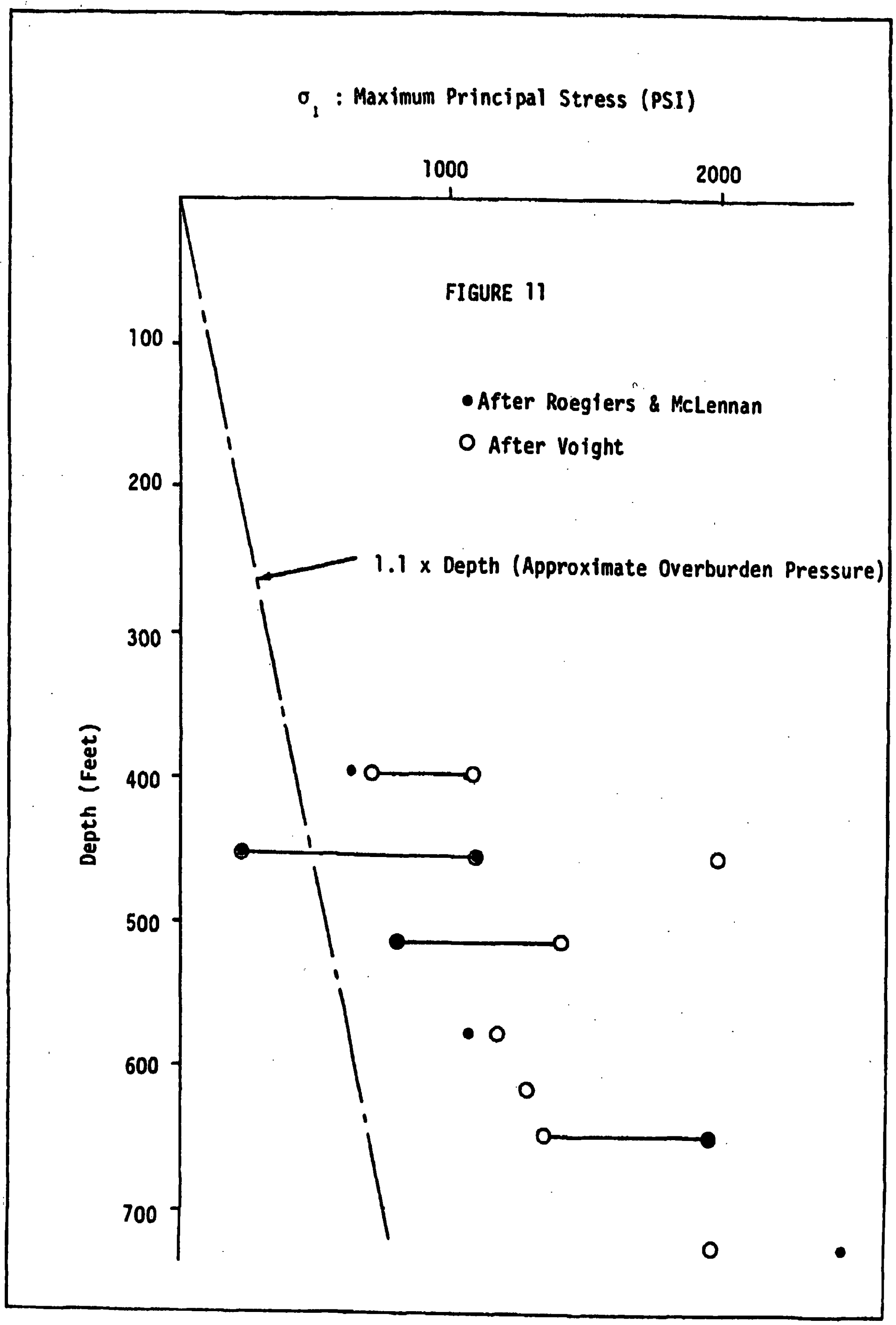


FIGURE 10

(After Haimson, 1978)
AVERAGE DIRECTION OF σ_{HMAX}


σ1 : Maximum Principal Stress (PSI)
1000
2000
FIGURE 11
100
200
300
400
500
600
700
Depth (Feet)
After Roegiers & McLennan
After Voight
1.1 x Depth (Approximate Overburden Pressure)

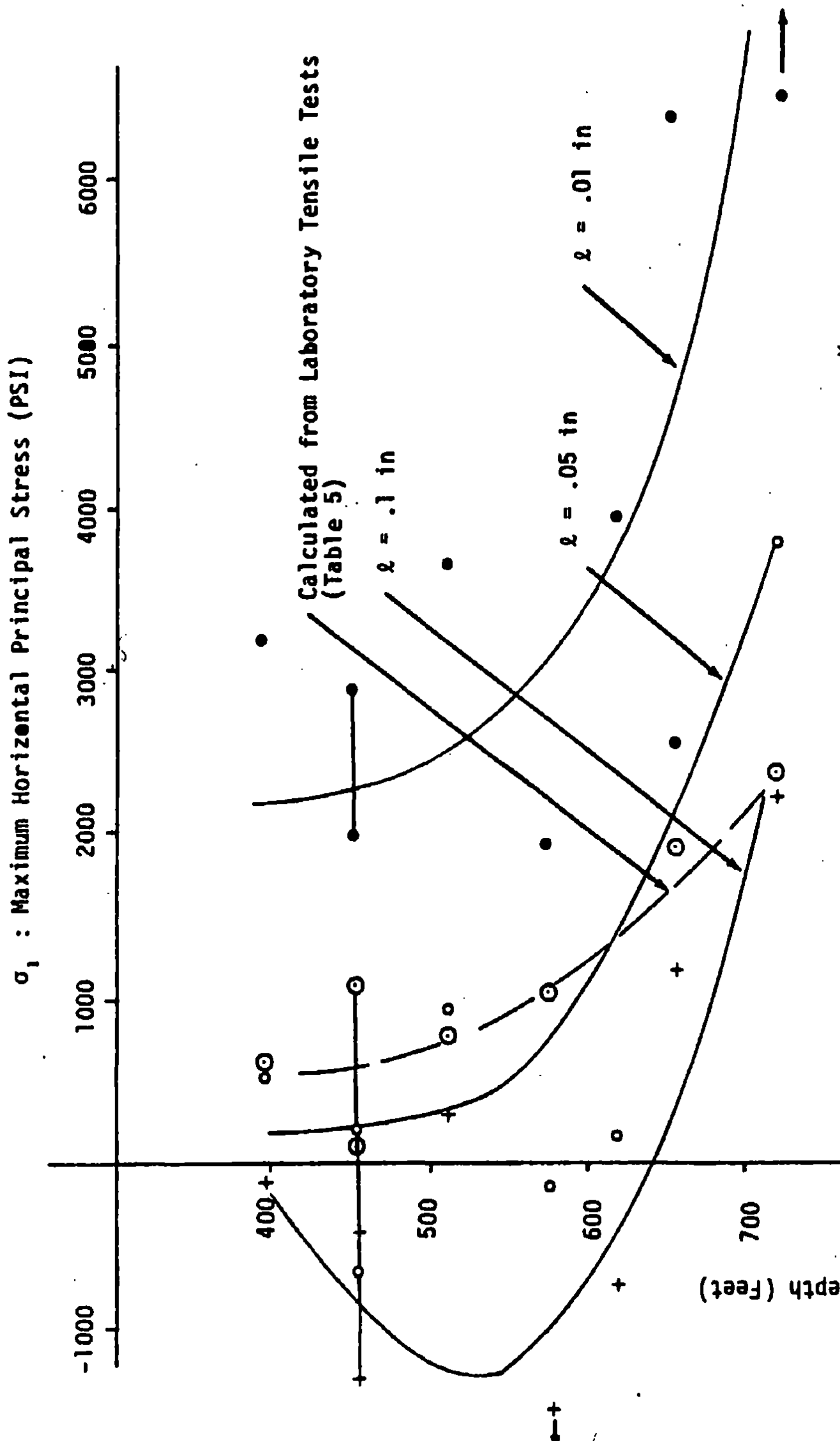


FIGURE 12: σ_1 Calculated From $\sigma_2 \approx 3\sigma_z - 2P_b + \frac{K_{IC}}{\sqrt{\pi \ell}}(0.6)$

(After Abou-Sayed, 1977)

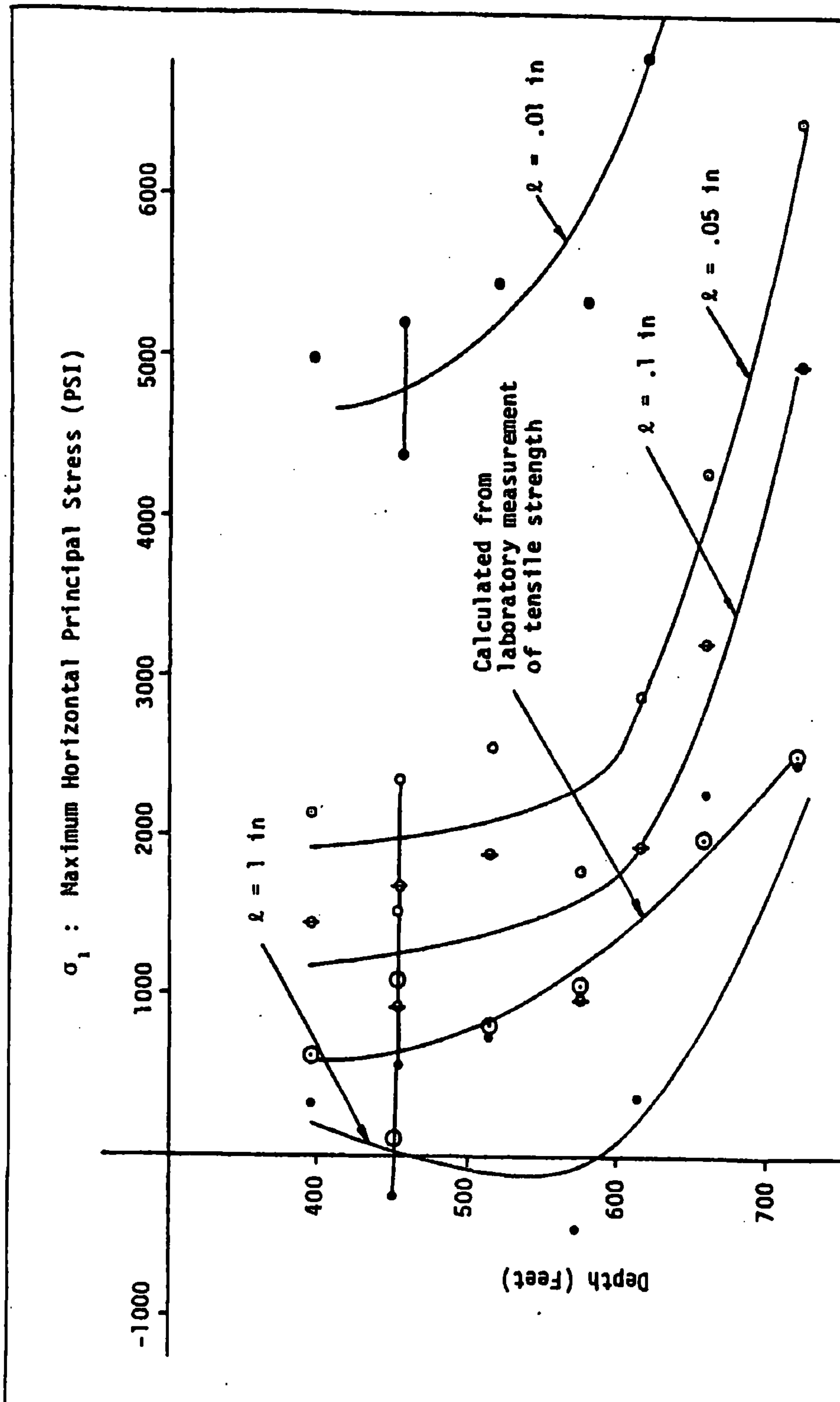


FIGURE 13: Calculated From $\sigma_1 \approx 3\sigma_2 - P_b - P_o + \frac{K_{IC}}{\sqrt{\pi \ell}\,(.56)}$ (After Cleary, 1979)

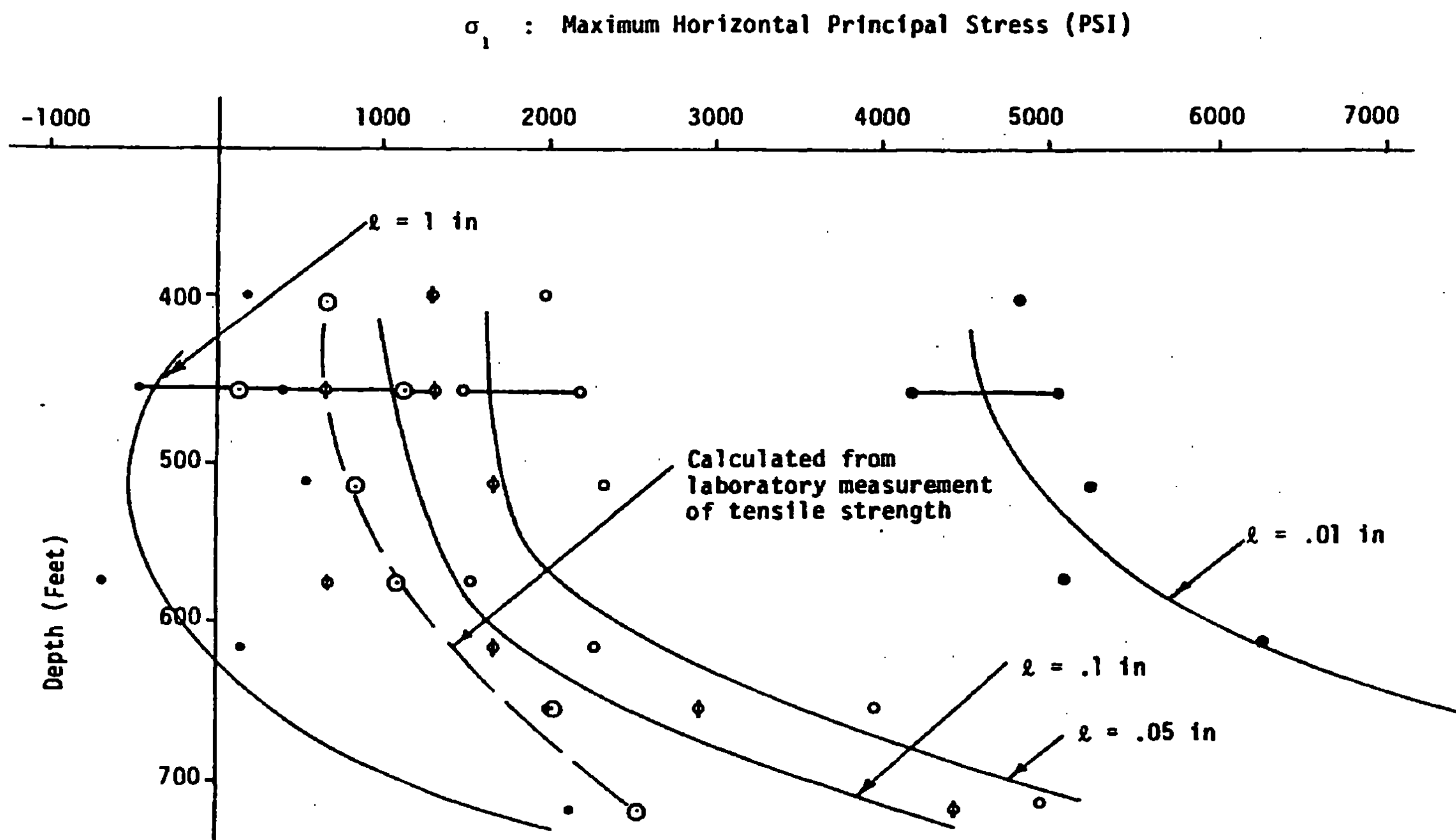
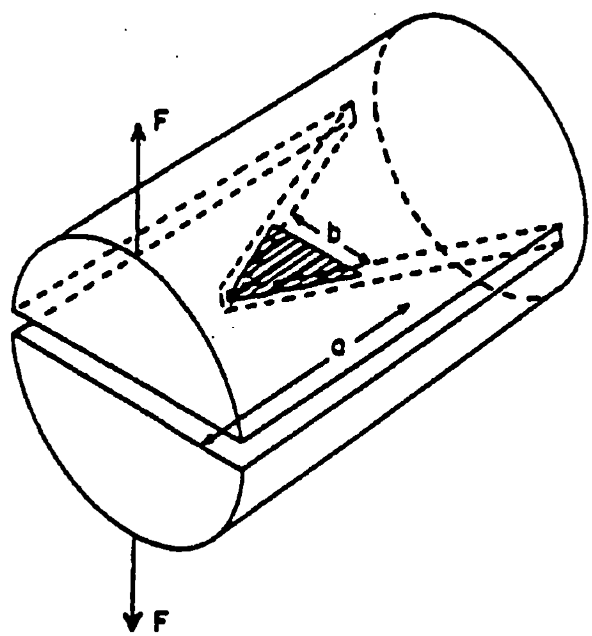


FIGURE 14: σ_1 Calculated From $\sigma_1 \approx 3\sigma_2 - P_b - 2P_o + \frac{K_{IC}}{\sqrt{\pi \ell}\,(.56)}$
(After Cleary, 1979)



F - Load

b - Instantaeous Crack Width (Shaded area denotes crack)

FIGURE 15: Short Rod Specimen Configuration (After Barker, 1976)

APPENDIX A

FRACTURING HISTORY

FRACTURE ONE

Date: May 2, 1979

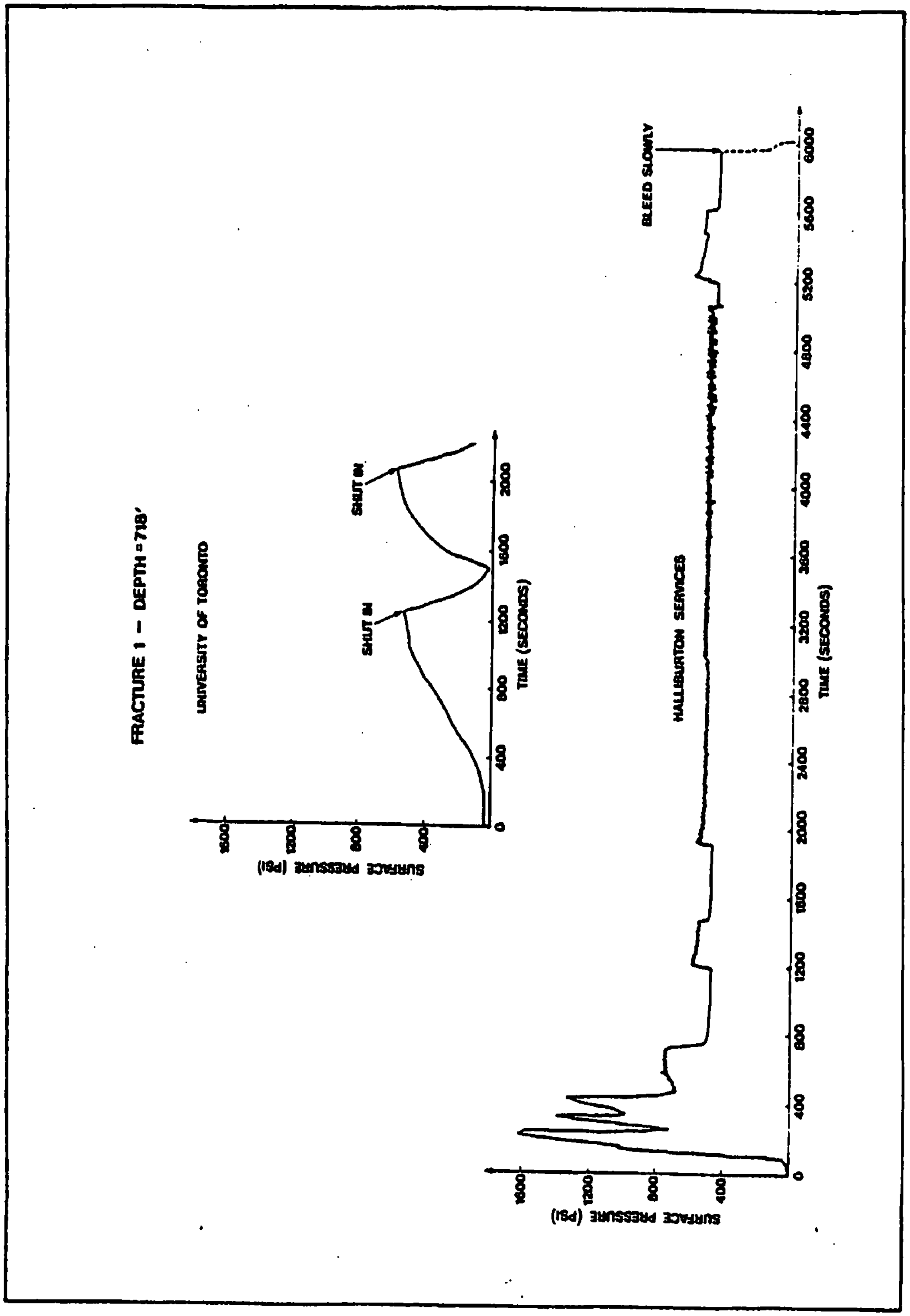
Depth: 718 feet

Injection History:

Pumping started with the University of Toronto, air operated pump. The flow rate was consequently small. The pressure built up to approximately 500 psi (surface), with considerable oscillation, and leveled off. The system was shut-in and pressure decayed rapidly. The pressurization-shut-in sequence was repeated again.

At this stage, 18 gallons of water had been pumped into the hole. Halliburton started pumping at approximately 1/4 bbl/min. Pressure increased rapidly. After breakdown, the system was shut-in and repressurized several times. Halliburton pumped in approximately 4 barrels of fluid. After initial breakdown, gel was started into the loop. The composition of the gel was:

Sodium Bicarbonate----K34 (buffer)
WG11------------------Gel
HYG3------------------Fumeric acid (lowers viscosity)
CL11------------------Increases viscosity
(Viscosity downhole was 150 cp)


FRACTURE 1 — DEPTH = 718'
UNIVERSITY OF TORONTO
SHUT IN
SHUT IN
SURFACE PRESSURE (PSI)
TIME (SECONDS)
HALLIBURTON SERVICES
BLEED SLOWLY
SURFACE PRESSURE (PSI)
TIME (SECONDS)

Critical Pressures:

Pump	Pressure[1] (psi)	Injection Rate (gpm)	Elapsed Time (min)
University of Toronto	841 891	~.3 ~.3	21 32
Halliburton	1941 1211[2] 901 706	~10.5 0 ~10.5 ~10.5	14.5[3] 20 25 35[4]

NOTES:

(1) Surface Pressure plus Formation Pressure

(2) Instantaneous Shut-in Pressure (Surface Pressure plus Formation Pressure)

(3) Time base was rezeroed for Halliburton pumping.

(4) Started pumping gel into the hole at this time.

The Influence of Flowrate:

It appears that pumping at the small flowrates, with the University of Toronto pump, allowed fluid to enter into horizontal laminations. This, in combination with leakage through drill pipe, caused the pressure to level off.

At the higher Halliburton flowrates, it is hypothesized that a vertical fracture was created. Away from the borehole wall this fracture probably became horizontal.

An estimate of the overburden pressure is:

$$\sigma_v = 718 \times 1.1 = 790 \text{ psi}$$

The shut-in pressure at the end of pumping was 786 psi (475 (surface) + 311 (formation pressure) = 786 psi). Hence σ_v/DEPTH = 1.1.

Orientation

This horizon was too close to the bottom of the hole for impressions to be performed.

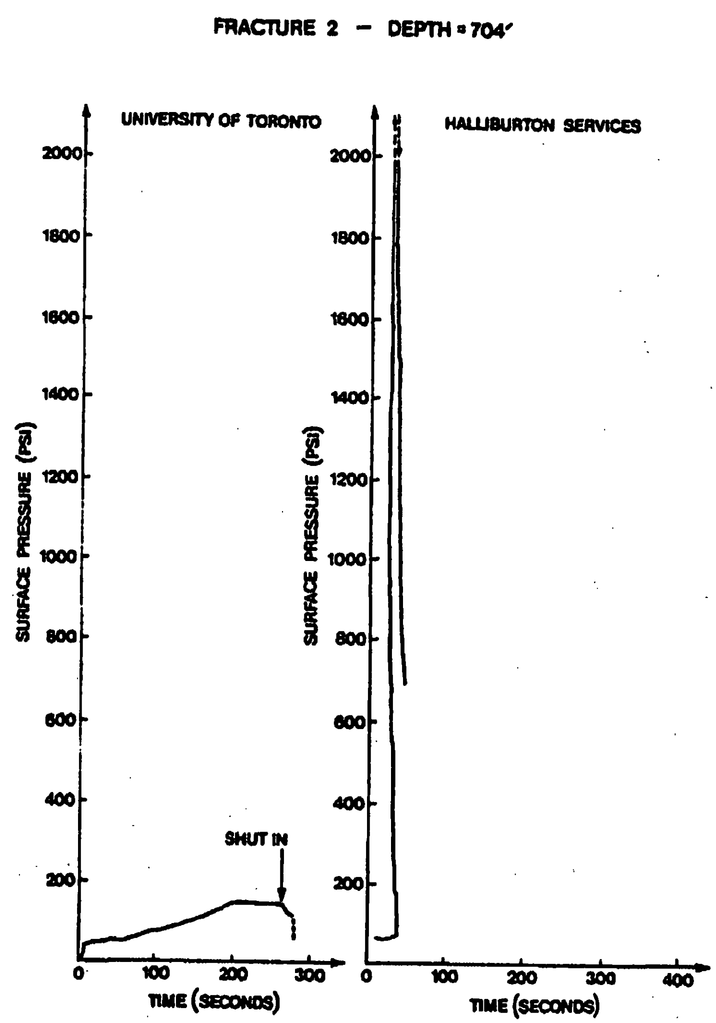
FRACTURE TWO

Date: May 2, 1979

Depth: 704 feet

Injection History:

Pumping at ~.3 gpm, using the University of Toronto pump, pressure leveled off at approximately 150 psi, suggesting considerable leakage either through the drill string or into the formation. This was bled off and Halliburton pumped at approximately .25 barrels per minute. Pressure rose rapidly. Before breakdown, a short sub at the surface burst. This horizon was then abandoned.


FRACTURE 2 — DEPTH = 704'
UNIVERSITY OF TORONTO
HALLIBURTON SERVICES
SURFACE PRESSURE (PSI)
200
400
600
800
1000
1200
1400
1600
1800
2000
SHUT IN
0
100
200
300
400
TIME (SECONDS)

FRACTURE THREE

Date: May 3, 1979

Depth: 654 feet

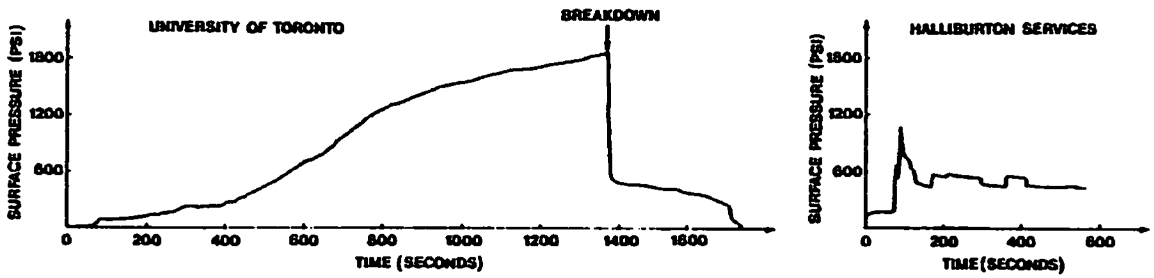
Injection History:

This fracture was originally to have been at a depth of 659 feet. However, in order to allow Halliburton to hook directly to the wellhead, the center of the interval was moved to 653'10" →654 feet.

Pumping first with the University of Toronto pump, the formation built up pressure slowly, but steadily until breakdown. A distinct shut-in pressure resulted and losses through the drill string and into the formation were small.

The system was bled off and Halliburton pumped in. Breakdown occurred at a lower pressure, probably reflecting reinflating a vertical fracture. Continued pumping ultimately seems to reflect propagation of a horizontal fracture.

FRACTURE 3 – DEPTH=654'



Critical Pressures:

Pump	Pressure[1] (psi)	Injection Rate (gpm)	Elapsed Time (min)
University of Toronto	2143	~.25	12.7
	1023[2]	0	12.7+
	778[3]	~.25	~15
Halliburton	1373	~10	1.4[4]
	763[2]	0	2
	843[3]	~10	6
	738[2]	0	7

NOTES:

(1) Surface Pressure plus Formation Pressure

(2) Instantaneous Shut-in Pressure (Surface Pressure plus Formation Pressure)

(3) Average Propagation Pressure (Surface Pressure plus Formation Pressure)

(4) Time based was rezeroed for Halliburton pumping

The Influence of Flowrate:

It is hypothesized that initial pumping opened a vertical fracture. Due to the small flowrate, it was not propagated far from the borehole wall. Pumping with the Halliburton unit probably reopened this fracture. The fracture extended and probably assumed a horizontal orientation.

Estimate of the Tensile Strength:

An approximation of the tensile strength in the horizontal direction, bearing in mind discrepancies in breakdown pressures due to drastically different flowrates, is the difference between the two tabulated breakdown pressures. This gives a tensile strength of approximately 770 psi.

Pressure in the Vertical Direction:

An estimate of the overburden pressure is:

$$\sigma_v = 654 \times 1.1 = 719\ \text{psi}$$

The shut-in pressure at the end of pumping was (455 + 283 = 738 psi). Hence σ_v/DEPTH = 1.13 psi/ft.

Orientation

The impression revealed traces of vertical fractures and a hairline horizontal fracture.

The orientation of the vertical fractures suggest the direction of the maximum principal stress is at N80E.

FRACTURE FOUR

Date: May 3, 1979

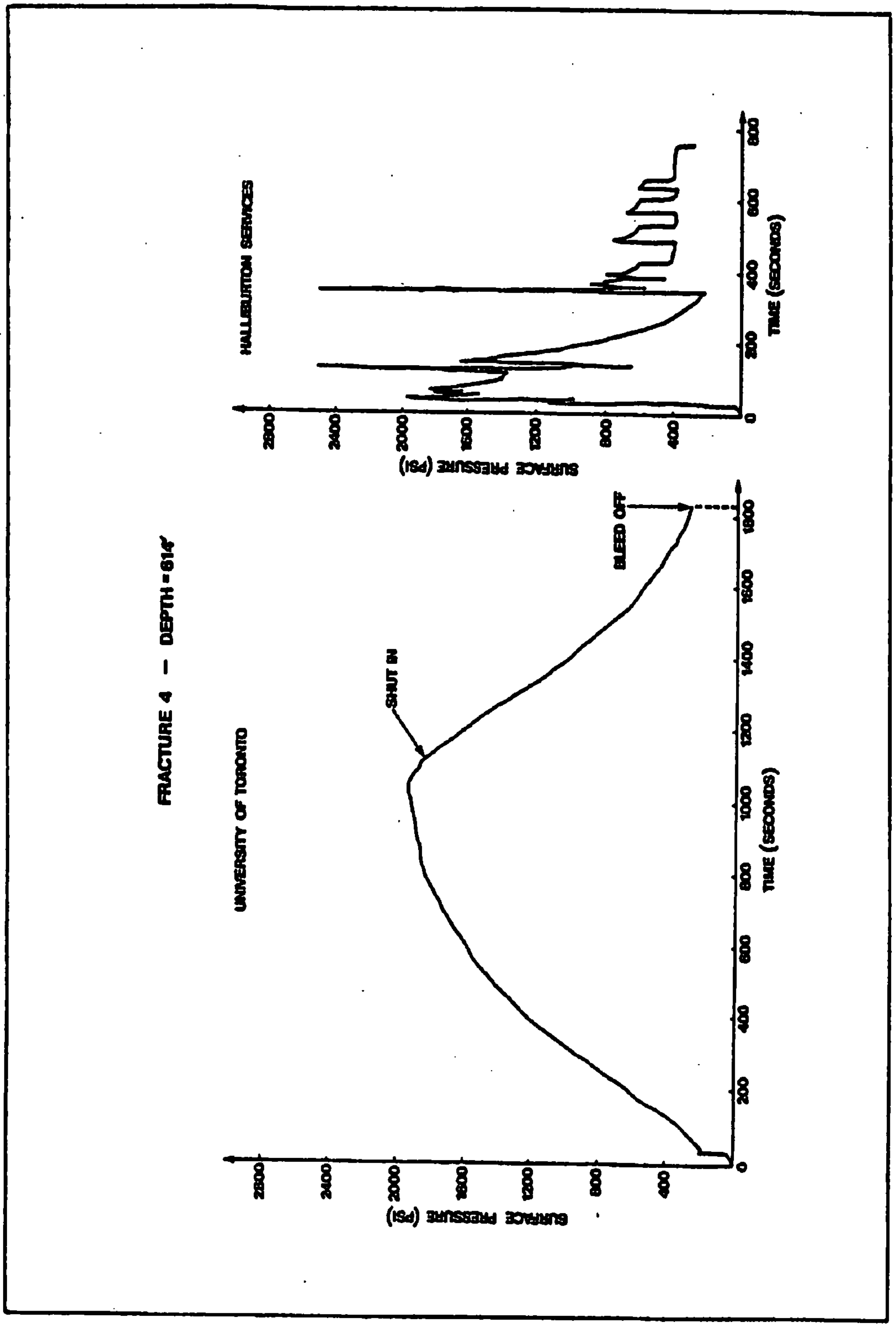
Depth: 614 feet

Injection History:

Pumping with the University of Toronto pump caused a steady increase in pressure. The pressure time curve peaks gradually. This could be due to inflation of a horizontal zone leakage (near the peak a valve started to leak at the surface), or fracture ‘initiation.

Halliburton pumped. The pressure-time curve suggests some small scale fracturing (or possibly slabbing) before actual breakdown. Alternatively, there is the hypothesis that the curve reflects reorientation of vertical to horizontal orientation.

The pressurization shut-in cycle was repeated several times.


FRACTURE 4 — DEPTH = 614'
UNIVERSITY OF TORONTO
SURFACE PRESSURE (PSI)
2800
2400
2000
1600
1200
800
400
0
200
400
600
800
1000
1200
1400
1600
1800
TIME (SECONDS)
SHUT IN
BLEED OFF
HALLIBURTON SERVICES
SURFACE PRESSURE (PSI)
2800
2400
2000
1600
1200
800
400
0
200
400
600
800
TIME (SECONDS)

Critical Pressures:

Pump	Pressure[1] (psi)	Injection Rate (gpm)	Elapsed Time (min)
University of Toronto	2246	~.25	17.5
Halliburton	2266	~10	.5[4]
	2806	~10	2
	906[3]	~10	2
	2791	~10	5.4
	836[3]	~10	5.7
	1171	~10	5.8
	716[3]	~10	6.2
	1076	~10	6.3
	696[2]	0	6.8
	1036	~10	7.7
	966	~10	9.2
	906	~10	10.4
	686[2]	0	10.7

NOTES:

(1) Surface Pressure plus Formation Pressure

(2) Instantaneous Shut in Pressure (Surface Pressure plus Formation Pressure)

(3) Pressure drop, but pumping continues

(4) Time base was rezeroed for Halliburton pumping

Discussion:

The University of Toronto pump could not definitely breakdown the formation. The pressure time curve gently rounds a peak due to leakage in the system into the formation or inflation of a horizontal feature.

Halliburton probably created a vertical fracture and subsequently a horizontal fracture. The situation is very complex and indicates a complex fracturing sequence. Hence, estimation of instantaneous shut-in pressure for an hypothesized vertical fracture is somewhat difficult.

Estimate of Tensile Strength from Field Results:

Based on different breakdown pressures, the tensile strengths are estimated to be:

Direction	Tensile Strength (psi)
In horizontal direction	1600 psi
In vertical direction	200 psi

Orientation:

There is a system of diametrically opposed vertical fractures. There is also a horizontal fracture near each end of the impression interval. σ_1 acts at approximately N67E.

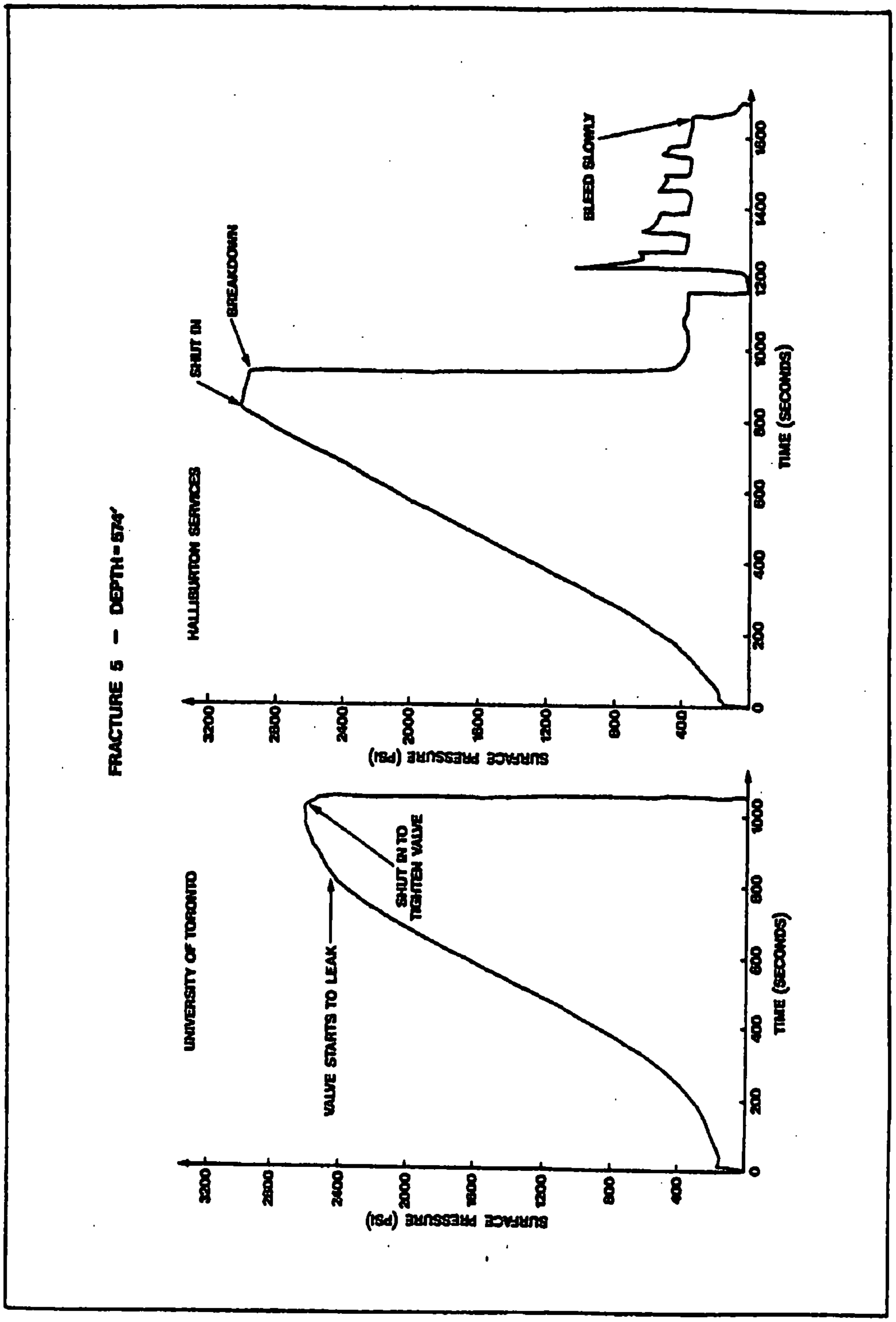
FRACTURE FIVE

Date: May 3, 1979

Depth: 574 feet

Injection History:

Pumping with the University of Toronto pump caused a steady increase in pressure up to approximately 2400 psi (surface). At this point a valve had to be tightened. Pressurization continued but pressure leveled off at approximately 2600 psi (surface) and subsequently decreased gradually. The system was bled off. Halliburton pumped. Pressure increased steadily at about the same rate as for the University of Toronto. At 3020 psi (surface), the system was shut-in. This was necessary in order to avoid bursting the drill pipe. After being shut-in for approximately 2 minutes, with only small pressure losses, breakdown occurred. The system was repressurized and then bled off completely. A series of pressurization-shut-in cycles followed. The system was then bled off slowly in order to study the pressure decay behaviour.


FRACTURE 5 — DEPTH = 574'
UNIVERSITY OF TORONTO
VALVE STARTS TO LEAK
SHUT IN TO TIGHTEN VALVE
SURFACE PRESSURE (PSI)
TIME (SECONDS)
HALLIBURTON SERVICES
SHUT IN
BREAKDOWN
BLEED SLOWLY
SURFACE PRESSURE (PSI)
TIME (SECONDS)

Critical Pressures:

Pump	Pressure[1] (psi)	Injection Rate (gpm)	Elapsed Time (min)
University of Toronto	2879	~.25	16.7
	2789	~.25	17.2
Halliburton	3269	~10	13.8[3]
	3329	~10	15.5
	809 → 1549[2]	0	15.6
	1299	~10	21.2
	909[4]	~10	21.8
	649[2]	0	21.9
	899	~10	22.8
	639[2]	0	23.8
	809	~10	24.7
	639[2]	0	25.1
	779	~10	25.6
	639[2]	0	26.1

NOTES:

(1) Surface Pressure plus Formation Pressure

(2) Instantaneous Shut-in Pressure (Surface Pressure plus Formation Pressure)

(3) Time base was rezeroed for Halliburton pumping.

(4) This small anomaly may reflect a change from a vertical to a horizontal fracture.

Discussion:

It appears that a vertical fracture first initiated and with continued pressurization a horizontal fracture followed. It appears that, as in the previous case, the fracture geometry is complex.

Orientation:

The impression reveals:

(1) Traces of a set of diametrically opposed vertical fractures.

(2) An inclined fracture (steeply) apparently related to the set of vertical fractures.

(3) Two horizontal fractures, offset by the inclined fracture.

The vertical fractures reflect a direction for the maximum principal stress of E10S.

FRACTURE SIX

Date: May 4, 1979

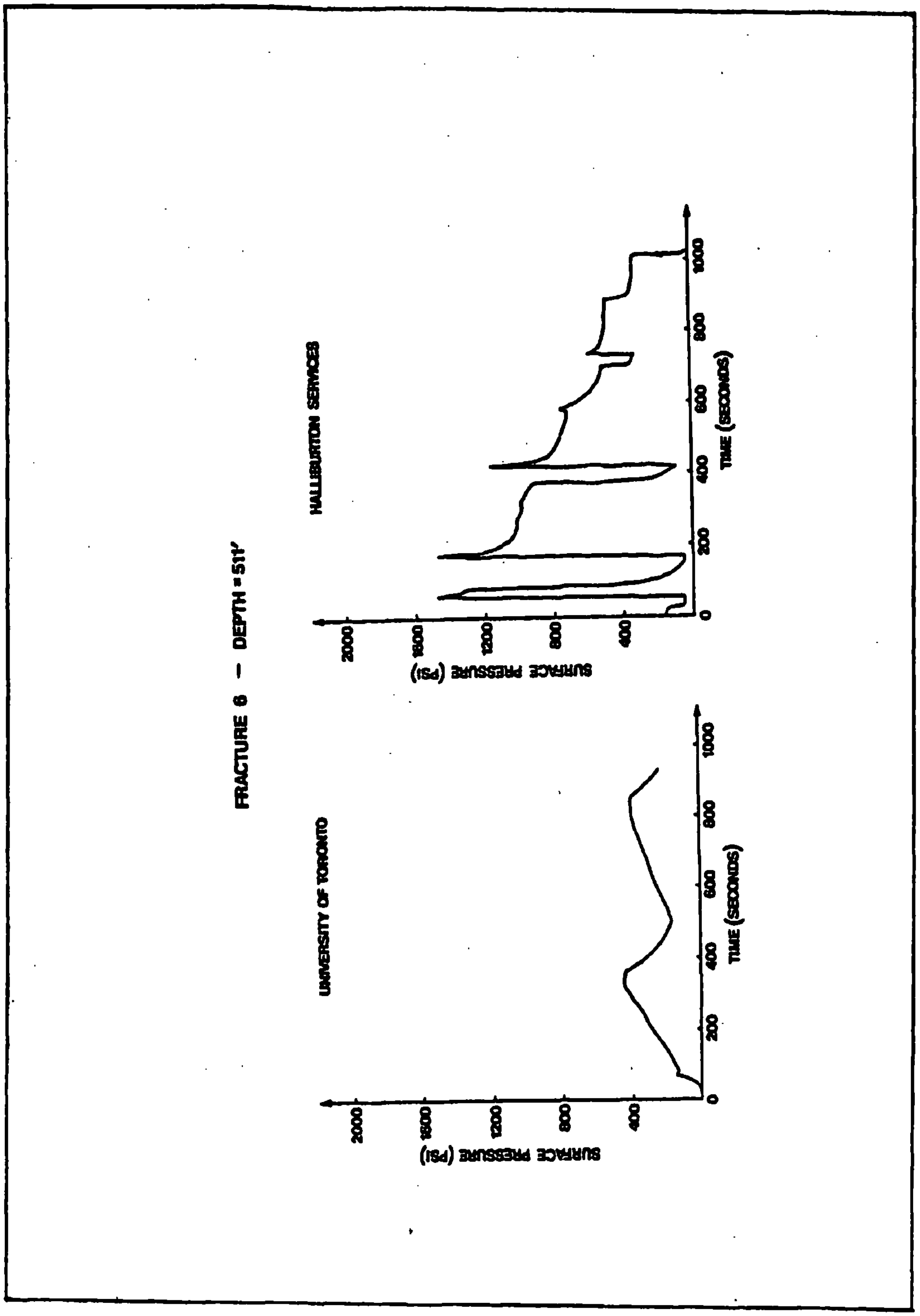
Depth: 511 feet

Injection History:

Pumping with the University of Toronto pump appears to have inflated a horizontal "discontinuity". Pumping at the Halliburton flowrates probably forced a vertical fracture to initiate. This fracture probably adopted a horizontal orientation at some distance away from the borehole. The tendency to a horizontal fracture may be indicated by:

(i) A slight "spike" during propagation in one of the pressurization cycles.

(ii) The tendency for shut-in pressures to become better defined after a certain number of pressurization cycles.


FRACTURE 6 — DEPTH = 511'
UNIVERSITY OF TORONTO
HALLIBURTON SERVICES
SURFACE PRESSURE (PSI)
2000
1600
1200
800
400
0
200
400
600
800
1000
TIME (SECONDS)

Critical Pressures:

Pump	Pressure[1] (psi)	Injection Rate (gpm)	Elapsed Time (min)
University of Toronto	671	~.3	5.5
Halliburton	1716	~10	.2[4]
	721[2]	0	.6
	1711	~10	2.2
	971[3]	~10	8.8
	586[2]	0	10.8
	826	~10	11.3
	601[2]	0	14.0

NOTES:

(1) Surface Pressure plus Formation Pressure

(2) Instantaneous Shut-in Pressure (Surface Pressure plus Formation Pressure)

(3) New fracture morphology?

(4) Time base was rezeroed for Halliburton pumping

Influence of the Flowrate:

It is hypothesized that the pumping at very small rates opened horizontal fractures, while pumping (later) at higher rates caused an initial vertical fracture which later became horizontal.

Estimate of the Tensile Strength from Field Results:

Based on differing breakdown pressures, the tensile strengths are approximated as:

Direction	Tensile Strength (psi
In horizontal direction	At least 300 psi (and) probably more
In vertical direction	100 psi

Pressure in the Vertical Direction:

An estimate of the overburden pressure is:

$$\sigma_v = 5.11 \times 1.1 = 562\,\text{psi}$$

The shut-in pressure, after the suspected change to a horizontal fracture was 586 psi (365 (surface) + 221 (formation pressure) = 586 psi) Hence σ_v/DEPTH = 1.15 psi/ft.

Orientation:

Impressions revealed:

(a) A set of diametrically opposed vertical fractures.

(b) Two inclined fracture-like features.

(c) A major horizontal fracture near the top of the impression interval.

The vertical fractures suggest that σ_1 is acting at E04S.

FRACTURE SEVEN

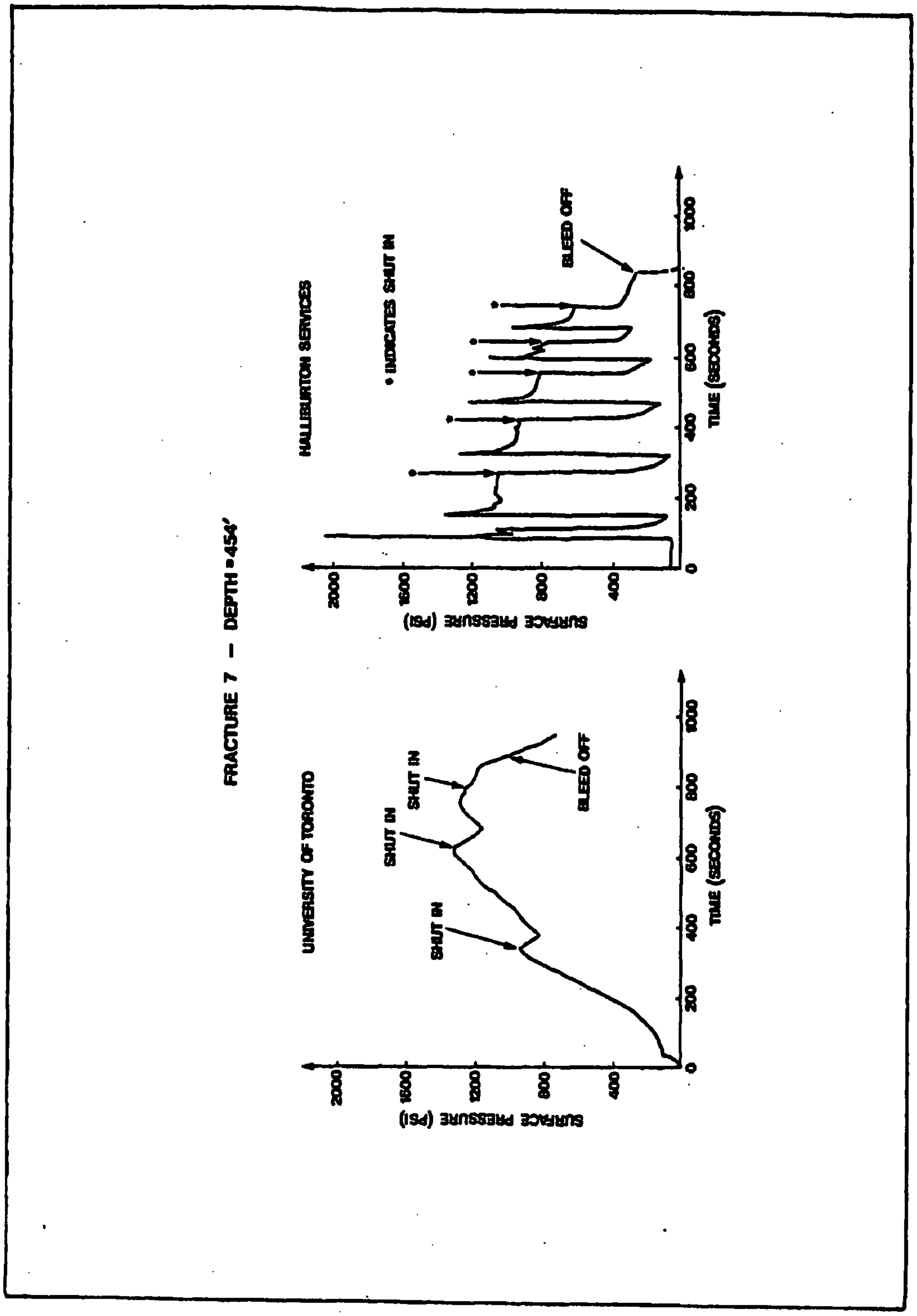
Date: May 4, 1979

Depth: 454 feet

Injection History:

No distinct breakdown was achieved with the University of Toronto pump. A gentle inflection of the pressure time curve suggests leakage in the system or into the formation.

Halliburton pumped and the pressure rose rapidly. A small anomaly evident on the pressure time plot immediately after this initial breakdown may reflect a change in fracture path as may a spike during the propagation portion of a subsequent propagation cycle.


FRACTURE 7 — DEPTH = 454'
UNIVERSITY OF TORONTO
SHUT IN
SHUT IN
SHUT IN
BLEED OFF
SURFACE PRESSURE (PSI)
2000
1600
1200
800
400
0
200
400
600
800
1000
TIME (SECONDS)
HALLIBURTON SERVICES
• INDICATES SHUT IN
BLEED OFF
SURFACE PRESSURE (PSI)
2000
1600
1200
800
400
0
200
400
600
800
1000
TIME (SECONDS)

Critical Pressures:

Pump	Pressure[1] (psi)	Injection Rate (gpm)	Elapsed Time (min)
University of Toronto	1507	~.25	10.3
Halliburton	2267	~10	.2[4]
	1137[3]	~10	.3
	837[2]	0	.7
	1557	~10	1.2
	697[2]	0	3.2
	557[2]	0	5.8
	1417	~10	6.5
	557[2]	0	7.7
	1297	~10	8.6
	1047[3]	~10	9.0
	597[2]	0	9.3
	1177	~10	10
	577[2]	0	11

NOTES:

(1) Surface Pressure plus Formation Pressure

(2) Instantaneous Shut-in Pressure (Surface Pressure plus Formation Pressure)

(3) Anomalous feature during propagation

(4) Time base was rezeroed for Halliburton pumping

Discussion:

It is extremely difficult to accurately determine shut-in pressures, especially during the early pressurization cycles. Regardless, it seems that P_{isip} (as taken at the point of inflection) does not vary appreciably for any of the pressurization cycles.

Difficulty in evaluating P_{isip} from either the surface or downhole plots makes interpretation of this fracture somewhat tenuous.

It may be unlikely that the University of Toronto pump inflated an horizontal fracture because the surface pressure exceeded 1300 psi. The anticipated weight of the overburden is approximately 500 psi.

Estimate of the Tensile Strength from Field Results:

An approximation of the tensile strength in the horizontal direction, based on the difference in breakdown pressures is T_o = 1070 psi.

Pressure in the Vertical Direction:

An estimate of the overburden pressure is:

$$\sigma_v = 454 \times 1.1 = 500 \text{ psi}$$

The shut-in pressure at the end of pumping was 577 psi. This is rather high; σ_v/DEPTH = 1.27 psi/ft.

Orientation:

There is a set of poorly defined, but diametrically opposed vertical fractures. There is also a major horizontal fracture immediately below the position of the upper straddle packer.

The downhole compass photograph is of poor quality but the direction of σ_1 is apparently about N37°E.

FRACTURE EIGHT

Date: May 4, 1979

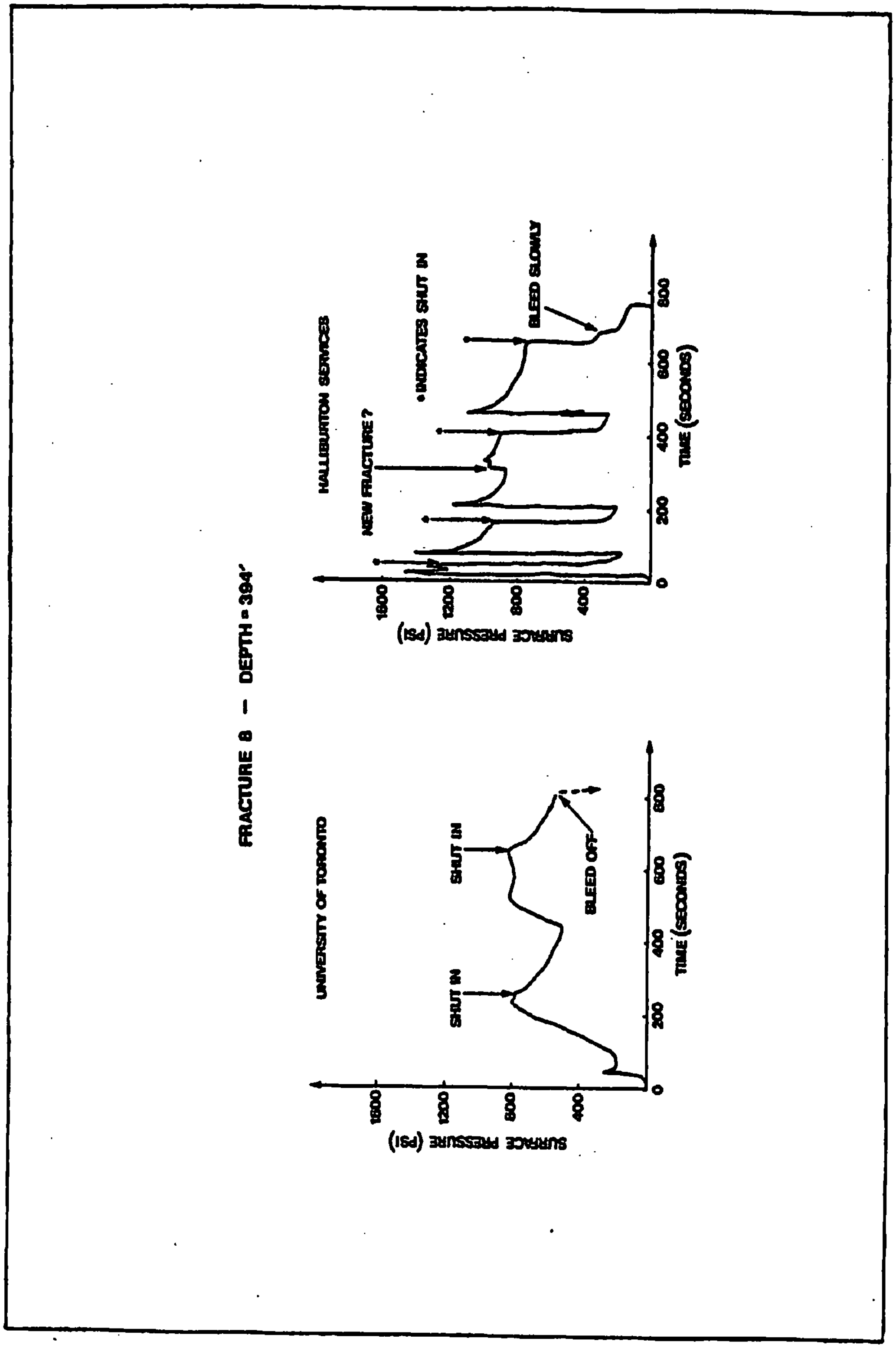
Depth: 394 feet

Injection History:

The pumping with the University of Toronto pump did not produce a distinct breakdown phenomena. Pressure reached a constant level and on shut-in bled off slowly.

When Halliburton pumped breakdown occurred in much the same manner as for other tests. As usual, several pressurization and shut-in cycles were performed.

FRACTURE 8 — DEPTH = 394'



Critical Pressures:

Pump	Pressure[1] (psi)	Injection Rate (gpm)	Elapsed Time (min)
University of Toronto	976	~.3	3.8
	991[2]	~.2	11
Halliburton	1646	~10	.5[5]
	1366[2]	~10	.6
	1506[2]	~10	.7
	611[3]	0	.8
	1581	~10	1.3
	561[3]	0	2.7
	1256	~10	3.5
	1146[2]	~10	5.4
	511[4]	0	6.9
	1276	~10	7.7
	551[3]	0	11
	481[4]	0	11.4

NOTES:

(1) Surface Pressure plus Formation Pressure

(2) Surface Pressure plus Formation Pressure; Fracture is Propagating (Anomalous readings)

(3) Instantaneous Shut-in Pressure (Surface pressure plus Formation Pressure)

(4) Plateau observed during slow bleed off

(5) Time base was rezeroed for Halliburton pumping

Discussion:

As with other tests at shallow depths, two unusual pressure fluctuations are evident probably revealing changes in fracture morphology. These are:

(i) Immediately after initial breakdown there is a drop and then a partial recovery in pressure. Whether this is due to the change in fracture orientation or the pumping procedure cannot be established.

(ii) During a propagation cycle, as fractures move away from the borehole, there is a sharp increase in pressure. It seems very likely that this indicates a change in the fracture morphology.

The most interesting characteristic of this fracture is the final shut-in pressure and the pressure decay during bleed off. The point of inflection during bleed off corresponds closely to the overburden pressure, while the other point of inflection may indicate closing of a vertical fracture.

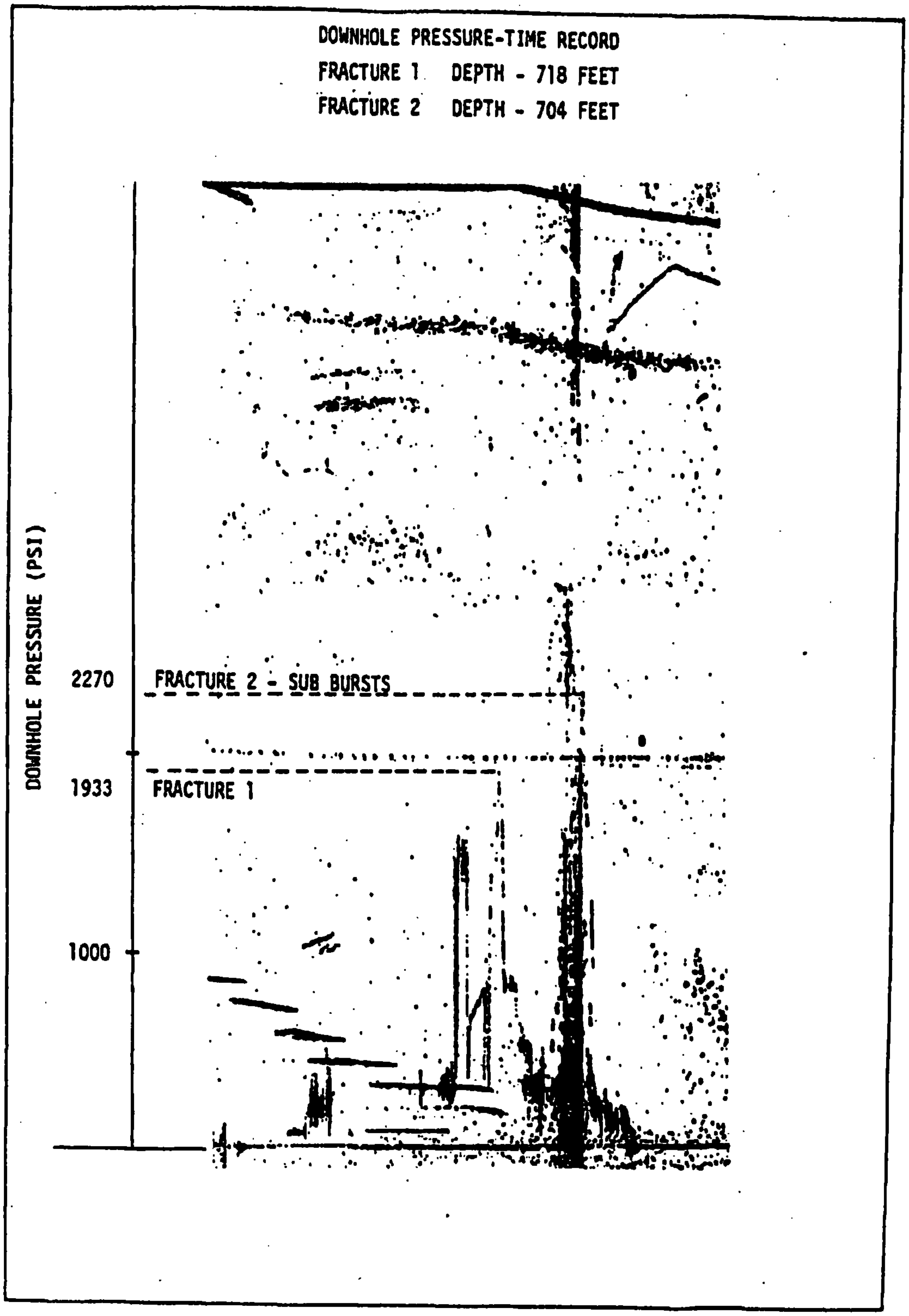
One feature possibly arguing against the formation of a vertical fracture in several of the upper horizons is the fact that the initial and second breakdown pressures have approximately the same value, suggesting small tensile strength.

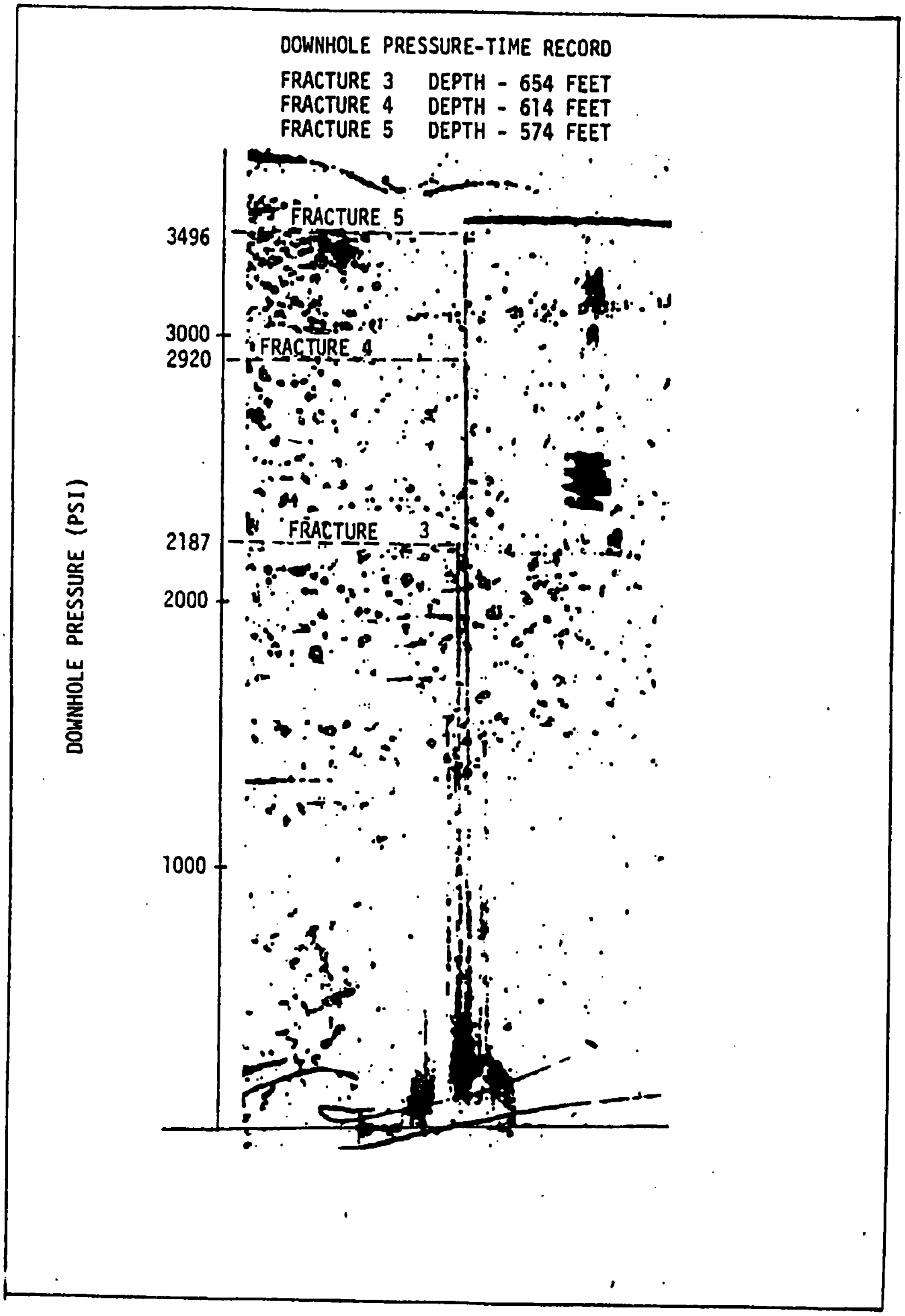
Orientation:

Vertical and horizontal features are visible. A poor quality downhole photograph prevents accurate interpretation of the direction of σ_1. Furthermore, the vertical fracture traces are only poorly defined on the impression.

APPENDIX B

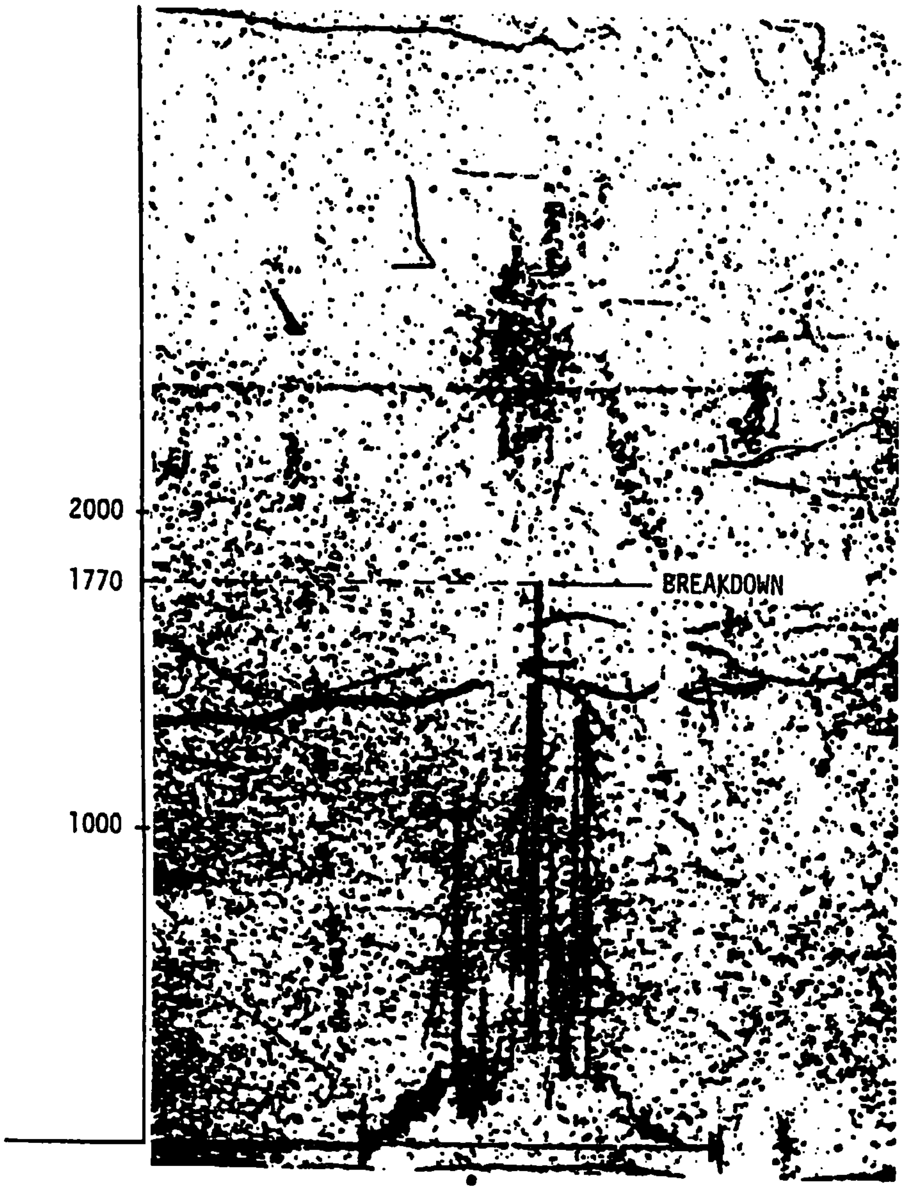
DOWN-HOLE PRESSURE-TIME RECORDS


DOWNHOLE PRESSURE-TIME RECORD
FRACTURE 1 DEPTH - 718 FEET
FRACTURE 2 DEPTH - 704 FEET
DOWNHOLE PRESSURE (PSI)
2270
FRACTURE 2 - SUB BURSTS
1933
FRACTURE 1
1000


DOWNHOLE PRESSURE-TIME RECORD
FRACTURE 3 DEPTH - 654 FEET
FRACTURE 4 DEPTH - 614 FEET
FRACTURE 5 DEPTH - 574 FEET
FRACTURE 5
FRACTURE 4
FRACTURE 3
3496
3000
2920
2187
2000
1000
DOWNHOLE PRESSURE (PSI)

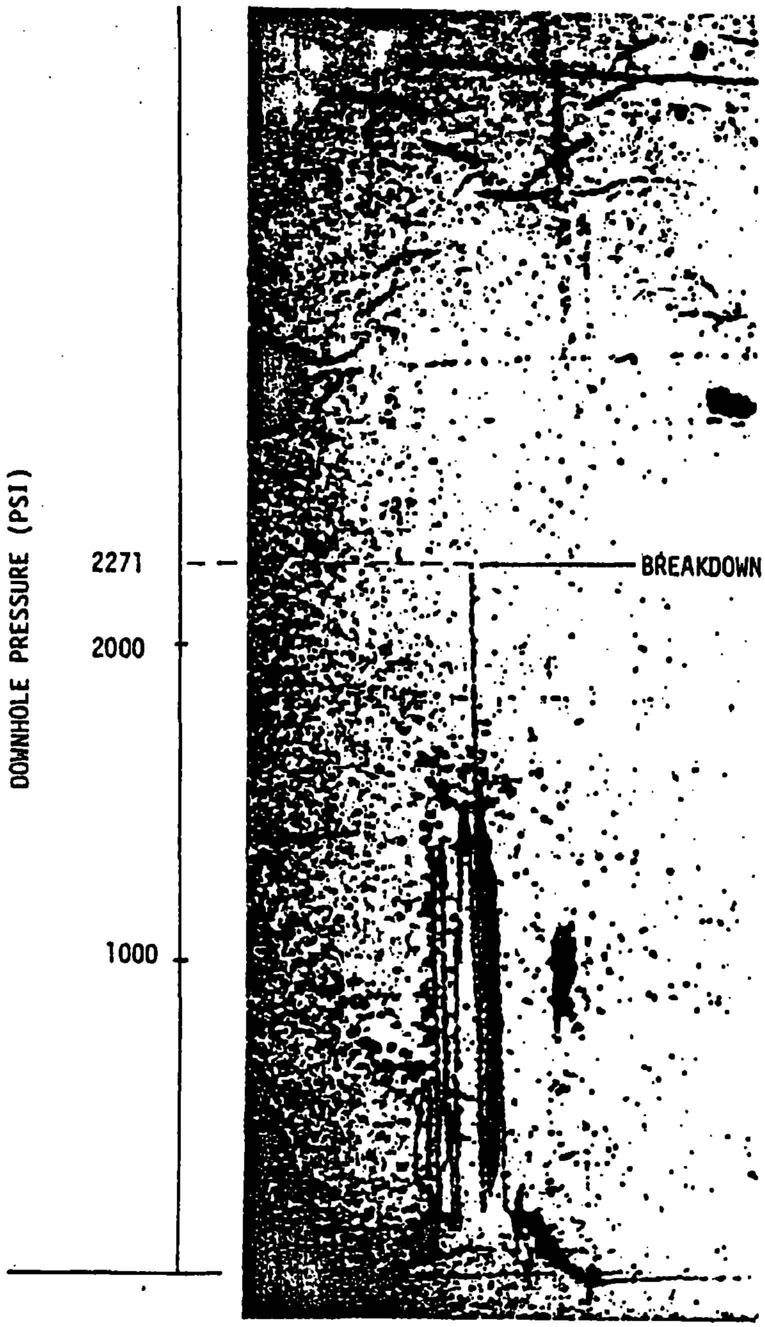
DOWNHOLE PRESSURE - TIME RECORD

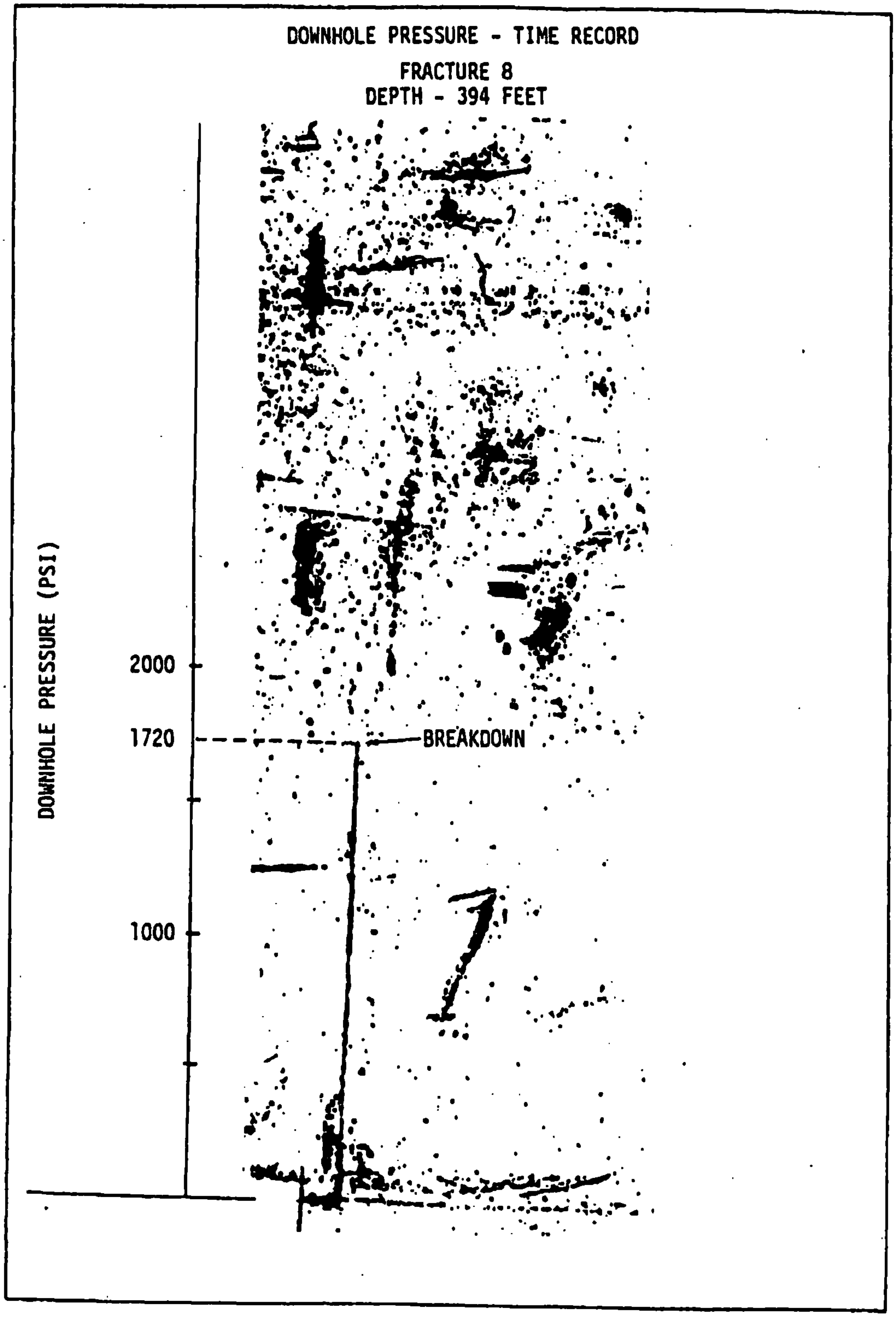
FRACTURE 6
DEPTH - 511 FEET



DOWNHOLE PRESSURE - TIME RECORD

FRACTURE 7 DEPTH - 454 FEET




DOWNHOLE PRESSURE - TIME RECORD
FRACTURE 8
DEPTH - 394 FEET
DOWNHOLE PRESSURE (PSI)
2000
1720
1000
BREAKDOWN

APPENDIX C

APPLICATION OF FRACTURE MECHANICS CONCEPTS TO HYDRAULIC FRACTURING ANALYSIS

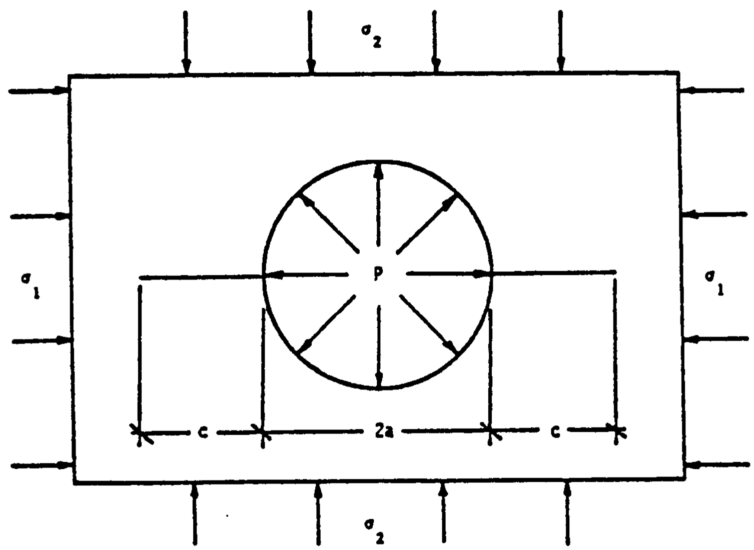
PART A

MODE I CONDITIONS

(C.1) GENERALITIES

Hardy, 1973, discussed fracture mechanics considerations applicable to hydraulic fracturing. His treatment can be briefly synthesized as follows.

Consider a fracture geometry as shown in Figure A, this being after initiation of a fracture from a pressurized borehole.



PRESSURIZED BOREHOLE (CRACKED) WITH STRESSES σ_1, σ_2 ACTING AT INFINITY

FIGURE A

Two parameters f(c/a) and g(c/a) have been defined by Cottrell in 1972.

$$f(c/a) = \frac{GE}{q^2 \pi a} \tag{C-1}$$

$$g(c/a) = \frac{GE}{p^2 \pi a} \tag{C-2}$$

where:

G - strain energy release rate

E - Young’s Modulus

q - Tensile stress perpendicular to the crack

p - Compressive stress parallel to the crack

a - Borehole radius

c - Crack length

Hardy, 1973, states that for a tensile stress ($p-\sigma_2$) perpendicular to the crack, the opening mode stress intensity factor is:

$$K_I \ (p - \sigma_2) = (p - \sigma_2) \left[\ \pi a f\left(\frac{c}{a}\right)\right]^{1/2} \tag{C-3}$$

For a compressive stress (σ_1 -p) parallel to the crack, the opening mode stress intensity factor is:

$$K_I \ (\sigma_1 - p) = (\sigma_1 - p) \left[\ \pi a g\left(\frac{c}{a}\right)\right]^{1/2} \tag{C-4}$$

By superposition,

$$K_I = (p - \sigma_2) \left[\pi a f\left(\frac{c}{a}\right)\right]^{1/2} + (\sigma_1 - p) \left[\ \pi a g\left(\frac{c}{a}\right)\right]^{1/2} \tag{C-5}$$

Hardy states that at crack extension $K_I = (\gamma E)^{1/2}$. This would seem to be appropriate only under plane stress conditions. In general, as has been shown, for a MODE I situation:

$$G_{ICR} = \frac{\pi (k + 1)\ k_1^2}{8\,\mu} \tag{C-6}$$

where:

$$k_1 = K_I/\sqrt{\pi} \tag{C-7}$$

Extension can allegedly occur when

$$G_{ICR} > \gamma \tag{C-8}$$

Under plane stress

$$G_{ICR} = \frac{\pi \left(\frac{3 - \upsilon}{1 + \upsilon} + \frac{1 + \upsilon}{1 + \upsilon}\right) k_1^2}{8\ \frac{E}{2(1 + \upsilon)}} \tag{C-9}$$

$$= \frac{k_1^2\ \pi \left(\frac{4}{1 + \upsilon}\right)}{\frac{4}{1 + \upsilon}\ E} = \frac{k_1^2\ \pi}{E} \tag{C-10}$$

At failure

$$k_1^2 = \frac{\gamma E}{\pi} \tag{C-11}$$

$$k_1 = \sqrt{\frac{\gamma E}{\pi}} \tag{C-12}$$

$$K_I = \sqrt{\gamma E} \tag{C-13}$$

However, if the situation is plane strain:

$$G_{ICR} = \frac{\pi \left(3 - 4\upsilon + 1\right) k_1^2}{8 \dfrac{E}{2(1 + \upsilon)}} \tag{C-14}$$

$$= \frac{4\pi \left(1 - \upsilon\right) k_1^2}{4 \dfrac{E}{1 + \upsilon}} = \frac{\pi \left(1 - \upsilon\right)^2 k_1^2}{E} \tag{C-15}$$

This implies that extension will occur for

$$k_1^2 = \frac{\gamma E}{\pi\left(1 - \upsilon^2\right)} \tag{C-16}$$

or,

$$K_I = \left(\frac{\gamma E}{1 - \upsilon^2}\right)^{1/2} \tag{C-17}$$

Consider $K_I = \left(\frac{\gamma E}{1 - \upsilon^2}\right)^{1/2}$, p at crack extension would be:

$$p = \frac{\left[\dfrac{\gamma E}{\pi a\left(1 - \upsilon^2\right)}\right]^{1/2} + \sigma_2\left[f\left(\dfrac{c}{a}\right)\right]^{1/2} - \sigma_1\left[g\left(\dfrac{c}{a}\right)\right]^{1/2}}{\left[f\left(\dfrac{c}{a}\right)\right]^{1/2} - \left[g\left(\dfrac{c}{a}\right)\right]^{1/2}} \tag{C-18}$$

p can be determined uniquely as a function of crack length.

$$\text{For } \sigma_1 = \sigma_2 = 0;\ \sigma_t = \frac{\left[\dfrac{\gamma E}{\pi a\left(1 - v^2\right)}\right]^{1/2}}{\left[f\left(\dfrac{c}{a}\right)\right]^{1/2} - \left[g\left(\dfrac{c}{a}\right)\right]^{1/2}} \tag{C-19}$$

(σ_t - tensile strength of the rock)

For $\sigma_1 = \sigma_2$

$$P = \frac{\left[\dfrac{\gamma E}{\pi a\left(1-\upsilon^2\right)}\right]^{1/2}}{\left[f\left(\dfrac{c}{a}\right)\right]^{1/2} - \left[g\left(\dfrac{c}{a}\right)\right]^{1/2}} + \sigma_1 \qquad \text{(C-20)}$$

As compared to conventional predictions:

$$P = \sigma_t + 2\sigma_1 \qquad \text{(C-21)}$$

If hydraulic fracturing were attempted in a region with a pre-existing crack or joint along the axis of the borehole, across the fault $\sigma_t = 0$ and $\gamma = 0$. An apparent discrepancy now arises since:

from (C-19) $\quad p = \sigma_1 \qquad$ (C-22)

from (C-20) $\quad p = 2\sigma_1 \qquad$ (C-23)

Hardy states that if the pressure at which flow from the borehole into the joint were recorded, and if this pressure were used as a measure of the stress state around the borehole, equation (C-22) should be used.

For some ratios of σ_1/σ_2 there may be a size effect on the breakdown pressure, expressed as:

$$p^* = f\left(\sigma_1,\ \sigma_2,\ c/a,\ c,\ E,\ \gamma\right)$$
$$\searrow$$
$$p \cdot \left(\pi a\left(1 = \upsilon^2\right)/ E\gamma\right) \qquad \text{(C-24)}$$

If σ_1/σ_2 is large and is constant and if the value of c is stationary on the (c/a) curve, then there will be a reduction in p_b for increases in the internal hole diameter.

(C.2) <u>NO FLUID PENETRATION INTO AN EXISTING FRACTURE</u>

If there is no penetration, this is analogous to having an impermeable membrane in the borehole. Oucherlony (1972) (Refer to Figure B) has considered such a situation:

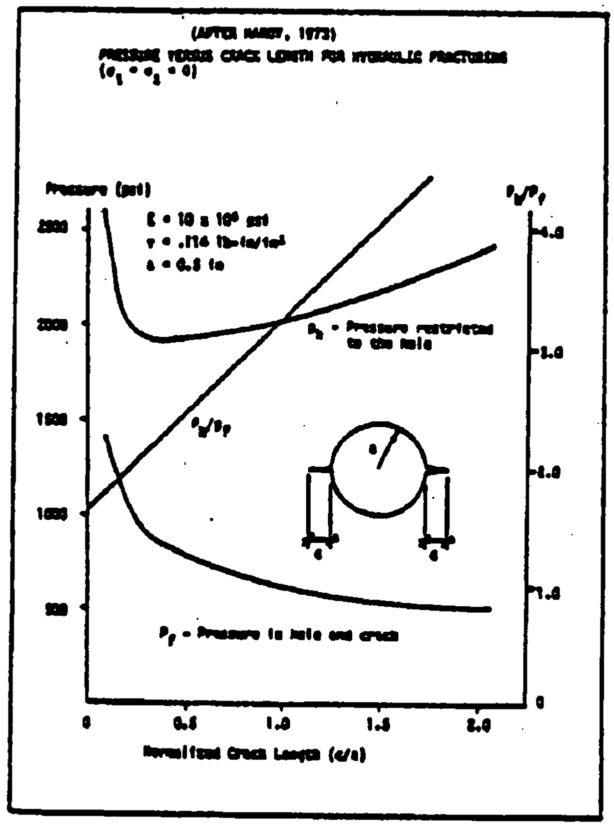


FIGURE B

For no penetration:

$$K_I = p(\pi a)^{1/2} F(c/a) \qquad \text{(C-25)}$$

For σ_1 parallel to the crack:

$$K_I = \sigma_1 [\pi a g(c/a)]^{1/2} \qquad \text{(C-26)}$$

For σ_2 perpendicular to the crack:

$$K_I = \sigma_2[\pi a f(c/a)]^{1/2} \tag{C-27}$$

Using superposition,

$$K_I = p\,(\pi a)^{1/2}\,F(c/a) - \sigma_2\,[\pi a f(c/a)]^{1/2} + \sigma_1\,[\pi a g(c/a)]^{1/2} \tag{C-28}$$

with,

$$K_I = \left[\frac{E\gamma}{(1-\upsilon^2)}\right]^{1/2} = (E')^{1/2}$$

$$P = \frac{(E')^{1/2} + \sigma_2\,[f(c/a)]^{1/2} - \sigma_1\,[g(c/a)]^{1/2}}{F(c/a)} \tag{C-29}$$

$$\text{if } \sigma_1 = \sigma_2 = 0 \rightarrow P = (E')^{1/2}/F(c/a) \tag{C-30}$$

$$\text{if } \sigma_1 = \sigma_2 \quad \rightarrow P = \frac{(E')^{1/2}}{F(c/a)} + \frac{\sigma_1\left[f(c/a)^{1/2} - g(c/a)\right]^{1/2}}{F(c/a)} \tag{C-31}$$

(C-31) indicates that for large crack lengths, the breakdown pressure increases very rapidly with increasing crack length. (* NO PENETRATION).

For a preexisting fracture intersecting the hole

$$p = \frac{\sigma_1\,\left[f(c/a)^{1/2} - g(c/a)\right]^{1/2}}{F(c/a)} \tag{C-32}$$

For small initial crack lengths (4-32) reduces to:

$$p = 2\sigma_1 \qquad \text{(C-33)}$$

(C.3) FLUID PENETRATION

Hardy considered a purely mode I situation. Zoback et al also did. However, they considered fluid penetration into diametrically opposed pressurized cracks. The pressure distribution was considered uniform throughout the fracture length.

For two fractures stemming from a circular hole in an infinite medium, Newman calculated the normalized stress intensity factors (K_I/p) as a function of crack length ℓ (using geometry shown in Figure C)

$\lambda = 0$ fluid pressure applied only to the borehole

$\lambda = 1$ fluid pressure applied over the fracture surface as well.

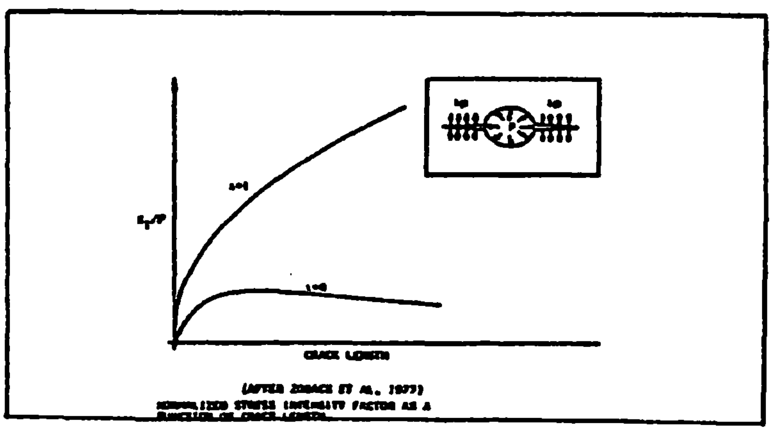


FIGURE C

If the fluid pressure is acting along the entire fracture surface, the stress intensity factor grows as the fracture extends and unstable crack growth would be consequent. When fluid acts only in the borehole, after an initially unstable growth, the stress intensity slowly

decreases with crack length (stable crack growth - requires increasing pressure for continued crack propagation). The reality lies somewhere between these two limits.

(C.4) VERTICAL FRACTURE MIGRATION

Abou Sayed et al, 1977 analyzed a vertically migrating hydraulic fracture. (If higher order terms are omitted this is still mode I analysis). An elliptical crack is considered. The crack is subjected to fluid pressure acting on the crack faces and a far-field in situ stress (both varying linearly with depth).

The problem considered is one of quasistatic crack extension, neglecting fluid flow, for a three dimensional crack configuration.

Let:

$\beta = \rho g$ (ρ - fluid density, g - gravitational acceleration)

α = vertical gradient of horizontal in situ stress.

Stress intensity factors, theoretically derived, vary around the crack periphery in a manner implying that an elliptical crack subjected to the prescribed loads will not grow uniformly, even if subjected to uniform pressure. For uniform pressure, the analysis predicts that an elliptical crack will grow into a circular one.

In addition, for nonuniform loading, a circular crack will tend to extend first at the tip which lies on the major axis and $\phi = 0$ (Refer to Figure D).

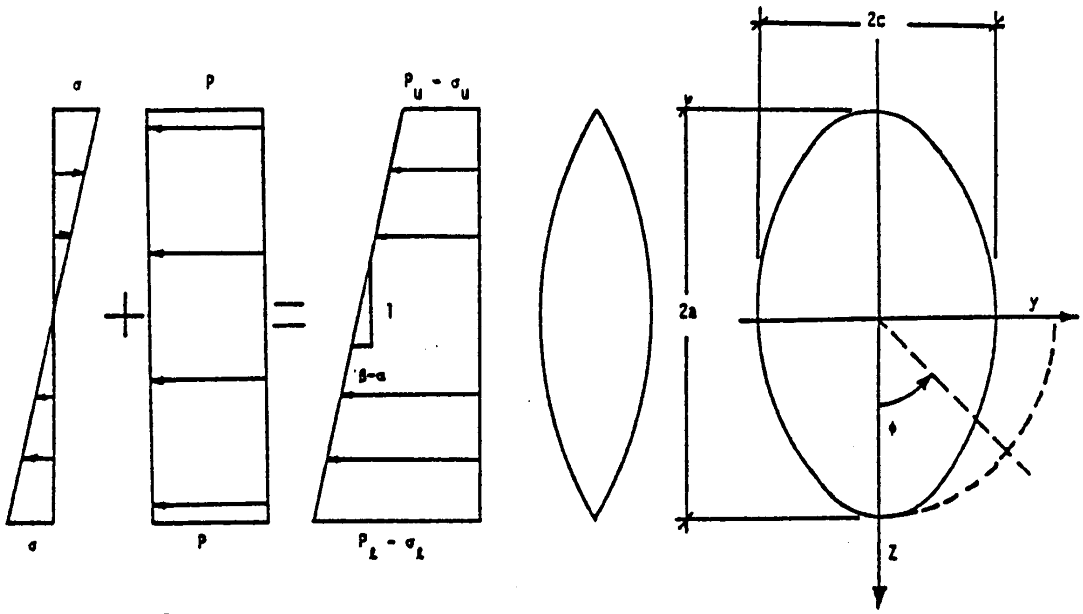


FIGURE D VERTICAL FRACTURE MIGRATION: EQUIVALENT LOADING OF THE ELLIPTICAL FRACTURE (AFTER ABOU-SAYED ET AL, 1977)

$$P = \frac{1}{2}(P_u + P_\ell) - (\sigma_u + \sigma_\ell)$$

$$\sigma = \frac{1}{2}(P_\ell - P_u) + (\sigma_\ell + \sigma_u) = (\beta - \alpha)\, a$$

"That is, for a downward fracturing condition, a circular crack will tend to become longer in the vertical direction than in the horizontal direction at its lower half, i.e. c/a will tend to decrease. Once this growth has occurred, the new crack will take an intermediate shape between a circle and an ellipse."

Abou Sayed et al, 1977.

(C.5) PARTICULAR FIELD CONDITIONS

"Hydraulic fracture containment is discussed from the point of view of linear elastic fracture mechanics. Three cases are analyzed: a) Effect of different material properties for the pay zone and the barrier formation, b) Characteristic of fracture propagation into region of varying in situ stress and, c) Effect of hydrostatic pressure gradients on fracture propagation into overlying or underlying barrier formations. The analysis shows the importance of the elastic properties, the in situ stresses and the pressure gradients on fracture containment."

Simonson et al, 1977.

"1. Hydraulic fractures in a pay zone located between two adjacent barrier layers will tend to be contained provided the stiffness of the pay zone is less than the stiffness of the barrier layers. Furthermore, if the opposite condition exists, barrier penetration is most likely.

2. Migration of a hydraulic fracture either upward or downward in an isotropic, homogeneous medium may be controlled by the density of the hydraulic fracture fluid. If the fluid density gradient is greater (less) than the in situ stress gradient downward (upward) migration is most probable.

3. If there exists a difference in in situ stress between the barrier layer and the pay zone with greater in situ stress in the barrier layer, then it may be possible to detect fracture propagation into the barrier formation. A sudden increase in pumping pressure will occur as the fracture crosses the interface and extends into the barrier layer. The increase in pressure is a function of the difference in in situ stress between the barrier and pay zone layers and the height of the pay zone."

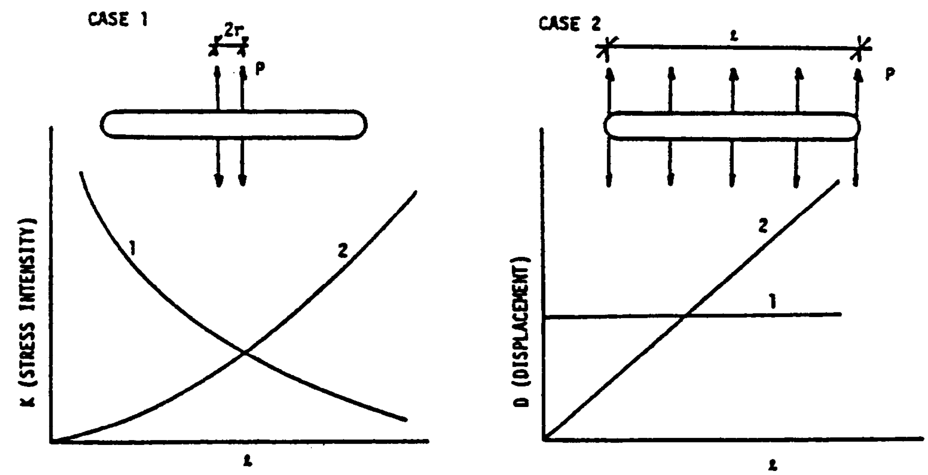
Simonson et al, 1977.

(C.6) PENETRATION OF A VISCOUS FLUID

Zoback and Pollard, 1978,considered fluid penetration using more realistic assumptions of distribution and character of fluid.

"In attempting to intuitively understand the fracture initiation and extension process, it is necessary to consider the coupled problem of the elastic deformation of a fracture and viscous fluid flow into it. The necessity of considering this coupled problem is illustrated by the extreme cases shown in Figure E."

Zoback and Pollard, 1978.



(AFTER ZOBACK & POLLARD, 1978)

SCHEMATIC REPRESENTATION OF STRESS INTENSITY FACTOR AND DISPLACEMENT, AS A FUNCTION OF CRACK LENGTH, FOR TWO LOADING CASES.

FIGURE E

These authors consider:

(CASE 1)
$$\left.\begin{aligned} K &= 2\,Pr\,\sqrt{1/2\;\ell\pi} \\ D &= 2\,Pr\,(1-\upsilon)\left[1-(2x/\ell)^2\right]^{1/2}/\,\pi G \end{aligned}\right\} \qquad \text{(C-34)}$$

(CASE 2)
$$\left.\begin{aligned} K &= P\,\sqrt{\ell\pi} \\ D &= P\,(1-\upsilon)\left[1-(2x/\ell)^2\right]^{1/2}/\,2G \end{aligned}\right\} \qquad \text{(C-35)}$$

where:

K - Opening mode stress intensity factor

P - Uniform Pressure

2r - Interval of Pressurization for Case One

ℓ - Fracture length

D - Opening displacement of Fracture Wall

υ - Poisson's Ratio

G - shear Modulus

A propagating fracture cannot be represented precisely by either of these extreme models. Fluid pressure may act in the fracture to some degree, but not necessarily such that fracture propagation is unstable at all times.

Zoback and Pollard utilize a two-dimensional plane strain fracture model in an infinite continuum which is linear elastic, homogeneous, and isotropic. Also considered is steady, constant property flow of a Newtonian viscous fluid "into" the fracture from the borehole. It is assumed that the fracture propagates perpendicular to the least principal compressive stress. Shear stresses on the fracture face due to fluid flow are ignored.

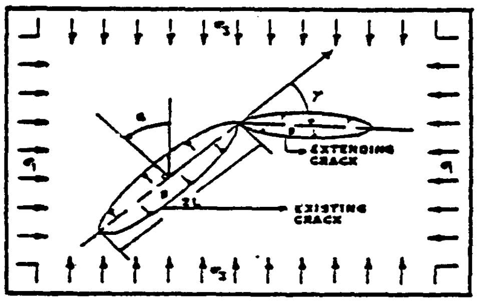
Also considered, using a one dimensional steady-state flow law is the crack-tip stress intensity factor as a function of the fracture half-length for various fluid viscosities. Figure F summarizes their findings. This figure, along with Figure G seem to be a good approach. The problem seems to lie with what must be regarded as seeming intuitively unlikely. This is that (Refer to Figure G) wall displacement is herein predicted to increase with decreasing viscosity. The likelihood of this is suspect.

PART B

MIXED MODE CONDITIONS

(C.7) THE EFFECT OF PREFERRED CRACK ORIENTATION ON HYDRAULIC FRACTURING CRACK GROWTH

Consider an existing pressurized crack randomly oriented with respect to the principal stresses (Figure H). Abou Sayed et al, 1977, outline conditions and characteristics of additional propagation.



(AFTER ABOU-SAYED ET AL., 1977)
SKEWED CRACK UNDER FAR FIELD STRESS AND INTERNAL PRESSURE

FIGURE H

For the situation shown in Figure H

$$K_I = \sqrt{\pi L}\left[p - \sigma_1 \sin^2 \alpha - \sigma_3 \cos^2 \alpha\right] \qquad \text{(C-36)}$$

$$K_{II} = \sqrt{\pi L}\left[1/2\,(\sigma_1 - \sigma_3) \sin 2\alpha\right] \qquad \text{(C-37)}$$

These are the stress intensity factors for the existing crack.

If the existing crack extends in an arbitrary direction

$$G(\gamma) = \frac{4(1-\upsilon^2)}{E}\left(\frac{1}{3+\cos^2\gamma}\right)\left(\frac{\pi-\gamma}{\pi+\gamma}\right)^{\gamma/\pi}\left\{(1+3\cos^2\gamma)\,K_I^{\,2} + 8\sin\gamma\,\cos\gamma\,K_I\,K_{II} + (9-5\cos^2\gamma)\,K_{II}^{\,2}\right\} \qquad \text{(C-38)}$$

$G(\gamma)$ -strain energy release rate as a function of the angle of extension measured clockwise with respect to the trace of the existing crack.

K_I, K_{II} -given in (C-36) and (C-37)

(after Hussain, et al, 1973, modified for plane strain).

For an open, stationary long crack, a prerequisite is $K_I = K_{II} = 0$. (These considerations seem dubious since it implies that a crack is unstable if $G(\gamma) \neq 0$. Propagation only occurs when $G(\gamma)$ exceeds a characteristic value $G_{CR}(\gamma)$).

$$P = \sigma_1 \sin^2 \alpha + \sigma_3 \cos^2 \alpha \qquad \text{(C-39)}$$

and

$$(\sigma_1 - \sigma_3) \sin 2\alpha = 0 \qquad \text{(C-40)}$$

For $\sigma_1 \neq \sigma_3$: $\alpha = 0$ or $\alpha = \pi/2$. This implies that the existing crack is stationary if it is parallel to principal stress directions and if the pressure p is equal to the principal stress acting perpendicularly to the crack face. Further considerations indicate extension will tend to be perpendicular to the direction of minimum compressive stress as expected.

A consequence is that σ_3 is equal to the shut-in pressure and if α is known, σ_1 can be evaluated.

(C.8) CRACK INITIATION WITH A PRE-EXISTING CRACK OF PRESCRIBED ORIENTATION

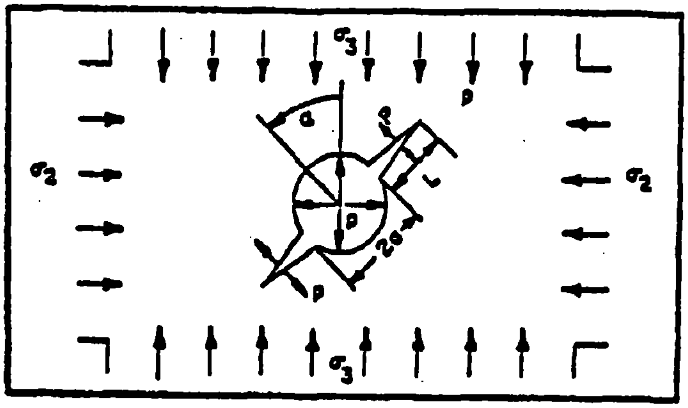


FIGURE I

(AFTER ABOU-SAYED ET AL, 1977)

INTERNALLY PRESSURIZED CRACKED BOREHOLE
UNDER FAR FIELD STRESS.

Abou Sayed et al, 1977, consider also a diametrically cracked hole which is internally pressurized (p). This is similar to the situation described earlier (Zoback et al, 1977) except that $K_{II} \neq 0$ in this case.

For this situation:

$$K_I = p\sqrt{L\pi}\, F\left(L/a\right) - \left(\sigma_2 \cos^2\alpha + \sigma_3 \sin^2\alpha\right) F\left(L/a\right)\sqrt{L\pi} + \left(\sigma_2 \cos^2\alpha - \sigma_3 \cos^2\alpha\right) \cdot G\left(L/a\right)\sqrt{L\pi} \qquad \text{(C-41)}$$

F(L/a), G(L/a) - Tabulated Functions (after Paris and Sih, 1965)

For a tensile crack: $\alpha = 0$

$$\left(G\left(L/a\right) - F\left(L/a\right)\right)\sigma_2 = \frac{K_{IC}}{L} - F\left(L/a\right) P_b + G\left(L/a\right)\sigma_3 \qquad \text{(C-42)}$$

For a shear crack: $\alpha = \pi/4$

$$\sigma_2 = 2P_b - \frac{2K_{IC}}{F(L/a)\sqrt{\pi L}} - \sigma_3 \quad \text{(C-43)}$$

where

P_b - Breakdown Pressure

K_{IC} - Mode I Fracture Toughness

In the opinion of the authors, this analysis seems a little tenuous since if hydraulic fracturing is the result of a shearing action, K_{II} should not be taken equal to zero. Both stress intensity factors K_I and K_{II} should be evaluated.

If the horizontal primitive stress distribution is $\sigma_2 = \sigma_3$ then:

$$\sigma_2 = \sigma_3 = \sigma = P_b - \frac{K_{IC}}{F(L/a)\sqrt{L\pi}} \quad \text{(C-44)}$$

With certain assumptions (C-44) can be expressed alternatively as:

$$\frac{K_{IC}}{F(L/a)\sqrt{L\pi}} - P_b + \sigma_3 = (\sigma_2 - \sigma_3)\left\{\frac{G(L/a)}{F(L/a)}\cos^2\alpha - \cos^2\alpha\right\} \quad \text{(C-45)}$$

"*Since the value of the expression in parentheses on the right hand side of equation (C-45) varies between - 1/2 and 1.5 and is near zero only for a limited range of values of a, it is reasonable to expect that, in general, its order of magnitude is not far from unity. Hence, the difference between* σ_2 *and* σ_3 *will be of the same*

order of magnitude as the value of $\left(\frac{K_{IC}}{F(L/a)\sqrt{L\pi}} - P_b + \sigma_3 \right)$.

The last expression contains quantities that either can be measured or evaluated during the field and lab experiments associated with mini-hydrofracturing. More precisely it involves the measurement

of the breakdown pressure, P_b, the shut in pressure $P_s = \sigma_3$, the fracture toughness K_{IC} and <u>an estimate of the length of the pre-existing natural cracks in the formation</u>."

Abou Sayed et al, 1977.

For an initial crack of length L intersecting the borehole and lying normal to the minimum in situ stress:

$$\sigma_2 = \frac{K_{IC}}{\sqrt{\pi L}\,(G - F)} - \frac{F}{(G - F)} P_b + \frac{G}{G - F} \sigma_3 \qquad \text{(C-46)}$$

G,F - Evaluated for a particular value of L/a

If K_{IC} is found in the laboratory to be:

$$K_{IC} = \sqrt{\pi L_o}\; P_i\; \dot{F}\;(L_o/a_o) \qquad \text{(C-47)}$$

where:

L_o -length of the crack intersecting the inner wall of a burst sample.

a_o -inner radius of burst sample.

$\dot{F}$ -for laboratory sample

$$\therefore \sigma_2 = P_i \frac{\dot{F}(L_o/a_o)}{(G - F)} \sqrt{\frac{L_o}{L}} - \frac{F}{(G - F)} P_b + \frac{G}{(G - F)} P_s \qquad \text{(C-48)}$$

For L/a and L_o/a_o small, $G \approx 1.5$ F, giving

$$\sigma_2 \approx 3P_s - 2\left(P_b - P_i\sqrt{\frac{L_o}{L}}\,\right) \qquad \text{(C-49)}$$

Abou Sayed et al (1977) state that using Haimson's analysis over estimates σ_2:

$$\sigma_2^H - \sigma_2^B \approx (P_b - P_i) \quad \text{(C-50)}$$

where

σ_2^H - estimated from Haimson's prediction

σ_2^B - estimated by Abou Sayed et al

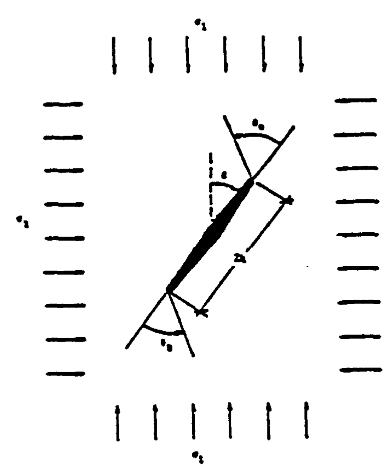
P_b - breakdown pressure

P_i - hollow cylinder burst pressure

(C.9) ADDITIONAL APPROACHES

Advani et al, 1973, discussed analytical, experimental, and numerical approaches to modeling pressurized fractures.

Analytical Considerations



(AFTER ADVANI ET AL., 1976)
TWO-DIMENSIONAL FIELD WITH PRESSURIZED INCLINED CRACK AND FAR FIELD STRESS.

FIGURE J

Figure J shows the idealized model used in the analytical predictions. For this:

$$\left.\begin{aligned} k_I &= \frac{K_I}{\sqrt{\pi}} = \left(p + \sigma_1 \sin^2\beta + \sigma_2 \cos^2\beta\right)\sqrt{a} \\ k_{II} &= \frac{K_{II}}{\sqrt{\pi}} = \left(\sigma_1 - \sigma_2\right)\sin\beta \cos\beta\sqrt{a} \\ k_{II} &= 0 \end{aligned}\right\} \quad \text{(C-51)}$$

The stationary angular derivative of the strain energy density is:

$$\begin{aligned} \frac{dS}{d\theta} = 0 = \frac{a(1+\upsilon)}{8E} &\left\{\left(p + \sigma_1 \sin^2\beta + \sigma_2 \cos^2\beta\right)^2 \sin\theta \left(2\cos\theta + 4\upsilon - 2\right)\right. \\ &+ 4\left(p + \sigma_1 \sin^2\beta + \sigma_2 \cos^2\beta\right)\sin\beta\cos\beta\left(\sigma_1 - \sigma_2\right)\left(\cos 2\theta - \left(1 - 2\upsilon\right)\cos\theta\right) \\ &\left. + \left(\sigma_1 - \sigma_2\right)\cdot \sin^2\beta \cos^2\beta\left(2 - 4\upsilon - 6\cos\theta\right)\cdot\sin\theta\right\} \end{aligned} \quad \text{(C-52)}$$

For stable crack growth $\frac{d^2S}{d\theta^2} \geq 0$. The critical strain energy density can be found from

$$S_C = \frac{\left(1 + \upsilon\right)\left(1 - 2\upsilon\right) K_{IC}^2}{2E} \quad \text{(C-53)}$$

where

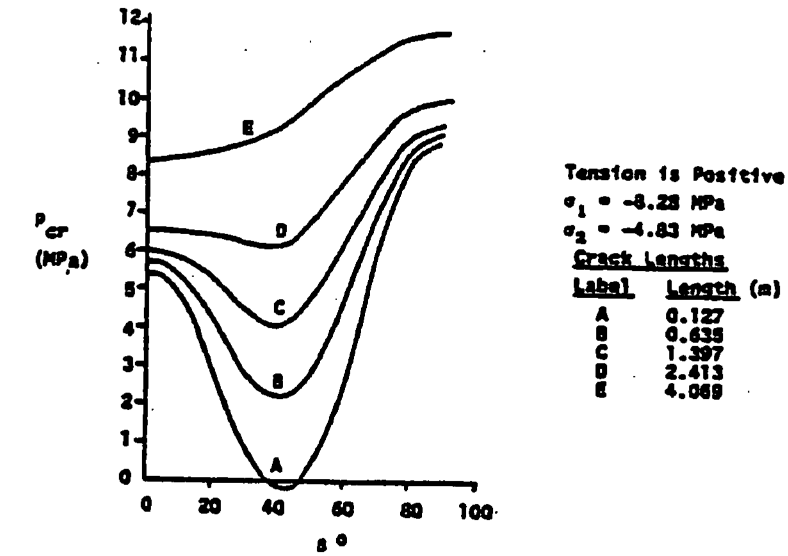
υ -Poisson's Ratio

K_{IC} -Critical Mode I stress intensity factor

E -Young's Modulus

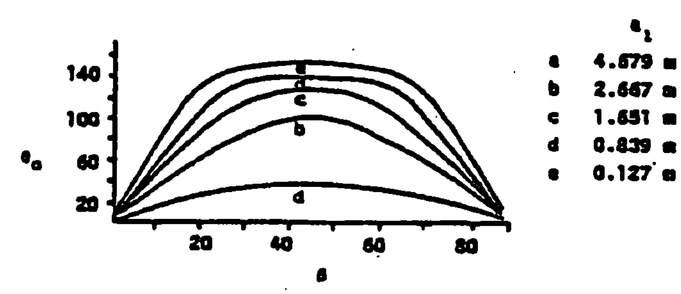
As a consequence, the angle of additional incremental crack propagation can be predicted.

Figures K and L summarize the analytical findings.



(AFTER ADVANI ET AL., 1976)
$P_{CRITICAL}$ VERSUS INCLINATION β FOR DIFFERENT
(AFTER DANESHY, 1973)

FIGURE K



(AFTER ADVANI ET AL., 1976)
FRACTURE EXTENSION ORIENTATION θ_o VERSUS INITIAL CRACK INCLINATION β FOR DIFFERENT CRACK LENGTHS a_1

FIGURE L

APPENDIX D

HYDRAULIC FRACTURING AS A STRESS MEASURING TECHNIQUE: POTENTIAL ERRORS

Any sort of stress measurement technique, including hydraulic fracturing, is subject to the necessity for assumption and interpretation. Without discussing the advantages of the hydraulic fracturing technique, some of the factors which can make interpretation difficult are:

(i) General Philosophy and Basic Assumptions

As mentioned, conventional hydraulic fracturing interpretation is based on the concepts of classical elasticity. This approach fails to take into account the actual influence of the hydraulic fracture. Fracture mechanics approaches address this problem, but are nevertheless in their early stages of development at the present time.

Further complications relate to assumptions concerning the orientation of the borehole with respect to the principal stress field, the field flow and porosity conditions and material isotropy.

(ii) Field Testing

Questions of immediate concern are:

(a) Despite the influence of the straddle packers, will the fracture initiate as vertical in a strongly anisotropic material?
(b) What is the influence of existing fractures and laminations?
(c) What is the orientation and morphology of the fracture away from the borehole?

(iii) Field Equipment

Existing field equipment (hydraulic, electronic, ...) probably gives an accurate record of pressurization history at the surface and downhole in the fracture interval.

<APPENDIX 2D F>

INDEPENDENT REVIEWS OF COOLING WATER TUNNEL FAULTING

Mr. James Murphy

Ohio Historical Society

Bedrock Deformation in the Water Intake Tunnel, Perry Nuclear Power Plant, Lake County, Ohio

James L. Murphy
The Ohio Historical Society
Columbus, Ohio 43211

On January 19, 1979, I examined bedrock exposures of the Chagrin Shale exposed in a water intake tunnel at the Perry Nuclear Power Plant, Lake County, Ohio. Details of this and a similar exposure in the outlet tunnel are described in GAI Reports 1986 and 1997, which have been available for study.

Based upon my examination of the actual outcrop and supplementary evidence presented in the above-mentioned reports, I believe that the low angle thrust fault and related small anticlinal fold are essentially identical with similar features found nearer the surface during excavations for the power plant (Gilbert & Associates, 1975).

It is my belief the such bedrock deformation was caused by the horizontal component of localized stresses created during the Pleistocene by either the advance of the ice sheet(s) and concomitant depression of the crust, or in reaction to removal of the weight of the overlying ice (glacial rebound). This would mean that the deformation occurred some time during the last one million years. I am inclined to believe that it is related to the last (Wisconsinian) glaciation but conclusive proof of this is lacking. The deformation could be related to any one of the major glaciations that covered northern Ohio, and different faults and folds may owe their origin to different glaciations. In any case, further movement along such features is not to be expected, and these are not, therefore, classifiable as capable faults.

In reviewing the original reports (GAI 1986, 1997) on the deformation exposed in the cooling system tunnels, I would make the following additional statements:

1) Based upon my knowledge of similar faults in the Chagrin Formation of northeastern Ohio, I believe that in all probability, two separate faults are represented, one in each tunnel. The chief evidence for this is the considerable difference in strike represented in the two exposures and the rather local nature of similar faults exposed elsewhere in the Chagrin.

2) I believe that the hypothetical subsurface projection of the fault(s) shown in Figure 2 (GAI 1997) is incorrect and doubt that the fault(s) extend quite so far, either laterally or vertically. (It should be noted that the vertical exaggeration used in Figure 2, though stated in the figure, gives a somewhat misleading impression of the magnitude and dip of the fault.) Presumed evidence of the extension of the fault seems somewhat equivocal and cannot be taken as conclusive proof of the existence of the fault at the distance and depth projected. Even were the fault of the size and extent presumed, I believe the proposed glacial mechanism still the most probable cause of the deformation.

3) The possibility of penecontemporaneous deformation of the unlithified Chagrin sediments is completely out of the question in these instances and, I think, would immediately be dismissed by any geologist who examines the exposure in the intake tunnel. In this regard, I suggest that detailed close-up photographs be taken of the lower portion of the fault as exposed in the (north) east wall, a few feet above the base of the tunnel, where rather large (approximately 3 inches in diameter) fragments of detached Chagrin shale occur in the fault "gouge", conclusively demonstrating that the deformation occurred subsequent to lithification.

4) Deformation by deep-seated late Paleozoic tectonism cannot be entirely ruled out of the question as a possible cause of some Chagrin deformation, but it is considered an unlikely possibility in the present instance, particularly in view of the fact that similar faulting and folding (notably in the on-shore NPNPP excavations) rapidly diminishes and disappears with depth. Such is also believed to be the case with the water system tunnel faults. Although they are deeper than previously studied examples in the Chagrin Formation, they are nonetheless comparatively shallow "surficial" phenomena unrelated to deep-seated tectonism.

James L. Murphy
February 19, 1979

Newspaper Account of 1818 "Kingston" Earthquake

Michael Hansen of the Ohio Division of Geological Survey has given me the following information regarding a newspaper account of an 1818 earthquake that has been believed to have had its epicenter at Kingston, Ross Co., Ohio.

The Cleveland Register of March 16, 1819, reprints a news item from the Quebec Gazette (no date) stating that "Two severe shocks of an earthquake were felt at Kingston and its vicinity on the morning of the 7th December. They were accompanied with a rumbling noise. The disturbance was not as long as those of 1812 but were equally violent."

Since the newspaper item originally appeared in a Quebec newspaper, it is evident that the earthquake occurred at Kingston, Ontario, rather than Kingston, Ohio. The only known copy of this issue of the Cleveland Register is at the Western Reserve Historical Society in Cleveland.

James L. Murphy

Dr. Robert G. LaFleur
Rensselaer Polytechnical Institute

Robert G. LaFleur
Geologist
Taborton Road
Sand Lake, New York 12153

January 30, 1979

Dr. Lane D. Schultz
Gilbert Associates Inc.
525 Lancaster Avenue
Reading, Pennsylvania 19603

Dear Lane:

On January 19, 1979, with L.D. Shultz and J. Murphy, I inspected the reverse fault which intersects the intake tunnel of the Perry Nuclear Power Plant, and subsequently reviewed GAI Reports No. 1986 and 1997 describing this feature and other near-surface bedrock deformations. The following comments summarize my impressions of the tunnel fault.

1.   I see no evidence which suggests the deformation occurred while the Chagrin shale was in a poorly consolidated state. Soft-sediment deformation is usually indicated by the presence of flow structure, wispy sediment tails, mess-bedding, deformed and pulled-apart plasts, etc. Early Paleozoic slope clastics and carbonates in the Taconics commonly show such features in deep water rocks - by comparison the Chagrin deformation, with the exception of bedding irregularities attributable to compaction and minor sole marks, is devoid of such features. Brittle fracture is represented by the tunnel fault. Drag and adjacent open folds maintain good parallel banding. Gouge breccia is angular and untorn. I would conclude from this the tunnel fault deformation occurred after consolidation was completed.

2.   The depth of active influence, observed elsewhere (200m.), of overriding ice may be enough to permit inclusion of the tunnel fault in the same glacitectonic category as the shallow features. However, 1) the fault sole shows no clear sign of passing into bedding plane

orientation at reasonable depth; 2) the fault dip direction is considerably at variance with the usual direction of Erie lobe movement (from the NE or N); 3) it seems difficult to see how glacier movement alone would produce a deep structure at all (when the ice can tear up the surface rocks instead) unless there were an existing weakness plane which override could activate. There is no indication in the tunnel that the fault might have a multiple movement history. Elevated methane pressure in the Chagrin would enhance movement along a deep fault, but there is little proof abnormal pressures existed during glaciation. I think it is unreasonable to expect the Chagrin was frozen deeply enough to permit ice expansion along such a weakness plane to motivate faulting.

I agree with the proposed glacitectonic origin for both the tunnel fault and shallow deformation, but I am not completely persuaded that active ice, ground-coupled in the presence of permafrost, is necessarily responsible for these features. I cannot rule this process out on the basis of the evidence at hand, but would point out that it is certain that glacier loading and unloading, glacial quarrying of the Erie basin, and episodic glacial lake development caused vertical stresses and might also have permitted horizontal stress development sufficient to produce the structures. In this sense a more passive role of glaciers in regional crustal movements is indicated. It may be important to this notion that the strike of the Chagrin deformations agrees well with the regional trend of the Erie basin axis and south edge - more than it appears to agree with a direction normal to common ice flow. In addition, deep permafrost, to my knowledge, does not appear to have been widely developed at this latitude during the Late Wisconsin - these glaciers rather were temperate, wet-based, and often advanced through proglacial lakes.

3. Although the upper and lower limits of the tunnel fault are not determined, I would expect the fault to intersect the bottom of Lake

Erie. The gouge water chemistry does not rule out hydraulic connection with the lake. Water movement along the fault should be directed, as recharge, toward the lake. Interpretation in the TX borings of intersections with the fault trace projected to depth appear reasonable. Absence of mineralized gouge suggests the fault is confined to the Chagrin, but one might also attribute this to a younger (than Paleozoic) age for the fault.

4. One can only conjecture what role the Salina salt played in glacier-induced crustal warpings, and particularly its influence in maintaining and cumulating abnormal horizontal stress. I point this out only to convey the idea that oscillating Pleistocene glaciers may have triggered more complicated "late" tectonic settings in which a ductile substrate influences development of faults in overlying rocks, perhaps like the one exposed in the intake tunnel.

In any event I support the conclusion that the tunnel fault is related to some manifestation of glaciation - not necessarily as young as Late Wisconsin. In view of its movement sense, it may be related to crustal loading (down-warping) of the Erie basin while near-surface rocks were in a state of horizontal stress. I see no reason to consider the tunnel fault active, capable, or of post-glacial age.

Yours truly,

Robert G. LaFleur

RGLaF:vb

At the request of Dr. Lane D. Schultz, I visited the office of Gilbert Associates on April 12, 1979 and inspected documents describing the shallow deformations at PNPP and those exposed at Warners Creek and Hell Hollow.

I support the conclusions reached by several others that the shallow structural features are the result of glacial ice drag - those exposed at PNPP and also the compressional folds and related thrusts shown in the creek sections. The correctly-oriented fold asymmetry, thrust sense, shallow depth, and participation of bedrock with till are all persuasive features indicative of an active glaciotectonic origin. There is little one can add to the carefully documented and considered opinions offered by C.E. Herdendorf, J.L. Murphy and the Gilbert Associates Staff.

As a minor point one might note the occurrence of rare near vertical faulting, illustrated by Hell Hollow faults No. 1, 2, and 3 which appear to post-date the compressional structures. Comparable relations are not apparent at PNPP; compressional (glacially induced) movement there is the terminal event. If high-angle faulting at Hell Hollow is the result of slumping, one might conclude there is no evidence for fracturing during application or removal of glacial ice load. That is, post-glacial uplift has no structural manifestation at PNPP. If, on the other hand, the Hell Hollow faults are due to post-glacial uplift, PNPP is still free of such features. My impression that the intake tunnel structure is neither of active or passive glaciotectonic origin remains - although the notion seems plausible that a million-year-old crack along a much older fault zone might be a manifestation of a passive, early glacial event. I see no reason to relate the tunnel fault to the surface structures. It is also clear that the shallow deformations do not resemble pop-ups. Stability of the bedrock since the glacial override seems apparent.

____

Robert G. LaFleur
4/12/79

Dr. Barry Voight
Penn State University

BARRY VOIGHT
CONSULTANT
GEOLOGY AND GEOTECHNICS

324 SOUTH PATTERSON STREET
STATE COLLEGE, PENNSYLVANIA 16801
TELEPHONE (814) 238-4431 U.S.A.

INVESTIGATION OF COOLING WATER TUNNEL FAULTS,
PERRY NUCLEAR POWER PLANT, OHIO

INVESTIGATION OF COOLING WATER TUNNEL FAULTS,
PERRY NUCLEAR POWER PLANT, OHIO

Barry Voight

LIST OF TABLES

LIST OF FIGURES

1. SUMMARY OF REPORT

The tunnel thrust faults represent a single fault with splays or a closely-associated en-echelon set of faults that extends at least 750 ft along northeast strike and at least 600 ft along a 15° dip angle to the southeast. Slip gradient information suggests that the faults die out at elevation 450 ft within about 20 vertical feet above the tunnel crown. If so a toe buttress of "solid" rock about 70 ft thick lies between the terminated fault and the lake bottom. Insufficient information is available to conclusively establish whether or not the faults terminate to the southeast between elevations of 300 ft and 150 ft, or continue to a deeper level. There is no evidence to suggest an increase in dip angle toward the southeast, but the possibility has not been eliminated.

Consolidation tests on two samples of the fault gouge suggest a maximum vertical effective consolidation pressure of about 9 ± 4 tsf. This value is consistent with vertical compression of fault gouge by a somewhat greater thickness of overburden than exists today, or by minor late Pleistocene ice sheets associated with deposition and compression of till deposits recognized at the PNPP site. The gouge consolidation pressure is not consistent with compression by the four or more Pleistocene ice sheet maxima. The latest of these events, associated with the Kent Till, occurred about 21,000 YPB, with an end moraine 70 miles or so south of the PNPP site and an inferred overburden pressure on the order of 100 tsf. Local arching effects are not considered so severe as to preclude such an event from leaving a marked imprint on gouge consolidation characteristics. It is therefore considered likely that the last movement of the tunnel fault occurred not more than 20,000 YBP.

An ENE maximum compression stress field orientation exists at the PNPP site, as determined by the hydrofracturing method. This

corresponds to a regional orientation of stress that extends throughout Ohio and across much of New York State and southern Canada. Inasmuch as a northwest orientation for causative maximum compression was associated with the tunnel thrust fault, the tunnel fault is considered to be older than the age of the existing system. A lower bound age for movement on the fault is thus suggested, viz. about 10,000 YBP, giving a rather restricted estimated age range, 10,000 - 20,000 YBP, and an estimated age of 15,000 YBP ± 5,000.

Magnitudes of rock stresses were measured for the depth range of 394-718 ft, giving the following rounded-off average values:

maximum horizontal stress = 1500 psi
minimum horizontal stress = 900 psi
vertical overburden stress= 400-800 psi

Similar values have been recorded throughout the midwest, New York, and southern Canada. Measured stresses were resolved for the vertical plane perpendicular to the tunnel fault, and the question of recurrent slip was examined. The results show that below about 200 ft depth (elevation about 300 ft), the fault plane may be considered to be strongly clamped by frictional resistance, and no recurrent motion seems possible. Accordingly, it may be academic whether or not the fault terminates at 150-300 ft elevation or continues in a down-dip direction. At shallower levels, the fault plane is apparently less strongly clamped (stresses are inferred by extrapolation), but slip is not considered likely because it would require deformation of the inferred toe buttress. On balance the data suggest that the tunnel fault should probably not be regarded as “capable” despite its relatively young age.

The last movements on the tunnel faults were apparently generated by northwest-orientated compressive stresses associated with a

rebounding crust during deglaciation of the Laurentide maximum ice sheet. Nucleation of the fault at some earlier time is not precluded by the available data.

2. INTRODUCTION

The writer was retained by Gilbert Associates, Inc., in February 1979 as a reviewing consultant with the principal task of establishing the origin of the tunnel faults, as considered in relation to the Perry Nuclear Power Plant. This report presents the results of the investigation which followed.

I am grateful to L.D. Schultz and R. Wardrop of Gilbert Associates, Inc., for their cooperation, assistance, and courtesy in many matters related to my investigation. At my recommendation Gilbert Associates, Inc. approved additional drilling, rock stress investigations, and consolidation testing of fault gouge, and the cooperation in these endeavors of the Pennsylvania Drilling Company, of J.C. Roegiers and J.D. McLennan, University of Toronto, and of A. Dvinoff, Woodward-Clyde Consultants, is hereby acknowledged. I also appreciate the cooperation of the Weston Geophysical Corporation in providing data from their tunnel mapping and regional seismicity programs.

3. TUNNEL FAULT DESCRIPTION

a. Intake Tunnel

The deformed zone begins at about station 10 + 40 and extends to station 10 + 90. The principal structure is essentially a low-angle thrust with approximate attitude of 050/17 SE (strike N 50°E, dip 17° SE). In detail, the fault zone is comprised of a series of irregular steps, with local dips varying from zero, parallel to bedding, to 50° SE on one of the riser surfaces. Dip slip, which virtually coincides with net slip, ranges from about 1.6 ft near the Crown to about 2.5 ft near the invert. The slip difference is taken up by splay faults and minor structures of various kinds which distribute the strain within a volume of rock adjacent to the main thrust surface.

The zone of observable deformation extends locally as much as 10 ft above and 6 ft below the fault, as measured perpendicular to the fault surface, but is ordinarily much less. Splay faults are best developed in the footwall above the spring line. The splays are themselves thrust faults, with dip slip on the order of an inch. Like the main thrust they are influenced by bedding-controlled anisotropy. Their attitude varies from "horizontal" (i.e., parallel to bedding) to an inclination of about 20° (average of 14 measurements) to bedding. They appear to die out in bedding planes at horizontal distances of 13 ft or less from the fault plant. Curvature of layering occurs adjacent to the main thrust and splays. Some of the curvature may be attributed to displacement along a fault surface of upward-increasing dip. Normal drag folds are locally well developed, affecting layering within a foot or two of the thrust.

Fold hinge lines are nearly horizontal and trend approximately 050°, parallel to the strike of the fault surface. Hinges are often rounded, and most folds are approximately parallel (bed-normal thickness about constant) and locally concentric. Angular hinges occur locally,

most often in close association with the fault boundary surface (e.g. East Wall, Station 10 + 63 - 65). Axial planes are not always well-defined but seem to strike about 050°, parallel to the fault surface.

Flexural slip is indicated by thin gouge zones parallel to layer boundaries on fold limbs. Most folds are fractured, intensely so adjacent to the main thrust where folding, splay faulting and fracturing are closely associated. Systematic small-scale open fractures appear locally on fold hinges at high angles to the deformed layers. No mineralization was observed in fractures. The fault zone is commonly filled with a gray breccia-gouge, about half of which is comprised of particles in the clay-silt range, with the remainder angular sand- to gravel- size fragments of shale and siltstone. Rock fragments contained within the brecciated or gouge-filled fault zone are not randomly orientated, but are preferentially orientated such that their mean strike azimuth is approximately parallel to that of the fault. This suggests rotation of the fragments about an axis normal to fault slip. Gouge is irregularly distributed along the main thrust, with the thickness range varying from about half a foot to less than an inch. The splays also contain gouge, to a maximum thickness of about half an inch. Gouge thickness appears to be a function of fault offset (slip), the relative attitudes of bedding and the fault surface, roughness of the fault surface, and deformability of fault boundary layers. Physical properties of the gouge are discussed subsequently.

Under low-angle illumination, striations and grooves were discovered on bedding and riser fault surfaces and on gouge adjacent to it. These features were produced by frictional wear associated with faulting. Groove lengths appear to be about 0.1 ft or more, adjacent to the main fault. Striation orientations are parallel to the fault dip azimuth. The orientations of striations, minor folds, and tabular fragments in the fault zone all require the dominance of dip-slip in

faulting. A small right-lateral component is indicated by striations orientated at 15° to the fault dip azimuth at Station 10 + 58, west wall.

A minor syncline with a steep axial plane appears in the hanging wall at Station 10 + 51. The hinge is rounded on the bottom and continues below the invert muck. The fold dies out toward the crown through a zone of conjugate shears and bedding plane slip, with offsets on the order of 0.1 ft. Local gouge on layer boundaries throughout the fold suggests deformation by flexural slip. The fold probably reflects the influence of a local shear force on the buckling of a multilayer under axial (horizontal) load. It could reflect a dip change in the thrust surface, located below the tunnel at about Station 10 + 50.

b. Discharge Tunnel

Two deformed areas are present. One such area extends from about Station 13 + 24 to 13 + 62. The principal structure is a low angle thrust, with approximate attitude 060/15 SW. In detail the thrust surface is comprised of connected bedding plane fault and riser segments, with local splays. In places a single fault zone is present, sometimes characterized by breccia-gouge as much as 0.3 ft thick, and sometimes by intensely fractured rock; in other places the fault zone is comprised of a “nested” sequence of a half-dozen individual faults, with thin gouge layers separated by fractured rock. The zone of significant deformation is rarely more than 3 ft thick. Conjugate splay faults are best developed between Station 13 + 50 and 13 + 60. The mean angle for riser faults (including splays) from bedding is 26° (13 measurements). Dip slip on the principal fault ranges from about 2 ft near the invert to about 1.5 ft near the crown, with splay faults and other minor structures accommodating the strain (associated with the slip difference) over a larger volume of rock adjacent to the fault surfaces.

On the whole the structure and its associated minor structural elements closely resembles the intake tunnel fault. Striations on the fault surfaces are normal to the fault strike, indicating dip slip motion.

Drag fold hinge lines have negligible plunge and have azimuths approximately parallel to the fault strike. Folds are essentially parallel, with hinges that vary from sharply angular to rounded. The strike of the axial planes parallels the fault strike, as do the strike of folded limbs.

From Station 11 + 50 to 11 + 80, a small thrust termination is exposed. Strike is about 020, with irregular dip, roughly 20SE. Vertical offset is less than half a foot near the invert. The fault terminates in a cluster of conjugate thrusts (displacement on the order of 0.1 ft) with NW and SE dips, which pass into bedding planes. The layering takes the approximate form of a monocline with axial plane attitude 015/25SE. Offset near the crown is virtually negligible.

c. Extent of Fault

Most of what is known about the faults is based on the tunnel exposures. In map view it is known that the faults extend at least 750 ft along strike. The extent of the faults beyond tunnel exposures to the southeast, along the dip, and southwest and northeast along strike is unknown. It might be inferred from the "splay" that the main fault will terminate toward the southwest, and increase in size toward the northeast. How far it goes, and how large the slip becomes, are purely matters of conjecture.

In profile, limited additional information on extent of fault is available from boreholes TX-1 to TX-6 in the intake tunnel, with the most distant of these holes penetrating the fault TX-4 at Station 7 + 44. Based on the assumption of a linear slip gradient,

approximately 14 ft of slip was predicted for the fault at the TX-4 location. This figure corresponds to 4.1 ft of predicted vertical offset. Two ironstone bands (key beds) in the TX-4 hole suggest (but do not prove) an actual vertical offset of 3.8 ft, corresponding to about 13 ft of slip (Figure 1).

A tentative identification of the fault in TX-7 was reported by GAI (Gilbert) (Nov. 78) based on core recovery loss and clay at elevation 245 ft (Figure 2), although no anomaly was later observed on the WGC (Weston) velocity log. This depth was consistent with a straight-line extrapolation, using the observed fault dip from tunnel exposures and previous borehole data. No fault was later distinctly recognized in the nearby TX-11 hole to elevation -100 (depth 730 ft), despite the fact that improved multiple-tube boring techniques were used so that core-recovery loss would not have been the necessary basis for fault identification. If the fault indeed passes through TX-11, it must do so along a thin bedding plane segment associated with little damage to hanging and foot walls.

A possible bedding plane fault in TX-11 (Figure 3) may be interpreted on the basis of thin clay seams observed at 470-425 ft and 485-490 ft depths (elevation approximately 140-160 ft). Unfortunately these segments of core were disturbed, e.g. by impact of the flying gas-propelled core barrel on the drill platform, so that the interpretation of broken rock here is not unambiguous. A gas pocket at this elevation would not be inconsistent with a fault interpretation (indications of gas pressure were sporadically observed in TX-11, especially between depths of 310-510 ft). The interpretation is strengthened by the fact that the 155 ft elevation in TX-11 corresponds exactly to a straight-line extrapolation from the known location of the fault in TX-12 and its inferred possible location in TX-7. If this interpretation is correct, the fault extends at least 1150 ft in the dip direction.

Core loss in TX-7 is possibly explicable by drilling technique, and because of the uncertainties associated with TX-7 and TX-11, an alternative interpretation was considered, namely that the fault surface steepens toward the southeast. Drilling of an inclined borehole (TX-12) using a multiple-tube wireline technique was recommended in order to assess this interpretation. The TX-12 hole was drilled from approximately the TX-7 site, but angled 30° toward the northwest. A zone of broken rock and gouge (three seams, 1.5-3 inches thick) was found between depths of 376.0 and 380.4 ft (elevation approximately 300 ft) which undoubtedly represents the fault zone. This depth corresponds exactly to a straight-line extrapolation from tunnel exposures through TX-4, and therefore no significant curvature of the fault surface is indicated to the 300 ft elevation. Despite excellent core recovery, local stratigraphy could not be used to determine offset. Drilling continued to 420 ft with no further structural disturbances noted. From the data of TX-12, the fault extends along dip with certainty at least 600 ft.

The drill data available at present permit three interpretations:

(1) The fault terminates between TX-12 and TX-11.

(2) The fault passes through TX-11 along a bedding decollement perhaps at elevation 140-160 ft.

(3) The fault steepens between TX-12 and TX-11 (indeed, probably between TX-7 and TX-11) and passes beneath TX-11 giving a minimum average dip angle between TX-12 and TX-11 of 36°.

Hypothesis (3) is weakened (but not ruled out) by the lack of any significant concave-downward curvature between the tunnel exposures and TX-12. Hypothesis (2) is enhanced by the straight-line correspondence of fault elevations between the tunnel exposures and boreholes TX-1 to 7 and TX-12, and by the offset suggested by TX-4.

d. Mutual Geometric Relationships

The three tunnel fault structures display similar deformational style, magnitude of slip, slip gradient, moderately brittle deformational mode, and are clearly genetically related. The main discharge tunnel fault is very nearly on strike (044°) with the intake tunnel fault. The two exposures are in many respects virtually identical, and interpretation in terms of a "single fault" model is reasonable. (In an alternative model the two structures are considered as separate elements in an en-echelon system). The Station 11 + 50 discharge tunnel structure strikes so as to intercept the main discharge tunnel fault. Because of its smaller slip magnitude, it is interpreted as a splay fault to the main discharge fault.

Similar slip gradient on all three fault exposures (Figure 4; data were taken from the tunnel maps prepared by Weston), and the observed termination in the discharge tunnel, suggest that the structures have propagated from some lower elevation. This conclusion has a bearing on genetic interpretation. Furthermore, the slip gradient (about 4 ft of slip per 100 ft of fault) suggests that the principal intake and discharge tunnel faults will terminate within about 40 ft or so of the tunnel crowns as measured along the fault surfaces, or within roughly 20 vertical feet above the crowns. The faults therefore should not reach the elevation of the lake bottom. In this light the Lake Erie bottom video survey results seem understandable.

The discharge tunnel "splay", if projected eastward, intercepts the intake tunnel. No such structure was observed in the intake tunnel, which indicates that either the entire splay dies out towards the southwest, or that it is present below the intake tunnel but has terminated on an elevation below the intake tunnel invert. Either interpretation is consistent with observed evidence.

4. AGE OF FAULTING

Based on test results and visual observation the gouge is classified in soil mechanics terminology as a gray, stiff to very stiff silty clay with abundant sand and gravel-sized soft friable shale fragments.

Consolidation tests were conducted on two relatively undisturbed samples from the Intake Tunnel, and on one remolded slurry specimen. Plasticity limits and compression indices were similar for all three samples. Details are given in the Woodward-Clyde report of July 5, 1979, in Appendix VII.

Maximum past consolidation pressure (Pc) was estimated for two samples of the gouge by the standard methods of Casagrande (1936) and of Schmertmann (1955). The results are summarized as follows:

	P_c (tsf)				
Sample	Casagrande	Schmertmann	Cc' (unit strain)	PL	LL
I-2	8.0	12.0	0.110	18	27
I-4	4.5	6.0	0.112	19	28

The agreement of the two methods is considered satisfactory, and on the basis of these results the maximum past consolidation pressure of the gouge is taken as about 9 ± 4 tsf (say 125 ± 55 psi). For comparison, consider that the tunnel depth at the fault locality is about 110 ft. Ignoring the 15 ft of lake water above the top of rock, the corresponding total vertical pressure is about 119 psi (8.6 tsf). Average effective vertical pressure, assuming a standard fluid pressure-overburden ratio of about 0.4 is 71 psi (5.1 tsf). (The fluid pressure gradient assumed is about 0.43 psi/ft). This value falls near the lower limit of the estimated range of uncertainty for maximum past

consolidation pressure. On these grounds, while one could not conclude with certainty that the fault gouge was subjected to greater vertical pressure than that existing at the present time, the results suggest such a possibility.

If it is assumed that, because of erosion, present overburden thickness at tunnel level is less than the maximum value of overburden to which the fault at tunnel level had once been subjected, a vertical pressure of perhaps 6-9 tsf can be postulated for tunnel level under lake level conditions similar to those at present. If a prehistoric decrease in pore pressure is postulated, e.g. associated with lake drainage prior to the establishment of Early Lake Erie (470-ft level) at 12,000 YBP. maximum overburden pressure can be increased to about 9-12 tsf. The entire range of values (6-12 tsf) is consistent with gouge data.

The maximum past consolidation pressure estimated by the Casagrande method for upper and lower tills at the PNPP site is 4.3 tsf (average of 3 tests; range 4.0-5.0 tsf) and 6.0 tsf (average of 10 tests; range 4.3-10.0 tsf). (Appendix 21, Foundation Investigations and Design Analyses, PNPP).

The results indicate that both tills have been consolidated in the geologic past to pressures well in excess of the pressure imposed by present overburden (about 1 tsf). The probable loading mechanism is glacial ice.

Assume for the moment that the tunnel fault was present at the time the lower till was subjected to its maximum consolidation pressure of about 6 tsf. This corresponds to an ice sheet at least 200 ft thick. Pressure at tunnel level was about 5 tsf more, and eroded rock and till could account for about 1 tsf, for a total of 12 tsf.

This is within the range of consolidation test results for the gouge, and it could be argued that the gouge and lower till were subjected to maximum consolidation loads by the same event. The argument is strengthened by lending more weight to the Schmertmann-method calculations (which seems reasonable), or by assuming a higher fluid pressure-overburden ratio for the gouge.

A consistent argument can also apparently be given in regard to the maximum past consolidation pressure sustained by the upper till (4 tsf) to which must be added 2 tsf for assumed intervening till and 5 tsf for rock overburden. The estimated total of 11 tsf at tunnel level falls within the range of uncertainty for P_c of the gouge.

These arguments are summarized as follows:

(1) Hypothesis: Maximum consolidation pressure for fault gouge corresponds to present overburden.
Result: Pressure estimate at tunnel level is 5 tsf, near lower limit of range of uncertainty for P_c.
Interpretation: Hypothesis cannot be rejected but additional pressure mechanism seems likely.

(2) Hypothesis: Maximum consolidation pressure for fault gouge corresponds to conditions of pre-existing overburden or pre-existing groundwater conditions.
Result: Pressure estimate at tunnel level is 6-12 tsf, consistent with estimated values for Pc.
Interpretation: Hypothesis cannot be rejected.

(3) Hypothesis: Maximum consolidation pressure for fault gouge corresponds to maximum pressurization of lower till.
Result: Pressure estimate at tunnel level is 12 tsf, near upper limit of data range for Pc.
Interpretation: Hypothesis cannot be rejected.

(4) Hypothesis: Maximum consolidation pressure for fault gouge corresponds to maximum pressurization of upper till.

Result: Pressure estimate at tunnel level is 11 tsf, within range of uncertainty for Pc.

Interpretation: Hypothesis cannot be rejected.

The radiocarbon date of 14,480 YBP ± 310 derived from the lacustrine sediments over the upper till suggests that the upper till is at least as old as Hiram Till (14,500 YBP). (GAI Report No. 1997, Nov. 7, 1978). Compression of the Hiram Till could be accomplished by an ice sheet associated with the Hiram advance or by a younger ice sheet, corresponding to the Ashtabula Till (13,000 YBP). The lower till may represent the first part of an advance-retreat glacial deposition couplet, in which case it could correspond to the Hiram advance, or it may represent a separate late Wisconsinian movement. In the latter case, it could correspond to Lavery Till (16,500 YBP).

The late Wisconsin maximum is associated with Kent Till about 21,000 YBP with an end moraine 70 miles or so south of the PNPP site. Sugden (1977) suggests a thickness for this Laurentide Ice Sheet of 1 km at the PNPP site. Comparable advances also occurred during the early Wisconsinian (Titusville Till, ca. 40,000 YPB), the Illinoisan, and perhaps pre-Illinoisan (Lessig and Rice, 1962) times. The increase in overburden pressure associated with a 1 km thick ice sheet is on the order of 100 tsf. It is difficult to conceive of circumstances that would prevent such events from leaving a marked imprint on gouge consolidation characteristics, even granting uncertainty in the selection of appropriate fluid pressure-over-burden ratios and some redistribution of stress in the vicinity of the fault. I conclude that the formation of fault gouge was to a large extent, and perhaps exclusively, associated with faulting younger than the Kent advance. For similar reasons exclusively Paleozoic or early Mesozoic faulting can be rejected; several thousand feet of overburden corresponds to an effective overburden pressure on the order of 100 tsf. The possibility

of incremental fault propagation is not excluded, but this discussion is focused upon the last fault movement capable of forming new gouge or significantly disturbing pre-existing gouge.

On the above grounds, assuming the data as representative, the tunnel fault reflects significant movement younger than about 20,000 YBP. The data are consistent with compression of fault gouge by a lesser ice sheet than that associated with the Laurentide maximum. Three candidate ice sheets are associated with Lavery, Hiram, and Ashtabula Tills. The youngest of these is about 13,000 YBP suggesting that if the fault is related to a glacial mechanism, its age is probably in the range 13,000-20,000. But the mechanism of faulting is uncertain, so the 13,000 age is not a firm lower bound. The hypothesis that maximum gouge consolidation pressure corresponds to present overburden and fluid pressure cannot be wholly rejected by consolidation test data, but the data suggest the operation of additional effective vertical pressure mechanisms. Drainage of the rock mass at about 12,000 YBP yields a more consistent predicted pressure, as does the assumption of a greater prehistoric thickness of overburden. But lacking adequate data on erosion rates it is not possible to be very precise in the matter of a lower-bound age on these grounds. I would judge the minimum age to be on the order of several thousand years, but this is merely a guess. However, rock stress orientation information (to be discussed in the following section) suggests that the fault developed under different stress conditions than that in evidence today. On these grounds a lower bound of about 10,000 YBP is proposed. Finally, it would not seem surprising if, over the past ten thousand years or so the gouge developed a few cracks, and mineralization in extremely small amounts (such as reported by WGC) occurred within them.

This estimate of the age of the last movement of the fault differs by two orders of magnitude with a “minimum age” estimate of 1,000,000 yr offered by WGC, based on rate of microfracture “healing”. However, the lack of agreement is not disturbing to me because I do not believe that

there is an adequately demonstrated basis for the “mineral growth vs. time function” proposed by WGC for the PNPP site. Inasmuch as this function forms the foundation for the WGC age estimate, the accuracy of the WGC inferred age is open to serious doubt. By the same token, the age of faulting as based on the consolidation tests reflects certain specific assumptions regarding boundary conditions and material behavior. Error is possible to the extent that actual behavior differed from that assumed. These aspects are discussed below:

(1) There is considerable precedent in the use of consolidation tests to establish past consolidation pressure. The adequacy of the method has been tested in civil engineering practice (e.g., Casagrande and Fadum, 1944; Zeevaert, 1953; Schmertmann, 1955). There is also precedent in the interpretation of past consolidation pressure in terms of geologic history, and in instances in which the maximum past consolidation pressure has been reliably determined by geologic evidence or other independent means, agreement between the actual maximum past consolidation pressure and that determined by consolidation tests on “undisturbed” samples has been quite satisfactory (Terzaghi and Peck, 1967, p. 77). There is also precedent for quantitative determinations of ice sheet thickness from consolidation test data, both in Europe and in North America (e.g., Kogler and Scheidig, 1948; Dücker, 1951; Harrison, 1957, 1958).

(2) The “sealed” block samples, from which the test specimens were prepared, sustained moisture loss during storage. The effect of water loss is commonly to produce intergranular stresses within the samples, which could lead to an overestimated value of past consolidation pressure. In the present instance no interpretive problem arises from this possible effect.

(3) Lateral strain and squeezing of gouge at the time of faulting seems likely. Therefore the early strain history of the gouge may be described as complicated. However, the strains associated with

subsequent vertical loading conditions, such as burial by ice, meet the standard assumptions associated with consolidation testing. The assumption of zero lateral strain associated with ice sheet compression seems valid, at least to a reasonable approximation.

(4) Because fault gouge exhibits a complicated strain history, it is possible that its past-fault consolidation characteristics are not necessarily identical to those of similarly-graded sediments of different origin. There is little information in the published literature to directly assist interpretation of the matter of fault gouge consolidation. On the other hand, silts of similar grain size gradation which have been contorted by the directional drag of overriding ice have been subjected to consolidation testing, and glacially-induced distortion of this kind seems reasonably analogous to disturbance by faulting. The directional stresses and associated strains in such disturbed silts were shown by Harrison (1958, p. 77) not to have affected the maximum past consolidation-pressure value induced by the thickest over-riding ice sheet.

(5) Pore water under pressure must be permitted to drain away during consolidation. The hydrostatic pore pressure distribution observed in most boreholes in shale in and near the PNPP site lend support to this assumption.

Because of the drainage factor, there may also be an effective upper limit to the distance from a glacial margin over which past consolidation pressures can be accurately determined (Harrison, 1958, p. 77). But in Indiana, this distance seems to be no smaller than about 30 miles (associated past consolidation pressures are about 50 tsf) (Harrison, 1958, p. 81, 83), suggesting that this factor does not pose a problem.

(6) Is the gouge so old that soil mechanics tests are no longer applicable, e.g., has the bulk material sustained changes due to aging

such that consolidation characteristics have been altered? The answer appears to be, no. Successful preconsolidation estimates by consolidation tests have been conducted on materials of Tertiary age. Tills and lake silts overridden by four oscillations of the Wisconsin ice margin were subjected to consolidation tests by Harrison (1958), and the past consolidation pressures thus established were used to reconstruct a paleoglacier map of the vanished East-White sublobe of central Indiana. There is no indication of diagenetic changes or significant chemical changes in the gouge material that would significantly alter consolidation properties. Further indication is that compression indices for undisturbed and slurry samples are identical. The consolidation behavior of the surface tills (which are also are comprised mainly of comminuted shales) is similar, and the past consolidation pressures established by consolidation tests of tills are consistent with the data obtained from tests on fault gouge.

(7) The bulk laboratory samples were not specifically orientated, but the prepared consolidation test samples are considered to be approximately horizontal (±15°) based on bulk sample shape and size and location sampled.

(8) As described in Section 3 of this report, the fault itself is not horizontal, but is comprised of a series of irregular steps with local dips varying from zero (parallel to bedding) to about 20° on riser surfaces. Gouge thickness is not uniform. One may therefore question whether or not the maximum pressure exerted by overburden and an overlying glacier is transmitted everywhere to the gouge, because of "arching" (stress concentration) effects.

My personal opinion is that severe arching effects associated with the distribution of vertical pressures in this case are extremely local. The slight average dip of the fault surface (15-17°) does not favor the development of vertical stress arching over large domains. (Horizontal stresses may be a different matter entirely). The shale strata of the

hanging wall have been disturbed (fractures, splays, etc.) to distances as great as 10 feet as measured perpendicular to the fault surface. The shale is wholly thin bedded, and there is evidence that the shear strength parallel to bedding is small. Evidence for bedding plane slip is observed where minor bending has occurred. Splay faults and fractures are common; thin gouge seams are associated with the fractures. The hanging wall rock mass is therefore weak and very flexible.

Therefore the capability of the bulk material to sustain significant horizontal shear stresses as required in order for significant arching to occur seems slight. Those portions of the fault zone characterized by broad patches of gouge, several feet long and several inches thick, are thus likely to be subjected to, at least to a first approximation, full overburden pressures.

The consolidation results themselves lend some support to this view. The gouge consolidation tests are internally consistent in that two separate samples from different locations produced results that are in good accord, with respect to consolidation behavior and past consolidation pressures. They are externally consistent in comparison to calculations considering present overburden pressure, and to pressures inferred from extensive consolidation testing of near-surface glacial tills. The burden of proof would seem to reside with those who might doubt the gouge results because of the possibility of nonrepresentative behavior associated with arching. Further sampling and testing is of course possible, although only at considerable effort and expense.

To conclude this section, it must be acknowledged that not all possibilities for error have been absolutely eliminated. Still, on balance, in my opinion the best available estimate of the age of the last movement on the fault is that provided by interpretation of the

consolidation test data for the fault gouge. Accordingly, the last movement of the fault probably occurred no more than 20,000 yr ago, and the age for this last movement is estimated at 15,000 YBP ± 5000.

5. ROCK STRESS INVESTIGATIONS

a. Orientation and Magnitude of Stresses

A program of stress measurements was strongly recommended, because I considered it incautious to select or render judgment on design details to ensure safety against possible fault displacement without adequate information on rock force fields.

The test program was carried out at my recommendation by J.C. Roegiers and associates using the hydrofracturing technique. I was at the PNPP site at the time the measurements were carried out at TX-11 and I am satisfied that the results obtained represent a state of the art capability.

This discussion is based on the data contained in the preliminary report by J.C. Roegiers and J.D. McLennan, dated July 1979, and subsequent telephone conversations. Details of the stress investigation are given in Appendix IV, and a summary of results is provided in Table 1.

The direction of maximum compression is east-northeast. The result on stress orientation was not wholly unexpected because stress orientations in western New York and southern Ohio were known to display similar trends (Figure 5). Specific tests at the PNPP site were nonetheless considered necessary in the interests of safety. Figure 6 is a sketch map which illustrates the relation of the tunnel fault and other structures to various stress fields. Stresses at (a) and (b) refer to stress orientations theoretically associated with a northeast-striking thrust with (a) the condition just prior to faulting, and (b) the condition after faulting has occurred, with the northwest stress system diminishing to some residual value. The northeast stresses remain relatively unchanged, but because in (b) they are greater than the relaxed northwest stresses, the assignment of principal

stresses changes. As a result of faulting, the assignment of σ_1 is changed from the northwest to the northeast. Still, the two principal stresses in map view are orientated perpendicular and parallel to the fault strike, for both conditions (a) and (b).

The measured stress orientations in the hydrofracturing program suggest an average azimuth for σ_1 of 076°; neglecting the measurement of Fracture 7, the mean value is 085°, and the range of four values is 067° to 100°.

At face value the 085° orientation of σ_1 is evidently not compatible with the formation of an 050° thrust either by the analogy in Figure 6 of (a) or (b), by directed pressure or stress-relaxation. There is no evidence of strong anisotropy in the rock mass which would permit structures to form at high obliquity to principal stresses. The present 085° orientation of σ_1 thus suggests that the local stress system formerly associated with the development of the tunnel fault has been altered. The stress field at the PNPP site closely corresponds now to a regional field that apparently extends from the upper Mississippi Valley area to New York. The tunnel fault is therefore considered to be older than the age of this regional stress system. Without doubt Pleistocene ice loading profoundly altered the stress systems in the upper crust, and the present stress system is considered to have developed following retreat of the ice sheet. A stress system associated with ice-deformed crust seems consistent with that inferred for the tunnel fault. A minimum age for faulting is therefore suggested, viz. on the order of 10,000 YBP. This is consistent with the interpretation of fault age based on gouge consolidation tests, and leads to an estimated age of 10,000-20,000 YBP.

The poorly defined fractures at 037° indicated for Fracture 7 differs from the 085° average from Fractures 3-6. This orientation permits an interpretation in terms of Figure 6(b), with 037° not greatly different from the strike of the tunnel fault. Fracture 7 lies above

the proposed intersection point of the tunnel fault with TX-11, so that it may be possible to formulate an argument in regard to behavior of the hanging wall as distinct from the foot wall. On the other hand, it may be simplest to interpret Fracture 7 as influenced by pre-existing joints. The pole maximum of 220 foundation joints as compiled and plotted by WGC is associated with 044°, with 037° lying within the range of significant pole concentrations, e.g. 026-054° (Figure 7).

Details concerning stress magnitudes must be interpreted with caution due to complex fracturing sequences associated with hydrofracturing. These sequences renders difficult the estimation of instantaneous shut-in and breakdown pressures. Some uncertainty must therefore be attached to the individual principal stresses σ_1 and σ_2 calculated from these selected critical pressures.[(1)]

The average values probably give a true indication of average stress conditions at the site. For the full depth range of 394-718 ft, and rounding off values to the nearest hundred psi:

maximum horizontal stress = 1500 psi = σ_1
minimum horizontal stress = 900 psi = σ_2
vertical overburden stress = 400-800 psi = σ_3

Similar values have been determined in other engineering and mining sites (including nuclear power plants) in Ohio, New York, and southern Canada.

Furthermore, despite uncertainties associated with individual measurements, certain trends seem to possess validity. The gradient of

NOTE:

[(1)] σ_1 and σ_2 are assumed to be in the horizontal plane.

σ_2 below about 500 ft seems to parallel that for overburden pressure, such that approximately $\sigma_2 = \sigma_v + 250$ psi (Figure 8). Some uncertainty must be attached to the Fracture 7 calculations; tabulated values based on $\sigma_2 = 1137$ are considered as upper bounds. If the orientation of Fracture 7 is considered controlled by pre-existing fractures, with actual σ_1 oriented at 085°, a range of values seems compatible with the data, viz. σ_2 = 730-1137, σ_1 = 1450-1137. Despite this uncertainty, Fractures 7 and 8 suggest possibly greater values of σ_2 than at lower levels; higher than average σ_1 values are also evident for Fractures 6-8. To a certain extent σ_1 reflects the selected values for σ_2, so that trends exhibited by the two principal stresses are not wholly independent.

Extrapolation of stress values to higher elevations is uncertain because of the apparent increase in stress between 511 and 394 ft. Estimation of σ_2 above 394 ft based on extrapolation of the data trend from Fractures 1 to 6 is considered to be a lower-bound. Upper-bound values are not clearly defined.

The reason for the apparent increase in stresses at and above 511 ft is not clear. One possibility, however, is that the tunnel fault indeed passes through TX-11 between Fractures 6 and 7. Higher horizontal stresses could therefore be interpreted as stress concentrations associated with this fault. One alternative possibility is to consider the high values as stress concentration effects below a downward-terminated stress-relief fault.

b. Possibility of Future Slip on Existing Fault

Consideration of this important matter is examined by comparing rock stress information to rock strength.

The value of horizontal stress in the vertical plane perpendicular to the tunnel fault ($\sigma_{H \perp F}$) was calculated from selected stress values

and θ_1 orientations as given in Table 1, assuming an 050° azimuth for the tunnel fault. Subtracting out formation pressure, effective stress values for the vertical plane perpendicular to the tunnel fault $(\sigma'_V, \sigma'_{H\perp F})$ are given in Table 2 and plotted in Figure 9. The average value of the horizontal effective stress $\sigma'_{H\perp F}$ is about 800 psi.

Stresses for Fractures 6-8 are greater than those for Fractures 1-5; the trend appears similar to that previously discussed for principal stresses. The specifics for Fracture 7 are uncertain, depending on interpretation of the 037° fracture orientation. Accordingly, $\sigma'_{H\perp F}$ for Fracture 7 could be as low as 669 psi.

Extrapolation of stresses to shallow elevations is uncertain. Data for Fractures 1-5 permit a lower-bound estimate. A reasonable estimate would appear to be the average of stresses calculated for Fractures 7 and 8. An upper-bound is not well defined.

Vertical effective stresses are given by average overburden pressure in psi (taken as 1.1 x depth in ft), subtracting out formation pressure (Table 2).

Consolidated-undrained triaxial compression tests with pore fluid pressure measurements, or other test methods appropriate for measuring the effective stress strength parameters, were not conducted owing to lack of suitable samples. The effective angle of internal friction for the fault gouge has been estimated at 30-37° based on published correlations (Woodward-Clyde Consultants, letter of November 20, 1978). This is also consistent with plasticity limit correlations (Voight, 1973). The increase of apparent friction angle at low confining pressures associated with roughness of the fault surfaces is estimated at 10°.

A conservative estimate of strength for a given segment of the fault zone is given by zero-cohesion envelopes inclined at 40-47° in a

sheer stress-normal stress diagram. These envelopes are lower-bound estimates inasmuch as additional strength may be obtained, e.g. through cohesive resistance.

These strength envelopes are plotted in Figure 10 along with Mohr circles which represent assumed conditions in the vertical plane normal to fault strike. For each circle, the overburden stress and an estimate of the $\sigma'_{H\perp F}$ horizontal stress is plotted. All stresses are "effective" values corrected for fluid pressure. Numbers attached to the stress circles are hydraulic fracture identification numbers. In addition, stress circles are estimated for the 335 ft level, corresponding to the tunnel fault positively identified in the TX-12 borehole, and for tunnel level. Minimum normal stresses which correspond to observed and inferred fault depths (in various boreholes) are noted on the horizontal axis.

Results are as follows. Stresses associated with Fractures 1-5 permit construction of a stress envelope well below minimum strength. The stress circles associated with Fractures 6-8, which include conservative stress estimates, are larger in diameter but lie within the field of stability. These circles bracket conditions for the possible location of the tunnel fault in TX-11. Similar stresses are predicted for TX-12 at fault depth, using the average stress value from Fractures 7 and 8, as a conservative estimate of $\sigma'_{H\perp F}$. The TX-12 circle therefore also lies within the field of stability. The inferred stress circles for tunnel level lie approximately tangent to the minimum strength envelope (lower-bound stress estimate) or slightly above it (more conservative stress estimates). This suggests that either the lower-bound stress estimate is correct, the actual strength envelope is positioned somewhere above the minimum strength envelope, or both. Indeed, the second argument is probably true.

The conservative interpretation is to suggest that stresses along the tunnel fault may be relatively marginal in terms of strength for a limited range of depth, viz. about 100-200 ft.

Below elevation 300 ft stresses are less than minimum strengths, so that the fault plane may be considered to be “clamped” by friction. From this viewpoint no motion seems possible below elevation 300 ft, and if so it may be academic whether or not the fault terminates between TX-12 and TX-11 or passes through TX-11.

Above the 100 ft depth the fault terminates, and a buttress of relatively less deformed bedrock perhaps 70 ft thick is inferred to be present between this termination and the lake bottom. Rupture of this buttress would require stresses measured in thousands of psi. The actual stress conditions within the buttress are not known. However, because deformation of the buttress would be required for significant fault slip to occur over the 100-200 ft depth range, the possibility of renewed fault slip seems small and probably could not be caused by small increases of boundary stress or of pore fluid pressure, or small local decreases in rock strength.

On balance the stress data suggests that the tunnel fault should probably not be regarded as “capable” despite its relatively youthful age.

6. REGIONAL STRUCTURAL FRAMEWORK

In the following sections, the regional tectonics for the area surrounding the PNPP site is briefly reviewed. The purpose of the review is to provide a framework for discussion of the origin of the tunnel faults and an examination of regional seismic patterns.

a. Structure under Lake Erie

Reconnaissance aeromagnetic studies by Myers (1977) and Ahern (1975) of Lake Erie suggest a pattern of discontinuous, narrow, approximately symmetrical 200-800 gamma positive anomalies aligned in a general east-west or E-NE trend. Details of contour configuration will undoubtedly change as additional data tracks become available, but analysis in broad terms seems justifiable with present data. Axes of the largest two anomalies are respectively located 7 and 30 miles offshore, north of the PNPP site. The anomaly nearer to the site has a maximum value exceeding 300 gammas and extends 40 miles or more along a trend of about 060°. The second of these anomalies has a maximum value over 800 gammas near its eastern end, and extends westerly for a similar distance. Models show that the observed anomalies could result from structurally-controlled intrusions composed of peridotite or gabbro of average magnetic susceptibility intruded along an E-W or NE-SW fracture zone during a magnetically normal epoch (Myers, 1977, p. 96). The anomaly source rocks could be clusters of stocks, sills, and dikes, rather than a single unit. Myer’s estimate of time of intrusion is Mesozoic, based on intensity of remanent magnetization. Dike and linearly-aligned pluton cluster trends suggest that extensional stress directions in the northeast shifted from northwest to north or northeast between Early Jurassic and Early Cretaceous time (McHone, 1978). The north-south extension direction inferred from the magnetic anomaly trends suggests an approximate age of 125-160 mBP, which supports Myers’ estimate.

Gravity anomaly distributions as given by WGC complement the magnetic data, and support the concept of a possible system of faults with northeast trend located just offshore from the PNPP site and extending tens of miles southwestward, virtually parallel to the shoreline. This trend corresponds with a straight-line segment of the Lake Erie shoreline southwest of the PNPP site, which M.J. Clifford (personal communication, 1979) considered as a possible (but unproven) reflection of structural control. Other high-gradient gravity anomaly areas within a 50 mile radius of the site conceivably could reflect faulting; there is a correspondence between observed surface faults and gravity contours in the Lake Erie region (e.g., Electric fault, Bowling Green fault).

b. Structure of Southwest Ontario

In southwest Ontario, normal faults with throw of 100 ft or more occur predominantly in east-west (Electric, Dawn faults) and north-south (Clearville, Willey faults) trends. The faults penetrate basement rocks and penetrate the Paleozoic section. Accumulation in lower Paleozoic oil and gas fields is structurally controlled.

The east-west trending Dover “syncline” south of the Electric fault is also of interest. Oil accumulation occurs in a structural depression containing porous dolomitized Ordovician limestones, a feature resulting from migration of Mg-bearing solutions through faults and fractures. The syncline structure reflects some faulting, but mainly is due to solution-influenced subsidence (Figure 11). The structure is of special interest inasmuch as it documents the relation of pre-existing structure to a solution feature. At Dover, deformation in the Upper Ordovician and above mainly reflects the geometry of zones of intense leaching which in turn reflects old structure. Analogous deformation may be present associated with the Salina, south of Lake Erie. The geometry of the zone of deformation at the Cleveland Salt Mine is not unlike Figure 11.

c. Structure South of Lake Erie

Much of what is known is based on information from oil and gas wells.

Structure contours indicate in Portage, Mahoning, and Columbiana Counties (40-60 miles south of PNPP site), structures with northwest trend and length up to 10 miles. They are probably faults but none has actually been drilled through. The structures were apparently active during the Paleozoic. Subsurface structure mapping tends to focus on "larger" structures that show up despite inadequate well-head elevations; low amplitude structures (closure or displacement <20 ft) are indistinguishable from apparent structure due to inaccurate well-head elevations (A. Janssens, personal communication, 1979).

In addition, local structural closures have been mapped on the Onondaga (Devonian) Limestone. As far as is known these structures are not present below the salt, and Janssens has presumed that the features may reflect post-depositional salt movements resulting in local "domes".

No regionally-mappable feature based on well control has been recognized at the PNPP site (although well control in the vicinity of the site is not particularly dense).

A small normal fault with easterly strike has been reported in the Fairport Harbor Salt Mine. A set of normal faults has been reported at the Cleveland Salt Mine (Jacoby, 1970; Heimlich et al., 1974). I visited this site in the company of L. Schultz in April 1979. The overall structure appears to be a NW-trending asymmetric "syncline" or "graben", in which the salt beds have deformed mainly by flowage, whereas dolomite beds have deformed by brittle fracture and faulting. Vertical offset is reported as 47 ft; this offset is distributed over a distance of 200 ft or so on the western border, and over a wider

distance on the east. Formerly open fissures are now filled with salt. No evidence of recent tectonic movement was observed.

I interpret the structure as a feature which developed over a period of time in association with withdrawal of subjacent support. The cause of the loss of support is not known from available evidence, but could reflect either the local tectonic development of a graben or a structurally-influenced solution channel. Smaller scale (to 6 ft diameter) solution channel features are present in the mine (see Heimlich et al., 1974), and at the moment I prefer the latter interpretation. In this regard the Dover "syncline" in southwest Ontario seems in many respects analogous.

A small normal fault with easterly strike has been reported in the Fairport Harbor (Morton) Salt Mine. Figure 12 shows a minor graben structure from the Grand River access shaft near the top of the salt. The salt beds show no displacement by faulting, but top beds of salt have been locally removed by solution. Normal faults with about a foot of maximum slip affect overlying beds. The observed fault slip directly reflects solution. On the other hand, the salt beds are themselves bent below the fault, suggesting that the solution sites may have been influenced by pre-existing structure.

In Ashtabula County, a structural "nose" has been defined by well control. Its location is indicated by the 2300-2500 contours of the lower Silurian Packer Shell carbonate unit, which has a northeast trend. Structural relief may be about 50-75 ft, with relative displacement upwards of the southern block. This structure can also be mapped on older rocks, down to basement, and on Devonian formations as well (A. Janssens, personal communication, 1979). Its movement history may be very complex.

There has been no certain identification of Alleghanian structures in northeast Ohio, but the Cambridge Arch structure in

east-central Ohio has been attributed to horizontal thrusting (slip on the order of 1 mile) above the Salina E Salt (much as the Burning Springs anticline in West Virginia is associated with a Salina F-4 decollement (Clifford and Collins, 1974, AAPG Bull. 58:1891; Janssens, Deyling and Ott, 1976, AAPG Bull. 60:1621). The NNE-trending Cambridge Arch follows the "pinchout" of the E salt. In northeast Ohio, the "pinchout" boundary swings generally ENE (Clifford, 1973, Ohio Geol. Surv. Rept. Inv. 90) passing by at least 8 miles south of the PNPP site. This is about the trend and position noted for the Ashtabula County "nose" structure, and it is possible that the stratigraphic "pinchout" was structurally influenced. Local "pinchout islands" occur within the area of E salt deposition, one of which occurs 25 miles south of the PNPP site. Such "islands" should have impeded movement on an E salt decollement. Still, accentuated arching and local thrusting in the vicinity of the Ashtabula "nose", related to E salt decollement tectonics, cannot be ruled out. Decollement jump to the F-1 salt which extends under the PNPP site also seems possible.

d. Relationship of Inferred Structure to Seismicity

This discussion deals basically with the seismic data base presented by MGC (the April 19, 1979 version of Appendix VIII). The main revision involves the March 1943 earthquake, now regarded as an event of approximate magnitude 4.7, located at 41.61N, 81.33W (D. Gordon, and G. Leblanc, personal communications, 1979).

Figure 13 is a map containing inferred epicentral locations and twenty possible zones of structural weakness as inferred from aeromagnetic data, Bouguer gravity anomalies, oil and gas drill information, and geologic mapping. A word of caution: it should be emphasized at this point that not all of these features are of proven tectonic origin. Whereas features suggested by mapping or oil and gas drilling are perhaps more likely tectonic in origin, alternative explanations may indeed apply to anomalies recognized from gravity or

magnetic patterns. Accordingly, to emphasize this uncertainty trends indicated by oil and gas or mapping data are indicated by dashed lines, and trends suggested by geophysical trends are dotted. Still, studies elsewhere have shown that earthquakes observed in conjunction with gravity anomalies commonly occur in high gradient areas (Hintze et al., 1977, p. 50, and cited references). This association may reflect fault reactivation (resurgent techtonics) or crustal rigidity variations effecting strain energy release patterns. Data concerning these anomalies are tabulated in Table 3.

Earthquakes possibly associated with each anomaly are also noted, with due allowance made for epicenter and structure location uncertainties. As suggested in WGC reports, to most epicenters must be assigned a relatively large uncertainty, e.g. a "radius of uncertainty" of 10 miles or so, sometimes more. Nevertheless, it is considered that the historical seismicity data, interpreted with care, provide valuable insights on the spatial distribution of seismic activity and its relation to inferred geologic structure. Epicentral uncertainties were expressed as radii mainly using values given by WGS (Appendix V, Evaluation of Local Seismicity around Perry Nuclear Power Plant Site) dated April 10, 1979. A radius of 10 miles was used where uncertainty was unspecified. To the 1858 epicenter is attached an eastward uncertainty of 20 miles.

Earthquakes are listed in association with all anomalies mapped within a "circle of uncertainty" surrounding the plotted epicenter. By this tabulation procedure, it was possible to separate anomalies which have essentially no association with seismicity from those which display a possible association. Table 4 identifies six anomalies which are considered to possibly represent zones having potential for seismicity within a 40 mile site radius (see also Figure 14).

Earthquake epicenters located <u>nearest</u> to a given anomaly are identified by underlined dates. Thus of eleven earthquakes registered for Anomaly 14-15, three epicenters are closer to this anomaly than to any other, six are considered rather close, but are at the same time equally close to other anomalies (the date is half-underlined), and two contain the anomaly within their radii of uncertainty, but are closer to other anomalies. A fairly strong argument can be made concerning the interpretation of this anomaly as a potentially seismic structural zone. No recent deformation is however in evidence at the Cleveland Salt Mine through which the anomaly passes, although the structural trend is reinforced by oil and gas well data. Any recent deformation along this inferred zone of structural weakness near Cleveland must occur at some different spatial location.

In contrast, Anomaly 3 lists only five earthquakes, only one of which is underlined. This (1858) event is not well located. As regards the others, 1857 is not well-located, 1943 is well-located but its connection with Anomaly 4 seems strong, and a 1955 (2) connection requires extrapolation along strike. In sum, a correlation of Anomaly 3 with seismicity is not well-founded. This is significant in view of its proximity to the PNPP site and its possible connections with Anomalies 13, 1-2 and 4.

Anomaly 13, identified mainly by oil-gas well data but possessing gravity anomaly attributes as well, registers four earthquakes. Two dates are underlined. The structure may continue westward (data is sufficient to establish its termination). This is the Ashtabula County "nose".

Seven dates are assigned to Anomaly 5, five of which are considered rather closely juxtaposed. Most of this activity is from the Cleveland area, where Anomalies 5 and 14 apparently intersect; Anomaly 1-2 perhaps intersects Anomaly 5 just offshore. Assignment of individual epicenters near Cleveland to specific anomalies is therefore not straightforward.

Both the magnitude 4.7 1943 earthquake and the 1951 Willoughby earthquake have been instrumentally located and are correlated with Anomaly 4. The 1955 Aurora earthquakes occur about on strike near the apparent southern limit of Anomaly 4.

Eleven earthquakes are listed for Anomaly 1-2, which approaches the PNPP site near its eastern boundary. However, many of the earthquakes listed are associated with the large regions of uncertainty for Cleveland area earthquakes. These epicenters are mostly plotted at near-shoreline locations, although the actual epicenters may in some cases be located under Lake Erie. The lack of "underlined dates" tabulated for Anomaly 1-2 could reflect this bias.

In sum, correlation with seismicity seem reasonably good for Anomalies 4,5,14-15,13, weak for Anomaly 3 and uncertain for Anomaly 1-2. Nearest strongly-correlated anomalies to the PNPP site are Anomaly 13 (12 miles) and Anomaly 4 (18 miles). The PNPP site itself lies within the circle of epicentral uncertainty only for the poorly-located 1858 earthquake.

But it must be observed that the "good correlations" referred to have not confirmed the reality of specific structures associated with the various anomalies, although our suspicion regarding them is enhanced. Seismicity in the greater Cleveland area is poorly understood, and the above correlations were attempted in the hope of merely providing a first approximation of the relation between seismicity and tectonics. Indeed, seismicity in the eastern United States remains poorly understood even in regions where active instrumental research has been conducted.

Finally, the relationship of structures inferred by anomalies to measured stresses is discussed. It is assumed that earthquakes occur on preexisting unhealed faults that are preferentially orientated within a region of (approximately) uniformly oriented stresses.

There is justification for assuming that the orientation for σ_1 is a representative regional orientation.

Anomalies 4 and 5 are approximately orthogonal to this stress trend, suggesting the possibility of thrust faulting in basement of the greater Cleveland area on N-S striking faults with shallow or moderate E or W dip. Thrust faulting of a possibly analogous nature has been reported from Attica, N.Y., and from Blue Mountain Lake in the Adirondacks, based on fault plane solutions from earthquakes. No fault plane solutions are available for earthquakes in the vicinity of the PNPP site region.

Slip can be expected to occur on preexisting faults lying within about 10-50° of σ_1, depending on the specifics of frictional coefficients. If faulting occurred on Anomaly 14-15, a left-lateral strike slip component could be expected. Similarly, motion on structures associated with Anomalies 3,13 or 1-2 would probably involve significant right-lateral strike slip motion. These predicted motions are clearly unlike those inferred for the tunnel faults. There is no evidence that favors a connection between the seismic and existing stress patterns in the greater Cleveland area and the PNPP tunnel fault.

7. ORIGIN OF TUNNEL FAULTS

Table 5 contains a relatively complete list of possible mechanisms considered in relation to the tunnel faults. These are grouped according to age. Apart from the evidence on age, distinctions between, on the one hand, faulting associated with differential warping mechanisms of Paleozoic or Mesozoic age, and Alleghanian compression on the other hand, would be based primarily on geometry. Geometric data on tunnel fault strike and shallow-level dip are available, but the extent of the fault remains uncertain. Sufficient data is not available to firmly establish whether the fault simple dies out to the southwest, steepens in attitude to merge with a high-angle basement fault, or merges with a bedding-plane decollement, perhaps at the level of Salina salt. Discrimination among all hypotheses is thereby rendered difficult.

As discussed previously, I believe the tunnel faults to be of Pleistocene age and the range of possibilities can therefore be reduced. A few comments seem nevertheless appropriate for other categories, inasmuch as Pleistocene deformation could be influenced by older structural features.

Regarding mid-Paleozoic deformation, the concept of sediment deformation can be conclusively ruled out by the brittle nature of the observed deformation. The tunnel fault formed following lithification of the shale sequence.

Differential compaction over buried reefs seems a potential mechanism for production of deformational structures, but to my knowledge the subject has not been previously discussed for this region. Leaching and collapse on a large scale has been discovered, particularly in relation to patch and pinnacle reefs in southwest Ontario. Elongated

collapse features have resulted from fault or joint influenced solution. The most extensive period of leaching occurred before the lower Devonian (Sanford, Geol. Survey Canada, Paper 65-9), although post-Devonian leaching is not rare. But reefs of significant dimensions do not appear to be present in the near-site region; reef-associated differential compaction or solution collapse mechanisms are not likely related to PNPP faulting, directly or otherwise.

Southeastward gravity movements on Appalachian Basin salt is a new concept, and cannot be addressed in much detail. No features described in the literature seem to clearly indicate such a mechanism on a large scale. But the salt beds extend from the Appalachian to Michigan Basins in a swath about 60 miles wide, so that for a limited region (which includes the PNPP site), such a mechanism would seem technically feasible. Most of the individual salt layers show however no such regional continuity, but the B salt is a possible candidate.

Local mine exposures do display evidence of dome-like fold growth in selected salt layers, and sporadic structural "domes" are in evidence within the general region of the PNPP site, so that some activity of the salt is in evidence. The Cambridge Arch- salt decollement association is further evidence for this. Activity of the salt is judged to have been most likely in late Paleozoic or early Mesozoic time, when overburden pressures and formation temperatures were about at peak values. Relatively high loading conditions were also probably associated with Pleistocene glaciations, with high stress gradients near ice sheet boundaries. It is possible that "domes" formed under these conditions and were somewhat elongate parallel to the ice sheet border. But available time for flowage was relatively brief, and temperatures may not have been very high.

With differential warping is commonly associated local faulting, usually of a dip-slip high-angle nature, in which preexisting zones of weakness are mobilized. Such fault movements with east or

northeast trends have been documented in the general region, both in Ontario and south of Lake Erie, and some of the anomalies previously discussed may reflect such features. When movements on deep high-angle discontinuities disturb overlying sedimentary formations, faulting in the younger formations can proceed with progressively decreasing dip angle. Thus shallow low angle thrusts (as observed at the PNPP site) are compatible with high-angle dip-slip movements at depth. Variations in fault dip depend on the specifics of the initial geometry, ambient stress conditions, boundary (displacement) conditions, and material properties, including anisotropy. In this regard, the observed influence of anisotropy for the tunnel faults (alternating shifts from bedding-plane to riser segments along the faults) would be expected to occur in any shallow thrust propagating through anisotropic shale. It should not be considered as evidence favoring a deeper similarly-styled mode of decollement tectonics rather than deeper high-angle faulting. High-angle basement faulting associated with proposed Mesozoic rifting would, however, tend to produce normal faulting in overlying formations, not thrust faults. But younger recurrent movements on such rift faults under different ambient stress conditions could indeed promote high-level thrusts, as discussed above.

The geometric extent of the tunnel fault is not known well enough to establish whether it is a discrete, shallow level structure analogous to features commonly classified under the category of "pop-up", or a shallow-level segment of a larger feature that extends directly or by en-echelon development to some deeper level, possibly to connect with some older fault or zone of structural weakness.

"Pop-up" structures may form at any time; some have been observed in the process of formation, whereas many are Pleistocene in age, associated with surficially-high stresses related to glacial[(1)] or glacio-isostatic adjustments. Under these conditions, genetic category 3e can be regarded as a sub-class of 3c or 3d.

Rock deformation by direct glacial loading has occasionally produced thrust structures in bedrock elsewhere to the depth observed at the PNPP site, but the direction of fault slip has invariably been in the direction of glacier flow. The geometry of features associated with the PNPP tunnel fault suggest growth from a lower to an upper level (toward the north), and slip gradient suggests termination of the fault well below lake bottom. This evidence argues against an origin through direct drag of an overriding ice sheet.

Significant crustal warping occurs due to glacial advance and retreat (glacio-isostasy). A fault produced by a major glacial advance would be subjected soon afterward to loading from the overriding glacier. But an imprint of this event should then be left in the consolidation behavior of the gouge.

In particular, intense faulting, fracturing, and seismic activity have been attached to the deglaciation phase, when the glacio-isostatic uplift rate is near its maximum (Morner, Geology, 6:41-45). This mechanism is clearly consistent with the age estimate of 20,000-10,000 YBP for the last movements on the tunnel fault, for this time represents deglaciation from the Laurentide maximum ice sheet.

In general terms I prefer the hypothesis of fault motion due to differential rebound associated with retreat from the Laurentide

NOTE:

(1) Horizontal stresses of considerable magnitude can be built up by cycles of glacial loading and unloading (cf. Voight, 1966; 1967, pp. 337-340).

maximum. Surficial stress relief, considered in these terms to be a subclass of glacial rebound, remains viable inasmuch as the extent of fault is uncertain.

If simple, near-surface stress relief has occurred, nucleation of the fault may presumed to be somehow related to stress and pore fluid (water and methane) pressure gradients within the Devonian shales. The alternative is that fault growth has been influenced by (probably recurrent) movement on deeper seated fractures or faults, either by direct propagation or by en-echelon deformation. The strike of the tunnel fault would then be conditioned in large part by the strike of the pre-existing feature. The possibility of nearby subsurface structural features of northeast strike is suggested by the anomaly maps, lending weight to a hypothesis in which motion on the tunnel faults were directly produced or were influenced by recurrent movements on old faults during deglaciation rebound. The salt tectonic mechanism is not rejected, but seems less likely in view of its somewhat exotic nature.

Finally, neither the age estimate as noted above, nor the observations of the fault zone preclude a more complex, possibly hybrid mechanism of fault development. Because emphasis in the above discussion has been placed on the last significant motion, two possibilities seem open: either the fault nucleated and propagated entirely within the 10,000-20,000 YBP range cited above, or nucleation occurred at some earlier date, with the last significant propagation event occurring with the 10,000-20,000 YBP period. Thus it is possible to conceive of incremental propagation of the tunnel fault, involving, for example, intermittent periods of growth associated with glaciations of Illinoisan, or early Wisconsinian age, separated by intervening periods of relative stability. The available data do not however permit resolution of the story in such fine details.

8. REFERENCES

Ahrens, J.L., 1975, Aeromagnetic reconnaissance survey of Lake Erie: M.S. Thesis, Ohio State University, 153 p.

Casagrande, A., 1936, The determination of preconsolidation load and its practical significance, Proc. 1st Int. Conf. Soil Mech. Found. Eng., p. 60.

Ducker, A., 1951, Ein Untersuchungsverfahren zur Bestimmung der Machtigkeit des diluvialen Inlandeis: Hamburg min.-geol. Staatsinst. Mitt., 20:3-14.

Harrison, P.W., 1957, A clay-till fabric: its character and origin, J. Geol. 65:275-308.

Harrison, W., 1958, Marginal zones of vanished glaciers reconstructed from the preconsolidation-pressure values of overridden silts, J. Geol. 66:72-95.

Heimlich, R.A., Manus, R.W., and Jacoby, C.H., 1974, General Geology of the International Salt Company Cleveland and Mine, Cleveland, Ohio. Field Trip No. 1, Field Trips in North-eastern Ohio (Contrib. 96, Dept. Geology, Kent State Univ., Kent, Ohio).

Hintze, W.J., Braile, L.W., Keller, G.R., and Lidiak, E.G., 1977, A tectonic overview of the central midcontinent, Purdue Univ. for U.S. Nuc. Reg. Comm., <NUREG-0382>, 106 pp.

Jacoby, C.H., 1970, Faults in salt mines - their impact on operations, in 3rd Symp. on Salt 2:447-542.

Kogler, F., and Scheidig, A., 1948, Baugrund und Bauwerk: Berlin, Wilh. Ernst.

Lessig, H.D., and Rice, W.A., 1962, Kansan drift of the Elkton, Ohio, rift, Amer. Journ. Sci., 260:439-454.

McHone, J.G., 1978, Distribution, orientations, and ages of mafic dikes in central New England, Geol. Soc. Am. Bull., 89:1645-1655.

Morner, N.A., 1978, Faulting, fracturing, and seismicity as functions of glacio-isostasy in Fennoscandia, Geology, 6:41-45.

Myers, C.P., 1977, Aseromagnetic reconnaissance survey of Lake Erie, M.S. Thesis, Ohio State Univ., 172 pp.

Schmertmann, J.M., 1955, The undisturbed consolidation of clay, Trans. ASCE, 120:1201.

Smith, W.E.T., 1966, Earthquakes of eastern Canada and adjacent areas, 1928-1959, Pub. Dominion Obs., XXXII (3), 121 pp.

Sugden, D.E., 1977, Reconstruction of the morphology, dynamics, and thermal characteristics of the Laurentide Ice Sheet at its maximum, Arctic and Alpine Res., 9:21-47.

Terzaghi, K., and Peck, R.B., 1968, Soil mechanics in Engineering Practice, 2nd ed., J. Wiley, 729 pp.

Voight, B., 1966, Correlation of large horizontal stresses with tectonics and denudation, Proc. 1st Int. Cong., Int. Soc. Rock Mech., Paper 4.9.

Voight, B., 1967, Interpretation of rock stress measurements, Proc. 1st Int. Cong., Int. Soc. Rock Mech, III: 332-348.

Voight, B., 1973, Correlation between Atterberg plasticity limits and residual shear strength of natural soils, Geotechnique 23:265-267.

York, J.E., and Oliver, J.E., 1976, Cretaceous and Cenozoic faulting in eastern North America, Geol. Soc. Am. Bull., 87:1105-1114.

TABLE 1

HOLE TX-11: SUMMARY OF STRESSES FOR HYDROFRACTURING DATA

Hydraulic Fracture Identification	Fracture Horizon (ft)	P_o (psi)	σ_3 (psi)	σ_2 (psi)	σ_1 T=Lab (psi)	σ_1 T=Field (psi)	σ_1 T=1000 (psi)	σ_2 (selected (psi)	σ_1 average) (psi)	θ_1[2] (deg)	$\sigma_{H\perp F}$[1] (psi)
1	718	311	796	1061	1971	--	1931	1061	1951	--	1230
3	654	283	733	1023	1943	1413	1643	923	1367	080	1030
				823	1343	813[4]	1043				
4	614	266	686	906	--	1281	646[4]	906	1281	067	930
5	574	249	634	849	929	1033	29[4]	849	981	100	930
6	511	221	586	921	1246	--	1826	821	1526	94	1150
				721	646[4]	--	1226				
7(a)	454	197	577	1137	1987	1917	1947	1137	1950	37	1170
(b)	pre-existing joint assumed:			730 min				730 min	1450 max	085	970 min
8(a)	394	171	411	971	1881	--	2096	761	1358	--	870
				551	681	--	836				
(b)[3]								971	1988	--	1150

NOTES:

(1) $\sigma_{H\ F}$ indicates calculated total horizontal stress in plane perpendicular to tunnel fault.
(2) θ_1 is azimuth of σ_1 axis; 076° assumed for Fractures 1, 8 in calculating $\sigma_{H\ F}$.
(3) 8(b) based on assumption σ_2 = 971.
(4) Indicates σ_1 values impossibly low.

TABLE 2

SUMMARY OF EFFECTIVE STRESSES IN VERTICAL PLANE PERPENDICULAR TO TUNNEL FAULT

Hydraulic Fracture Identification	σ'_v (psi)	$\sigma'_{H\perp F}$ (psi)	
1	479	919	
3	436	747	
4	409	664	
5	382	681	
6	341	929	
7(a)	302	973	
(b)		668	
8(a)	262	699	
(b)		979	
TX-12	226	836	Average of 7,8
Tunnel Level (a)	69	836	Average of 7,8
(b)		400	Lower-bound extrapolation

TABLE 3

ANOMALIES AND POSSIBLY-ASSOCIATED EARTHQUAKES
WITHIN 50-MILE RADIUS OF PNPP SITE

Minimum distance to PNPP site miles	Anomaly	Trend	Basis	Possible Seismic Association	Remarks
<5	1	ENE	gravity	1858,1943,1951,1929	1,2 could reflect same structure
<5	2	ENE	magnetic	1857,1858,1928,1958, 1906a,1836,1850,1898, 1951	″ ″ ″
<5	3	NE	gravity	1857,1858,1943,1955(2)	
18	4	N-S	gravity	1943,1955(2),1929,1951	
25	5	NNE	gravity	1960a,1928,1958,1836, 1850,1898,1929	
30	6	NE	gravity		
35	7	E-W	gravity	1823	7,8 may reflect same structure
30	8	E-W	magnetic	1823	″ ″
10	9	N-S	gravity	1823	9,10 could reflect same structure
10	10	N-S	magnetic		″ ″
10	11	NNE	gravity	1857,1858	Anomaly indicated by WGC (2/5/79) Figure 2-5 G.4.
40	12	ENE	gravity	1857,1921,1934o	
12	13	ENE	oil-gas drilling; gravity	1857,1934n,1934o, 1858	
35	14	NW	Cleveland Salt Mine structure	1906a,1928,1958, 1836,1850,1898,1929	14.15 could reflect same structure weak-ness zone.
35	15	NW	oil-gas drilling	1885a,1955(2), 1885j	″ ″
50	16	NW	oil-gas drilling	1885j,1932;1940m	3 structures indicated

TABLE 3 (Continued)

Minimum distance to PNPP site miles	Anomaly	Trend	Basis	Possible Seismic Association	Remarks
15	17	N-S	gravity	1857,1885(2),1858	
55	18	E-W	gravity oil-gas drilling	1823	extension of Electric fault
45	19	E-W	gravity	1857,1934o, 1934n	
50	20	NNW	oil-gas drilling; gravity		extension of Clearville caults.

Earthquakes are identified by year; month where needed given by lower case letter following date. Dates underlined for anomaly closest to plotted epicenter. Half-underlined dates indicate several anomalies are equally close to earthquake. Bracketed number indicates several earthquakes in same year.

TABLE 4

ANOMALIES WITH POSSIBLE POTENTIAL FOR SEISMICITY
WITHIN 40-MILE RADIUS OF PNPP SITE

Anomaly	Trend	Possible Seismic Association	Minimum distance to site (miles)
1-2	ENE	1943;1836,1850,1857,1858,1898, 1906a,1928,1929,1951,1958	5
3	NE	1858;1857,1943,1955(2)	5
4	N-S	1943;1951;1955(2);1929,1943	18
5	NNE	1929,1836,1850,1898,1928,1943, 1958	25
13	ENE	1857,1934n;1934o;1858	12
14-15	NW	1960a,1928,1958;1885a, 1836,1850,1898,1955(2); 1885j;1929	35

Underlined dates indicate anomaly is closest to plotted epicenter. Half-underlined dates refer to earthquake epicenters equally close to two anomalies. Bracketed number indicates several earthquakes in same year.

TABLE 5

POSSIBLE GENETIC CLASSES FOR TUNNEL FAULT ORIGIN

1. Paleozoic Tectonics

   a. Soft or semi-lithified sediment deformation

   b. Basin-arch differential warping

   c. Appalachian (Alleghanian) Orogenesis

   d. Gravity salt tectonics

   e. Differential compaction over Niagaran (Mid-Silurian) reef

   f. Collapse following structural - or reef-influenced solution of salt

2. Mesozoic-Tertiary Tectonics

   a. Regional differential uplift

   b. Rifting (Taphrogenesis)

   c. Gravity salt tectonics

   d. Collapse following solution of salt

3. Pleistocene-Recent Tectonics

   a. Ice-sheet traction (glacitectonics)

   b. Subsurface salt tectonics activated by glacial loading

   c. Differential down-bowing with glacial advance

   d. Differential rebound with glacial retreat

   e. Surficial stress-relief (“Pop-up” family of structures)

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 18 OF 19

PROJECT: P.N.P.P. W.O. ______ SITE AREA ______ DRILL HOLE NO. TX-4

CONTRACTOR: ______ COORDINATES ______ ELEVATION ______

DRILLER: ______ GWL 0 HRS ______

CLASSIFIED BY: RTW DATE: 9/15/78 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
85					85.0-86.45 - Med. hard, med. gy. shale and siltstone, tr. lt. gy. siltstone					Lt. gy. wash
					"Fe" band @ 85.35'					9/15/78 Man cage accident @ 12:33 p.m. prevented afternoon coring
86					Possible offset = 3.8'					Coring stopped @ 87.0' -Core barrel raised several inches and water left running in hole over night - Coring resumed - 9/18/78
					Top of Fault Zone - 86.45'					
87					15.5" of recovery over 30.5" of run					
					4" lt. gy. sandy shall					
					4" med. gy. shale					Driller notes starting @ 87.0 - continuing to 88' - Milky gray wash
					3 1/2" Broken, lt. gy. siltstone		30%	5.0	3.65	
					4" lt. gy. sandy shale					
88					Clay remenants in partings and around broken prices.					
89					Bottom of Fault Zone - 89.0'					
					89.0-90.0 - Med. hard, med. gy. shale, some lt. gy. siltstone in 1/4" bands					
					"Fe" band @ 89.15'					Lt. gy. wash
90					Long piece - 14"					

Fig. 1 GAI - 227 3/72

Figure 1 Drillhole log, TX-4; fault intercept

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 8 OF 8

PROJECT: P.N.P.P. W.O. ______ SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-7

CONTRACTOR: Herron Testing COORDINATES N 50, 490.93 E 9, 095.96 ELEVATION 618.1

DRILLER: Joe Minarchick GWL 0 HRS ______

CLASSIFIED BY: R. T. Wardrop DATE: 10/12/78 48 ~~24~~ HRS 99.7"

Columns: Depth Ft. | Sample No. | SPT Blows/6 in. (6, 12, 18) | Ft. Rec. | Profile | DESCRIPTION: Density (or Consistency), Color, Rock Or Soil Type - Accessories | U.S.C.S. | R.Q.D. | Soil Or Rock: Range Size / Core Run; Grain Shape / Rec. Core | REMARKS: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.

Depth Ft.: 350, 355, 365, 375, 385, 395

DESCRIPTION

338.2'-363.6' - Med. hard, med. gy. shale w/some dk. gy. brn. siltstone lam. little lt. gy. sandy shale bands, tr. thin lt. gy. siltstone lam.
- a) High concentration of siltstone lam. from 350.2'-351.4'
- b) Thin fissil shale seams @ 362.8' and 364.0'
- c) Clay remnants in partings @ 352.65', 362.8', and 361.6'
- d) 1/8" seam of pyrite @ 356.5'

363.6'-371.3' - Med. hard, dk. gy. shale to med. gy. shale, w/ some dk. gy. brn. siltstone lam. 1/8"-1/2" thk. tr. lt. gy. sand shale, tr. thin siltstone lam.
- a) X-bedded sandy bands @ 365.95 and 366.3'
- b) Clay rems. in partings @ 368.5'
- c) Seam of thin fissile shale @ 368.4'

FAULT ZONE -371.3'-372.4'

10" of core missing (2) 1" core pieces w/clay remnants - pieces do not interlock w/each other or w/core above and below

372.4'-395.0' - Med. hard, dk. gy. shale w/some dk. gy. brn. siltstone lam., some lt. gy. sandy shale bands, tr. thin lt. gy. siltstone lam.
- a) 4" thk. sandy band @ 380.6' and 6-1/2" @ 386.4'

BOTTOM OF HOLE 395' (elev.223.1')

R.Q.D.	Core Run	Rec. Core	Remarks
29.2%	10.0'	10.0'	Long piece - 5-1/2"
41.7	10.0'	10.0'	Long piece - 10"
36.9%	10.0'	9.17'	Long piece - 6 1/2"; 365-375' run cored smoothly, yet @ fast rate. Driller has very difficult time pulling barrel after 365'-375' run
57.1%	10.0'	9.96'	Bottom 3' of barrel coated w/1/16 thk. layer of lt. gy. clayey film when retrieved; Long piece - 28"
29.2%	10.0'	9.79'	Drill water getting plugged up in bottom of hole; Pieces 2 1/2"-4"; Long piece-10"; No detectable methane

(b) clay rems. in partings @ 376.5', 379.0', 382.55', 382.65', 383.6', 391.35'.

(c) Broken seams of rock frags. @ 375.4', 385.05', 392.45' (4"), associated w/clay rems. @ 392.45' and 393.8'

(d) Thin fissile seams @ 386.1'

(e) Possible "Fe" band @ 394.3'

Fig. 2

GAI - 227 3/72

Figure 2 Drillhole log, TX-7; possible fault intercept

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 10 OF ____

...: P.N.P.P. W.O. ____ SITE AREA NE Parking Lot DRILL HOLE NO. TX-11

...ACTOR: Pa Drilling Co. COORDINATES N 781,586.77 ELEVATION 624.04

...LER: ~~R. Wardrop~~ Jim Adams E 2,369,806.12 GWL 0 HRS ____

...ASSIFIED BY: R. Wardrop DATE: 4/25/79 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
450		Retained for Hydro-fract.			Med. hard, m. grey, shale interlam. w/ little hard, lt. gy. siltstone, little dk. br. shale — fissil shale seam ¼" thick @ 451.5' — load cast horizons @ 451.35' & 454.2'		92%	5.0'	5.0'	Minimal gas bubbling wash in hole — Lt. gy wash w/ occasional brn. influxes — long piece -18"
					Same, w/ some hard, lt. gy. siltstone lam., brn. shale lam. 0-1" thick. Sandy shale band @ 458.0'-458.6' (x-bedded) Siltstone band @ 458.85'-459.15'		83%	5.0'	5.0'	Same wash & gas; long piece -17"
460					Same, w/ little lt. gy. lam. & some gy. brn. oily shale lam. 0-3" thk, heavily concentrated in the 463.75-465.0' interval		85%	5.0'	5.0'	Same; long piece -14"
					Same, lt. gy. siltstone band from 465.3-465.7' & @ 466.55 (1¼")		83%	5.0'	4.94'	Same; long piece -18"
470					Same, rock shattered from 473.7-474.3'. Thin clay seams and fissile shale @ 470.75, 472.85, 474.5 (¾"). Very thin clay seam @ 471.6'	4/25/79	Rx disrupted see remarks	5.0'	5.0'	Gas blows column of water out of hole. Barrel lifted 20' out of hole when retreated only ½ way by wire line — barrel lands on drillers platform greatly disturbing sample. Work stopped gas left to bleed off over-night
					Same, shale is med. to lt. gy, w/ trace gy. brn. lam. Lt. gy. siltstone band @ 479.4-479.85' Fissil shale @ 476.2' (v. thin)		95%	5.0'	4.96'	long piece -13"
480					Same, tr. lt. gy. siltstone lam. w/ one band @ 480.55, tr. of iron staining in thin seams @ 483.4' Load cast horizon @ 481.3'		100%	5.0'	5.0'	Min. gas; long piece -30"
					Same, little lt. gy. siltstone lam, little dk. brn. shale lam. Lt. gy., x-laminated sandy shale band @ 485.8'-486.05'		Rx disrupted see remarks	5.0'	4.75'	Barrel pulled to half way retreat when gas raises it up into rotation block.
490		Retained for Hydro-fract			Fractured rx. w/ clay (probably pulverized rx. from hammering effect) @ 486.05 (¼"), 487.9 (¼"); 488.4 (½"). Same, tr. siltstone lam., tr. brn. shale & siltstone band from 494.6'-494.9'		93%	5.0' long	5.0' piece-14"	Barrel left there while gas bleeds off over lunch. — Upon returning barrel is being repeatedly hammered into rotation block under slightly less pressure
500					Same w/ some lt. gy. siltstone to sandy shale lam., bands 499.8-500.4' (x-laminated)		97%	10.0'	9.92'	Driller pulls barrel slowly allowing Hydro-static head on gas pressure; long piece 30"

Continued on Page 11

Fig. 3 GAI-227 3/72

Figure 3 Drillhole log, TX-11; possible fault intercept

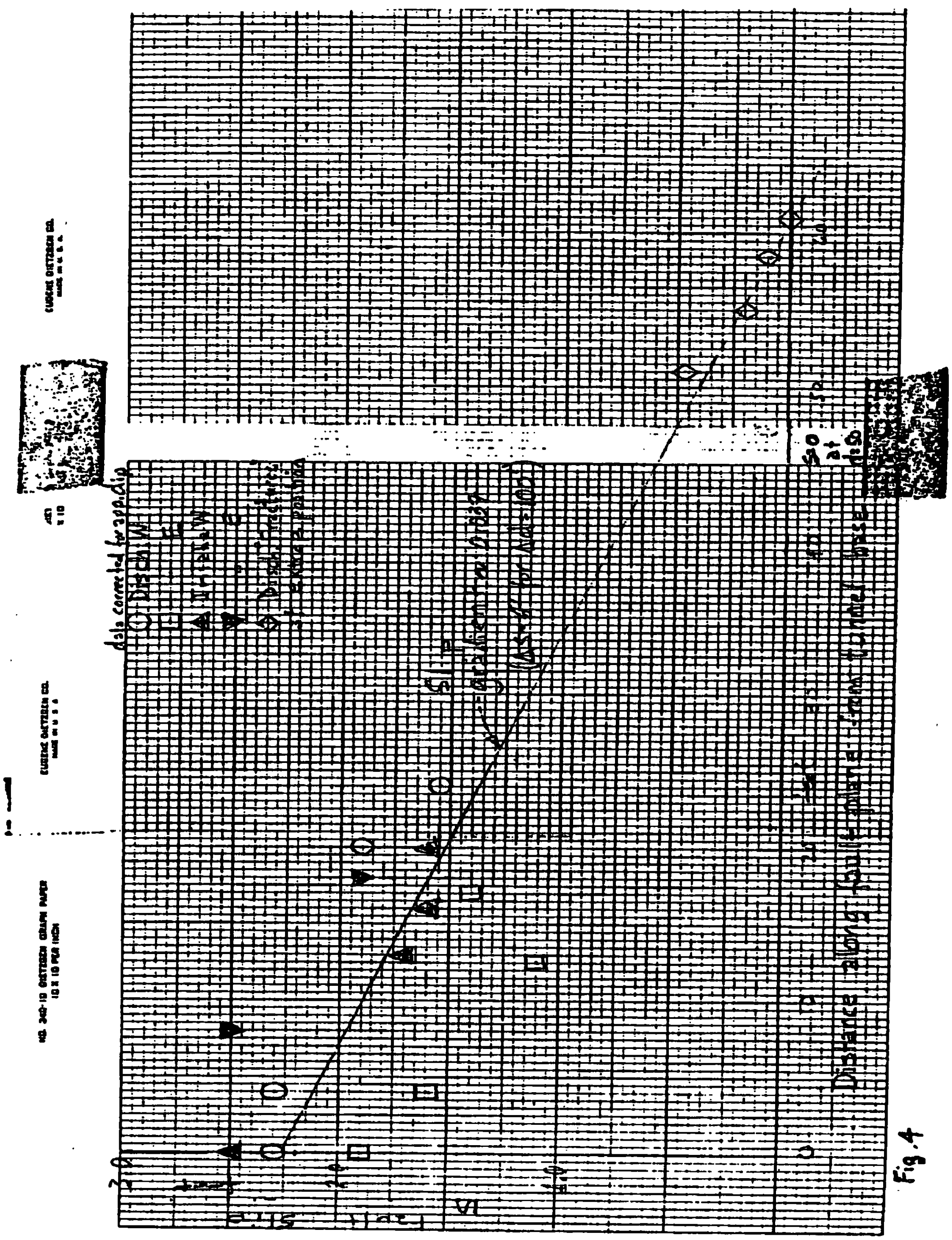


Figure 4   Fault slip vs. distance along fault plant from tunnel base

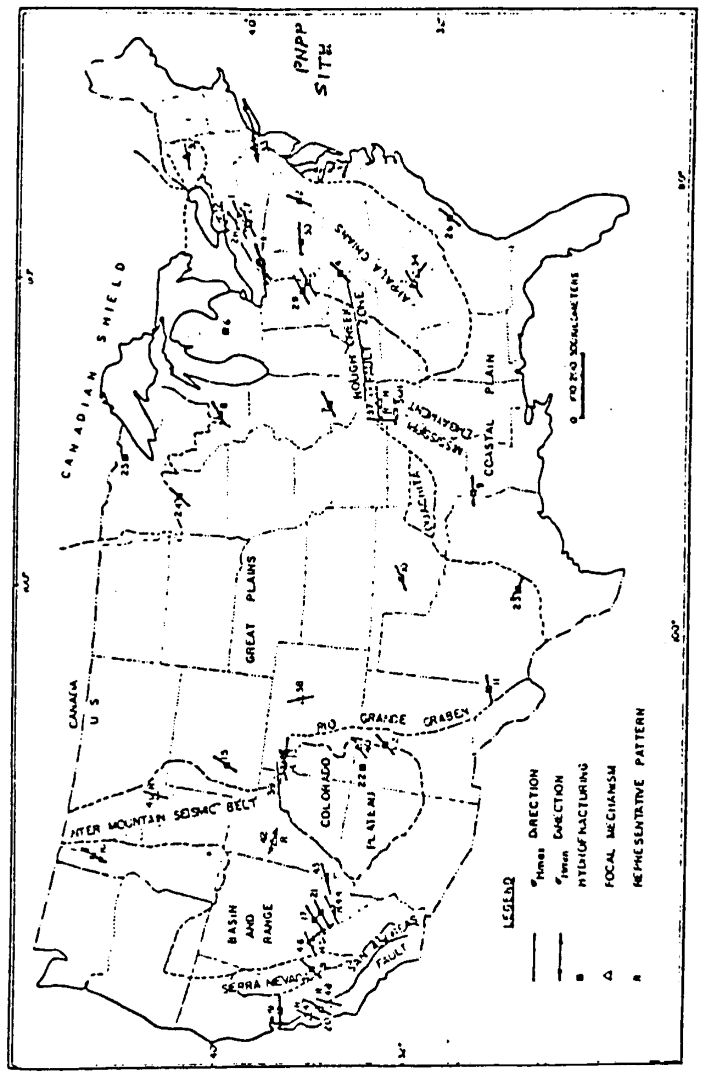


Fig. 5

Figure 5 Direction of σ_{max} at the PNPP site in comparison to regional measurements

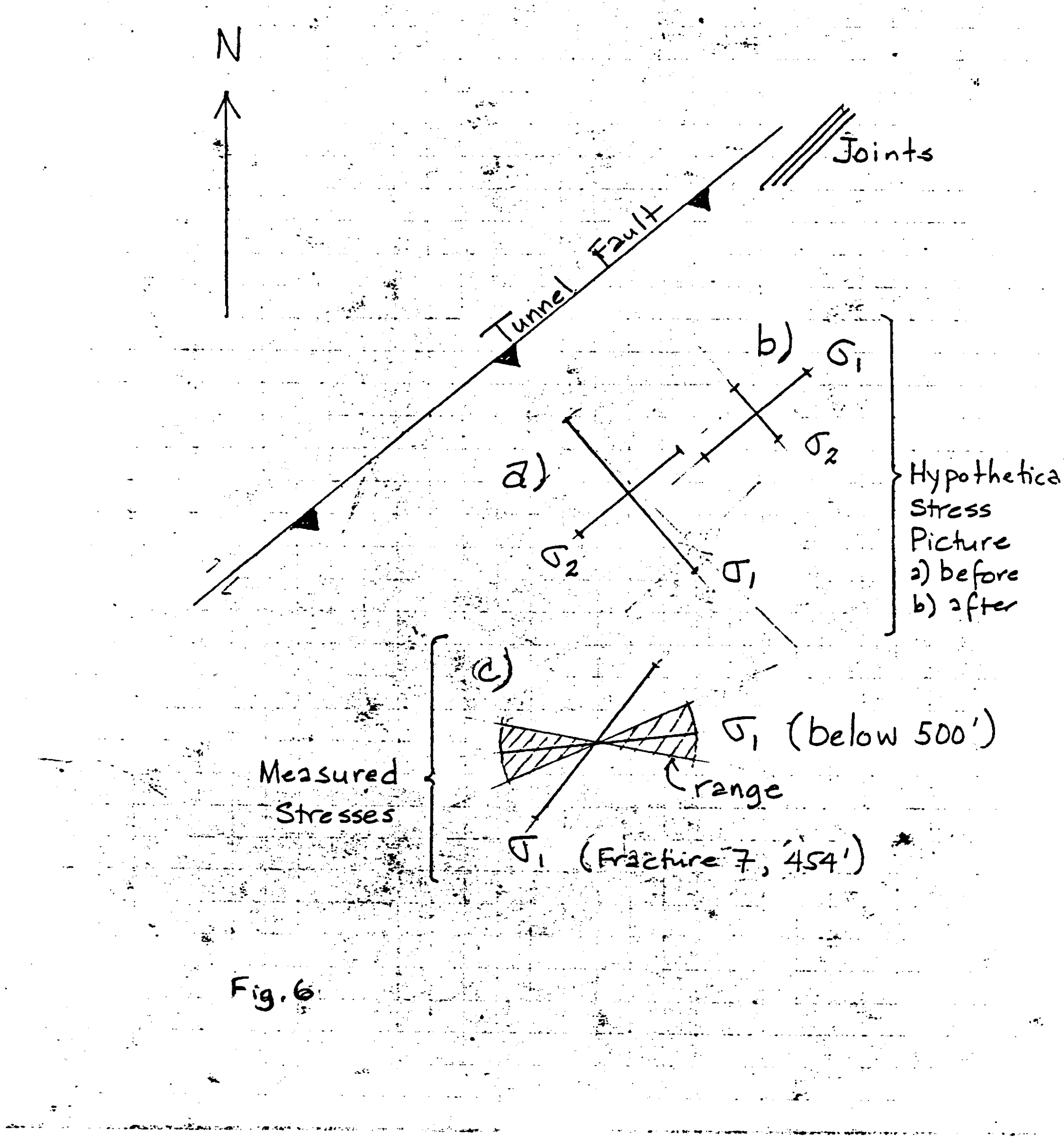


Figure 6 Sketch of PNPP structural trends with hypothetical stress orientations (a) before and (b) after faulting, and (c) measured stress orientations in TX-11

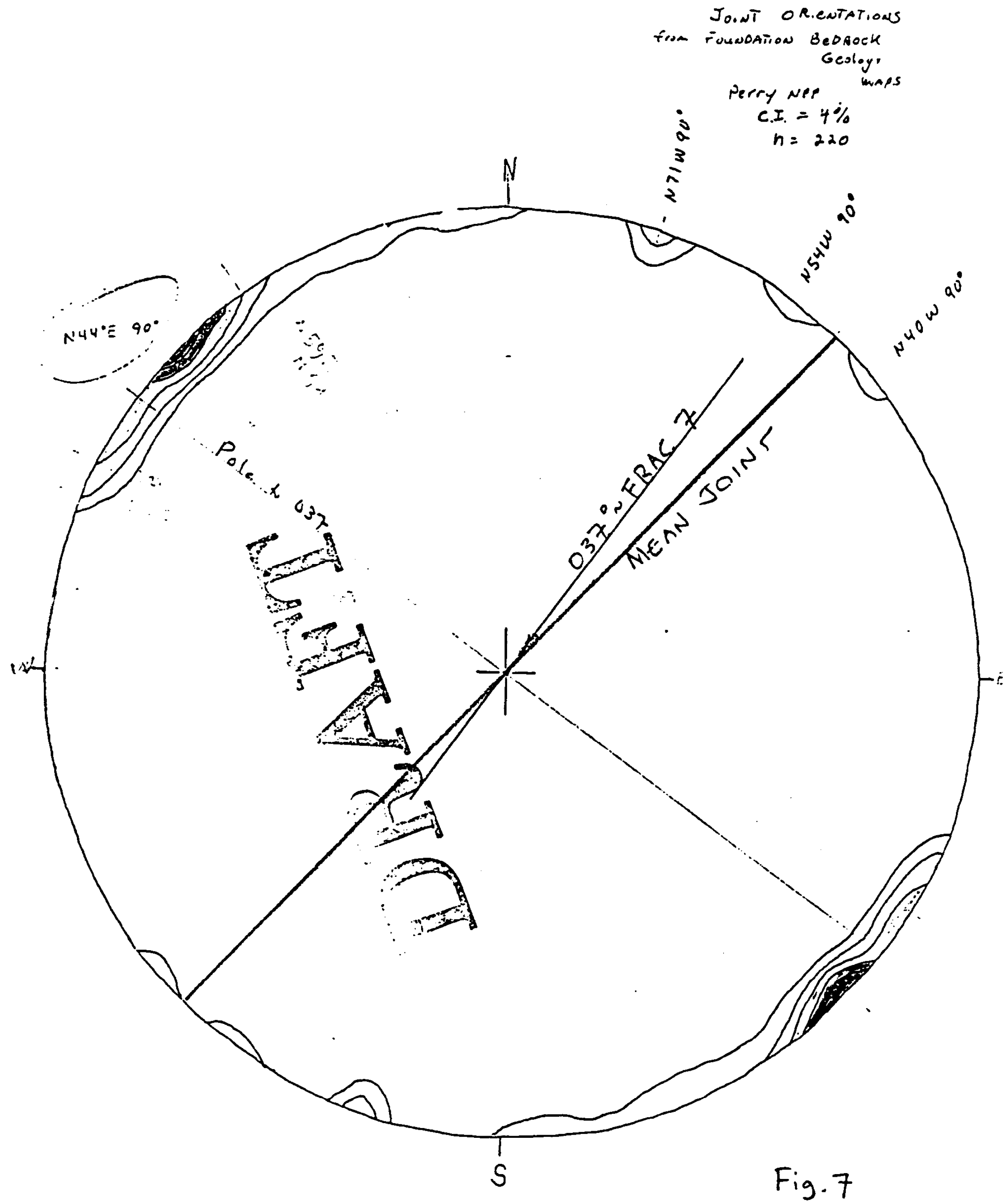


Figure 7 Joint orientations PNPP foundation exposures.
220 Measurements. Plot by WGC

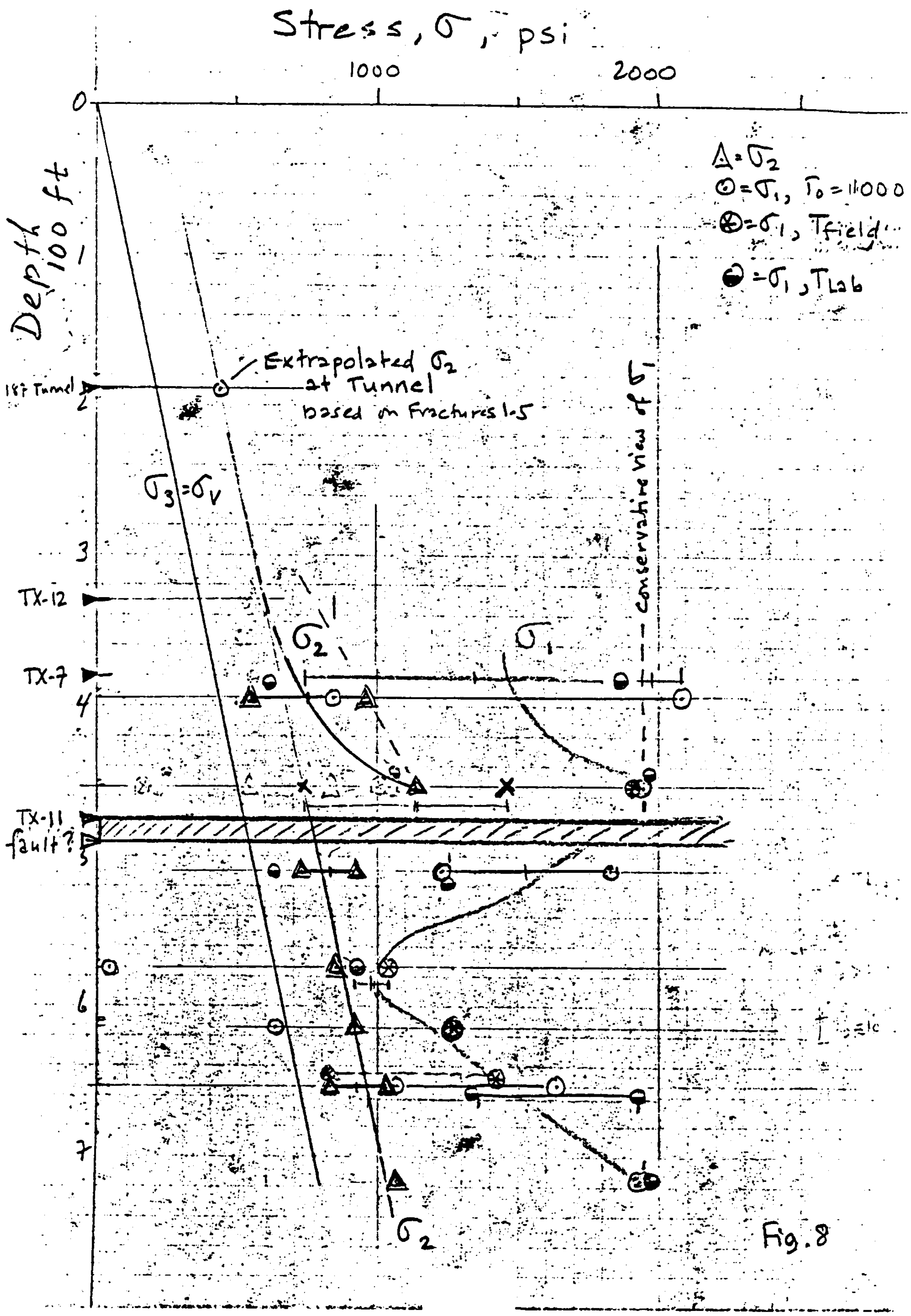


Figure 8 σ_1 and σ_2 vs depth, TX-11

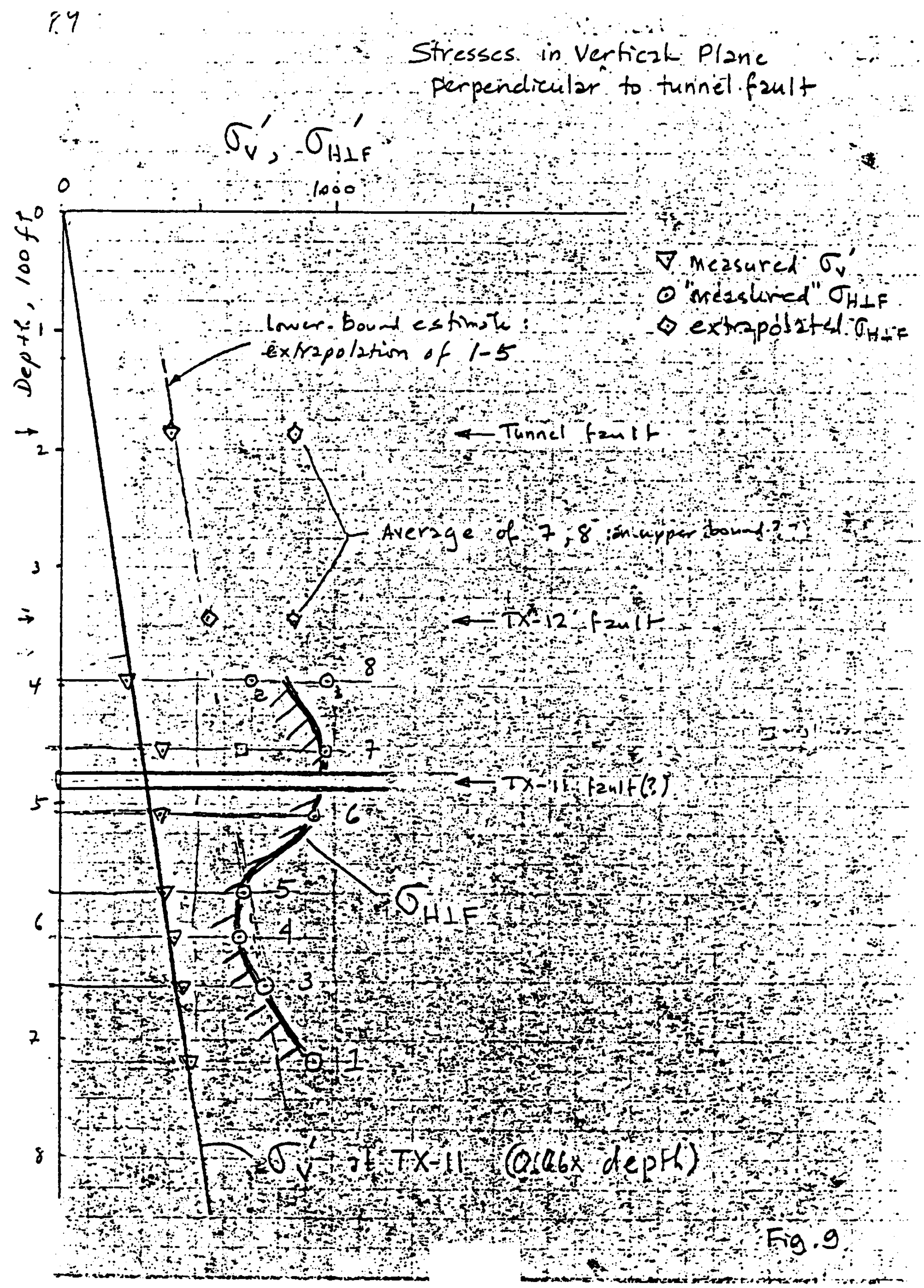


Figure 9 Stresses in vertical plane perpendicular to tunnel fault

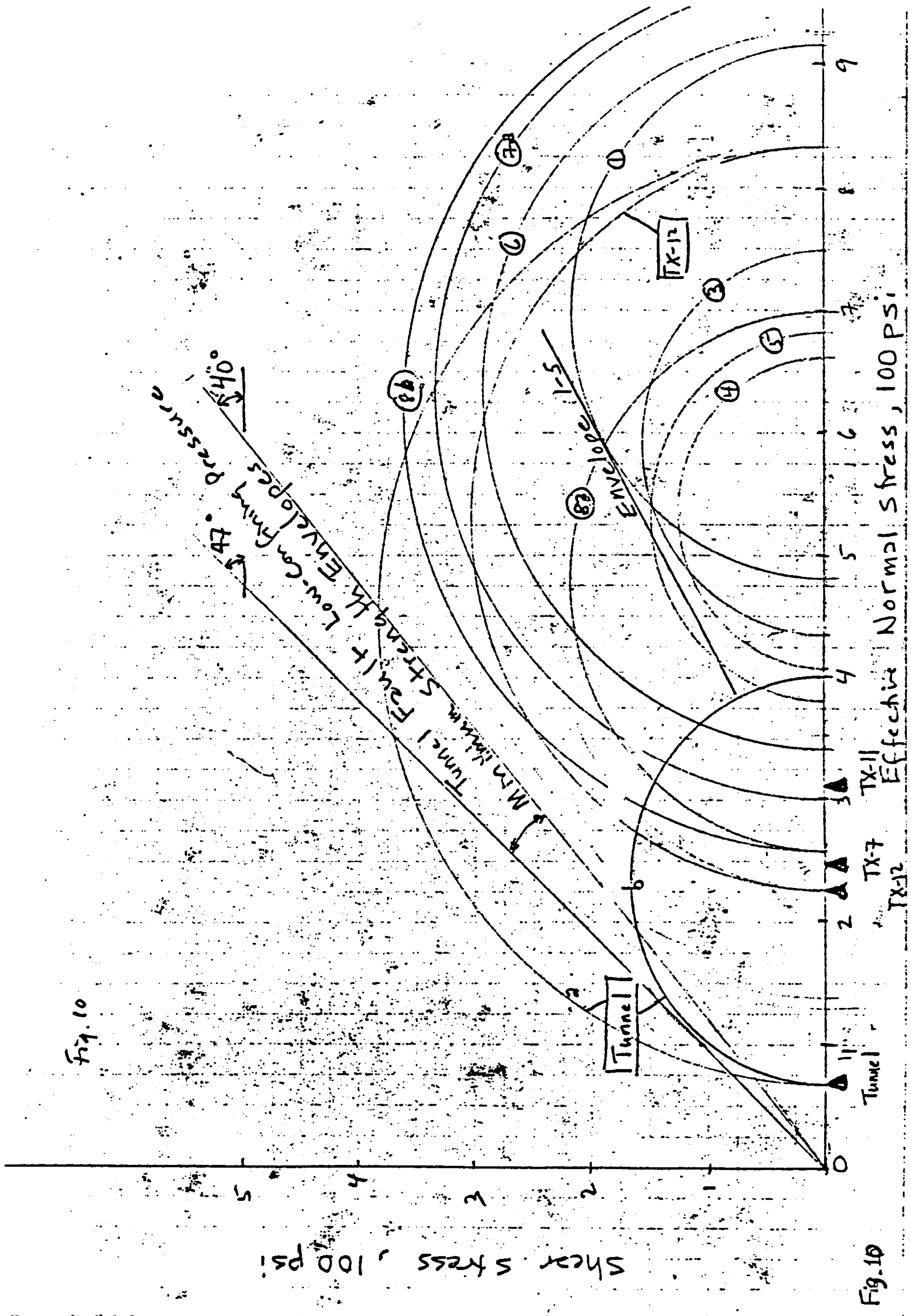


Figure 10 Mohr diagram comparing calculated stresses in vicinity of tunnel fault to minimum strength envelopes

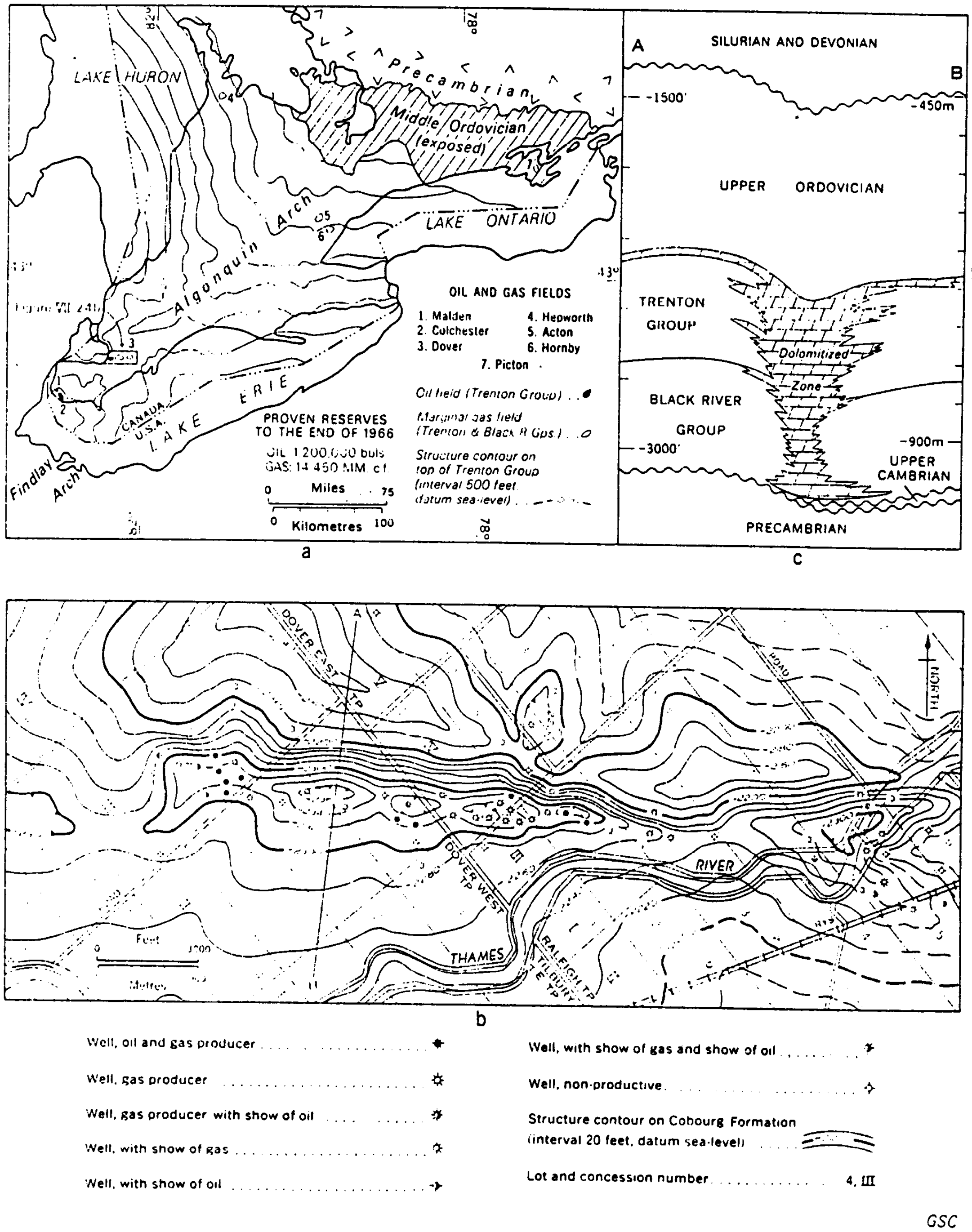


FIGURE 11 Middle Ordovician oil and gas fields of southwestern Ontario (by B. V. Sanford). (a) Distribution. (b) Structure contours on Middle Ordovician Trenton limestones in the Dover field. (c) Cross-section along line A–B through Dover field.

Fig. 11

ECONOMIC MINERALS OF SOUTHEASTERN CANADA

Figure 11 Structure in the Dover field, Canada

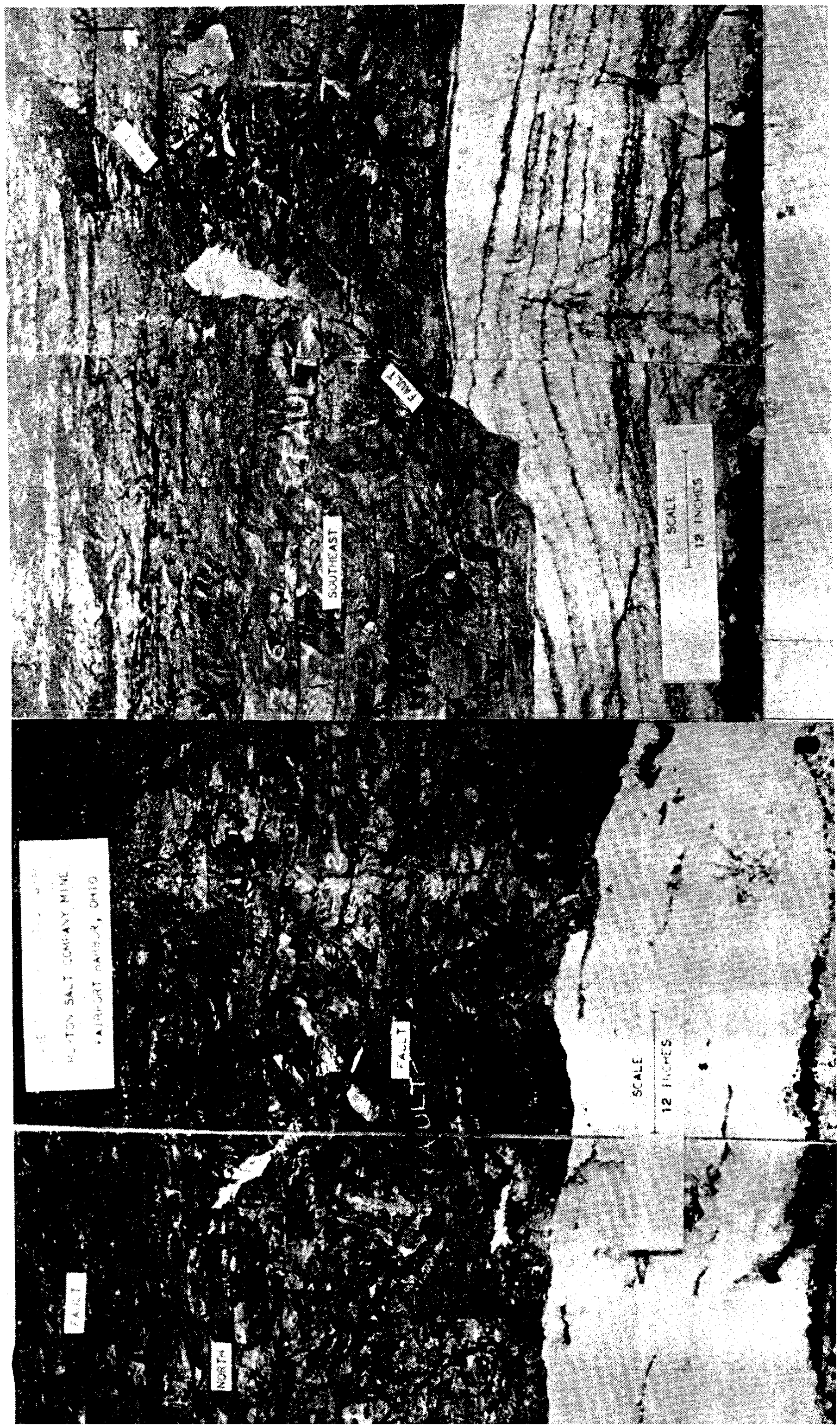


FIGURE 12
"GRABEN" IN PRODUCTION SHAFT
MORTON SALT COMPANY MINE
FAIRPORT HARBOR, OHIO

Figure 12 "Graben" in salt production shaft, Fairport Harbor, Ohio

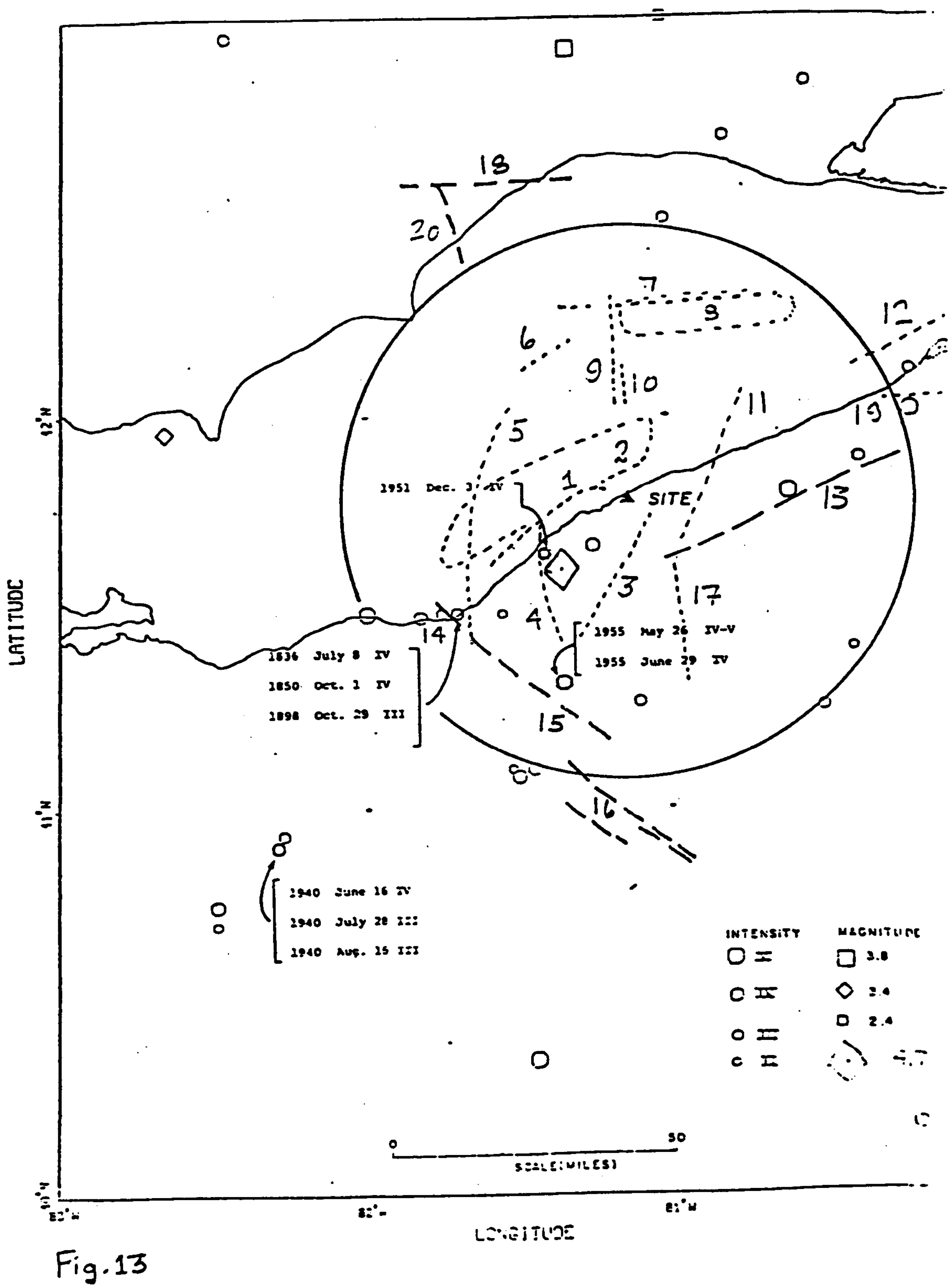


Figure 13 Regional seismicity (WGC base) and structural anomalies

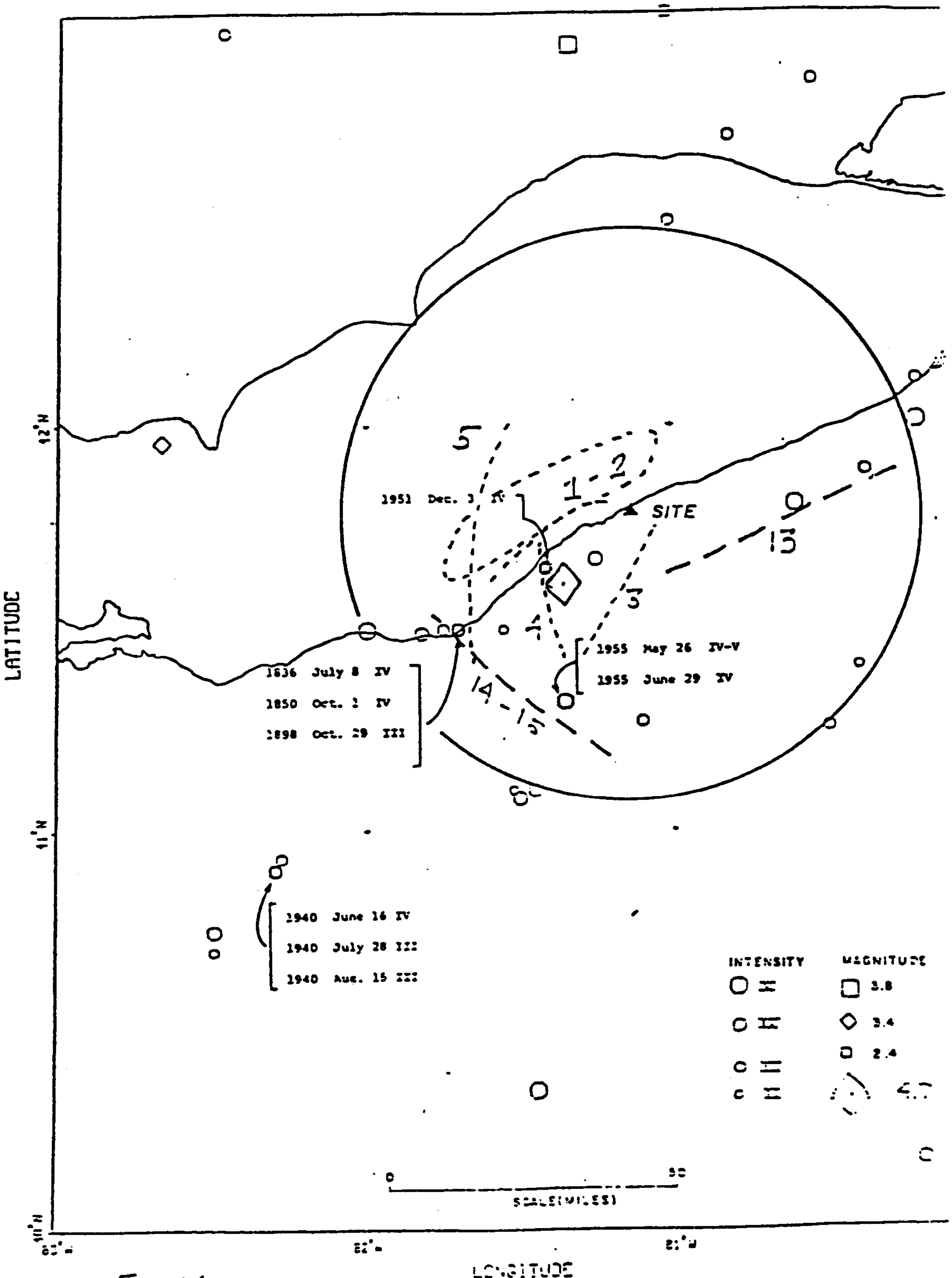


Fig. 14

Figure 14 Regional seismicity and selected structural anomalies

<APPENDIX 2D G>

TX-SERIES BORING LOGS

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 3

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel

DRILL HOLE NO. TX-1

CONTRACTOR: Herron Testing COORDINATES Sta. 10+30 N 781950 E 2368660

ELEVATION 440.2'

DRILLER: Joe Minarchick

GWL 0 HRS

CLASSIFIED BY: R. T. Wardrop DATE: 8/21/78

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					Med. hard, med. gy., silty shale interlam w/little dk. gy. brn. shale lam., little fracts. in various orientations, flat lying.		0%	.75'	.46'	First run taken w/3-3/4" I.D. bit to set top casing. Machine running rough - rpms inconsistent.
1					Same, interlam w/some lt. gy., v. fi. gr., sandy siltstone stringers and lenses, little dk. gy. brn. lam. (1/16"-1/4" thk.), tr. bedding fracts., flat.		0%	1.0'	.67'	No gas. Lt. gy. wash. Machine still rough. Occasional brown influx to wash.
2					Same. Top of gouge zone felt w/probe @ 2.9'.		33%	1.0'	.71'	No gas. Machine stabilizing rpms. Lt. gy. wash. No gas.
3					Gouge Zone felt w/probe. Fault Zone indicated by recovery. Bottom of gouge zone felt @ 3.67'.		0%	1.0'	0'	Cream gy. wash w/lt. gy. platy clay particles. Lost water momentarily. Gas bubbling in hole. (20-40% LEL 1" abv. hole.) (0-3% LEL 1' abv. hole.)
4					Same as above fault zone, more sandy shale than siltstone 2" thk. ss band @ 4.1' - interlam w/ a 1/4" thk., gy. shale lam. dipping @ 25°-3/4" long fracts. in ss band parallel dip of gy. shale lam.		0%	1.0'	.71'	Lt. gy. wash. Water bubbling in hole after run 0% LEL.
5										

G-1 GAI-227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 3

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel

DRILL HOLE NO. TX-1

CONTRACTOR: Herron Testing COORDINATES Sta. 10+30 N 781950 E 2368660

ELEVATION 440.2'

DRILLER: Joe Minarchick

GWL 0 HRS

CLASSIFIED BY: R. T. Wardrop DATE: 8/21/78

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
5					Med. hard, med. gy., shale, void of sandy stringers and lenses, flat bedded, 2" thk., lt. gy., ss band @ 5.4'.		0%	1.0'	.9'	Lt. gy. wash. Gas bubbling in hole - No methane detected.
6					Bottom of Hole - 5.75'.					8/22/78 - Gas continuous to bubble in TX-1 until the 1.6'-2.6' interval was encountered in TX-2. At this point, TX-1 did not bubble and TX-2 commenced.

G-2 GAI-227 9/72

INSPECTOR'S COMMENT:

TX-1 was drilled approximately five feet down dip of where the fault intersects tunnel invert. This location enabled the boring to encounter faulted rock at a shallow depth. Indicators from the drilling process and core inspection were carefully noted for fault identification in other, deeper test holes.

The fault was recognized in the 2.9-3.67' interval for the following reasons. A creamy grey influx with platy clay particles dominated the typically light grey wash in the 2.75-3.75' run. All fractured rock and clay gouge was ground up during drilling. An influx of gas made drill water churn in the 2.75'-3.75' run.

Identification of fault was confirmed through the use of a steel feeler probe with which the faulted interval (fractured rock and clay gouge) was actually detected.

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
DRILL HOLE NO. TX-2
CONTRACTOR: Herron Testing COORDINATES Sta. 10+25, N 781930, E 2368680
ELEVATION 440.1'
DRILLER: Joe Minarchick
GWL 0 HRS ____
CLASSIFIED BY: R. T. Wardrop DATE: 8/22/78
24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0							Med. hard, med. gy., silty shale, interlam. w/some lt. gy. sandy shale lenses (0-1/4" thk.), tr. dk. gy. brn. lam. (1/8" thk.) - Broken along flat lying bedding fracts., Long piece - .25' flat bedded.		0%	.6	.6	4" hole on first run to set top casing. No gas.
1							Same		0%	1.0	.7	Lt. gy. wash
2							Same, Hard, tn. brn., cherty, "Fe" band (1-1/8" thk.) @ 1.7'. Hard, lt. gy., fi. gr., ss band (2-1/2" thk.) @ 2.5'. 2 jts. dipping @ 35° @ 2.2' and 2.25'. Core pieces broken every 1/2" - 2-1/2".		0%	1.0	1.0	No gas. Gas begins to bubble in TX-2, stops in TX-1. Lt. gy. wash. 0% LEL detected.
3							Same, w/tr. sandy lenses & stringers. Soft seam of highly fract. fissile shale (3/4" thk.) @ 3.2' - w/35° dip. Core pieces 1/8 - 3" long		0%	1.0	1.0	Lt. gy. wash. Gas bubbling in hole, 0% methane
4							Same, flat lying. Hard, lt. gy., sandy shale band (1" thk.) @ 3.65'. Top of zone probed @ 4.5'		0%	1.0	.8	Lt. gy. wash w/ occasional brn. influx
5							Fault Zone. Top of zone indicated by recovery. See note on Page 6					No gas detected. Water bubbling in hole.

GAI - 227 3/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA: Intake Tunnel SHEET 2 OF 6

CONTRACTOR: Herron Testing COORDINATES: Sta. 10+25 DRILL HOLE NO. TX-2

N781930 ELEVATION 440.1'

DRILLER: Joe Minarchick E 2368680 GWL 0 HRS

CLASSIFIED BY: R. T. Wardrop DATE: 8/22/78 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
5					Fault Zone		0%	1.0	.1'	Cream gy. wash
					Bottom of 5.5'. 5.5-6.6' - Same as abv. fault Tn. brn., cherty, "Fe" band (3/4" thk.) @ 5.65'. Flat bedded w/localized variation. Core pieces 3/4" to 3-3/4" long		0%	1.0	.77'	Water bubbling in hole - No gas detected. Lt. gy. wash
6, 7, 8					6.6'-9.6' - Hard, lt. gy., sandy shale and siltstone, interlam w/ some med. hard, med. gy., shale in v. thin lam. (1/16" - 3/4" thk) Med. gy. shale bands @ 7.4' (1" thk.), 7.8' (1-1/2" thk.), 8.5' 2-1/4" thk.), & 9.3' (1-1/4" thk.) Concentrations of fi. sand high from 7.0 - 7.35' (x-bedded), 7.95-8.3', and 9.35-9.6'. Core pieces 3/4" to 5-1/2" long		31%	1.5'	1.4'	Water bubbling 0% LEL. Lt. gy. wash Gas same.
9					9.6'-10.3' - Hard, lt. gy. to gy. shale w/some sandy stringers and lenses up to 1/2" thk. Long piece - 7-1/2" long		74%	1.5'	1.4'	Lt. gy. wash Gas detector registers 10% LEL 1' abv. hole.
10										

G-5 GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA: Intake Tunnel SHEET 3 OF 6

CONTRACTOR: Herron Testing COORDINATES: Sta. 10+25 DRILL HOLE NO. TX-2

N 781930 ELEVATION 440.1'

DRILLER: Joe Minarchick E 2368680 GWL 0 HRS

CLASSIFIED BY: R. T. Wardrop DATE: 8/23/78 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
10, 11, 12					10.3'-10.8' - Lt. & dk. gy., med. hard, shale interlam in 1/4-1/2" bands. 10.8'-11.75' - Hard, lt. gy. to gy. shale w/some sandy stringers and lenses up to 1/2" thk. w/ minor x-bedding. Long piece - 11-1/2" 11.75-12.05 - Med. hard, dk. gy. shale, tr., v. thin sand stringers 12.05-12.35 - Hard, lt. gy. to gy. shale w/some sandy lenses & stringers up to 1/2" thk. 12.35-12.5 - Hard, th. gy., sandy shale.		88%	3.0	3.0	Water bubbling in hole @ start of day 3-4% LEL detected. Wash varies from lt. gy. to dk. gy. to dk. brn.
13, 14					12.5-12.85 - Med. hard, dk. gy. shale, thinly lam. 12.85 - 13.15 - Med. hard, th. gy. sandy shale. 13.15-13.75 - Med. soft, dk. gy. silty shale, w/little sandy shale, little med. gy. shale, lam. 1/2" to 1-1/4" thk. 13.75-15.8 - Hard, lt. gy., v. sandy shale. Tn. gy., fi. gr., ss bands (1"-2" thk.) occurring @ 13.8', 14.15', 15.1', 15.25', and 15.65' (w/"Fe" band inside, pinching, 0"-1/2" thk)		83%	4.4	4.4	Gas bubbling in hole. 0% LEL detected. Dk. and lt. gy. wash.
15										

G-6 GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 6

PROJECT: PNPP W.O. 04-4569-310 SITE AREA Intake Tunnel DRILL HOLE NO. TX-2

CONTRACTOR: Herron Testing COORDINATES Sta. 10+25 N 781930 E 2368680 ELEVATION 440.1'

DRILLER: Joe Minarchick GWL 0 HRS ____

CLASSIFIED BY: R. T. Wardrop DATE: 8/23/78 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
15										Lt. gy. wash
					15.8-16.15 - Med. hard, dk. gy. & med. gy., shale, interlam in 1/4"-1/2" thk. bands.		83%	4.4	4.4	
16					16.15-16.95 - Med. hard, dk. gy. shale in 1" thk. bands interlam. w/lt. gy. sandy shale in 1-1/2" thk. bands @ 16.55 and 16.85. Flat bedded Long piece - 15"					
17					16.95-17.2 - Med. hard, dk. gy. silty shale.					Gas begins to bubble violently in hole when core barrel is removed - Water surging out of hole up to 1'. 20-40% LEL detected 1' abv. hole.
					17.2-17.85 - Hard, tn. gy., v. sandy shale, x-bedded - Sand content & x-bedding increasing w/ depth. Thin clay seams seem as gy. clay remanants in partings @ 17.45, 17.55, and 17.65'.					
18					17.85-18.55 - Dk. gy. shale interlam w/some thin, lt. gy. shale lam.		76%	4.0	3.85	Lt. gy. wash varying to dk. gy. and brown.
					18.55-19.75 - Med. hard, dk. gy. shale, interlam w/same lt. gy. sandy shale in 1"-2" thick bands.					
19					Lt. gy. lam. of sandy shale show elipsoid nodules which appear to be concretions w/concentric growth Nodules avg. 1/4" length, 1/8" width, w/long axis lying horizontal w/bedding. Nodules occur approx. 1 every 1" @ 18.6'.					
					19.75-20.7 - Dk. gy., med. hard, shale interlam w/little dk. gy. brn. lam. (1/2" thk.) Flat bedded.					
20										

G-7 GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 5 OF 6

PROJECT: PNPP W.O. 04-4569-310 SITE AREA Intake Tunnel DRILL HOLE NO. TX-2

CONTRACTOR: Herron Testing COORDINATES Sta. 10+25 N 781930 E 2368680 ELEVATION 440.1'

DRILLER: Joe Minarchick GWL 0 HRS ____

CLASSIFIED BY: R. T. Wardrop DATE: 8/23/78 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
					20.7-21.0 - Med. hard, dk. gy. shale interlam w/lt. gy., v. sandy hard shale in 1-1-1/2" bands.		76%	4.0	3.85	Dk. gy. wash
					Bottom of Hole - 21.0'					Gas bubbling lightly. 8/24/78 - 5-10% LEL 1' abv. hole.

G-8 GAI-227 8/72

INSPECTOR'S COMMENT:

TX-2 was also located relatively close to the fault/tunnel invert intersection.

Here a creamy grey wash influx occured in the 4.6 to 5.6' run. One and one-tenth feet of sample was absent from the 4.5' to 5.6' interval. The feeler probe detected broken rock and clay gouge at appropriate depth.

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel SHEET 1 OF 5

CONTRACTOR: Herron Testing COORDINATES Sta. 10+05 DRILL HOLE NO. TX-3

DRILLER: Joe Minarchick N 781900 ELEVATION 440.0'

CLASSIFIED BY: R. T. Wardrop DATE: 8/24/78 E 2368700 GWL 0 HRS

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					Broken, med. hard, med. gy., silty shale, w/little dk. gy. brn. shale bands (1/8-1/4" thk.) Lt. gy., v. sandy shale band (3/4" thk.) @ 1.1'. Core pieces 1-1/2"-2" long		0%	.75	.75	No gas.
1					Same. Tn. brn., cherty, "Fe" band, pinch., @ 1.7'. Flat bedded. Core pieces 1/4" - 2-1/4" long.		0%	1.5	1.1	Lt. gy. wash w/occasional brown influx. No gas.
2–3					Hard, lt. gy., sandy shale bands (3/4" thk.) @ 2.3', (2-1/2" thk. broken) @ 3.0', and (1/4" thk.) @ 4.6'. Same. Core pieces 1/4" - 2-1/4" long.		0%	1.5	9.5	Wash same. Gas starts bubbling in TX-3 - Continued to bubble in TX-2. Gas bubbling in hole - 0% LEL.
4–5					Same to 4.65'. Flat bedded. 4.65-6.85 - Hard, lt. gy., sandy shale bands, stringers & lenses, w/little med. gy., little, dk. gy. grn. shale. Hard, tn. brn., cherty "Fe" band (1/4" thk.) @4.95'.		0%	2.0	1.6	Lt. gy. wash.

GAI-229 2.72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 5

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel DRILL HOLE NO. TX-3

CONTRACTOR: Herron Testing COORDINATES Sta. 10+05 ELEVATION 440.0'

DRILLER: Joe Minarchick N 781900 GWL 0 HRS

CLASSIFIED BY: R. T. Wardrop DATE: 8/24/78 E 2368700 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
5					Concentration of sand high from 5.0-5.25 and 6.1-6.3.		0%	2.0	1.6	Gas bubbling 80-100% 1" abv. hole. 5% 1' abv. hole
					Broken in 1/2"-3-1/2" pieces.					
6							77%	2.0	2.0	Wash turns lt. gy., to tn. brn., to brn.
					6.85-7.2 - Med. hard, dk. gy. shale interlam w/some lt. gy. sandy, shale in 1/8"-1/4" thk. bands.					
7					7.2-7.5 - Hard, med. gy. & dk. gy-brn., siltstone in 1-3/4" bands.					
					7.5-8.0 - Lt. gy., sandy shale in thin lam.					
					Flat bedded Long piece - 9"					0% LEL 1' abv. hole.
8					8.0-8.5 - Med. hard, med. gy. & dk. gy. shale and lt. gy. thin lam., sandy shale interlam.					
					5° jt. @ 8.15'					
					8.5-9.1 - Same, w/little sandy shale lam.		70%	2.0	1.6	Lost core in hole replaced core retainer recovered core.
9					Flat bedded Long piece - 18"					
					9.1-9.35 - Hard, lt. gy. sandy shale, tr. x-bedding becom. lt. gy. to tn. gy. siltstone.					Driller notes reduced resistance @ 9.4'.
					Last piece recovered - 1-1/2" long tn. brn. siltstone interlam w/a 1/4" thk. med. gy. shale band-dipping @ 25°.					Lt. creamy gy. wash w/platy clay particles.
10					Fault Zone					

See note on Page 5

G-11

GAI-327 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 5

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel DRILL HOLE NO. TX-3

CONTRACTOR: Herron Testing COORDINATES Sta. 10+05 ELEVATION 440.0'

DRILLER: Joe Minarchick N 781900 GWL 0 HRS

CLASSIFIED BY: R. T. Wardrop DATE: 8/24/78 E 2368700 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
10					.6' of hard, lt. gy., iron stained sandy shale interlam w/little med. gy. shale, tr. x-bedding - Upper 3" of core, beveled by over-core. Clay remanants in partings.		0%	.75	.7	Lt. gy. wash darkening occasionally.
11					1.2' of med. hard, med. gy. broken shale w/some dk. gy. brn. shale lam. (1/2" thk.) dipping @ 10°- remanants of gy. clay (gouge) throughout pieces. Lt. gy. sandy shale band (1" thk.) .6' into section, x-bedded. Pieces - 1-1/2"-1-3/4" long Edges of pieces rounded.		0%	1.0	.8	Gas begins to bubble violently in hole - lifts core barrel - 80% LEL detected 1' abv. hole. Worked stopped @ 10.75 when methane readings stay consistently high.
12					End of Fault Zone 11.95' 11.95-13.15 - Med. hard, med. gy. shale, w/some dk. gy. brn. lam (1/4-1/2" thk.). Remanant clay in partings - flat bedded.		32.5%	2.0	1.7	8/25/78 - Pulled off TX-3 - began TX-5 due to gas 8/29/78 - 100% LEL 1' abv. hole 8/30/78 - Resumed TX-3 w/ blo-jo apparatus to dissipate gas in flow.
13					13.15-13.4 - Hard, lt. gy. sandy shale interlam w/little med. gy. shale in v. thin lam., x-bedded. Pieces - 1/2-4-1/2" long. 13.4-14.4 - Med. hard, dk. gy. shale interlam w/lt. gy. siltstone in 1"-2" bands.					Lt. gy. wash turning brown occasionally.
14										Lt. gy. wash.
					14.4-15.1 - Hard, lt. gy. sandy shale, w/little med. gy. shale in 1/4" bands. Sandy shale broken w/clay remanants @ 15.1'.		77%	1.5	1.4	
15										

G-12

GAI-327 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 5

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel

DRILL HOLE NO. TX-3

CONTRACTOR: Herron Testing COORDINATES Sta. 10+05

ELEVATION 440.0'

DRILLER: Joe Minarchick N 781900

E 2368700

GWL 0 HRS ______

CLASSIFIED BY: R. T. Wardrop DATE: 8/24/78

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
15							15.1-15.9 - Hard, lt. gy. siltstone interlam w/some v. thin dk. gy. shale lam.					Lt. gy. wash.
16							15.9-16.5 - Med. hard, dk. gy. & med. gy., shale in 1" thk. bands, interlam w/tr. lt. gy. siltstone.					Lt. to dk. gy. wash w/influx of brn. occasionally.
							16.5-17.05 - Hard, lt. gy., sandy shale, w/band of lt. gy. siltstone 1-1/2" thk. @ 16.6, tr. dk. gy. brn. shale.					
17							17.05-17.65 - Med. hard, med. gy. shale, w/tr. siltstone and sandy shale.		51%	4.6	4.4	
							17.65-18.75 - Hard, lt. gy. sandy shale, and siltstone in 1/2" - 1" thk. bands - interlam w/little dk. gy. shale in 1/4" - 1" bands.					Wash same.
18												
							18.75-19.6 - Med. hard, dk. gy. shale dky. gy. brn. siltstone band (1/2" thk.) @ 19.25'.					
19							Broken, sandy shale seam w/clay remanants @ 18.75'					Gas Bubbling in hole 0% LEL w/blo-jo 0% LEL w/minimal bubbling.
							Bottom piece broken off @ 65° fract.					80-100% - 1' abv. hole @ irregular surges shooting water 1'-2' abv. hole
							Bottom of Hole - 19.6'.					
20												

G-13

GAI • 42/ %.6

Sheet 5 of 5
Drill Hole No. TX-3

INSPECTOR'S COMMENT:

An influx of very light creamy grey wash with platy clay particles was noted at the end of the 7.75' to 9.75' run. Four-tenths of a foot of core was lost in this run. Further evidence of test hole intersection with fault zone was found in the bottom 1-1/2" piece of core extracted from the barrel. This piece consisted of a 1/4" thick band of medium grey shale, dipping 25° and interlaminated on top and bottom by light grey siltstone.

Very little core loss occurred in the 9.75'-10.5' and 10.5' to 11.5' runs. Pieces of core did, however, show a slight dip to laminae and grey clay (gouge) remnants. Penetration through the clayey gouge zone released a quantity of methane sufficient enough to delay work on hole.

Fifteen percent core loss experienced at the top of the 11.5' to 13.5' run indicated advance through the bottom of faulted strata.

Weston Geophysical confirmed the existence of faulted rock from 9.35' to 11.95' by recognizing a zone of low sonic velocity via sonic logging.

Weston also ran a gamma log in TX-3. That log further supported fault zone location by detecting zones of low radiation between 9.4' and 12.0'.

G-14

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Harron Testing COORDINATES STA. 7+44, N 777333, E 2365924
DRILLER: Joe Minarchick
CLASSIFIED BY: R. T. Wardrop DATE: 9/11/78
SHEET 1 OF 20
DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					0.-2.85- Med. hard, dk.gy. & med. gy., shale interlam. w/some thin H.gy. sandy shale lam. (1/16-1/8"), tr. siltstone lam.			.5	.5	4" Core for 1st 1/2 foot to set top casing
1					Pieces 1/2-7 1/2" long		78%	1.5	1.5	Lt. gy. wash
2–3					2.85-4.05 - Hard, lt.gy. sandy lenses and thin gy. shale lam. in (1/2-1" bands), slightly broken Pieces 2-5 1/2" long		63%	1.5	1.4	Encountered gas @ 3.0' 100% L.E.L. 1' abv. hole 0% w/blo-jo
4–5					Bedding flat 4.05-4.25 - Hard, lt. gy. siltstone 4.25-4.7 - Med. hard, dk. gy shale interlam w/thin lt. gy siltstone lam, tr. sandy shale 4.7-6.75 - Hard, lt.gy. sandy shale and dk. gy. brn. shale to siltstone in 1/16-2 1/2" bands Pieces 2-5 1/2" long		53%	1.5	1.5	This condition remains for entire coring of hole w/ notable increases where indicated Gas bubbling in hole -

G-15

GAI-337 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Harron Testing COORDINATES STA. 7+44, N 777333, E 2365924
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW DATE: 9/12/78
SHEET 2 OF 20
DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
5–6										Foul, LP-gas like order associated w/ methane occurrence
6–7					6.75-7.5 Hard, lt.gy., siltstone and sandy shale 1/4"-3/4" bands					Wash, lt. gy. for the most part, except where noted different
7–8					7.5-8.85 - Med. hard., med. gy., shale interlam w/lt. gy. siltstone in 1/2-1" bands, little dk. gy. brn. siltstone lam.		100%	5.0	5.0	Brown wash
8–10					8.85-9.0 - Med. hard, dk. gy. shale interlam w/ little lt. gy. siltstone lam. 1/8" thk. 9.0-9.75 - Med. hard, dk. gy. shale interlam. w/some lt. gy. siltstone lam. (1/8") Hard lt. gy. sandy shale bands (3/4") @ 9.25 and 9.35 9.75-10.0 - Med. hard, dk. gy. shale interlam. w/some dk. gy. brn. shale, tr. lt. gy. siltstone lam. Long piece 4 ft.					

G-16

GAI-337 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 06-4549-310 SITE AREA Intake Tunnel
SHEET 3 OF 20
CONTRACTOR: Herron Testing COORDINATES N 777333 E 2365924
DRILL HOLE NO. TX-4
DRILLER: Joe Minarchick
ELEVATION 438.7
CLASSIFIED BY: RTW DATE: 9/12/78
GWL 0 HRS
24 HRS

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Core Run	Core Rec.	Remarks
10	10.0-14.4 - All, Med. hard, dk. gy. shale interlam. with thin lt. by. sandy shale and siltstone Heavy concentrations of sand X-bedded, in bands @ 10.2 (1 1/2"), 10.75 (2 1/2), 11.5 (3), 11.9(1/2), 12.6 (3 1/2), 14.05 (3 1/2")				
11					
12		34%	5.0	5.0	
13					
13.9	Bedding flat				
14	14.4-15.9 Med. hard, dk. gy. shale interlam. w/some lt. gy. (1/2-3/4") sandy shale and siltstone bands				
15	Long piece 21 1/2"				

G-17

GAI-227 8/73

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 06-4549-310 SITE AREA Intake Tunnel
SHEET 4 OF 20
CONTRACTOR: Herron Testing COORDINATES STA. 7+64 N 777333 E 2365924
DRILL HOLE NO. TX-4
DRILLER: Joe Minachick
ELEVATION 43.87'
CLASSIFIED BY: R. T. Wardrop DATE: 9/12/78
GWL 0 HRS
24 HRS

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Core Run	Core Rec.	Remarks
15	1" Vertical fract. @ 15.8"				
16	15.9-16.85 - Med. hard, dk. gy. shale and lt. gy. sandy shale in 1/2" bands, tr. siltstone lam. 16.85-17.0 - Hard lt. gy. sandy shale, X-bedded				
17	17.0-17.4 - Med. hard, dk. gy. shale, interlam. w/little dk. gy. brn. shale (1/4" thk.) 17.4-17.6 - Hard, lt. gy. sandy shale, X-bedded	71%	5.0	4.7	Momentary Brown influx to wash
18	17.6-18.3 - Med. hard, dk. gy. shale interlam. up 1/4-1" thk. sandy shale to siltstone bands 18.3-19.1 - Med. hard dk. gy. shale and lt. gy. sandy shale				
19	19.1-19.6 - Med. hard, dk. gy. shale, tr. lt. gy. sandy shale 9.6-20.0 - Med. hard, dk. gy. shale and lt. gy. sandy shale Lt. gy., sandy shale band, 2" thk. @ 19.75 (X-bedded)				
20	Long piece 21 1/2"				

G-18

GAI-227 8/73

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 5 OF 20

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES N 777333 / E 2365924
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW DATE: 9/12/78

DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
20					20.0-20.45 Med. hard, dk. gy. shale, some dk. gy. brn shale, little lt. gy. sandy shale					
					20.45-20.75 - Hard. lt. gy. sandy shale, w/little dk. gy. shale lam.					
21					20.75-21.75 - Med. hard, dk. gy. and dk. gy. brn. shale					
					Lt. gy. sandy shale band @ 21.45 - 1 1/4" thk.					dk. gy. wash
22					21.75-22.15 - Med. hard, dk. gy. shale w/some thin, lt. gy. sandy lam.					
					22.15-22.6 - Med. hard dk. gy. shale w/tr. lt. gy. sandy shale lam.		80%	5.0	4.9	
23					22.6-24.1 - Med. hard, dk. gy. shale, w/tr. siltstone, tr. lt. gy. sandy shale in feeding pattern type clast. @ 23.2'					
					Bedding flat w/minor local variations (depositional)					
24					24.1-26.0 - Med. hard, dk. gy. shale, w/some lt. gy. sandy shale					
					lt. gy. sandy band, 1-1/2" thk., @ 24.5 X-bedded					
25					Long piece 17"					

G-19

GAI-237 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 6 OF 20

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES N 777333 / E 2365924
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW DATE: 9/12/78

DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25										Lt. gr. wash
26					26.0-26.2 - Hard, lt. gy. sandy shale, X-bedded					
					26.2-26.35 - Med. hard, dk. gy. shale					
					26.35-26.5 - Hard, lt. gy. sandy shale					
					26.5-27.8 - Med. hard, dk. gy. shale w/little lt. gy. sandy shale, little dk. gy brn. shale					
27					Lt. gy. sandy band @ 27.1' (1/2")					
							71%	5.0	5.0	
28					27.8-28.1 - Hard, lt. gy., siltstone, dk. gy. shale, and lt. gr. sandy shale, thinly lam.					
					28.1-29.15 - All, med. hard, dk. gy. shale w/little lt. gy. sandy shale					
29					29.15-29.3 Hard, lt. gy., sandy shale, interlam w/little dk. gy. shale lam.					
					29.3-30.0 - Med. hard, dk. gy. shale w/tr. lt. gy. sandy shale in 1/8" thin lam.					
30										

G-20

GAI-237 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.H.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES N 777333 E 2365924
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW DATE: 9/12/78
SHEET 7 OF 20
DRILL HOLE NO. TT-4
ELEVATION 638.7
GWL 0 HRS
24 HRS

Depth Ft.	Description	R.Q.D.	Core Run	Core Rec.	Remarks
30	30.0-30.8 - Med. hard, dk. gy. shale				
	lt. gy. sandy shale band @ 30.3 (1" thk.)				
	30.8-32.3 - Med. hard, med. gy. silty shale, tr. lt. gy. lam. (1/8-1/4" thk.)				
31					
32	32.3-32.85 - Med. hard, dk. gy. shale, tr. lt. gy sandy shale, tr. dk. gy. brn. shale lam.	62%	5.0	4.85	Momentary brown influx to wash
	32.85-33.4 - Med. hard, med. gy. silty shale w/little lt. gy. lam. (1/16-1/4" thk.)				
33	33.4-34.1 - Med. hard., dk. gy. shale				
	lt. gy. sandy shale band @ 33.75 (1 1/2" thk.)				
34	34.1-35.0 - Med. - dk. gy. shale, tr. dk. gy. brn. shale, tr. lt. gy. sandy shale, thinly lam.				
35	Long piece 17 1/2"				

G-21

GAI-237 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.H.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel STA 7+64
CONTRACTOR: Herron Testing COORDINATES N 777333 E 2365924
DRILLER: Joe Minachick
CLASSIFIED BY: R. T. Wardrop DATE: 9/12/78
SHEET 8 OF 20
DRILL HOLE NO. TT-4
ELEVATION 638.7
GWL 0 HRS
24 HRS

Depth Ft.	Description	R.Q.D.	Core Run	Core Rec.	Remarks
35	35.0-35.5 - Med. hard, dk. gy. shale and lt. gy. sandy shale in 1/16-1/4" lam.				
	35.5-35.75 - Med. hard, med. gy. to dk. gy. silty shale				
36	Clay remnants in parting @ 36.0				
37	37.25-38.3 - Med. hard, dk. gy. to med. gy. shale, w/some siltstone in 1" bands @ 37.3, 37.4, 37.6	64%	5.0	4.9	
38	2" lt. gy. sandy, X-bedded band @ 38.4'				
	38.4-38.85 - Med. gy. shale 20° fract. @ 38.6'				
	38.85-40.0 - Hard, lt. gy. sandy shale, X-bedded - minature fracts along X-bed laminae				Gas shot water out of hole at 39.5' Fracts. indicate new influx of gas.
39	lt. gy. siltstone band @ 38.7 (2" thk.)				
	Bedding flat				100% L.E.L. recorded 3-4 ft. abv. hole w/o blo-jo on
40	Long piece 12"				

G-22

GAI-237 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Barron Testing COORDINATES N 777333 E 2365924
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW DATE: 9/12/78
SHEET 9 OF 20
DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Dens., Ground Water, Construction Problems, etc.
40					40.0-43.0 - Med. hard, med. gy. to dk. gy. silty shale w/little lt. gy. sandy shale thinly lam.					Momentary loss of water @ 40.0'
					Lt. gy. sandy shale bands @ 40.5 (1 1/4") and 41.0 (1 3/4", X-bedded)					
41										
42							74%	5.0	5.0	
43					43.0-43.6 - Hard, lt. gy. siltstone, tr. dk. gy. brn. lam. sandy ooze or feeding pattern @ 43.4"					
					43.6-45.25 - Med. hard, dk. gy. to med. gy. silty shale					
44					Lt. gy. sandy band @ 44.7' (1-1/4")					
45					Long piece -2'					

G-23

GAI-557 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Barron Testing COORDINATES N 777333 E 2365924
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW DATE: 9/13/78
SHEET 10 OF 20
DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Dens., Ground Water, Construction Problems, etc.
45					45.25-46.0 - Hard lt. gy. sandy shale, X-bedded					
46					46.0-46.9 - Med. hard, med. gy. shale, to siltstone					
47					46.9-47.15 Hard, tn. lt. gy., sandy shale, X-bedded					
					17° fract. @ 46.9					
					47.15-48.3 - Med. hard, dk. gy. to med. gy. shale, w/little lt. gy. sandy lam.		57.5%	5.0	4.85	
48					Clay remnants in parting @ 47.5'					
					48.3-48.8 Med. hard, med. gy. shale					Dk. gy. wash
49					48.8-50.2 - Hard lt. gy. sandy shale to siltstone - X-bedded @ bottom - some dk. gy. shale					
					Bedding flat					
50					Long piece 27"					

G-24

GAI-557 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel SHEET 11 OF 20
CONTRACTOR: Herron Testing COORDINATES N 777333 E 2365924 DRILL HOLE NO. TX-4
DRILLER: Joe Minarchick ELEVATION 438.7
CLASSIFIED BY: DTW DATE: 9/12/78 GWL 0 HRS 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
50					50.2-50.4 - Med. hard dk. gy. shale					
					50.4-50.5 - lt. gy. sandy shale					
					Possible "Fe" band missing from core @ 50.55					
51					50.5-51.05 - Hard, lt. gy. siltstone					
					51.05-51.2 - Med. hard, dk. gy. shale					
					51.2-51.3 - Hard, lt. gy. siltstone					
					51.3-51.75 - Med. hard, med. gy. siltstone, w/some dk. gy. shale, little lt gy. sandy stringers					
52					51.75-52.7 - Hard, lt. gy. sandy shale to siltstone (X-bedded), tr. thin gy. shale lam.		81%	5.0	4.95	
53					52.7-53.7 - Med. hard, med. gy. shale, tr. dk. gy. brn. shale lam., w/little lt. gy siltstone lam.					
					53.7-54.0 - Hard lt. gy. sandy shale, X-bedded					
54					54.0-55.2 - Med. hard, med. gy. and lt. gy. sandy shale, cozed features present @ 55.2'					Increase in constant gas seen as increased pressure in bubbling hole @ 55.0
55					Long piece -19"					

G-25

GAI-337 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel SHEET 12 OF 20
CONTRACTOR: Herron Testing COORDINATES STA 7+44 N 777333 E 2365924 DRILL HOLE NO. TX-4
DRILLER: Joe Minarchick ELEVATION 438.7
CLASSIFIED BY: R. T. Wardrop DATE: 9/13/78 GWL 0 HRS 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
55					55.25-possilbe "Fe" band					
					55.3-55.4 - Hard, lt. gy. sandy shale					
					55.4-56.3 - Med. hard, med. gy. and lt. gy. shale, tr. siltstone in 1-2" bands					
56					Clay remnants in parting @ 55.7					
					56.3-56.55 - Hard, lt. gy. sandy shale, X-bedded					
57					56.55-57.7 - Med. hard, dk. gy. shale and lt gy. siltstone in 1/4-1" lam.					
					57.7-58.25 - Hard, lt. gy. siltstone, ooze features present, w/little med. gy shale, thinly lam.		72%	5.0	4.95	
58					58.25-58.85 - Med. hard, med. gy. shale w/little lt. gy. depositional features of silty concentric rings-actual size @ 58.55					
59					58.85-60.4 - Med. hard, med. gy. shale interlamd w/lt. gy. siltstone bands @ 59.0 (1 1/2") 59.3 (1"), and 59.75 (2")					
					tr. dk. gy. brn. thin lam.					
60					Long piece 19.5"					

G-26

GAI-337 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.H.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES N 777333 E 2365924
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW DATE: 9/13/78
SHEET 13 OF 20
DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Desc., Ground Water, Construction Problems, etc.
60					60.4-60.65 - Hard, lt. gy. siltstone, thinly lam.					
					60.65-61.9 - Med. hard, med. gy. shale, w/little lt. gy. sandy shale, tr. dk. gy. brn. lam.					
61					61.9-62.1 - Hard, lt. gy., sandy shale, X-bedded					
62					62.1-62.95 - Med. hard, dk. gy. shale, tr. dk. gy. brn shale lam. tr. lt. gy. sandy stringers	78%		5.0	4.9[illegible]	
63					62.95-63.1 - Hard, lt. gy., sandy shale, X-bedded					
					63.1-64.9 - Med. hard, dk. gy. and med. gy., siltstone bands, 2" thk.					
64					64.9-65.2 - Hard, lt. gy. sandy shale					
65					Long piece 17"					

GAI-337 8/78

G-27

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.H.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES N777333 E 2365924
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW DATE: 9/14/78
SHEET 14 OF 20
DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Desc., Ground Water, Construction Problems, etc.
65					65.2-66.1 - Med. hard, dk. gy. shale and lt. gy. X-bedded, sandy shale in 1/4"-1" bands					
66					66.1-66.45 - Med. hard, lt. gy. siltstone, thinly lam up little dk. gy. shale					
					66.45-67.35' - Med. hard, med gy. shale, w/little lt. gy. sandy shale, tr. dk. gy. brn. shale, thinly lam.					
67					67.35-67.45 - Lt. gy. sandy, shale, X-bedded	68%		5.0	5.0	
					67.45-67.9 - Med. hard, med. gy. shale, w/little lt. gy. siltstone					
68					67.9-68.05 - Lt. gy. sandy, X-bedded, shale					
					68.05-69.5 - Med. hard, dk. to med gy. shale, tr. lt. gy. siltstone lam., tr. dk. gy. brn. shale, tr. lt. gy. sandy shale lam.					Brown influx to wash Dk. gy. wash
69					69.8-70.0 - Med. hard, dk. gy. shale					
					Bedding flat					
70					Long piece 16.5"					

GAI-337 8/78

G-28

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 15 OF 20

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel DRILL HOLE NO. TX-4

CONTRACTOR: Herron Testing COORDINATES N 777333 E 2365924 ELEVATION 438.7

DRILLER: Joe Minarchick GWL 0 HRS

CLASSIFIED BY: RTW DATE: 9/14/78 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core / Run	Grain Shape / Rec. / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
70					70.0-70.35 - Hard, lt. gy., siltstone					
					70.35-72.4 - Med. hard, med. gy. shale, some lt. gy. siltstone lam.					
71					Siltstone band @ 72.0 (1.5") and @ 72.5 (2")					
					72.6-72.85 - Hard, lt. gy. sandy shale to siltstone, X-bedded @ top					
72							85%	5.0	5.0	
					72.85 - 73.1 - Hard, lt. gy. sandy shale, X-bedded					
73					73.1-76.9 - Med. hard, dk. gy. shale, tr. siltstone, w/little sandy bands @ 73.6 (2.5") and 74.5 (1")					
74										
75					Long piece - 18"					

G-29

GAI-227 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 16 OF 20

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel DRILL HOLE NO. TX-4

CONTRACTOR: Herron Testing COORDINATES STA 7+44 N 777333 E 2365924 ELEVATION 438.7

DRILLER: Joe Minarchick GWL 0 HRS

CLASSIFIED BY: R. T. Wardrop DATE: 9/14/78 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core / Run	Grain Shape / Rec. / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75										
76										
77					76.9-77.3 - Hard, lt. gy., sandy shale, tr. X-bedding					
					77.3-77.85 - Med. hard, med. gy. shale, w/some lt. gy. siltstone in 1/4" lam.		84%	5.0	4.9	
					77.85-78.2 - Hard, lt.gy, sandy shale, X-bedded					
78					78.2-78.6 - Med. hard, med. gy. shale w/some lt. gy. siltstone, tr. dk. gy. brn. shale lam.					
					78.6 - 79.4 - Hard, lt. gy. sandy shale, X-bedded					
79					clay remnants in parting @ 79.2'					
					79.4-80.6 - Med. hard, med. to dk. gy. shale, tr. thin siltstone lam.					
					clay remenants in parting @ 80.7					Brown influx to wash
80					Long piece - 15"					

G-30

GAI-227 2/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 17 OF 20

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW
COORDINATES N 777333 E 2365924
DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS
DATE: 9/15/78

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Core Run	Core Rec.	Remarks
80						
	80.6-81.2 - Hard, lt. gy. sandy shale and med. gy. shale in 1/2-2" bands					
81	clay remenant in parting @ 81.2					
	81.2 -84.65 - Med. hard, med. gy. to dk. gy. shale of little lt. gy. sandy shale, tr siltstone, tr. dk. gy. brn. shale					
82	Lt. gy. sandy shale bands @ 81.95 (1 1/2") @ 83.55 (2 1/2") and 84.0 (2")		85%	5.0	4.8	
83						
84	Bedding flat					
	84.65-85.0 - Hard, lt. gy. sandy shale, X-bedded, and med. gy. shale					
85	Long piece - 11"					

G-31

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 18 OF 20

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW
COORDINATES N 777333 E 2365924
DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS
DATE: 9/15/78

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Core Run	Core Rec.	Remarks
85	85.0-86.45 - Med. hard, med. gy. shale and siltstone, tr. lt. gy. siltstone					Lt. gy. wash
	"Fe" band @ 85.35'					9/15/78 Man cage accident @ 12:33 p.m. prevented afternoon coring Coring stopped @ 87.0' -Core barrel raised several inches and water left running in hole over night - Coring resumed - 9/18/78 Driller notes starting @ 87.0 - continuing to 88' - Milky gray wash
86	Top of Fault Zone - 86.45' See note on Page 20					
87	15.5" of recovery over 30.5" of run					
	4" lt. gy. sandy shall					
	4" med. gy. shale					
	3 1/2" Broken, lt. gy. siltstone		30%	5.0	3.65	
	4" lt. gy. sandy shale					
88	Clay remenants in partings and around broken prices					
89	Bottom of Fault Zone - 89.0'					
	89.0-90.0 - Med. hard, med. gy. shale, some lt. gy. siltstone in 1/4" bands					
	"Fe" band @ 89.15'					Lt. gy. wash
90	Long piece - 14"					

G-32

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4569-310 SITE AREA Intake Tunnel SHEET 19 OF 20

CONTRACTOR: Herron Testing COORDINATES N 777333 DRILL HOLE NO. TX-4

DRILLER: Joe Minarchick E 2365924 ELEVATION 638.7

CLASSIFIED BY: BTW DATE: 9/18/78 GWL 0 HRS ______

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
90							90.0-90.8 - Med. hard, dk. gy. shale and lt. gy. sandy shale, X-bedded in 1/4-1 1/4" bands					
							90.8-91.35 - Hard, lt. gy. sandy shale, X-bedded, w/little dk. gy. shale in 1/4" bands					
91							91.35-91.65 - Med. hard, dk. gy. shale, w/little lt. gy. siltstone, thinly lam.					
							91.65-91.85 - Hard, lt. gy. siltstone					
							91.85-92.35 - Med. hard, dk. gy. shale, w/little, thin, lt. gy. siltstone lam.					
							92.35-92.9 - Hard, lt. gy., sandy shale, X-bedded		82%	5.0	4.85	
93							92.9-93.3 - Med. hard, dk. gy. shale					
							93.3-93.75 - Hard, lt. gy. siltstone					Dk. gy. wash
							Bedding flat					
							93.75-94.05 - Med. hard, dk. gy. shale					
94							94.05-94.3 - Hard, lt. gy. siltstone					
							94.3-94.55 - Med. hard, med. gy. shale					
							94.55-95.0 - Hard, med. gy. and lt. gy. siltstone					
95							Long piece - 22"					

Bottom of hole - 95.0'

G-33

GAI-237 9/72

INSPECTOR'S COMMENT:

The fault was logged between depths 86.45' and 89.0' for the following reasons. One and one tenth feet of core was not recovered over two and five tenths feet of advance in a five foot run between 85.0' and 90.0'. Clay remnants adhered to core pieces from the zone in question. A milky grey influx surfaced in the wash while drilling at 88.0'. The 85.0' to 90.0' interval of faulted rock was consistent with down dip feature projections derived from the occurrence of faulted rock in TX-1, TX-2, TX-3, TX-5 and TX-6.

Weston Geophysical Corporation confirmed the fault in TX-4 by demonstrating low sonic velocity and low gamma partical emission as compared to sections of country rock above and below the 86.45' to 89.0' faulted interval.

G-34

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
SHEET 1 OF 7
DRILL HOLE NO. TX-5
ELEVATION 439.8'
CONTRACTOR: Herron Testing COORDINATES Sta. 9+65, N 781890, E 2368730
DRILLER: Joe Minarchick
CLASSIFIED BY: R. T. Wardrop DATE: 8/25/78
GWL 0 HRS ______ 24 HRS ______

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Run	Core Rec.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
0–0.5	Highly broken, med. hard, med. gy. silty shale w/little dk. gy. brn. lam. (1/8" thk.), flat.	0%	.5	.5	4" core taken to set top casing.
0.5–2	Same, broken in 1/2" - 2-1/2" pieces, tr. sandy stringers. Lt. gy. sandy shale band (1") @ .85', flat.	0%	1.5	1.0	No gas. Lt. gy. wash.
2–3.5	Pieces 1/4-2-1/2" long. Same. Tn. brn., pinching, cherty, "Fe" band (1/2-1-3/4" thk.) @ 2.65.	0%	1.5	.75	No gas. Lt. gy. wash.
3.5–5	Pieces 1/2-2" long. Same to 4.4'. Tn. brn., pinching, "Fe" band (0-3/4" thk.) @ 3.85'. 4.4-5.05 - Lt. gy., sandy shale, some dk. gy. shale in 1/8-1" bands broken in 3/4" pieces.	39%	4.0	3.85	No gas.

G-35

GAI-337 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
SHEET 2 OF 7
DRILL HOLE NO. TX-5
ELEVATION 439.8'
CONTRACTOR: Herron Testing COORDINATES Sta. 9+65, N 781890, E 2368730
DRILLER: Joe Minarchick
CLASSIFIED BY: R. T. Wardrop DATE: 8/25/78
GWL 0 HRS ______ 24 HRS ______

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Run	Core Rec.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
5–7.5	5.05-5.25 - Hard, lt. gy., sandy shale. 5.32 - 2" band of med. hard, gy. shale. 5.35-5.7 - Hard, lt. gy. sandy shale, w/little, thin, dk. gy. shale lam. (1/16" thk.) 5.75 - 1-1/4" gy. shale. 5.85 - 1-3/4" hard, lt. gy. siltstone. 5.9-6.85 - Med. hard, dk. gy. shale and lt. gy. siltstone in 1/4" bands. 6.85-7.3 - Med. hard, dk. & med. gy. shale w/little sandy shale lam. (1/8"-1/4" thk.) 7.3-7.95 - Hard, lt. gy., sandy shale w/little med. gy. shale lam. in 1/4"-1/2" thicknesses.	39%	4.0	3.85	Lt. gy. wash.
7.5–10	Long piece - 7" long. Slight local variness to lam - dep. features - generally flat-bedded. 7.95-8.4 - Med. hard, med. gy. & dk. gy. shale in 1/4"-3/4" lam., w/tr. lt. gy., thin sandy stringers. 8.4-9.6 - Hard, lt. gy., sandy shale in stringers, thin lam., and lenses - several lam. iron stained upon contact w/tunnel atmosphere - these occur @ 8.75, 8.85, and 9.05. 9.6-12.0 - Med. hard, med. gy. dk. gy., & dk. gy. brn. shale w/bands of hard, lt. gy. sandy shale @ 10.35 (1/4" thk.) 11.15 (3/4" thk) 11.4 &1-3/4" thk.)(x-bedded) & 11.65 (1" thk.).	93%	3.5	3.5	No gas. Lt. gy. & dk. gy. wash. Lt. gy. and brn. wash.

G-36

GAI-337 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel SHEET 3 OF 7

CONTRACTOR: Herron Testing COORDINATES Sta. 9+65 DRILL HOLE NO. TX-5

DRILLER: Joe Minarchick N 781890 ELEVATION 439.8'

CLASSIFIED BY: R. T. Wardrop DATE: 8/28/78 E 2368730 GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
10										
11					Long piece - 11-1/2"					No gas.
					11.65-11.8 - Med. hard, dk. gy. shale. 11-8-11.95 - Hard, lt. gy., sandy shale (tr. x-bedding).		95%	2.0	1.9	
12					11.95-13.25 - Med. hard, dk. gy. & med. gy., shale and lt. gy., hard sandy shale interlam in 1/8" - 1-1/2" bands.					
13					Long piece - 12-1/2" long					No gas.
					13.25-13.55 - Hard, lt. gy., fi. gr. sandy, shale to siltstone.					
					13.55-13.45 - Med. hard, dk. gy. shale w/little med. gy. lam. (1/8" - 1/4" thk.) Lt. gy. sandy shale bands (1-1/2" thk. avg.) @ 13.9, 14.05, 14.35, and 14.65.		75%	2.0	1.65	Gas bubbling around core-barrel in top casing -. 0% LEL w/blo-jo on.
14					Thin clay seams seen as remnants in bedding fracts. @ 13.85 and 14.0 Bedding flat.					
15										

G-37 GAI-257 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel SHEET 4 OF 7

CONTRACTOR: Herron Testing COORDINATES Sta. 9+65 DRILL HOLE NO. TX-5

DRILLER: Joe Minarchick N 781890 ELEVATION 439.8'

CLASSIFIED BY: R. T. Wardrop DATE: 8/28/78 E 2368730 GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
15					15.45-16.45 - Hard, lt. gy., sandy shale (x-bedded).					
16					Flat bedded.		77.5%	2.0	1.85	Lt. to dk. gy. wash.
					16.45-17.25 - Med. hard, dk. gy. shale interlam. w/little, thin, lt. gy. siltstone lam.					
17					Long piece - 5-3/4" long					Gas bubbling in hole. 5% LEL w/blo-jo (1' abv. hole)
					17.25-17.45 - Hard, lt. gy. sandy shale to siltstone (x-bedded).					
					17.45-19.0 - Med. hard, dk. gy. & med. gy. shale interlam. w/some dk. gy. brn. siltstone lam. (1/2" thk.) - Remnants of clay seams in partings from 18.5-19.0.		7.5%	2.0	2.0	60-80% LEL w/o blo-jo (1' abv. hole) Lt.-dk. gy. & brn. wash.
18					18.5-19.0 - Vertical fracts from 17.8-18.0.					
					2 jts. - 1-1/2" apart dipping @ 45° intersected by a 80° (near vertical) fract @ 18.3'.					
					Core pieces - 1/2" - 3-1/2"					Gas same.
19					Fault Zone 19.0-19.75 - 3" of highly fract. shale w/clay remnants on most pieces (1) piece overcored.		50%	3.0	2.5	See Note on Page 7
					19.75-21.45 - Med. hd., dk. gy. & med. gy. shale interlam w/some dk. gy. brn. siltstone lam. (1/2" thk.) Rem. of clay in partings.					
20										

G-38 GAI-257 2/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 5 OF 7

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel DRILL HOLE NO. TX-5
CONTRACTOR: Herron Testing COORDINATES Sta. 9+65 ELEVATION 439.8'
DRILLER: Joe Minarchick N 781890 GWL 0 HRS
CLASSIFIED BY: R. T. Wardrop DATE: 8/29/78 E 2368730 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
20–22					20.45-22.0 - Hard, lt. gy., sandy shale, x-bedded and interlam. w/ med. hard, dk. gy. lam. (3/4" thk) tr. minute fracts. parallel to x-bedding @ 20.65'.		50%	3.0	2.5	Lt. gy. wash w/occasional dk. gy. influx.
22–25					Long piece outside of fault zone - 7" long. 22.0-25.1 - Med. hard, dk. gy., lt. gy. & dk. gy. brn. (1-1-1/2" lam.) shale, w/little lt. gy. siltstone bands @ 22.5, 22.9, 23.3 and 24.3 (all 1/4-1/3" thk.) tr. thin iron stained lam. - All flat bedded.		78%	4.5	4.2	Gas same. Lt. gy., dk. gy. & brn. wash.

G-39 GAI-227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 6 OF 7

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel DRILL HOLE NO. TX-5
CONTRACTOR: Herron Testing COORDINATES Sta. 9+65 ELEVATION 439.8'
DRILLER: Joe Minarchick N 781890 GWL 0 HRS
CLASSIFIED BY: R. T. Wardrop DATE: 8/29/78 E 2368730 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25–26.5					25.1-26.1 - Hard, lt. gy. sandy shale and dk. gy. - med. gy. shale w/little dk. gy. brn. shale interlam in 1/4"-3/4" bands - Concentrations of sand high in 1-1/2" band @ 25.15'. Flat bedded. 26.1-27.1 - Med. hard, dk. gy. shale interlam w/little sandy lam (x-bedded), @ 26.25 (1/2" thk.) and 26.55 (1-1/2" thk.) Long piece - 23" long		78%	4.5	4.2	Lt. gy., dk. gy., and brn. wash.
26.5–29.25					Remanant clay in bedding fracts @ 26.5, 26.65, 27.2 and 27.4. 27.1-27.3 - Hard, lt. gy., sandy shale (x-bedded). 27.3-29.25 - Med. hard, dk. gy. - med. gy., shale interlam. in 3/4" 1-1/4" bands, little dk. gy. brn. shale lam. in 1/4"-3/8" bands, tr. lt. gy. siltstone. Lt. gy. sandy shale bands, x-bedded @ 28.65 (3-1/4" thk.) and 28.9 (1-3/8" thk.), tr. iron staining in thin lam. Flat bedded.			2.75	2.67	Gas same. Gas same.
29.25–30					Bottom of Hole - 29.25'					

G-40 GAI-227 9/72

Revision 12
January, 2003

INSPECTOR'S COMMENT:

The fault was logged in TX-5 at the 19.0'-19.75' interval for the following reasons. One half foot of core was not recovered from the 19.0' to 22.0' run. In addition, the upper portion of the run consisted of three inches of highly fractured core and grey clay (gouge) remnants. A one-inch piece was over-cored, probably the result of a shale fragment in clay adjusting to the downward force of the core barrel.

Weston Geophysical Corporation attempted to geophysically log TX-5 but local caving at the fault interval prevented complete lowering of recording probes.

The 19.0'-19.5' interval of faulted rock was consistent with down dip feature projection derived from occurrences in TX-1, TX-2, and TX-3.

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95, N 781840, E 2368790
DRILLER: Joe Minarchick
CLASSIFIED BY: R. T. Wardrop DATE: 8/30/78

SHEET 1 OF 11
DRILL HOLE NO. TX-6
ELEVATION 639.5'
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					0-.5 - Med. hard, broken, med. gy. shale w/tr. sandy shale in stringers and lenses		0%	.5	.5	4" core taken in first .5' to set top casing
1					.5-1.5 - Med. hard-hard, dk. gy. shale and lt. gy. siltstone, tr. dk. gy. brn. shale. 1.5-2.0 - Hard, lt. gy. sandy shale Core pieces 1/4" - 9-3/4" long		53%	1.5	1.3	Gas occurrence in first 6". 100% LEL - 1' abv. hole 0% w/blo-jo Lt. gy. wash
2					2.0-3.3 - Med. hard, med. & dk. gy. shale in 1/2"-1" bands, interlam w/little bands of lt. gy. siltstone, 1/4" thk. Flat bedded w/local waviness due to deposition 3.3-3.5 - Hard, med. gy., siltstone interlam w/ a 3/8", th. brn. cherty, "Fe" band		76%	1.5	1.2	Gas same Lt. gy. wash
3										
4					3.5-4.2 - Med. hard, med. gy. & dk. gy. shale in 1/2"-1-1/4" thk. bands, tr. lt. gy. siltstone, vertical fract. from 3.5-4.05 4.2-4.65 - Lt. gy. siltstone, interlam w/1-1/4" dk. gy. shale lam. 4.65-5.8 - Hard, lt. gy. sandy shale, tr. x-bedding interlam w/ 1/4" bands of dk. gy. shale		95%	5.0	5.0	Gas same Lt. gy. wash w/ infrequent tn. brn. influx
5										

GAI-227 8/78

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 11

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel DRILL HOLE NO. TX-6
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95 ELEVATION 439.5'
DRILLER: Joe Minarchick N 781840 GWL 0 HRS
CLASSIFIED BY: R. T. Wardrop DATE: 8/30/78 E 2368790 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
5					1-1/2" seam of weath. shale to clay @ 5.1'					
					5.8-7.5 - Med. hard to hard, thinly lam. lt. gy. sandy shale, dk. gy. shale, and dk. gy. brn. siltstone					
6					except for: a 4-1/2" thk. band of dk. gy. shale from 6.7-7.0'					Lt. gy. wash w/occasional brn. influx
7					Flat bedded		95%	5.0	5.0	
					7.5-7.85 - Hard, lt. gy., sandy shale w/little dk. gy. shale lam. (1/4" thk.)					
8					7.85-8.5 - Med. hard, dk. gy. shale and dk. gy. brn. shale inter lam. w/v. thin, lt. gy. siltstone lam. - shale bands (1/2-1-1/2")					
					Long piece - 3.1'					Gas 1' abv. hole
					8.5-9.1 - Hard, lt. gy. sandy shale, interlam w/some dk. gy. shale lam (1/4" thk.) - A type of feeding pattern appears in sandy areas @ 8.65 and 9.1.					100% LEL w/o blo-jo; 3-5% w/blo-jo
9					approx. actual size					
					9.1-10.05 - Med. hard, dk. gy. shale, thinly lam. w/dk. gy. brn. shale, and lt. gy. sandy shale.					
10										

G-43 GAI-227 2/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 11

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel DRILL HOLE NO. TX-6
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95 ELEVATION 439.5'
DRILLER: Joe Minarchick N 781840 GWL 0 HRS
CLASSIFIED BY: R. T. Wardrop DATE: 8/30/78 E 2368790 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
10					10.05-10.1-dk. gy. brn., hard, silty shale					dk. brn. wash
					10.1-10.3 - Hard, lt. gy. sandy shale, tr. x-bedding					
					10.3-11.25 - Med. hard, dk. & med. gy. shale, thinly lam w/little th. gy. siltstone					
11					11.25-12.1 - Hard. th. gy., siltstone (1-1/2 - 2-1/2") interlam by 3/8" dk. gy. shale seams					Lt. gy. wash
					Flat bedded		97%	5.0	5.0	
12					12.1-12.4 - Med. hard, dk. gy. & med. gy., shale in 1/4"-3/4" bands					
					12.4-12.5 - Hard, lt. gy. sandy shale					occasional brn. influx to wash
					12.5-13.1 - Med. hard, dk. gy. shale, interlam w/some dk. gy. brn. shale, little lam of lt. gy. siltstone					
13					13.1-13.4 - Hard, lt. gy. sandy shale interlam w/little (1/4") lam. of dk. gy. shale					
					13.4-13.7 Long piece - 2' Med. hard, dk. gy. shale, tr. lt. gy. sand stringers					Gas same
					13.7-14.05 -					
14					Hard, th. gy., sandy shale, x-bedded		76%	5.0	5.0	Lt. to dk. gy. wash
					14.05-15.7 - Hard, lt. gy. sandy shale, lt. gy. siltstone, dk. gy. shale, dk. gy. brn. shale, and med. gy. shale - all interlam in 1/16" - 3/4" lam					
15										

G-44 GAI-227 2/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95
DRILLER: Joe Minarchick N 781840
CLASSIFIED BY: R. T. Wardrop DATE: 8/30/78 E 2368790

SHEET 4 OF 11
DRILL HOLE NO. TX-6
ELEVATION 439.5'
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Sample Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
15					15.7-16.05 - Hard, lt. gy., sandy shale, interlam w/some v. thin, dk. gy. shale lam. in a wavy depositional pattern - tr. x-bedding					
16					16.05-19.1 - Med. hard, dk. gy. brn. shale, and dk. gy. shale interlam in 1/4-3-1/4" bands w/ little lt. gy. siltstone and sandy shale in 1/16-1/4"					Lt. gy. wash
					Flat bedded		76%	5.0	5.0	
17										
18					Long piece - 19"					Gas same
19					19.1-19.5 - Hard, lt. gy., sandy shale interlam w/a 1/2" band of dk. gy. shale @ 19.25 - lam. are locally wavy & x-bedded		96%	5.0	4.95	Wash same w/ occasional brn. influx
					19.5-20.45 - Med. hard, dk. gy. shale interlam w/some lt. gy. siltstone, sandy shale, and dk. brn. shale in 1/4-1/2" bands					
20										

G-45 GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95
DRILLER: Joe Minarchick N 781840
CLASSIFIED BY: R. T. Wardrop DATE: 8/30/78 E 2368790

SHEET 5 OF 11
DRILL HOLE NO. TX-6
ELEVATION 439.5'
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Sample Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
20					20.45-24.05 - Med. hard, dk. gy. shale (1-1-1/2") interlam w/1/4" dk. gy. brn. shale, nearly void of other lithologies, except:					
21					@ 21.05-21.35 w/v. thin lam of sandy shale, 1/2-1-3/4" apart.					Med. gy. wash
					21.35 - 1/2" band of lt. gy. sandy shale					
					22.9 - 1-1/2" band of lt. gy. siltstone					
					23.2 - 3/8" band of lt. gy. siltstone		96%	5.0	4.95	
22					23.5 - Suspect occurrence of "Fe" band here (pinching) where a high degree of splintering during coring may have left illustrated void.					
23					1"Fe" band Long piece - 30-1/2"					Bubbling diminished in hole - 8/31/78 Gas - 0% LEL
24					24.05-24.55 - Hard, lt. gy. sandy shale interlam w/little med. gy. shale in 3/4-2" bands, tr. dk. gy. brn. shale in 1/4" lam		85%	5.0	5.0	
					24.55-25.65 - Med. hard, dk. gy. shale interlam w/thin dk. gy. brn. shale (0-3/8" thk.)					
25					Lt. gy. sandy shale @ 24.8 (1/2" thk.) and 25.05 (2-1/4" thk.)					

G-46 GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95
DRILLER: Joe Minarchick N 781840
CLASSIFIED BY: R. T. Wardrop DATE: 8/31/78 E 2368790

SHEET 6 OF 11
DRILL HOLE NO. TX-6
ELEVATION 439.5'
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25					25.65-26.55 - Med. hard, dk. gy. shale, interlam w/little dk. gy. brn. lam (1/4" thk.)					
26					26.55-27.1 - Med. hard, dk. th. gy. siltstone interlam w/little dk. gy. brn. lam (1/4" thk.) into 1" bands		85%	5.0	5.0	Lt. gy. to med. gy. wash w/ occasional brn. influx
27					27.1-27.4 - Lt. gy. sandy shale, broken along dep. wavy partings, x-bedded.					
					27.4-28.45 - Med. hard, dk. gy. shale w/tr. thin dk. gy. brn. lam, tr. sandy stringers					
28					Flat bedded					
					28.45-28.6 - Hard, lt. gy. sandy shale Long piece - 16"					Gas bubbling in hole
29					28.6-29.9 - Med. hard, dk. gy. shale, interlam w/some (1/8-1/2" thk.) dk. gy. brn. shale lam @ 1-1/2-2" intervals, little lt. gy. sandy shale, thinly lam.		94%	4.5	4.4	10-30% LEL 1' abv. hole w/o blo-jo 0-5% w/blo-jo Wash same
30										

G-47

GAI-227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95
DRILLER: Joe Minarchick N 781840
CLASSIFIED BY: R. T. Wardrop DATE: 8/31/78 E 2368790

SHEET 7 OF 11
DRILL HOLE NO. TX-6
ELEVATION 439.5'
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
30					29.9-30.2 - Hard, lt. gy. siltstone w/little lt. gy. sandy stringers					
					30.2-33.1 - Med. hard, dk. gy & med. gy. shale to siltstone in 1/2 - 2" bands - interlain w/little lt. gy. sa. shale lam., little dk. gy. brn. siltstone (0-3/8" thk)					
31					Lt. gy. sandy shale bands (1/2" thk.) @ 30.65, (1" thk.) @ 31.4, (1/4" thk.) @ 32.35, & (1/4" thk.) @ 32.8					
					Gy. clay remanants in parting @ 31.7, top of sandy band		94%	4.5	4.4	
32										
33					Long piece - 16-3/4"					
					33.1-33.4 - Hard, lt. gy., sandy shale lenses (1/4-1/2") interlam w/some dk. gy. brn. lam. (1/4-1/2")					
					33.4-33.5 - Med. hard to hard dk. gy. brn. siltstone		91%	5.0	4.8	
					33.5-34.2 - Hard, med. gy. siltstone interlam w/dk. gy. brn. lam. (1/4-1/2"), tr. sandy stringers					
34					34.2-34.45 - Med. hard, dk. gy. to med. gy. shale interlam w/some dk. gy. brn. siltstone bands (1/4")					
					34.45-38.5 - Same, w/little lt. gy. siltstone (1/4") @ 1"-2" intervals					
35										

G-48

GAI-227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95
DRILLER: Joe Minarchick N 781840
CLASSIFIED BY: R. T. Wardrop DATE: 8/31/78 E 2368790

SHEET 8 OF 11
DRILL HOLE NO. TX-6
ELEVATION 439.5'
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
35					Gy. clay remanant of thin clay seam in parting @ 35.7					
36					1/4" sandy shale bands @ 36.45, 36.8, and 36.95		91%	5.0	4.8	Lt. gy. wash
37										
38					Long piece - 15"					0% LEL 1' abv. hole w/blo-jo
					38.5-38.7 - Hard lt. gy. sandy shale					
					38.7-38.85 - Med. hard, dk. gy. shale					Lt. gy. wash
39					Remanant clay in parting @ 38.85					
					38.85-39.0 - Hard, lt. gy. sandy shale					
					39.0-39.6 - Med. hard, dk. gy. shale interlam w/little lt. gy. sandy shale in 1/4-1/2" lam.					
40					39.6-39.75 - Lt. gy. sandy shale to siltstone					

G-49

GAI-227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95
DRILLER: Joe Minarchick N 781840
CLASSIFIED BY: R. T. Wardrop DATE: 8/31/78 E 2368790

SHEET 9 OF 11
DRILL HOLE NO. TX-6
ELEVATION 439.5'
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
40					39.75-40.3 - Med. hard, dk. gy. shale interlam w/tr. lt. gy. siltstone lam. (1/16" thk.) @ 1/4-2-1/4" intervals					
					Fault zone indicated by 2.35' of recovery in 3.2' of run + 12° dip in bedding parting w/clay remanant @ 40.3'.					
41					a) 5" of core parted every 1/4"-1-1/2" of dk. gy. shale and lt. gy. sandy shale (x-bedded) gy. clay remanants between all pieces.					
					b) 5-1/4" of competant, med. hard, dk. gy. shale, tr. thin sandy lam.		55%	5.0	4.35	Lt. gy. wash
					c) 3" of dk. gy. shale & lt. gy. (x-bedded) sandy shale in 1/2-1" bands.					
42					d) 1/2" of lt. gy. sandy shale, (x-bedded) vertically fractured.					
					e) 3-1/4" dk. gy. shale.					
					f) 2-1/4" of lt. gy. sandy shale broken in half-upper piece w/ 10° dipping jt.					
					g) 1-3/4" of broken sandy shale frags. and clay.					
43					k) 2" of tn. gy. sandy shale fract. in half @ 80°.					Pieces outside of fault - 4-1/2 - 13" long
					See note page 11					Gas same
					Bottom of fault zone @ 43.5'.					
					43.5-44.7 - Med. hard, dk. gy. & med. gy. shale interlam w/little lt. gy. siltstone (1/16" thk.)		51%	5.0	4.8	
44					44.7-44.8 - Hard, lt. gy. sandy shale.					
					44.8-45.2 - Med. hard, dk. gy. & med. gy. shale w/tr. lt. gy. siltstone lenses.					
45										

G-50

GAI-227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel SHEET 10 OF 11

CONTRACTOR: Herron Testing COORDINATES Sta. 8+95 DRILL HOLE NO. TX-6

DRILLER: Joe Minarchick N 781840 ELEVATION 439.5'

CLASSIFIED BY: R. T. Wardrop DATE: 8/31/78 E 2368790 GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
45					45.2-46.2 - Med. hard, dk. gy. shale, and lt. gy. siltstone to sandy shale in 1/8-1/4" lam.					
					46.2-47.45 - Dk. gy. & med. gy. shale, tr. thin siltstone lam.					
46					1/4" th. gy. siltstone band @ 46.5'		51%	5.0	4.8	Lt. gy. wash
47					47.45-47.7 - Hard, lt. gy. sandy shale to siltstone - broken in 3 1" pieces.					
					47.7-48.0 - Med. hard, dk. gy. shale, flat.					
48					Bottom of Hole - 48.0' Long piece - 5-3/4"					0% w/blo-jo 10-20% LEL 1' abv. hole w/o blo-jo

G-51 GAI-227 9/72

INSPECTOR'S COMMENT:

The fault was logged in the 40.3' to 43.5' interval for the following reasons. Nine-tenths of a foot of core loss occurred over ten feet of drilling, the sum of two five foot runs which stradled the feature. A slight dip to normally horizontal laminae is noted at 40.3'. Core pieces, recovered from the faulted zone exhibit grey clay remnants, vertical fracturing, and low angle fracturing. The 40.3' to 43.5' interval of faulted rock was consistent with down dip feature projection from fault recognitions in TX-1, TX-2, TX-3, and TX-5.

Weston Geophysical Corporation was able to demonstrate low sonic velocity and low gamma partial emission at the faulted interval.

G-52

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff SHEET 1 OF 9

CONTRACTOR: Herron Testing COORDINATES N50,490.93 DRILL HOLE NO. TX-7

DRILLER: Joe Minarchick E 9, 095.96 ELEVATION 618.1

CLASSIFIED BY: R. T. Wardrop DATE: 9/21/78 GWL 0 HRS

48 ~~24~~ HRS 99.7'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					9/21/78 Advanced to 63' w/hollow stem augers-unable to seal augers on top of bedrock for casing-abandoned hole					
					9/22/78 Advanced to 63' in second hole - roller bit advanced to 105' - Augers unable to seal hole - losing water					
10					9/23/78 - Bentonite slurry added to hole to seal					
					9/24/78 - Bentonite will not seal hole - hole abandoned					
20					9/25/78 - Casing inserted after augering 63' in third hole - casing seals hole properly					
30										
40										
50										

G-53

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff SHEET 2 OF 9

CONTRACTOR: Herron Testing COORDINATES N50, 490.93 DRILL HOLE NO. TX-7

DRILLER: Joe Minarchick E 9, 095.96 ELEVATION 618.1

CLASSIFIED BY: R. T. Wardrop DATE: 9/25/78 GWL 0 HRS

48 ~~24~~ HRS 99.7'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50										
60					Augered to top of bedrock @ 63.0' - Augers removed, casing driven					
63					start of Roller Bit Advance					
70										
80										Mostly lt. gy. wash occasional influxes of dk. gy. and and brn. wash
90										
100										

G-54

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 9

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-7

CONTRACTOR: Herron Testing COORDINATES N50, 490.93 ELEVATION 618.1'

DRILLER: Joe Minarchick E 9, 095.96 GWL 0 HRS

CLASSIFIED BY: R. T. Wardrop DATE: 9/30/78 48 HRS 99.7'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100–150					Entire Section Spudded w/Roller Bit					Mostly lt. gy. wash w/ occasional influxes of dk. gy. and brn. wash

G-55

GAI - 227 3/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 9

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-7

CONTRACTOR: Herron Testing COORDINATES N50, 490.93 ELEVATION 618.1'

DRILLER: Joe Minarchick E 9, 095.96 GWL 0 HRS

CLASSIFIED BY: R. T. Wardrop DATE: 10/3/78 48 HRS 99.7'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
150–168					Roller bit employed from 63' to 168' below top of ground NX Coring starts @ 168'					
168–175					168-171.7 Med. hard, med gy. shale, tr. lt. gy. sandy shale lam. fissile seam @ 170.6'		23%	7.0'	7.0'	Pieces 4-9.5" long
175–185					175.0-178.35 Dk. gy. shale w/ little sandy shale in 1 1/4" bands @ 175.95, 176.55 and 177.45" "Fe" band @ 176.85' feeding patterns in tr. siltstone @ 177.75 and 178.05'		91%	10.0'	9.89'	Lt. gy. wash w/ occasional influx of dk. gy. or brn. wash
185–195					178.35-195.85 Hard, lt. gy. sandy, shale interlam w/some dk. to med. gy. shale in 1 1/2 - 6" bands, tr. lt. gy. siltstone lam. "Fe" bands occurring @ 180.45; 181.5; and 184.6' clay remnants in partings @ 185.0 and 193.10 Feeding patterns in siltstone, @ 195.1'		80%	10.0	9.83'	Pieces 3.5-12" long
195–200							28%	10.0'	9.73'	Pieces 2 1/2-7 1/2" long

G-56

GAI - 227 3/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 5 OF 9

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-7

CONTRACTOR: Herron Testing COORDINATES N 50, 490.93 / E 9, 095.96 ELEVATION 618.1'

DRILLER: Joe Minarchick GWL 0 HRS

CLASSIFIED BY: R.T. Wardrop DATE: 10/5/78 48 HRS 99.7'

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Core Run	Core Rec.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
200–205	195.85'-220.15' Med. hard, dk. gy. shale, little lt. gy. sandy shale, little, lt. gy. siltstone, tr. dk. gy. brn. thin lam.	28%	10.0'	9.73'	Pieces 4-6"
205–215	Cone type clasts in lam. from 195.85-198.05. Broken medium soft shale from 199.05-199.75. 1" lt. gy. siltstone band @ 199.9' Zones of broken shale from 202.05-203.5 and 204.8-205 thin clay seam in parting @ 205'	77.5%	10.0'	10.0'	Long piece 11"
215–225	Broken sandy shale band @ 206.9' Vertical fracts in core @ 202.1' (2 1/2", long) and 204.3' (1" long)	56.7%	10.0'	10.0'	Black oily film floating in drill water catch barrel Long piece - 12.5"
225–235	3.5" lt. gy siltstone band @ 219.25	60.8%	10.0'	9.88'	Long piece - 17"
235–245	220.15'-232.7' Med. hard, dk. gy. to med. gy. shale, w/some lt. gy. sandy shale, little lt. gy. siltstone, tr. dk. gy. brn. lam. (2) 2 1/2", X-bedded sandy bands @ 229.75 and 230.3	76.7%	10.0'	9.96'	Long piece - 10"
245–250	232.7'-242.3' Med. hard, dk. gy. to med. gy. shale w/little lt. gy. sandy shale in 2-4" bands, 4-1/2" lt. gy. siltstone band @ 233.5' tr. lt. gy. siltstone, thinly lam.	87.0%	10.0'	9.96'	

GAI-337 8/78

G-57

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 6 OF 9,

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-7

CONTRACTOR: Herron Testing COORDINATES N 50, 490.93 / E 9, 095.96 ELEVATION 618.1'

DRILLER: Joe Minarchick GWL 0 HRS

CLASSIFIED BY: R. T. Wardrop DATE: 10/7/78 24 HRS

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Core Run	Core Rec.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
250–255	247.3'-254.45' - Med. hard, med. gy. to dk. gy. shale w/tr. lt. gy. sandy shale, tr. lt. gy. siltstone, tr. dk. gy. brn. thin lam	87.[illegible]%	10.0'	9.96'	Dk. gn. brn. wash Long piece - 14"
255–265	254.45'-255.8' - 16" of lt. gy. sandy, X-bedded bands w/some dk. gy. shale, bottom 2" broken along X-beds 255.8'-258.5' - Dk. gy. shale, tr. thin dk. gy. brn. lam.	[illegible]9.[illegible]%	10.0'	10.0'	Momentary loss of water @ 269.0' Long piece - 17"
265–275	258.5'-265' - Med. hard, dk. gy. shale and hard, lt. gy. sandy shale to siltstone a) X-bedded sandy band @ 259.0' b) 3 1/2" siltstone bands @ 261.2', 262.35', and 263.15' c) tr. clay remnants in parting @ 260.5'	[illegible]0.[illegible]%	10.0'	10.0'	Long piece - 18"
275–285	265-266.15 - Hard, lt. gy. sandy shale and siltstone in 2" bands interlam of little thin dk. gy. shale lam. 266.15-268.35 - Med. hard, dk. gy. shale, w/little lt. gy. sandy shale lam.	[illegible]2.[illegible]%	10.0'	10.0'	Long piece - 11"
285–295	268.35-275.0 - Hard, lt. gy. sandy shale, w/some lt. gy. siltstone, little dk. gy. shale lam. X-bedded in lower 1' foot 275.0-278.7 - Med. hard, dk. gy. and med. gy. shale w/tr. lt. gy. sandy shale lam. "Fe" band @ 277.7'	[illegible]0.[illegible]%	10.0'	9.875'	Long piece - 16"
295–300	278.7'-295.05' - Med. hard, dk. gy. to med. gy. shale and hard, lt. gy. sandy shale, tr. lt. gy. siltstone lam. a) 10" of sandy shale at top of sert. b) X-bedded from 280.7'-281.35' c) clay remnants in parting @ 291.0'				

GAI-337 8/78

G-58

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff
CONTRACTOR: Herron Testing COORDINATES N 50,490.93
DRILLER: Joe Minarchick
CLASSIFIED BY: R. T. Wardrop DATE: 10/10/78

SHEET 7 OF 9
DRILL HOLE NO. TX-7
ELEVATION 618.1
GWL 0 HRS
48-XX HRS 99.7'

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
300–305					295.05-296.2' - Med. hard dk. gy. shale w/some 3" thk. lt. gy. siltstone bands - broken band @ 295.5' 296.2'-297.5' - Hard, lt. gy. sandy shale		71.6%	10.0'	10.0'	
305–315					297.5'-299.05' - Dk. gy and med. gy. shale interlain w/little lt. gy. sandy shale, little lt. gy. siltstone lam. - 4 1/2" X-bedded, sandy, band @ 298.5 299.05-303.45' Hard, lt.-gy. siltstone		68.8%	10.0'	9.88'	Long piece-11"
315–325					303.45'-318.3' - Dk. gy to med. gy. shale, and lt. gy. sandy shale, little dk. gy. brn. shale lam. tr lt. gy. siltstone a) X-bedded @ 309.2 and 318.2 b) 2" long overcored piece @ 315.1 c) 13" band of hard, lt.gy.sandy shale and siltstone from 307.95'-309.05' 318.3'-320.6' - Med.hard, med.gy. shale, some lt.gy. sandy shale, some lt. gy. siltstone		77.9%	10.0'	9.75'	Long piece-12.5" Small seam of oil encountered in 315-325' run Barrel left in hole over weekend, 0.1 had seeped up to top of hole, along casing by Monday morning.
325–335					320.6'-329.3' - Hard, lt.gy. sandy shale w/some dk.gy.shale, tr.dk. gy. brn. lam. a) Badly broken zone from 325.0'-325.35' - clay remnants around pieces, no loss of recovery! b) Clay remnants in partings @ 324.3' & 324.7'		58.3%	10.0'	10.0'	Long piece-12.5" Methane bubbling in drill water.
335–345					329.3'-336.3' - Dk. to med. gy. shale, w/little lt. gy. sandy shale, tr. dk. gy. brn. lam., tr. lt. gy. siltstone lam., overcored piece @ 335.1' 336.3'-338.2' - Hard, Dk. gy. brn. siltstone, w/little med. gy. shale, little sandy shale 1" broken seam @ 337.25'		61.3%	10.0'	9.71'	Long piece 14" Oily film floating in drill water catch barrel, Wash-Dk. gn. brn.
345–350							29.3%	10.0'	10.0'	Long piece-11 1/4"

G-59

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff
CONTRACTOR: Herron Testing COORDINATES N 50,490.93 E 9,095.96
DRILLER: Joe Minarchick
CLASSIFIED BY: R. T. Wardrop DATE: 10/12/78

SHEET 8 OF 9
DRILL HOLE NO. TX-7
ELEVATION 618.1
GWL 0 HRS
48-XX HRS 99.7"

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
350–355					338.2'-363.6' - Med. hard, med. gy. shale w/some dk. gy. brn. siltstone lam. little lt. gy. sandy shale bands, tr. thin lt. gy. siltstone lam.		29.2%	10.0'	10.0'	Long piece - 5-1/2"
355–365					a) High concentration of siltstone lam. from 350.2'-351.6' b) Thin fissil shale seams @ 362.8' and 364.0' c) Clay remnants in partings @ 352.65', 362.8', and 361.6' d) 1/8" seam of pyrite @ 356.5'		51.7	10.0'	10.0'	Long piece - 10"
365–375					363.6'-371.3' - Med. hard, dk. gy. shale to med. gy. shale, w/some dk. gy. brn. siltstone lam. 1/8"-1/2" thk. tr. lt. gy. sand shale, tr. thin siltstone lam. a) X-bedded sandy bands @ 365.95 and 366.3' b) Clay rems. in partings @ 368.5' c) Seam of thin fissile shale @ 368.4'		36.3%	10.0'	9.17'	Long piece - 6 1/2" 365-375' run cored smoothly, yet @ fast rate Driller has very difficult time pulling barrel after 365'-375' run
375–385					Suspected FAULT ZONE -371.3'-372.4' 10" of core missing (?) 1" core pieces w/clay remnants - pieces do not interlock w/each other or w/core above and below		57.1%	10.0'	9.96'	Bottom 3' of barrel coated w/1/16 thk. layer of lt. gy. clayey film when retrieved
385–395					372.4'-395.0' - Med. hard, dk. gy. shale w/some dk. gy. brn. siltstone lam., some lt. gy. sandy shale bands, tr. thin lt. gy. siltstone lam. a) 6" thk. sandy band @ 380.6' and 6-1/2" @ 386.4' BOTTOM OF HOLE 395' (elev.223.1')		29.2%	10.0'	9.79'	Long piece - 28" Drill water getting plugged up in bottom of hole Pieces 2 1/2"-6" Long piece-10" No detectable methane

(b) clay rems. in partings @ 376.5', 379.0', 382.55', 382.65', 383.6', 391.35'.
(c) Broken seams of rock frags. @ 375.6', 385.05', 392.45' (6"), associated w/clay rems. @ 392.45' and 393.8'
(d) Thin fissile seams @ 386.1'
(e) Possible "Fe" band @ 394.3'

G-60

GAI-227 8/72

INSPECTOR'S COMMENT!

A suspected fault was noted in the 371.3' to 372.4' interval for the following reasons. Eight-tenths of a foot of core was lost in the 365.0'-375.0' run. A thin grey clay seam in a bedding parting occurred at 368.5', topped by fissil shale at 368.4'. Two, vertically adjacent, 1" long core pieces were recovered from the suspect zone, speckled by grey clay (gouge remnants). These pieces, though vertically adjacent would not interlock.

In addition, drilling of the 365'-375' run took less time than the average for other ten foot runs. After run completion, the driller had a very difficult time retrieving the core barrel. Barrel would not pull. When the driller was finally able to recover the barrel, a thin grey clay film was seen covering the bottom three foot of steel cylinder. The tool could have been stuck in a gouge zone.

Down dip feature projection derived from TX-1, TX-2, TX-3, TX-5, TX-6, and TX-4 fall slightly lower than the suspected fault interval in TX-7.

Weston Geophysical Corporation recognized no zones of low sonic velocity nor low gamma partical emission at any depth in TX-7.

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 4

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-7 (cont.)

CONTRACTOR: PA Drilling Co. COORDINATES N 781,963.08 E 2,369,376.54 ELEVATION 618.1

DRILLER: Jim Adams GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 6/22/79 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							Continuation of NX-Hole TX-7 w/NC coring					Driller reams NX-Hole TX-7 to Bottom, 395.5', w/NC size roller bit. No indication of new gas influxes, TX-7 has emitted methane since original boring. No significant soft zones (gouge) were noted in the 372' area where a suspected fault was recorded on the original TX-7 log.
390												
395							Top of new NC size coring - 395.5'					Lt. gy. wash
							M. hard, m. gy., flat lying shale w/some dk. gy. brn. shale in very thin laminations	6/22/79	93%	4.5'	4.2'	long piece = 12"
400												

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 4

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-7(Cont)

CONTRACTOR: PA Drilling Co. COORDINATES N 781,963.08 E 2,369,376.54 ELEVATION 618.1'

DRILLER: Jim Adams GWL 0 HRS ____ 24 HRS ____

CLASSIFIED BY: R. Wardrop DATE: 6/25/79

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
400				Continuation of NX Hole-TX-7 w/NC coring M. hard, m. gy., flat lying, shale w/some hard, lt. gy., sandy shale to siltstone laminae, some dk. gy. brown shale, all in thin lamination Bands of lt. gy ≥ 2" thk. @400.25-401.05', 401.25'(2" thk.), 403.25' (2"), m. gy. siltstone @ 406.6' (2")		99%	10'0	9.9'	Lt. gy. wash No gas Long piece= 14"
410				Bands of dk. gy. brn. shale @ 403.0'(1-1/2"), & 408.55'(2") Load cast horizon at 407.1' Same, w/tr. lt. gy. laminae,		90%	10.0'	9.5'	Rig running roughly, rattling rods at top of run No change in drill watercolor- water pressure rises to avg. of 350 psi from avg. of 250 psi @ top of run long piece=12"
				Suspected fault Top 412.8' .5' of core missing from 1.1' of core where highly fractured rock occurs, approx. 50% of ~~fracts~~ appear rounded from coring, 50% angular; all pieces spotted w/remenant gy. clay. Bot. 413.9' Bands lt. gy. lam. at 415.4'(1/2") 417.4'(1/2"), 419.55'(1/2") Bands of dk. gy. brn. shale at 410.8'-411.05; 411.5'(2"), 413.9'(3/4") & 419.4'(1-1/2")		97%	10.0'	10.0'	No change in dip of horizontal beds @ suspected fault zone. L.P. = 8"
				load cast horizons at 411.95' & 418.6' partings which do not interlock at 417.5' & at 416.3' (w/clay remenants)		100%	10.0'	10.0'	No gas L.P. = 20"
				Same, w/some lt. gy. laminae Lt. gy. bands at 422.0'(3-1/2"), 422.35'(2"), 422.6'-423.0'(fi. gr. ss., x-lam.) 423.9(2.5"), 426.65-426.85, 427.15-427.8(x-lam.) Dk. gy. brn. bands at 425.7'(2") seam of broken ss at 428.8'(1") 4" fract. at 85° dip, 428.0' Same v. thinly laminated Same, little lt. gy. lam., little dk. gy. brn. lam. flat lying		98%	10.0'	10.0'	No gas L.P. = 15"

G-63

GAI-227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 4

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-7(cont)

CONTRACTOR: PA Drilling Co. COORDINATES N 781,963.08 E 2,369,376.54 ELEVATION ____

DRILLER: Jim Adams GWL 0 HRS ____ 24 HRS ____

CLASSIFIED BY: R. Wardrop DATE: 6/25/79

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
450 460				M. hard, greenish, gy. shale, w/little dk. gy. brn. shale lam., tr. lt. gy., sandy shale to siltstone lam. Lt. gy. band at 457.15-457.7' (x-lam.) Flat and thinly bedded Tr. pyrite in horizontal seams	6/25/79	100%	10.0'	10.0'	Lt. greenish gy wash No gas Long piece=10"
470				Same, w/some dk. gy. brn. shale lam., little lt. gy. lam., tr. pyrite Lt. gy. bands at 465.3'(3") & 468.2'(1-3/4") siltstone Dk. gy. brn. bands at 462.9'-463.3' & 464.05'-464.4'		100%	10.0'	10.0'	Minimal gas, 0 psi shut in pressure on gauge L.P. = 9"
480				Same, little lt. gy. lam., little dk. gy. brn. lam. Lt. gy. band at 478.4-479.25 (siltstone)		100%	10.0'	10.0'	No gas L.P. = 11"
490				Same, Lt. gy. bands at 484.8'-485.1', & 488.5'(2") both siltstone Load cast horizon at 486.25' Pyrite seam at 481.65' (1/8")		100%	10.0'	10.0'	Minimal gas 0 psi shut-in pressure L.P. = 9"
				Same Lt. gy. band at 496.85' (x-lam.)		100%	7.6'	7.6'	Minimal gas, 0 psi shut-in pressure on gauge LP=10" Gas bubbles violently outside of outer rods when lifted 8' off bottom
497.6				Bottom of Hole 497.6 6/26/79					

G-64

GAI-227 9/72

Sheet 4 of 4
Drill Hole No. TX-7
Continuation of
NX-Hole w/NC coring

INSPECTOR'S COMMENT:

The zone of highly fractured rock from 412.8'-413.9' may represent a splay off the main gouge zone, if not the primary fault itself. Exposed fault zones in the Cooling Water Tunnels display a high degree of variance for clay/shale fragment ratios in gouge. Minimal clay means minimal binding of shale fragments which could have prohibited the NC-double core barrel from actually coring fault gouge. Six-tenths of a foot of highly fractured rock with gray clay remenants was recovered from the one and one-tenth foot interval (412.8-413.9) in question. Fifty percent of the fragments displayed rounding from coring as compared to fifty percent angular fragments, typical of brecciated fault zones. Angularity, however, may be a natural characteristic of fragments generated by the drilling of fractured shale. In addition, drill water pressure increased from an average of 250 psi to 350 psi while drilling the upper portion of the 410-420 foot run. Pressures returned to an average of 250 psi at approximately 415 feet.

G-65

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4596-310 SITE AREA Beach, West of Site
SHEET 1 OF 9
DRILL HOLE NO. TX-8
CONTRACTOR: Herron Testing
COORDINATES N 779,218.19 E 2365 760.881
ELEVATION 576.6'
DRILLER: Joe Minarchick
GWL 0 HRS ______
CLASSIFIED BY: R. T. Wardrop DATE: 11/20/78
48 Hours 10.0'

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0										
1					Driller augered through 19.0' of overburden, beach sand, glacial till, and weathered shale					
2										
3										
4										
5										
6										
7										
8										
9										
10										

G-66

GAI-237 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 9

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Beach, West of Site
DRILL HOLE NO. TX-8
CONTRACTOR: Herron Testing
COORDINATES N779 218.19 / E 2365 760.881
ELEVATION 576.6'
DRILLER: Joe Minarchick
GWL 0 HRS
CLASSIFIED BY: R. T. Wardrop DATE: 11/20/78
24 HRS 10.0'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
10										
11										
12										
13										
14					Top of weathered shale 14.5'					Driller notes change in resistance on augers @ 14.5', this continues to 19.0' when augers will no longer advance
15										
16										
17										
18										
19					Augers advanced to 19.0' Casing to 19.5'					
					Top of weathered rock 19.5'					NX coring starts
20										

G-67

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 9

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Beach, West of Site
DRILL HOLE NO. [illegible]
CONTRACTOR: Herron Testing
COORDINATES N 779 218.19 / E 2365 760.881
ELEVATION 576.6'
DRILLER: Joe Minarchick
GWL 0 HRS
CLASSIFIED BY: R. T. Wardrop DATE: 11/20/78
24 HRS 10.0'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
20										
21					19.5 - 29.5' Med. soft to med. hard, med. gy. shale w/little sandy shale in v. thin lam. (1/16" thick) and tr. tn. brn. "Fe" bands @ 26.6' (3/4" thk.), 25.15' (3/4), 23.45' (1"), 21.3' (1/4")					
22										Lt. gy. drill wash
23					clay remnants in partings @ 19.5' (1" of clay @ top of run, seam), 21.85 (1/8" thk, seam), 22.0', 23.1', 23.2' 23.45, 24.85' & 25.65'					
24					Thin seams of fissile shale @ 19.75' & 21.65'		49%	10.0'	9.5'	Dk. gy. brn. to black oily film collecting on surface of drill water catch barrel
25										
26										
27										
28										
29					fract. dipping @ 30° @ 29.5' 29.5'					Core Pieces - 1 1/2-8" long
30										

G-68

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Beach, West of Site
SHEET 4 OF 9
DRILL HOLE NO. TX-8
CONTRACTOR: Herron Testing
COORDINATES N 779 218.19
E 2365 760.881
ELEVATION 575.6'
DRILLER: Joe Minarchick
GWL 0 HRS
CLASSIFIED BY: R. T. Wardrop
DATE: 11/21/78
24 HRS 10.0'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
30					29.5' - 37.2' Same, med. gy. to dk. gy, med. hard, tr. "fe" bands @ 30.0', 30.8', 31.6'(1/2"), 32.65'(3/4"), 35.25'(3/4"), 36.4'(1/2"), Clay rems. in partings @ 30.5', 37.25', & 37.6'					Lt. gy. drill wash w/oily film
35							91%	10.0'	10.0'	
37					37.2' - 37.6' - some sandy lam, w/tr. small sandy depos. features 37.6' - 39.5' - Same as above 37.2'					
39.5'					39.5'					Long piece-12"
40										

G-69

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Beach, West of Site
SHEET 5 OF 9
DRILL HOLE NO. TX-8
CONTRACTOR: Herron Testing
COORDINATES N 779 218.19
ELEVATION 576.6'
DRILLER: Joe Minarchick
GWL 0 HRS
CLASSIFIED BY: R. T. Wardrop
DATE: 11/21/78
24 HRS 10.0'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
40					39.5'-44.9' Med. hard, med. gy. shale w/little lt. gy., sandy shale lam (v.thin) tr. "fe" bands @ 40.75'(3/4"), 41.55'(1/2"), Clay rems in partings @ 39.55' & 42.15',					Lt. gy. wash
43										Oily film on drill water
45					44.9'-45.5' Hard, med. gy, siltstone & sandy shale, thinly lam.		85%	10.0'	9.95'	
46					45.5'-49.5' Med. hard, med. gy, shale w/little lt. gy. sandy shale lam, tr. "fe" bands @ 46.2'(1"), 46.7'(3/4"), 48.2'(1/4"), & 48.65'(1") clay rems @ 48.8' & 49.3' in partings					
48					1" band of slightly x-bedded sandy shale @ 48.6'					
49.5					49.5					Long piece 13"
50										

G-70

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Beach, West of Site SHEET 6 OF 9
CONTRACTOR: Herron Testing COORDINATES N 779 218.19 DRILL HOLE NO. TX-8
DRILLER: Joe Minarchick E 2365 760.881 ELEVATION 576.6'
CLASSIFIED BY: R. T. Wardrop DATE: 11/21/78 GWL 0 HRS ___ 24 HRS 10.0'

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50					49.5'-55.1' Same, "fe" bands @ 52.3'(1") & 53.55(1"), clay seams in partings @ 50.75', 52.95'					
51										
52										
53										
54							86%	10.0'	9.95'	
55					55.1'-56.1' Same, w/some sandy shale lam.					
56					56.1'-57.65' Same, w/little sandy shale lam., tr. "fe" bands @ 56.4'(1/2"), & 56.7'(1") clay seams. in parting @ 56.45'					
57					57.65'-59.1' Same, w/some sandy shale lam. in 1/2" bands @57.7', 58.6', & 59.1'					
58										
59										
60										

G-71

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Beach, West of Site SHEET 7 OF 9
CONTRACTOR: Herron Testing COORDINATES N 779 218.19 DRILL HOLE NO. TX-8
DRILLER: Joe Minarchick E 2365 760.881 ELEVATION 576.6'
CLASSIFIED BY: R. T. Wardrop DATE: 11/22/78 GWL 0 HRS ___ 24 HRS 10.0'

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
60					59.1'-69.5' Med. hard, dk. gy. shale and hard lt. gy. sandy lam. (v. thin) tr. tn. brn. "fe" band @ 68.8'(1" thk.) clay remnants in partings @ 60.75' & 67.35'					
61										
62										Lt. gy. wash, Oily film decreasing
63										
64										
65					Band of dk. gy. shale, nearly absent of sand influx from 65.6'-64.95'		70%	10.0'	9.35'	
66					Suspected fault - 65.85' .65' of core missing in .85' of run. 3 (3/4" thk.) pieces of core and 2 frags. w/minimal clay remnants					No notable change in drilling
67										
68										Gas released through hole when core barrel pulled-water rose up and out of boring
69					69.5					Long piece 12"
70										

G-72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Beach, West of site
CONTRACTOR: Herron Testing COORDINATES N 779 218.19
DRILLER: Joe Minarchick E 2365 760.881
CLASSIFIED BY: R. T. Wardrop DATE: 11/22/78

SHEET 8 OF 9
DRILL HOLE NO. TX-8
ELEVATION 576.6'
GWL 0 HRS
24 HRS 10.0'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
70–71					69.5'-72.7' Med. hard. to hard, dk. gy. shale and lt. gy. sandy shale (thinly lam.) 1/2" bands of hard lt. gy. sandy shale @ 72.05' & 72.35', clay rems in partings @ 71.75'.					
72–73					72.7'-73.5' Same, w/little lt. gy. sandy shale-band of dk. gy. brn. shale from 73.5'-73/7'					Lt. gy. drill wash
73–75					73.7'-75.5' Med. hard to hard, dk. gy. shale and lt. gy. sandy shale lam. in 1/2" thk. bands @ 73.75'. Clay rems in parting @ 75.5'					
75–76					75.5'-76.8' Same, w/little lt. gy. siltstone in 1/4"-3/4" bands					
76–79					76.8'-79.5' Same, no siltstone, bands of hard lt. gy. sandy shale @ 77.0'(1/2" thk.), & 77.2'(1 1/4"). Tr. tn. brn. "Fe" bands @ 78.4'(1") & 78.95'(1"). Clay rems. in partings @ 78.5' & 79.1'					
80					Bottom of Hole 79.5'					

G-73

INSPECTOR'S COMMENT:

A fault was suspected in the 65.85' to 66.75' interval at TX-8 for the following reasons. Sixty-five hundreths of a foot were lost over eighty-five hundreths foot of advance in the 59.5'-69.5' run. Traces of clay remnants were found adhering to fragmented core pieces in the above mentioned interval. Gas pushed water up and out of TX-8 when the barrel was retrieved at the end of the 59.5'-69,5' run.

Weston Geophysical Corporation did not confirm fault occurrence by either sonic velocity or gamma logging.

G-74

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Shoreline West of Site
SHEET 1 OF 9
DRILL HOLE NO. TX-9
CONTRACTOR: Herron Testing
COORDINATES N779,333.051 E2,365,924.335
ELEVATION 576.5'
DRILLER: Joe Minarchick
GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 12/4/78
24 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Grain Shape / Core Run / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
1					Driller augers 20 feet and sets casing.				
3					Beach sand and gray lacustrine.				
7					Top of till - 7.5'				Driller notes change in resistance to augering.
					Gray, clayey glacial till.				
10									

G-75

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P W.O. 04-4549-310 SITE AREA Shoreline West of Site
SHEET 2 OF 9
DRILL HOLE NO. TX-9
CONTRACTOR: Herron Testing
COORDINATES N779, 333.051 E2, 365,924.335
ELEVATION 576.5'
DRILLER: Joe Minarchick
GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 12/4/78
48 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Grain Shape / Core Run / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
10									
11					Gray, clayey glacial till.				
12					Top of weathered rock (12.5')(?)				Driller notes change in resistance to augers.
13					Gray weathered shale.				
19									Driller sets casing @ 20.0'.
20									

G-76

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Shoreline West of Site SHEET 3 OF 9

CONTRACTOR: Herron Testing COORDINATES N779,333.051 E2,365,924.335 DRILL HOLE NO. TX-9

DRILLER: Joe Minarchick ELEVATION 576.5'

CLASSIFIED BY: R. Wardrop DATE: 12/5/78 GWL 0 HRS ______ 48 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
20					20.0-22.2 Soft to med. soft, gray weathered shale w/little gray clay in 2" seam @ top of run, tr. tn. brn., cherty "Fe" band @ 20.7'. (Weathered zone)					
22					22.2-41.25 — Bottom of Weathered Zone Med. hard, med. gy. shale w/little lt. gy. sandy shale in thin lam. tr. tn. brn. "cherty, "Fe" bands @ 23.1'(1" thk.), 24.7'(1"), 27.45'(1"), 28.45'(1-1/2"), 29.25 (1/2"). Clay remenants in parting @ 28.85 and 29.55'. Sandy feeding pattern @ 29.55'.		54%	10.0'	9.8'	Lt. gy. wash w/oily film floating in drill water catch barrel.
30										Long piece 8.5"

G-77

GAI-337 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Shoreline West of Site SHEET 4 OF 9

CONTRACTOR: Herron Testing COORDINATES N779,333.051 E365,924.335 DRILL HOLE NO. TX-9

DRILLER: Joe Minarchick ELEVATION 576.5'

CLASSIFIED BY: R. Wardrop DATE: 12/5/78 GWL 0 HRS ______ 48 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
30					Med. hard, med. gy. to dk. gy. shale w/little lt. gy. sandy shale in thin laminae, tr. tn. brn. cherty "Fe" bands @ 32.2' (1/4" thk.), 33.3'(1/4"), 33.7 (1/2"), 35.15(1"), 35.5'(1/4"), 38.05'(1/4"), 39.35'(1"), 39.9 (1-1/2"). Clay remenants in partings @ 30.5', 30.8', 33.05'. 1/4" thick clay seam under "Fe" band @ 39.4'. 2 fracts intersecting in core @ 32.8', one dipping 10°, one approximately 75°.		52%	10.0	9.95	Lt. gy. wash w/oily film.
40										Core pieces 2"-6" long. Long piece - 8"

G-78

GAI-337 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Shoreline West of Site
SHEET 5 OF 9
DRILL HOLE NO. TX-9
CONTRACTOR: Herron Testing COORDINATES N779,333.051 E2,365,924.335
ELEVATION 576.5'
DRILLER: Joe Minarchick
GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 12/5/78
48 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp. Geologic Data, Ground Water, Construction Problems, etc.
40										
41					41.25-42.05 Med. hard, med. gy. shale w/some lt. gy. sandy shale laminae 2" dk. gy. brn. siltstone band @ 41.95'.					
42					42.05-42.8 Same, w/little lt. gy. sandy shale lam.					
43					42.8-43.6 Same, and thin lt. gy. sandy shale lam., hard.					Lt. gy. wash w/oily film in catch barrel
44					43.6-46.2 Same, med. gy. to dk. gy. shale w/little lt. gy. sandy lam. Tn. brn. "Fe" band @ 44.0' (1" thk.)					
45							100%	10.0	9.9'	
46					46.5-46.9 Med. hard, dk. gy. shale, tr. sandy thin laminae.					
47					46.9-48.5 Hard, med. gy. to dk. gy. shale and sandy shale. 6" sandy band from 46.9-47.25 x-bedded. 1" band @ 48.25' x-bedded. Clay remnants in partings @ 47.25' and 48.3'.					
48					48.5-54.75 Same, w/little sandy shale lam. 1-1/4" thk. "Fe" band @ 49.95'.					
49										Long piece 13.5".
50										

C-79

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Shoreline West of Site
SHEET 6 OF 9
DRILL HOLE NO. TX-9
CONTRACTOR: Herron Testing COORDINATES N779,333.051 E2,365,924.335
ELEVATION 576.5'
DRILLER: Joe Minarchick
GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 12/5/78
48 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp. Geologic Data, Ground Water, Construction Problems, etc.
50					"Fe" band @ 53.6' (1/2" thk.) clay rem in partings @ 53.5'.					
51										
52										
53										Lt. gy. wash w/oily film in drill water catch barrel.
54					54.75-56.7 Med. hard, dk. gy. shale w/some lt. gy., thin, sandy shale lam., tr. lt. gy. siltstone lam.		77	10.0	10.0	
55										
56					Slight dip to bedding starting @ 58.7'.					
57					56.7-62.15 Same, and lt. gy. sandy lam. feeding pattern @ 61.75'.					
58										
59					1/2" band of lt. gy. siltstone @ 61.45'.					Pieces 3-7" long.
60										

C-80

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Shoreline West of Site
SHEET 7 OF 9
CONTRACTOR: Herron Testing COORDINATES N779,333.051 E2,365,924.335
DRILL HOLE NO. TX-9
ELEVATION 576.5'
DRILLER: Joe Minarchick
GWL 0 HRS ______
CLASSIFIED BY: R. Wardrop DATE: 12/5/78
48 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
60–62										
62					62.15-65.8 Same, w/some thin lt. gy. sandy shale lam. Feeding pattern @ 62.65'. Sandy bands @ 62.9' (1-1/4") x-bedded, and 63.2' (3/4") x-bedded. Clay rems in partings @ 62.3', 62.85' and 64.2' seam of clayey fissile shale @ 62.4' (1/8"). 12° fract. @ 62.35'.					
65							54%	10.0	10.0	
65.8					65.8-72.2 Same, and lt. gy. sandy shale laminae, hard. "Fe" band @ 65.9' (1/2") Bands of sandy shale @ 68.75 (1/2") 69.1' (1/4"), 69.45' (1"). Clay rems in partings @ 66.8', 67.3', 67.5', and 69.2'.					
69–70										Core pieces 3-7".

GAI-337 8/78

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P W.O. 04-4549-310 SITE AREA Shoreline West of Site
SHEET 8 OF 9
CONTRACTOR: Herron Testing COORDINATES N779,333.051 E2,365,924.335
DRILL HOLE NO. TX-9
ELEVATION 576.5'
DRILLER: Joe Minarchick
GWL 0 HRS ______
CLASSIFIED BY: R. Wardrop DATE: 12/5/78
48 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
70					"Fe" band @ 70.4' (1-1/2" thk.) Clay rems in partins @ 70.2', 70.4', 70.5' and 71.35'.					
72.2					72.2-82.3 Same, w/little sandy shale lam. tr. tn. brn. cherty "Fe" bands @ 73.2' (1") 75.3' (1"), 75.85' (1/2") and 77.25 (3/4"). Clay rems in partings @ 73.2', 73.7', 74.15', 74.6', 75.2', 75.6', 76.2', 76.6', 76.8', 77.9' 79.1', and 79.7'.		65%	10.0'	10.0'	
79–80										Core pieces 3-8" Long piece 8"

GAI-337 8/78

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Shoreline West of Site
SHEET 9 OF 9
CONTRACTOR: Herron Testing COORDINATES N779,333.051 E2,365,924.335
DRILL HOLE NO. TX-9
DRILLER: Joe Minarchick
ELEVATION 576.5'
CLASSIFIED BY: R. Wardrop DATE: 12/5/78
GWL 0 HRS
48 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
80					Hard lt. gy. brn. siltstone band @ 81.0 (1-1/2").					
81					"Fe" bands @ 80.3'(1-1/4") and 80.45' (1/4") sandy shale band @ 81.3 (1/2").					
82					82.3-83.65 Same, w/some lt. gy. sandy shale lam.					
83					"Fe" within (1-1/2") sandy band @ 82.4" and 83.25'. Sandy bands @ 82.55'(1/4" thk.) 82.7'(1-3/4"), 82.9'(1/2"), 83.45 (3/4") slightly x-bedded feeding patterns @ 83.65'. Clay rem in parting @ 83.5'.		5%	10.0'	10.0'	
85					83.65-90.0 Same, w/little sandy shale thin lam. "Fe" bands @ 84.65(1/2"), and 85.1'(1/2") sandy band @ 86.45-86.7'(3" thk.), w/x-bedding to feeding patterns, broken), 86.95' (1/2"), 87.4'(1) x-bedded, and 88.05(1-1/2") x-bedded.					
87					Clay rems in partings @ 83.75', 84.1', 854.4', 86.6', 87.35' 89.25', and 89.75'.					
88					Clay seams @ 87.45' (1/4") and 88.55' (1/4").					
89										Core pieces 3"-6.5".
90					Bottom of Hole - 90'					

G-83

GAI-227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Boat Slip, Perry Park
SHEET 1 OF 9
CONTRACTOR: Herron Testing COORDINATES N 778, 675.86 E 2, 365, 078.76
DRILL HOLE NO. TX-10
DRILLER: John Clark
ELEVATION 593.4
CLASSIFIED BY: R. Wardrop DATE: 11/27/78
GWL 0 HRS
48 HRS 6.15'

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					Driller augered to 31.0' (lacustrine and glacial till)					New driller, other TX series holes drilled by Joe Minarchick
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

G-84

GAI-227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 9

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Boat Slip, Perry Park DRILL HOLE NO. TX-10
CONTRACTOR: Herron Testing COORDINATES N 778, 675.86 E 2, 365, 078.76 ELEVATION 593.6
DRILLER: John Clark GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 11/27/78 48 HRS 6.15'

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
10					Continued augering in glacial till					
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										

G-85

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 9

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Boat Slip, Perry Park DRILL HOLE NO. TX-10
CONTRACTOR: Herron Testing COORDINATES N 778, 675.86 E 2, 365,078.76 ELEVATION 593.6'
DRILLER: John Clark GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 11/27/78 48 HRS 6.15'

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
20					Continued augering in glacial till					
21										
22										
23										
24										
25										
26										
27										
28										Driller did not recognize top of weathered rock due to change in resistance on augers
29										
30										

G-86

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 9

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Boat Slip, Perry Park DRILL HOLE NO. TX-10
CONTRACTOR: Herron Testing COORDINATES N 778, 675.86 E 2, 365,078.76 ELEVATION 593.4'
DRILLER: John Clark GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 11/27/78 48 HRS 6.15'

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Core Run	Core Rec.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
30–31					Driller augered to 31.0' casing to 31.0'-Gy. shale frags in bottom augers
31–34	31.0-32.0-Hard, lt. gy., sandy shale and dk. gy. brn. shale 32.0-33.9-Med. Hard, dk. gy. weath. shale to gy. clay (med. soft) rock sections of core fractured, vertically	47%	3.2'	3.15'	Oily film floating in drill water catch barrel
34–40	Bottom of weathered rock @ 33.9' 33.9-51.2 Med. hard, med. to dk. gy. shale, hard tn. brn. "Fe" bands @ 35.15 (0-1/2" thk.) 36.6' (1/2"), 38.35' (1"), 38.95' (1"), 40.5' (3/4"), 41.8' (1/4"), 45.45' (1"), Gy. clay remenants in partings @ 37.0', 37.45; 38.9; 39.45; 41.3; 42.6; 47.65; 48.0' Lt gy. sandy ooze or feeding patterns @ 47.1' - bands of sandy shale @ 47.5' (1/2" thk.) 48.9' (3/4"), and 50.7' (1/4").	33%	10.0'	9.95'	Pieces - 1/2"-6-1/2" Lt. gy. wash

G-87

GAI-227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 5 OF 9

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Boat Slip, Perry Park DRILL HOLE NO. TX-10
CONTRACTOR: Herron Testing COORDINATES N 778, 675.86 E 2, 365, 078.76 ELEVATION 593.4'
DRILLER: John Clark GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 11/27/78 48 HRS 6.15'

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Core Run	Core Rec.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
40–44	Same to 51.2' "Fe" bands @ 40.5' (3/4"), 41.8' (1/4"), and 45.45' (1") Clay rems. in partings @ 41.3', 42.6', 47.65', and 48.0' Lt. gy. sandy feeding pattern or ooze @ 47.1' Lt. gy. sandy shale bands @ 47.5' (1/2") and 48.9' (1/2") Flat bedded	33%	10.0'	9.95'	
44–50		60%	10.0'	9.95'	Pieces 2"-6" Lt. gy. wash

G-88

GAI-227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 6 OF 9

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Boat Slip, Perry Park

DRILL HOLE NO. TX-10

CONTRACTOR: Herron Testing COORDINATES N 778, 675.86

E 2, 365,078.76

ELEVATION 593.4'

DRILLER: John Clark

GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 11/29/78

48 HRS 6.15'

Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Core Run	Core Rec.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
51.2-51.9 Med. hard, dk. gy. shale w/some lt. gy., thin, sandy shale lam. Sandy feeding pattern or cone @ 51.9' (1/2" thick) clay rems. in parting @ 51.8'	60%	10.0'	9.95'	Lt. gy. wash
51.9-52.9' Same, w/littile sandy shale lam. "Fe" band @ 52.55 (1") clay rem in parting @ 52.1, and 52.65'				
52.9'-53.75' Same w/some sandy shale lam. "Fe" band @ 53.4' (1") clay rem in parting @ 53.15'				
53.75'-54.2' Same w/little sandy shale lam. tn. brn. "Fe" band @ 54.15 (1/2" thk.)				Pieces 3"-7"
54.2'-54.8' Med. hard to hard, dk. gy. shale and lt. gy. sandy shale lam. *Thin fissile seam @ 54.5'	56%	10.0'	9.3'	
54.8'-56.2' Same w/little sandy shale lam. med. hard "Fe" band @ 55.65' (1/2")				Driller makes several machine adjustments during run - this is untypical of previous TX runs
56.2-56.7' Same w/some sandy shale lam. "Fe" band @ 56.5' (3/4")				
56.7'-59.0' Same w/little sandy shale lam. "Fe" bands @ 57.1' (1") and 57.85' (1/2") *Fissile shale seams @ 58.2' *Fissile seams end in partings which do not interlock with bottom shale - fissile seams may have been larger and ground up in drilling, accounting for recovery loss				

Depth Ft.: 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60

G-89

GAI-337 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 7 OF 9

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Boat Slip, Perry Park

DRILL HOLE NO. TX-10

CONTRACTOR: Herron Testing COORDINATES N 778, 675.86

E 2, 365,078.76

ELEVATION 593.4

DRILLER: John Clark

GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 11/29/78

24 HRS 6.15'

Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Core Run	Core Rec.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
59.0-59.4' Med. hard med. gy. to dk. gy. shale, w/some thin lt. gy. sandy lam.				
59.4'-62.3' Same, w/little sandy shale lam. 1/2" "Fe" band @ 59.75				Oily film on wash, stops
62.3'-63-05' Same, w/some sandy shale lam.				1/2" overcored piece @ 60.5'
63.05-63-5 Same w/little sandy shale lam. 1/2" "Fe" band @ 63.45' Clay rems on partings @ 63.5'	56%	10.0'	9.3'	
Possible fault from 63.5'-64.9' a) 1/2" core piece w/clay rems. all around, overturned b) 5-1/4" core w/pinching "Fe" band, shale lam. dipping w/pinch bottom grooved, w/clay rems. c) 2-1/4" core beveled at top w/clay rems.				Core Pieces 2"-6" long. No gas when barrel pulled @ end of run
All core pieces seem to interlock in 64.2'-74.2' run, except where clay rems are found on smooth horizontal partings. If these represent only very thin clay seams, then bulk of recovery loss would be at top of run - supporting fault occurence.				
64.9'-68.3' Med. hard, med. gy. to dk. gy. shale w/little, thin sandy lam. "Fe" band @ 65.4' (1/4" thk)	56%	10.0'	9.3'	
68.3'-68.9' Same, w/some sandy shale lam.				
68.9'-71.9' Same, w/little sandy shale lam. "Fe" bands @ 69.4' (1" thk.) 71.3' (1") and 71.85' (1/4") clay rems in partings @ 71.15 and 71.45 sandy bands @ 71.15 (1/4") and 71.45 (1") Flat bedded				

Depth Ft.: 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70

G-90

GAI-337 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Boat Slip, Perry Park

SHEET 8 OF 9

DRILL HOLE NO. TX-10

CONTRACTOR: Herron Testing COORDINATES N 778, 675.86

E 2, 365,078.76

ELEVATION 593.6'

DRILLER: John Clark

GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 11/29/78

48 24 HRS 6.15'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
70					71.9-72.35' Hard, dk. gy. shale, lt. gy. siltstone, and sandy shale lam.					
71					Sandy band @ 71.93' (1/2" thick)					
					72.35'-73.85' Med. hard, dk. gy. shale, w/ some lt. gy. sandy shale lam		56%	10.0'	9.3'	Lt. gy. wash
72					Sandy band (1-1/4" thk) @ 73.4' feeding patterns of sand through shale from 73.65'-73.75'					
73					73.85'-74.2' Same, w/little sandy shale lam. (All pieces interlock, hole measured at 74.2', recovery loss must be at top of run.)					No gas when barrel pulled from hole
74										
					Bottom of Hole - 74.2 feet					Pieces 3-7 3/4" long.

G-91

GAI-227 9/73

INSPECTOR'S COMMENT:

A fault was suspected in the 63.5' to 64.9' interval of TX-10 for the following reasons. Clay remnants were found in a bedding parting at 63.5'. Overturned core pieces with clay remnants occurred at the top of the suspect interval. One and four-tenths feet of core was lost in the two ten foot runs stradling the interval (See note on sheet 7 of 9).

Weston Geophysical did not recognize a zone of low velocity or low gamma partical emission in the sonic and gamma logs of TX-10.

G-92

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 16

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot

DRILL HOLE NO. TX-11

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12

ELEVATION 624.04'

DRILLER: Jim Adams

GWL 0 HRS

CLASSIFIED BY: LDS DATE: Logged 5/8/79

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp. Geologic Data, Ground Water, Construction Problems, etc.
0					Hole Started 4/19/79					
10–50					OVERBURDEN					Augered to bedrock

G-93

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 16

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot

DRILL HOLE NO. TX-11

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E 2,369,806.12

ELEVATION 624.04'

DRILLER: Jim Adams

GWL 0 HRS

CLASSIFIED BY: LDS DATE: Logged 5/8/79

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp. Geologic Data, Ground Water, Construction Problems, etc.
50–60					Boulder Horizon in Lower Till	4/19/79				Grinding on augers at 550' boulder zone in till
60–67					Top of weathered bedrock					Driller notes increased resistance on augers at 630', top of weathered rock.
68–80					Top of unweathered rock, 68.0' Shale scratch but Slt. is hard Med. gray fissile shale & minor lt. gr. slt. Fe stones (1/2"-3/4") at 68.75, 70.2, 70.67, 71.9, 73.25, 75.0, 76.4, 76.5. Core parts parallel to bedding (spacing 1/4 to several ins.) slight to moderate weathering 2 in. vertical fracture at 70' & 71.9'; irregular fracture at 73.2-73.3' (could be due to coring.) Horizontal bedding		0	10'	10'	Originally roller bit, advanced was concieved to a depth of 180' driller opted to core from 68-180'. This interval logged two weeks after drilling. Longest = 3½"
80–90					As above but shales are slightly darker from 80-84'. Slt are rippled at 79.5 and inter-laminated with shale. Partings parallel to bedding as before.		20%	10'	9.9'	Longest 6"
90–100					Fe stone bands less distinct. Occasionally as thin as ¼" but overall more freq. occur at 77.4, 77.5, 78.3, 82.2, 86.9, 86.6. Some shale bed surfaces show scour at top where overlain by slt.		32%	10'	9.75'	Longest 12"

(continued)

G-94

GAI-227 8/72

(continued)

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2a OF 16

PROJECT: ______ W.O. ______ SITE AREA ______
DRILL HOLE NO. ______
CONTRACTOR: ______ COORDINATES ______
ELEVATION ______
DRILLER: ______
GWL 0 HRS ______
CLASSIFIED BY: ______ DATE: ______
24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
90					As before but med. dark shale dominate; partings parallel to bedding less frequent.					
					Fe stone (1") at 89.75 in contact with underlying x-bedded gr. alt. Interlaminated sh. & alt. bed sets about 1" thick occur occasionally Fe. stone at 94.8, 95.5, & 96.		32%	10'	9.75'	Longest = 12"
100					Bottom of Sheet 2					

G-95

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 16

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot
DRILL HOLE NO. TX-11
CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12
ELEVATION 624.04
DRILLER: Jim Adams
GWL 0 HRS ______
CLASSIFIED BY: R. Wardrop Logged DATE: 5/8/79
24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100					As before with slight increase in amount of thin lt. gr. alt. laminae Dk. gr. concretionary nodule at 98' with abundant finely disseminated pyrite Fe stone beds (1/2-1") at 102.6, 103.2, 105.7; other fine pyrite observed occasionally.		25%	10'	9.8'	
110					Shales return to med. gr. and exhibit greater tendency to part parallel to bedding; lt. gr. alt. interbedded laminae to 10%; Zones of load casts at 107.6', 107.3 & 116. Fine pyrite laminate at 112, Fe stone bed at 111, 113.5, 112.8		16%	10'	9.8'	Longest = 11"
120					2" alt. bed on scour base of shale at 116. Possible clay remenants at 109.5' & 110' As before - fine pyrite disseminated at 121.3'. Darker shale at 122.3 to 122.6'.		16%	10'	9.9'	Longest = 6"
130					Generally alt. laminae becoming thicker, more frequent and exhibiting rippling at upper surface. Fe stone beds at 121.2, 121.3, 122.6, 125.3, 125.7, 126.6. Lithology as before but rock parts parallel to bedding with greater frequency. Some breakage probably due to coring and some may be natural.		3%	10'	9.8'	Longest = 4"
140					Fe stone beds up to 1" at 134.1, 135.3 and 1/4-1/2" at 128.1; 128.7, 134.3; Sh. laminae sets in last ft. reveal scour base load casts, & rippling. Some sets up to 2". Initial 2 ft. as before; At appx. 139 alt. laminae increase significantly. Large Fe stone		65%	10'	9.9'	Longest = 8"
150					(continued)					

G-96

GAI-227 8/72

(continued)

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: ______ W.O. ______ SITE AREA ______ SHEET 1a OF 16

CONTRACTOR: ______ COORDINATES ______ DRILL HOLE NO. ______

DRILLER: ______ ELEVATION ______

CLASSIFIED BY: ______ DATE: ______ GWL 0 HRS ______ 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
140					alt. in fine-grained lt. gr. sand at 139.8 with considerable current rippling showing flame structure. Fe stone (2) at 139.5' slt. decrease at 140' to base of 145' where return to more typical 10% alt sequences.		65%	10'	9.9'	Longest = 8"
150					Vertical fractures at 140-140.5 due to coring.			1.0'	1.0'	
					Bottom of Sheet 3					

G-97

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot SHEET 4 OF 16

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12 DRILL HOLE NO. SY-11

DRILLER: Jim Adams ELEVATION 626.06

CLASSIFIED BY: LDS - 150 to 180' RTH 180' - 200' DATE: 5/8/79 GWL 0 HRS ______ 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
150					As before Med. hard med. gray sh. and 10-20% lt. gr. alt. Fe. stone beds at 161.75 X-beds at 153 & 154.3, load casts at 154.5 and less well developed at 153.3 Horizontal bedding No change			10.0"	9.92"	Longest = 9"
160					Slt. beds up to 2" with x-beds & or rippling at 157.7, 157.9 Fe. stone bed at 161.3. Very dark gr.-bl. laminae between 162.8 & 165 occur with irregular frequency.			10.0'		
170					No change in lithology, load casts at 165.7, 166.45, SH interbeds less than 10%, breakage at 167.9' due to coring. SH darkens at 169' although still interlayered with lt. gr. alt. and previous med. gr. shale. Parts parallel to bedding. Rippling at 174.5' Increased frequency of lt. gr. alt. Same occurs at 176.5. 2½" of x-bedded alt. at 178.6. Fe stone bed and alt bed in contact at 177.5'	4/20/79		10.0'		
180					Med. hard, med. gy. shale, and hard lt. gy. sandy shale (v.fi. grained) to siltstone, bands (0-2" thk.), thicker bands at 181.6'(2.5") (with. tn. fi. gr. influx) 184.3'(4") siltstone, 186.5 to 187.25', and 188.45' to 189.0', all x-bedded. Load cast horizons at 188.2' & 188.5'.		76%	10.0'	9.92'	Lt. gy. wash Long piece 14½"
190					little dk. gy. brn. shale, one band 5-1/2" thick at 186.5' on 1/4 pinching "Fe" band at 180.0' Same sandy shale to siltstone laminae 0-1-1/2" thk., tr. dk. gy. brn. shale lam.		75%	10.0'	10.0'	
200										

G-98

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 5 OF 16

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot

DRILL HOLE NO. TX-11

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E 2,369,806.12

ELEVATION 624.06

DRILLER: Jim Adams

GWL 0 HRS

CLASSIFIED BY: R. Hardron DATE: 6/21/79

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type • Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
200					Same, Hard; lt. gy bands at 203.4(2") 205.0 (2-3/4"), & 205.7(2"), all X-bedded. Horizontal bedding, thinly laminated		63%	10.0'	10.0'	Lt. gy. wash
210					Same, some hard, lt.gy. sandy shale to siltstone laminae(0-2" thk.), little dk. gy. brn. oil shale lam; w/one band from 214-215.3; Thinclay seams at 212.9' & 213.4' one X-bedded siltstone band at 219.8'(3") Fracture dipping 80° at 215.9' lined with clay remenants, no displacement		92%	10.0'	10.0'	
220					Same, and hard, lt. gy. laminae, tr. dk. gy. brn laminae Hard, lt. gy. sandy bands at 221.7' (3"), 222.3'(3"), 126.5' (2½"), 127.0'(2½") 127.5'(5"), 128.6'(6"), & 129.3'(4), all x-bedded	6/21/79	68%	10.0'	10.0'	Lt. gy. wash
230					Same Hard, lt. gy., sandy shale to siltstone bands at 231.2(2"), 231.7 (4"), 233.2 to 234.5, & 238.0 to 238.6, all x-bedded, ~~load casts~~ horizons at 235.0', 235.2' & 239.5' Bedding parting at 239.0'		92%	10.0'	10.0'	
240					Same Hard, lt. gy, bands at 241.9(2½") & 247.4' (2½ siltstone), x-bedded Bedding partings at 241.65' & 249.2'		80%	10.0'	10.0'	
250										

GAI-237 6/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 6 OF 16

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot

DRILL HOLE NO. TX-11

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12

ELEVATION 624.06'

DRILLER: Jim Adams

GWL 0 HRS

CLASSIFIED BY: R. Hardron DATE: 6/22/79

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type • Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
250					Med. Hard, med. gy., shale interlaminated with some, thin, hard, lt-gy., sandy shale to siltstone bands (0-2½"), tr. dk. gy. brn shale lam. one 2½" lt. gy. band at 255.0' Bedding partings at 252.3', 255.5', 255.7', 257.4', 258.9', & 259.9'		93%	10.0'	9.88'	Lt. gy. wash
260					Same, and lt. gy. sandy shale to siltstone laminae bands at 260.9' (2½") and 261.5 to 262.3, x-bedded load casts at 268.5' & 268.75' Bedding parting at 266.75'		76%	10.0'	9.92'	Long piece 30"
270					Same, Lt. gy. bands at 274.5(2½"), 274.9(2½"), 276.0 to 276.5, & 279.4-280.0' all x-bedded Bedding parting at 270.6'		76%	10.0'	9.83'	Long piece 10"
280					Same, Hard, lt. gy. bands from 280-280.55', 280.8-281.2', 281.6'-282.5', & 286.2'-286.75' Horizontal Bedding parting at 286.75'		90%	10.0'	10.0'	Long piece 29"
290					Same, interlaminated with some, hard, lt. gy., sandy shale to siltstone laminae 0-2" thick. Bands of greater thickness at 292.3-292.65, 292.9-293.1, 298.0-298.3', all x-bedded.		92%	10.0'	10.0'	
300										

GAI-237 6/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot SHEET 7 OF 16
CONTRACTOR: Pa. Drilling Co. COORDINATES N781,586.77 E2,369,806.12 DRILL HOLE NO. TX-11
DRILLER: Jim Adams ELEVATION 624.04
CLASSIFIED BY: R. Wardrop DATE: 6/23/79 GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Core Run	Core Rec.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
300	Med. hard m. grey, shale, and hard lt. gy., siltstone to sandy shale laminae 0-2" thk. Bands of greater thickness at 300.1 to 302.6 (x-bedded) 303.45(2.5"), 304.0(3.5"), 304.8(3") & 309.0(4"), trace of dk. gy. brn. shale laminae. Load cast horizon at 305.2'	94%	10.0'	10.0'	long piece 41½"
310	Same, lt. gy. siltstone bands >2" thk. at 318.3 to 318.9, 317.3 (1.5"), 316.5-316.9, 312.75-313.15, 313.45-313.75, 314.0-314.35, & 314.5-314.85, all x-laminated. ¼" thk. clay seam at 318.3'	98%	10.0'	10.0'	Gas shoots water out of hole when barrel pulled long piece-29"
320	Same lt. gy. bands >2" at 326.9' (3") & 328.75-329.65, both x-laminated. Bedding parting at 327.85' Horizontal Bedding	72%	10.0'	9.88'	gas indicated as above long piece-14"
330	Same, lt. gy. bands >2" thk. at 333.65 to 334.0', little dk. gy. brn shale laminae, concentrated from 338.5-340.0. Bedding parting at 337.5	79%	10.0'	9.83'	gas bubbling in hole when barrel pulled' long piece-27½"
340	Med hard. m. grey, shale interlam w/little lt. gy. sandy shale to siltstone lam., little dk. gy. brn. (oil shale) lam. concentrated between 340.6' to 341.9', one 1½" band at 344.25 1/4" thk. fissile shale seam at 346.75.	95%	10.0'	10.0'	gas in hole
350					

G-101

GAI-337 8/78

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot SHEET 8 OF 16
CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12 DRILL HOLE NO. TX-11
DRILLER: Jim Adams ELEVATION 624.04
CLASSIFIED BY: R. Wardrop DATE: 6/23/79 GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Core Run	Core Rec.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
350	Med. hard, med. gy., shale, w/ some dk. gy. brn. shale lam. every 1-6", little hard lt. gy. siltstone to sandy shale lam., Pyrite traces at 353.8', 354.9', 355.55, & 356.4' Seams of soft fissile shale at 350.15, 350.3 (broken, ½" thk.) 351.2, 354.95(½"), & 357.7(1")		94%	10.0'	10.0'	Gas bubbling in hole Long piece-29.5"
360	Same, lt. gy. siltstone bands at 362.8(2-1/4") 364.1(3"), f1. sandy bands at 366.5'(3"), 367.1' (1.5") both x-bedded, concentration of dk. gy. brn. (oil sh.), lam. at 365.5-366.1'	6/23/79	93%	10.0'	9.96'	Gas bubbling in hole Long piece-26" strong odor to gas from hole at start of day
370	Med. hard, med. gy. shale interlam w/1/4" to 1-1/2" dk. gy. brn. lam. with little lt. gy. sandy shale lam. one 3" band at 378.4' x-bedded. Fissile seam at 378.25'(1/4") Broken rx in seam at 376.0'		96%	10.0'	10.0'	Long piece-23"
380	Same, with some lt. gy. sandy shale to siltstone bands at 383(4.5"), 386.7-386.5 bec. med. lt. gy., 385.7'-386.0', little thin lam. of dk. gy. brn. shale, concentrated from 382.3 to 382.8.		95%	10.0'	9.67'	Long piece-16"
390	Same, with tr. lt. gy. lam.		91%	5.0'	5.0'	Long piece-20"
	Same, some dk. gy. brn lam (0-2-1/4")		95%	10.0'	10.0'	Gas pushes water out of hole, 5' high
400						

G-102

GAI-337 8/78

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 9 OF 16

PROJECT: PHPP W.O. 04-4549-310 SITE AREA NE Parking Lot
DRILL HOLE NO. TX-11
CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12
ELEVATION 624.04
DRILLER: Jim Adams
GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 4/24/79
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
400					Hard, lt. gy. sandy shale to siltstone at 400.3-401.0(x-laminated) & 403.2 to 403.3' Fissile seams at 400.3'(1/6") & 404.4'(1/2"), Load cast horizon at 402.7'		96%	10.0'	10.0'	Lt. gy. wash with dk. brn. influxes. Long piece-30"
410					Med. hard, med. gy. shale interlam. with little dk. gy. brn. shale lam. (0-2-1/4"). tr. lt. gy. lam.		93%	5.0'	5.0'	Minimal Gas. L.P. - 25"
					Same, and dk. gy. brn (oil shale) lam. (0-1-1/2")		96%	5.0'	5.0'	Minimal Gas. LP-23"
					Same, some dk. gy. brn. lam. (0-1") Bedding parting at 416.7'		93%	5.0'	5.0'	LP-22"
420					Med. hard., med. gy., shale, and hard lt. gy. fi. gr. sandy shale to siltstone with little dk. gy. brn. lam. (0-1/2"), lt. gy. bands at 420.5-420.85, 421.4-422.7, & 423.5-423.8 bec. lt. gy. brn.		92%	5.0'	5.0'	LP-21"
430					Same, concentration of lt. gy. lam. from 425.3-427.75 (siltstone bec. x-laminated, sandy sh.)	4/24/79	98%	5.0'	4.96'	LP-17"
					Med. gy. shale with little lt. gy. lam. tr. dk. gy. brn. lam. (0-1/2")		90%	5.0'	5.0' LP=21"	Gas blowing out of hole at start of day
440					Same, tr. lt. gy. lam. Thin seam of broken shale at 435.35'		96%	5.0'	4.96' LP=14"	Gas expands like gun shot when helper breaks drive on casing, 40 sec. later water column fountains 30' into air - high gas
					Same, flat lying, v. thinly lam., bands of cone-in-cone limestone bordering 1" siltstone from 440.6'-441.0'. Upper band (1/2"), lower band (3/4"). Fract. dipping 60° at 444.5'.		86%	5.0'	4.92' LP=12"	
450					Same		73%	5.0'	4.94' LP=15"	Minimal Gas. LP-15"

G-103

GAI-227 2/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 10 OF 16

PROJECT: PHPP W.O. 04-4549-310 SITE AREA NE Parking Lot
DRILL HOLE NO. TX-11
CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12
ELEVATION 624.04
DRILLER: Jim Adams
GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 4/25/79
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
450					Med. hard, m. grey, shale inter-lam. with little hard, lt. gy. siltstone, little dk. br. shale, Fissile shale seam. 1/4" thick at 451.5' - load cast horizons at 451.35', & 454.2'		92%	5.0'	5.0'	Minimum gas bubbling wash in hole-lt. gr. wash w/occasional brn. influxes - long piece-18"
460					Same, with some hard lt. gy., siltstone lam., brn. shale lam. 0-1" thick. Sandy shale band at 458.0'-458.6' (x-bedded), siltstone band at 458.85'-459.15'		83%	5.0'	5.0'	Same wash & gas long piece-17"
					Same with little lt. gy. lam. & some gy. brn. oily shale lam. 0-3" thick, heavily concentrated in the 463.75-465.0' interval.		85%	5.0'	5.0'	Same. Long piece-14"
470					Same, lt. gy. siltstone band from 465.3-465.7' & at 466.55'(2-1/2")		83%	5.0'	4.94'	Same. Long piece-18"
					Same, rock shattered from 473.7-474.3'. Thin clay seams and fissile shale at 470.75, 472.85, 474.5(3/4"), Very thin clay seam at 471.6'.	4/25/79 Sample disturbed		5.0'	5.0'	→ Gas threw volume of water out of hole followed by barrel lifted from approx. 300' 20' out the cased hole. Sample on barrel lands on platform greatly disturbed sample. [illegible] gas left to blow-off over night.
480					Same shale is med. to lt. gy. with trace gy. brn. lam., lt. gy. siltstone band at 479.4-479.85' Fissile shale at 476.2'(v. thin)		95%	5.0'	4.96'	Long piece-13"
					Same, tr. lt. gy. siltstone lam. w/ one band at 480.55, tr. of iron staining in thin seam (?) at 483.4'-Load cast horizon at 481.3'		100%	5.0'	5.0' Long piece 30"	Min. gas
490					Same, little lt. gy. siltstone lam., little dk. brn. shale lam. lt. gy., x-laminated sandy shale band at 485.8'-486.05' Fractured rx. with clay (pulverized from hammering) at 486.05'(1/4") 487.8(1/4"); & 488.4(1/2")	Sample disturbed		5.0'	4.75'	→ Barrel pulled to 300' below surface when gas caused it slowly to top of hole. Have down block of drill steps and held barrel under pressure. Gas left to blow-off over lunch.
							93%	5.0'	5.0' Long piece 19"	Upon retrieving barrel is being repeatedly hammered against block under slightly less pressure.
500					Same, tr. siltstone lam., tr. brn. shale, siltstone band from 494.6'-494.9'		97%	10.0'	9.92' Long piece 20"	→ Driller is pulling barrel slowly allowing hydrostatic head at gas ~ hole.

(continued)

G-104

GAI-227 2/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

(continued)

SHEET 10a OF 16

PROJECT: ______ W.O. ______ SITE AREA ______
CONTRACTOR: ______ COORDINATES ______
DRILLER: ______
CLASSIFIED BY: ______ DATE: ______
DRILL HOLE NO. ______
ELEVATION ______
GWL 0 HRS ______
24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Des., Ground Water, Construction Problems, etc.
500					Same with some lt. gy. siltstone to sandy shale lam., band from 499.8 500.4' (x-laminated)		97%	10.0'	9.92'	
					Bottom of Sheet 10					

G-105

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 11 OF 16

PROJECT: FNPP W.O. 04-4549-310 SITE AREA NE Parking Lot
CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77
E2,369,806.12
DRILLER: Jim Adams
CLASSIFIED BY: R. Wardrop DATE: 4/26/79
DRILL HOLE NO. TX-11
ELEVATION 624.04
GWL 0 HRS ______
24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Des., Ground Water, Construction Problems, etc.
500					Med. hard, m. gy. shale, with some hard lt. gy. sandy shale to siltstone lam., some brn. (oil shale) lam. Lt. gy. bands at 501.55-501.8' and 503.8'-504.2' (x-laminated).		97%	10.0' (495' to 505' run)	9.92'	Min. gas-no problems. Lt. gy. wash w/ brn. influxes. Long piece-20"
510					Tan, sandy (fi. grained) influx at 506.5' (1/4"). Med. hard brn. shale concentrated from 506.7-508.7', with some gy. shale lam, little lt. gy. lam. with band at 505.2' (2-1/2"). (x-laminated)	4/26/79	[illegible]	5.0'	5.0'	[illegible] Barrel left in hole overnight-sample pushed up to top of 10' barrel
					Same, brn. lam. 0"-3" thick concentrated between 515.6' and 518.5' with some gy. shale, little lt. gy. siltstone in bands at 513.3' (3"), 514.25' (2"), and from 514.7'-515.0'. Vertical fract. at 510.77'-511.05'		98%	10.0'	9.88'	Brown wash w/ lt. gy. influxes. Oily film in drill water. Long piece-18"
520					Fissile shale seam with clay at 518.75 (1/4") Very thinly bedded	4/27/79	92%	2.5'	2.5'	Barrel blocks up, increase in water pressure [illegible] @ 523.5' barrel pulled.
					Same with little gy. shale lam. Vertical fract from 520.0' - 520.3'. Lt. gy. band from 520.55-521.05.		96%	7.5'	7.5'	Greenish brown wash. Minimal gas
530					Same tr. lt. gy. lam., brn. shale in 0-4" thick bands. Rock broken with some overcoring between 523.5' and 523.85'					Long piece-15"
					Same gy. shale, thinly laminated, one 3-1/2" thick band at 532.5'. Lt. gy. siltstone band at 3-3/4" thick at 538.7'. Horizontal Bedding		91%	10.0'	10.0'	No indication of gas
540					Same, and med. hard gy. shale lam. Lt. gy. lam. at 549.55' (1-1/4" thick)		100%	10.0'	10.0'	Long piece-28". No indication of gas. Long piece-21"
550										

G-106

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 12 OF 16

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot

DRILL HOLE NO. TX-11

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12

ELEVATION 624.04

DRILLER: Jim Adams

GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 4/28/79

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
550							Med. Hard, med. gy. shale and brn. oil shale 0-6" thick bands, larger brn. shale bands at 551.7-552-25, 558.5-558.9, & 559.5-560.0' Some laminae seem to have slight dip, probably local depositional feature		100%	10.0'	10.0'	Lt. gy. and dk. brn. wash. No gas
560							Med. hard, brn. shale and med. gy. shale laminae. Brn. shale band at 560.0-561.9' Pryrite deposited along laminae at 566.65, 568.5, & 569.15' Vertical fract. 2" long at 566.9'		43%	10.0'	10.0'	Long piece-15" No gas
570							Med. hard. med. gy. shale and brn. shale 0-5" thick, band at 574.1-574.8, trace v. thin lt. gy. siltstone lam. Very slight dip to laminae between 577.7 and 578.1' Pyrite in circular bleb at 574.0' (1/4" diameter)	4/28/79	98%	10.0'	9.92'	Long piece-65" Brown and grey wash, smooth coring, No gas
580							Same, with only traces of brn. shale laminae, tr. very thin lt. gy. siltstone lam. med. hard Partially developed, tr. brn. siderite bands at 582.35' (1"), 583.4' (1"), 586.6' (1"), 587.4 (3/4") & 588.25 (1")		100%	10.0'	9.92'	Long piece-21"
590							Same with little brn. shale, little lt. gy. siltstone becoming brown shale at 594.95' with traces of v. thin lt. gy. siltstone and gy. shale laminae, pyrite in lam. 594.95 Between 592.35 and 594.95, every 1"-2". Other trace deposits in seams at 598.45 and 598.7' (1/8" thick a piece)		100%	10.0'	10.0'	Long piece-60"
600												Long piece-76-½

GAI - 337 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 13 OF 16

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot

DRILL HOLE NO. TX-11

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E 2,369,806.12

ELEVATION 624.04

DRILLER: Jim Adams

GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 6/29/79

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
600							Hard, brown, shale (oil shale) to siltstone w/trace lt. gy. siltstone in 3/4" laminae @ 608.75, tr. thin gy. shale lam. Traces of pyritic, micro-crystalline mineralization @ 603.4', 605.85', & 607.85'		100%	10.0'	10.0'	Dk. brown wash
610							Same, traces of pyrite at 613.15, 615.05, 616.45, 610.6, 611.5		100%	10.0'	10.0'	Long piece 56½" Core catcher fails-sample left in hole-retrieved in one attempt-no overcoring
620							Same to 623.9' Trace pyrite to 623.9' becoming med. hard, gray shale with little dk. brn. oil shale, trace thin, lt. gy. siltstone lam. Thinly laminated, tight, flatlying	6/29/79	95%	10.0'	10.0'	All one piece-120"
630							Beds of med. hard., grn. gy. shale and dk. brown shale to siltstone in the following sequence: 630-633.8 lt. greenish gy. shale, some brn shale. with 0-4" thicknesses; 633.8-634.65-brn. shale, 634.65-634.9-lt. grn. gy. shale, 634.9-637.5-brn. shale, hard, 637.5-640.0-lt. grn. gy. shale w/ some brn. shale. Slightly broken in partings at 638' & 638.8' Trace micro-crystalline pyrite at 637.77 & 636.6'		96%	10.0'	10.0'	Long piece-48"
640							640.0-650.0-brn. oil shale to siltstone, hard, trace, v. thin gy. shale lam., trace pyrite at 645.6', 649.1', & 649.5'		100%	10.0'	10.0'	Long piece-55"
650												All one piece-120"

GAI - 337 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 14 OF 16

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NP Parking Lot

DRILL HOLE NO. TX-11

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12

ELEVATION 624.06

DRILLER: Jim Adams

GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 4/30/79

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Core Run	Core Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
650					Hard, brn. shale to siltstone with traces of thin gy. shale lam., traces of lt. gy. siltstone lam. at 653.95-654.25, 654.55-654.9, 657.0-657.15, & 657.75(3/8") traces of micro-crystalline pyrite at 653.6, 651.85, & 655.5 Same to 661.4', becoming, greenish gy. shale-siltstone, and brn. shale hard, in the following sequence		100%	10.0'	10.0'	Lt. gy. and brown wash; long piece-63"
660					661.4-661.7 - M. grey, siltstone 661.7-662.35-br. shale 662.35-662.6-lt. gy. siltstone becoming shale 662.6-663.3-br. shale; 663.3-665.3-lt. grey siltstone; 665.3-666.2 - br. shale 666.2-666.9 - lt. gr. gy. siltstone; 666.9-668.6-br. shale 668.6-669.5 - lt. gy. gr. siltstone; 669.5-670-interlaminated w/ lam. of above lithologies		100%	10.0'	9.92'	long piece-17"
670					Hard, brn. shale-siltstone to 670.4', then med. hard. to hard. lt. gr. gy. shale (670.4-679.55) with some bands of br. shale at 672.6-673.1, 673.7-675.35 & 677.35 (1-1/2") 679.55-680 brn. shale-siltstone with (1") lt. gr. gy. band at 679.15'	4/30/79	92%	10.0'	10.0'	Gas splashes drill water out of hole during run. Driller vents pressure out water gauge to safety gas release hose. P.25
680					Hard gr. gy. shale and brn. shale siltstone to 684.0-becoming hard, brn. shale with trace of lt. gr. gy. shale at 684.7(2") & 688.7-689.3		94%	10.0'	10.0'	Gauge reads 400 psi w/valve 1/2 open. Pressure decreases to 300 psi in 20 minutes. Hole left to bleed-off overnight. Long piece-113"
690					Hard lt. gy. gr. shale and br. shale to siltstone interbedded in the following sequence. 690.0-690.8-br. siltstone; 690.8-691.2-lt. gr. gy. shale-siltstone; 691.2-691.55 br. shale siltstone; 691.55-692.65 lt. gr. gy. shale siltstone		96%	10.0'	10.0'	Long piece 45"
700										

(continued)

GAI-227 8/72

(continued)

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 14a OF 16

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NP Parking Lot

DRILL HOLE NO.

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E 2,369,806.12

ELEVATION

DRILLER: Jim Adams

GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 4/30/79

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Core Run	Core Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
					Brn. Shale to Siltstone: 692.55-694.9 " "; 695.5-696.3 " "; 698.6-699.2 " " — Lt. grn. gy shale to siltstone: 694.9-695.5 " "; 696.3-698.6 " "; 699.2-700.1 " "					long piece-45"
700					Bottom of Sheet 14					

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12

DRILLER: Jim Adams

CLASSIFIED BY: R. Hardron DATE: 5/1/79

SHEET 15 OF 16

DRILL HOLE NO. TX-11

ELEVATION 624.04'

GWL 0 HRS

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
700					Lt. greenish gy. shale-siltstone and br. shale laminae in the following sequence: Br. Shale / Lt. Gr. Gy. Shale — / 700.1-704.55 704.55-704.95 / 704.95-707.5 707.5-709.4 / 709.4-710.0 w. some lt. gr. gy. lam. (0-.2")		96%	10.0'	10.0'	Brown and lt. gy. wash. Minimal gas
710					SAME 714.55-715.1 / 710.0-714.55' — / 715.1-715.5' 715.5'-720.0' / Very thin pyritic seams in brn. tr. lt. gr. gy. lam. (1") at 717.1 / shales Bands of tan brown calcareous siltstone at 710.85(1") & 713.25(1")		100%	10.0'	10.0'	Long piece-20" Minimal gas Long piece-55"
720					All brn. shale-siltstone, hard, traces of micro-crystalline pyrite at 723.05', 720.2', 728.75 in. Thin seams at 726.05' & 728.4' 2 massive Horizontally bedded		100%	10.0'	10.0'	Minimal gas All one piece-120"
730					Bottom of Hole - 730.0' 5/1/79			-		

GAI-XXX 9/72

Sheet 16 of 16
Drill Hole No. TX-11

INSPECTOR'S COMMENT:

Little evidence suggests that 730' deep TX-12 advanced through any zones of faulted rock. The "Remarks" column of sheet 10 of 16 describes two (2) situations during drilling where core samples were disturbed due to problems arising from influxes of natural gas. Although distrubed sections of core lie in close proximity to a straight line fault dip projection derived from TX borings encountering faulted rock at shallower depths, the very character of distrubed seams (i.e. lack of stiff, relatively dry clay) precludes a fault gouge zone interpretation. Disturbed seams had a freshly made appearance.

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P W.O. 04-4549-310 SITE AREA North ShorelineBluff
SHEET 1 OF 11
DRILL HOLE NO. TX-12
CONTRACTOR: Pa. Drilling Co.
COORDINATES N 781,318.50 E 2,369,051.21
ELEVATION 618.4'
DRILLER: Jim Adams
GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 6/1/79
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Pc. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	Advance Date	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0										Driller drilling through over-burden w/bentonite slurry, Angle set @ 33° from vertical
10					Lacustrine & Glacial Tills					
20						6/1/79				Coupling threads stripping when new rods added, Driller obtains tapered, threaded male ends over weekend
30										
40										
50										

G-113

GAI · 227 8/'72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North ShorelineBluff
SHEET 2 OF 11
DRILL HOLE NO. TX-12
CONTRACTOR: Pa. Drilling Co.
COORDINATES N 781,318.50 E 2,369,051.21
ELEVATION 618.4'
DRILLER: Jim Adams
GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 6/4/79
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Pc. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50					Glacial Till	6/4/79				Hole drilled @ angle 30° to vertical Tapered male ends also strip driller couples male ends w/ torch. Driller injures leg when trying to break rods, when rig accidentally kicks into gear no work Tuesday 6/5/79
60–70					boulder zone 68.0' – 70.0'	6/6/79				Sandy wash @ 68.0', hard drilling. Grey shale chips @ 70.0' in wash
70					Top of weathered shale @ 70.0' m. soft, m. grey, weathered shale, w/little lt. gy. siltstone laminae, some (1/2-3") clay seams in fissile shale Tn. brn. "Fe" stone band @ 76.0' Bottom of weathered zone - 80'			10.0'	6.2'	Casing set @ 68.0' Hole left over-night to check caving - No caving 6/7/79- Casing remains @ 68.0' long piece 8"
80					Same, m. hard, unweathered, w/ trace thin fissile seams and clay @ 87.8' (1/4), 88.4' (1/4) & 89.3' (3/4") "Fe" bands @ 85.6' (1/2), 86.85' (1/2), 87.25' (1) & 89.25' (1/2) Load casts horizon @ 88.5'	6/7/79		10.0	9.6' / 10.	Grey wash 5' Casing added after drilling- casing now @ 72.0' long piece 21.5"
90–100					Same, Bedding Partings @ 92.15', 97.8', & 98.65' "Fe" bands @ 90.3' (1" thick) 91.75' (1"), 94.25' (1/2"), 95.6' (1/2") 96.25' (1/2"), 97.1' (1/2"), 98.7' (1"). Flat lying beds			10.0'	9.9'	long piece 16"

G-114

GAI · 227 8/'72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North ShorelineBluff
SHEET 3 OF 11
DRILL HOLE NO. TX-12
CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,318.50
E 2,369,051.21
ELEVATION 618.4'
DRILLER: Jim Adams
GWL 0 HRS ____
CLASSIFIED BY: R. Wardrop DATE: 6/8/79
24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100					M. hard, m. gy., shale w/some lt. gy. siltstone to v.fi. grain sandy shale laminae, very thin. Trace tn. brn. "Fe" bands @ 104.4'(1/2"), 104.8'(3/4"), 106.0'(1"), 107.0' (1/2"), 107.8'(1/4"), 108.7'(1/4"), 109.0'(1/2") Partings @ 101.0' & 103.2', clay seam @ 105.5'(1/2")		84%	10.0'	10.0'	Lt. gy. wash; long piece 15"
110					Gy. shale w/tr. fi. gr. sandy shale to siltstone, one band @ 116.8'(2") "Fe" bands @ 111.2'(1/2"), 111.35' (1/4"), 113.4'(1/2"), 113.9'(1/4"), 117.5'(1/4"), 117.7'(1/4") & 118.2'(1/4") Partings @ 115.4' and w/tr. clay @ 119.4'		96%	10.0'	10.0'	L. P. = 14"
120					Same, load cast horizon @ 125.7' "Fe" bands @ 120.1'(1/2"), 121.2' (1/4"), 121.5'(1"), 123.3'(1"), 124.7'(2"), 126.5'(2"), 127.6'(1/2") 128.4'(1"), & 129.9'(1-1/2") Little dk. gy. brn. shale lam.	6/8/79	98%	10.0'	10.0'	L. P. = 22"
130					Same, w/little lt. gy. laminae, tr. "Fe" bands @ 131.8'(1"), 136.2'(2"), 137.7'(1"), & 140.0'(2"), tr. dk gy. brn. lam. Partings @ 132.6', 133.4', 134.2', and 134.8' Flat lying beds		93%	10.0'	9.9'	L.P. = 13"
140					Same, w/some lt. gy. lam., load cast horizon @ 147.0' Trace tn. brn "Fe" bands @ 143.6'(1/2"), 144.' (1"), 145.1'(1/2"), 148.0'(1-1/2"), 148.9'(1"), 149.5'(3/4") Partings @ 144.6', 149.2', & a fissile shale seam w/tr clay @ 149.97', v. thin.		85%	10.0'	10.0'	Assuming horizontal laminae, angle hole is maintaining 30° from vertical; Lt. gy. wash.; L.P. = 15"
150										

G-115

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North ShorelineBluff
SHEET 4 OF 11
DRILL HOLE NO. TX-12
CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,318.50
E 2,369,051.21
ELEVATION 618.4'
DRILLER: Jim Adams
GWL 0 HRS ____
CLASSIFIED BY: R. Wardrop DATE: 6/11/79
24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
					M. Hard, M gy. shale, and hard, lt. gy. sandy shale to siltstone laminae, one band @ 157.2' (1 1/2") Load cast horizons @ 150.0', 150.4', 151.8', 156.7', & 157.7' Tr. Tn. brn. "Fe" bands @ 150.5' (1/4") 155.3' (1/2") 157.1' (1") 157.6' (1/4") Thin fissile shale seams w/tr. clay @ 156.7', 157.8', & 158.7'		91%	10.0'	9.7'	Lt. gy. wash; Core rotated in barrel, pulverizing shale @ 154.0', broken rock dry; Long piece=20"
					Same, some lt. gy. bands @ 165.2' (2"), & 169.25' (2.5") Tr. Tn. brn. "Fe" bands @ 160.2' (1/2") 161.7' (1/4") & 169.9'(1/4") Tr. dk. gy. brn. shale from 166.0'-167.6' Partings @ 163.' & 165.2', fissile shale seam @ 169.9'		95%	10.0'	10.0'	L.P. = 25-1/2"
					Same, and lt. gy. band from 173.75 to 174.25', load cast horizon @ 172.1'. Tr. Tn brn. "Fe" bands @ 171.75' (1/2"), 176.3' (1/4"), 178.0' (1") 178.7' (1/2"), & 179.5' (1/2") Partings @ 172.1', 172.4', 173.2', 179.0', & 179.7'		95%	10.0'	10.0'	L.P. = 15"
					Same, w/some lt. gy. laminae, load cast horizon @ 184.6', 186.2', 188.75' Tr. tn brn. "Fe" bands @ 184.85' (1/4") 185.5'(1/2"), 186.5'(1"), 187.6'(1/2"), 188.5'(1") & 190.0' (1") Parting @ 186.0'	6/11/79	97%	10.0'	10.0'	Torque on rods begin to rattle drill rig - stopped when next 20' rod section added.; L.P. = 15"
					Flat lying beds. Same, white gy. sandy shale band @ 198.5'(2" thk.) No "Fe" bands Dk. gy. brn. shale lam. occur in 20% of core starting @ 191.8' (2" thk) other lam. thin Parting @ 197.2'		98%	10.0'	10.0'	L.P. = 20"

G-116

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 5 OF 11

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-12

CONTRACTOR: PA Drilling Co. COORDINATES N 781,318.50 E 2,369,051.21 ELEVATION 618.4'

DRILLER: Jim Adams GWL 0 HRS ______

CLASSIFIED BY: R. Wardrop DATE: 6/12/79 24 HRS ______

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
200	M. hard, m. gy. shale, w/some hard lt. gy. sandy shale to siltstone lam., bands at 202.35'(2")(fi. gr. sandstone), 207.15'(1.5"), & from 208.3'-208.7', load cast horizon at 205.1', 207.6', 208.7', & 208.9' Tr. "fe" bands at 205.5'(2"), 207.0'(1"), 208.05'(1"). Partings at 204.8' & 209.8'		98%	10.0'	10.0'	Lt. gy. wash Long piece=33.5"
210	Same, and lt. gy. lam. bands at 211.3'(2"), 213.2'-214.6'(v. thin lam.), & 215.3'-216.5', dk. gy. brn. sh. from 212.1'-212.7' (v. thinly lam.). Fizzle seams at base of lt. gy. bands at 211.2', 212.1', & 214.7'		96%	10.0'	10.0'	L.P. = 40"
220	Same w/some lt. gy. lam., bands at 221.6'(1-1/2"), 227.2'(2"), 228.5(3"), 228.8'(2") & 229.4'(2") Load cast horizons at 271.1', 224.8', 225.25', 225.7', 226.3' Tr. dr. gr. brn. lam. (0-1/4" thk) Broken sandstone band at 228.5' (2"), w/tr gy. clay.		97%	10.0'	10.0'	L.P. = 30"
230	Same, and lt. gy. lam., bands at 233.35'(1.5"), & 234.5-235.0' (x-bedded) Partings at 236.1' % of shale increases at 236.4', w/little lt. gy. bands, tr. dk. gy. brn. lam.		98%	10.0'	9.9'	L.P. = 42"
240–250	Same, w/ tr. v. thin lt. gy. lam. band of dk. gy. brn. shale at 245.5'(2"), Partings at 245.7', & 249.7' 80° fract. striking perp to drill hole azmith from 248.0'-248.6' Flat lying bedding	6/12/79	95%	10.0'	9.9'	L.P. = 18"

G-117 GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 6 OF 11

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-12

CONTRACTOR: PA Drilling Co. COORDINATES N 781,318.50 E 2,369,051:21 ELEVATION 618.6'

DRILLER: Jim Adams GWL 0 HRS ______

CLASSIFIED BY: R. Wardrop DATE: 6/13/79 24 HRS ______

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
250	M. hard, m. gy. shale and hard, lt. gy. siltstone to sandy shale lam-inae, lt. gy. bands at 251.7'(1.5") & v. thin lam. concentrated from 256.3'-258.0', tr. dk. gy. brn. sh. Partings w/tr. clay at 252.5 & 253.3. Broken rock from rotation in barrel from 259.6'-260.0'		93%	10.0'	10.0'	Lt. gy. wash No gas Long piece=24"
260	Same, lt. gy. bands at 260.2'(2"), 260.5'(2"), 261.5'-262.7'(x-bedded) 264.9'(4.5"), 265.8'(4"), 266.5'-267.9'(x-lam.), & 269.9'(2") Partings at 264.5' & 267.35'		96%	10.0'	9.9'	Hole is maintain-ing 30° dip according to dip of beds in core, assuming horizontal bed-ding L.P. = 29"
270	Same, lt. gy. bands at 271.1'-271.45', 271.65'-272.7, 274.4(2"), 276.7(3.5"), 279.2(2") Partings at 272.1; 272.6' Fissile shale seam w/tr. clay at 276.0(1/4"), & 277.5'(1/8")		95%	10.0'	9.9'	L.P. = 24"
280	Same, lt. gy. bands at 281.0'-282.0' (x-lam.) 284.7'(1.5") (x-lam.), & 288.4'(1.5")(x-lam.) Partings at 285.8' & 285.2' Broken rock at 287.0'(3"), 287.9'(2.5"), & 289.0'(2")		90%	10.0'	10.0'	Tape split at bottom of barrel causing broken seams in last 3' of core. L.P. = 60"
290–300	Jt. at 285.5'-285.75', strike approx. perp. to bore azmith, dip 65° N. Same, w/some hard. lt. gy. sandy sh. to siltstone bands, 2" at 290.1(2")(x-lam.), 295.0-295.3' (x-lam.), & 295.0'(3")(x-lam.) Partings at 295.85' & 299.2'		98%	10.0'	10.0'	Minimal gas when barrel pulled. 0 psi shut-in pressure L.P. = 30"

G-118 GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 7 OF 11

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. 618.6'

CONTRACTOR: PA Drilling Co. COORDINATES N 781,318.50 E 2,369,051.21 ELEVATION ______

DRILLER: Jim Adams GWL 0 HRS ______

CLASSIFIED BY: R. Wardrop DATE: 6/13/79 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
300					M. hard, m. grey shale and hard lt. gy. sandy shale to siltstone laminae, bands at 300.1'(2"), 300.9'(2"), 301.9'(3.5")(x-lam.), becoming mostly lt. gy. bands w/some gy. shale at 305.3', tr. dk. gy. brn. shale. Load cast horizon at 304.6'. Weathered shale in parting at 306.85'(1/2")		97%	10.0'	10.0'	Lt. gy. wash. No gas
310					M. hard, m. gy. shale w/little lt. gy. lam., becoming mostly lt. gy. lam. w/little gy. shale at 316.2', trace dk. gy. brn. shale, lt. gy. bands at 311.3-311.85'(x-lam), 310.4',(2.5') 316.2,-317.0'(x-lam., silt.) 317.35'-318.1', 318.4'-319.7'. Parting at 319.7'		99%	10.0'	10.0'	Long piece=36". Assuming horizontal bedding, hole is maintaining a 30° dip angle from vertical
320					M. hard, m. gy., shale w/some hard lt. gy. lam., bands at 322.8'(1/4"), 323.0'-323.55'(x-lam) 323.8'-324.2', 328.35'(2.5")(x-lam) 329.5'-330.0' (siltstone). Load cast horizon at 325.6'. Tr. dk. gy. brn. lam. Fissile shale seams at 322.65' & 329.5'. Partings at 321.0'		98%	10.0'	10.0'	L.P. = 30°. Gas pushed small stream of water out of rod. Pressure gauge leaked at welds on collar, driller repairs for subsequent readings
330					Same, w/little lt. gy. lam. bands at 330.1(2"), 330.6(2.5"), 331.55-332.3, (thinly lam. w/sh.) 332.9(2.5"), 333.8(2"), 335.7'(2.5"), 336.8'(2.5"), 337.4(3"), tr. dk. gy. brn. sh., becoming 100% lt. gy. siltstone at 338.2'. Parting at 339.35'. Thin pyrite seam at 336.0'		99%	10.0'	9.9'	L.P. = 34°. No gas
340					hard lt. gy. siltstone to 340.7'; becoming, m. hard, m. gy. shale w/some lt. gy. lam., bands at 341.05'-341.5', 341.9'(3.5"), 344.35'(4"), & 348.9'-349.3', tr. dk. gy.brn. shale laminae		99%	10.0'	10.0'	L.P. = 53°. No gas. L.P. = 24"
350										

Flat lying bedding

G-119

GAI-227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 8 OF 11

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-12

CONTRACTOR: PA Drilling Co. COORDINATES N 781,318.50 E 2,369,051.21 ELEVATION 618.4'

DRILLER: Jim Adams GWL 0 HRS ______

CLASSIFIED BY: R. Wardrop DATE: 6/14/79 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
350					M. hard, m. gy. shale w/some hard, lt. gy. siltstone to sandy shale lam. w/bands . 2" at 351.4'(2"), 353.15'-353.85-354.25' 354.8'-355.1', 355.3'-355.6', 356.65'(2"), 357.3'-358.1', 358.35-358.65', tr. dk. gy. brn. shale in 0-1/4" laminae. Thin bleb of coal at 350.15' (1/8" thick). Parting at 358.75'		99%	10.0'	10.0'	Lt. gy. wash. No gas
360					Same and lt. gy. lam. bands at 361.3'-361.55'(x-lam.), 363.7'(3"), 364.15'(2-1/4"), 364.4'(2"), 366.25'(2"), 366.7'-367.0', 369.4(2-1/2")(x-lam.), tr. dk. gy. brn. sh. lam., all very thinly laminated. Load cast horizon at 369.7'. Partings at 364.25' & 368.9'		100%	10.0'	10.0'	Long piece=30". No gas. Assuming horizontal bedding hole is maintaining 30° dip angle from vertical. L.P. = 24"
370				FAULT	Same lt. gy. bands at 370.25-370.7, 371.2-371.7, 373.7-373.9 (thinly interlam. w/gy. shale). 374.2-374.3, 374.5-374.7, 375.2-375.5, 375.7-376.0. Parting at 372.0'. Fault Zone top 376' 376.0-376.5-Highly fract. rock 375.5-376.8-Lt. gy. Siltstone 377.5-377.7-fault gouge 378.2-378.4-fault gouge Btm. 380.3' 378.7(1/8")-fissile sh. w/clay 379.0-379.25-fault gouge 379.25-379.50-Lt. gy. siltstone. Bottom 380.3'	6/14/79	60% / 95%	10.0' / 10.0'	9.7' / 10.0'	30° dip angle. Fault Zone displays several varied dips to bedding planes. Assuming horizontal bedding rods have assumed @20° dip angle from vertical after advancing through fault zone. L.P. = 15"
380					Same as above fault w/some lt. gy. bands, @380.3-380.4, 380.5-380.6, 381.45-381.55, 381.7-381.9, 382.7-382.8, 383.6-384.05 (thinly lam. w/gy. shale) 385.7-386.0 (thinly lam. w/gy. sh.) Dk. gy. brn. bands @382.5-382.7, 385.0-385.4, & 385.5-385.7		100%	10.0'	9.9'	L.P. = 24"
390										

G-120

GAI-227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff

SHEET 8 (Continued) OF 11

DRILL HOLE NO. TX-12

CONTRACTOR: PA Drilling Co. COORDINATES N 781,964.39 E 2,369,414.82

ELEVATION 618.4'

DRILLER: Jim Adams

GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 6/13/79

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
390					Same, w/little dk. gy. br shale lam. (0-1/2" thk.) Lt. gy. bands @ 391.9'(2") & 399.6' - 399.9' Dk. gy. bru. band @ 398.8'(2") Load cast horizon @ 393.2' Parting @ 399.8'		100%	10.0'	9.9'	
400										

G-121

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 9 OF 11

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff

DRILL HOLE NO. TX-12

CONTRACTOR: PA Drilling Co. COORDINATES N 781,318.50 E 2,369,051.21

ELEVATION 618.4'

DRILLER: Jim Adams

GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 6/15/79

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
400					M. hard, m. gy., shale w/little dk. gy. brn. shale, tr. lt. gy. lam. Shale turns greenish gy. at 408.9'		100%	10.0'	10.0'	Lt. gr. gy. wash Minimal, gas no shut-in pressure Long piece=24"
410					Same, w/little lt. gy. siltstone to sandy shale lam. some dk. gy. brn. shale lam. Lt. gy. bands at 414.0(2.5") & 414.45'(2") Dk. gy. brn. shale band at 412.8'(4-1/2") Parting at 416.75'	6/15/79	98%	10.0'	9.9'	Minimal gas, 5 psi shut-in pressure. Hole maintains 20° angle from vertical L.P.=13"
420					Same, w/some dk.gy. brn. lam., tr. lt. gy. lam. Lt. gy. bands at 422.1'(1.5") Dk. gy. brn. bands at 421.2'(2"), & 421.7'(2") down to 422.3', after that core is overcored, turned, and ground to 430.0'		23%	10.0'	8.5'	Minimal gas no shut-in pressure Inner barrel does not lock in place, & is pushed up during coring-no sample, sample has to be over-cored, 1.5' rec. lost during overcoring
430					Same, w/little lt. gy. lam, bands, at 431.85'(2", x-lam.) 434.25' to 434.8'(m. gy. siltstone) 435.15-435.6'(wh. tn. siltstone), 435.6'-435.9'(lt. gy. siltstone) Same w/some dk. gy. brn. sh. bec. mostly dk. gy. brn. shale by end of run, and m. gy. shale. Lt. gy. bands at 443.7'(2") Dk. gy. brn. bands at 440.2'-440.5', 445.8'(2"), 448.3'(2"), 449.8'(2-1/2") Broken seam at 440.7'(1/2", fi. gr. sandstone) Partings at 441.3' & 443.8'	6/18/79	98%	10.0'	10.0'	Minimal gas, 0 psi shut-in pressure L.P. = 20"
440							99%	10.0'	10.0'	Minimal gas, 0 psi shut-in pressure Hole maintaining 20° angle L.P. = 19"
450										

G-122

GAI-227 8'72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff SHEET 10 OF 11

DRILL HOLE NO. TX-12

CONTRACTOR: PA Drilling Co. COORDINATES N 781,318.50 E2,369,051.21 ELEVATION 618.4'

DRILLER: Jim Adams GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 6/19/79 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
450					Hard, lt. gy., sandy shale to siltstone, tr. gy. shale to 451.05; becoming:					Lt. gr. gy. wash Minimal gas, 7 psi shut-in pressure
					M. hard, m. gr. gy. shale, and hard, dk. gy. brn. shale lam., w/little lt. gy. laminae, lt. gy. bands ≥2" at 453.3-453.6'; 454.3'(1.5"), 459.1' (2.5")		100	10.0'	10.0'	25° dip to hole
460					1/2" of broken core at 459.6'					long piece = 12"
					Same, w/little dk. gy. brn. lam. Lt. gy. bands at 463.95-464.3' & 468.4'(1-1/2", x-lam.)		100	10.0'	10.0'	8 psi shut-in on methane gas 25° dip to hole
					Parting at 468.7'					
470										L.P. = 15"
					Same, w/some lt. gy. laminae, bands at 472.65'(2.5", x-lam.), 473.65-473.85, 474.1(2.5", x-lam.) 474.45-474.75, & 479.3-479.7' (x-lam.)	6/19/79	99%	10.0'	9.9'	27° dip to hole 5 psi shut-in pressure
480					Dk. gy. brn. shale bands at 470.65(2"), & 477.7'(2-1/4")					L.P. = 18"
					Bottom of Hole - 480.0' Completed 6/19/79					

G-123

GAI-227 2/72

Sheet 11 of 11
Drill Hole No. TX-12

INSPECTOR'S COMMENT:

Fault zone identification was readily accomplished in TX-12. NC-size, double barrel, wire-line coring recovered three distinct clayey gouge zones in highly fractured rock between 376.0 and 380.4'. Also present in the zone were several distinct laminae orientations, indicative of plastic deformations to normally flat lying beds, prior to the brittle failure of actual faulting.

G-124

<APPENDIX 2D H>

CONSOLIDATION TESTS ON

COOLING WATER TUNNEL

FAULT GOUGE SAMPLES

Prepared by

WOODWARD-CLYDE CONSULTANTS

5120 Butler Pike
Plymouth Meeting
Pennsylvania 19462
215-825-3000
Telex 846-343

Woodward-Clyde Consultants

July 5, 1979
74 C 62

Gilbert Associates, Inc.
525 Lancaster Avenue
Post Office Box 1498
Reading, Pennsylvania 19603

Attention: Mr. Rodney D. Boyer,
Project Civil Engineer

Re: Consolidation Tests on
Fault Gouge Samples
Perry Nuclear Power Plant

Gentlemen:

Two consolidation tests were conducted on undisturbed samples (Nos. I-2 and I-4) obtained from the fault gouge region of the intake water tunnel at the Perry Nuclear Power Plant. The specimens tested were trimmed from block samples provided by your personnel. The block samples had lost moisture during storage of approximately seven months and were relatively dry when trimmed. Index property tests were also conducted on both block samples. Also, one consolidation test was conducted on a slurry mixed at a water content approximately equal to the liquid limit of the material. The slurry was made of the minus No. 4 sieve material from Block I-2. Demineralized water was used and the mixture was cured overnight before testing.

The test procedures and results are described in detail in the following sections.

TEST PROCEDURE

The trimming of the specimens was carried out very carefully so as not to disturb the material. Knives, saw-blades and files were used to trim the specimens into the consolidation rings. Specimen ends were patched to achieve smooth surfaces. The consolidation tests were conducted in general accordance with the recommended procedure for "One-Dimensional Consolidation Properties of Soils", ASTM D 2435-70, except that the samples were not allowed to swell after the addition of water at an initial pressure of 0.25 tsf.

Consulting Engineers Geologists
and Environmental Scientists

Offices in Other Principal Cities

The loading was continued until the swelling of the specimen was stopped and the sample started compressing. The specimen was left overnight at this seating load and the rest of the loads were allowed to remain for 24 hours. This is in accordance with the procedure recommended for swelling soils in the U.S. Army Engineers Manual EM 1110-21906, Laboratory Soil Testing, Washington, D.C. 1970.

For all the tests, back pressure was not used. The specimens were loaded to 110 tsf (capacity of equipment) in standard oedometers. To achieve higher loads, the specimens were transferred to the soil and rock strength testing frames. This enabled the loading of specimens up to 880 tsf. The pressures were maintained constant in these loading frames throughout each load increment by adjusting the deformations frequently. (Note: The rock strength testing machine which was used for loadings in excess of 220 tsf is not calibrated in accordance with safety related Quality Assurance requirements, but the test results obtained are consistent with the results from the calibrated oedometers and soil strength testing frame.)

MAXIMUM PAST CONSOLIDATION PRESSURE

To compute the maximum past consolidation pressure, both the Casagrande[1] and Schmertmann[2] methods were used. Casagrande's method is generally used to compute the preconsolidation pressure (P_c) for comparatively undisturbed, high quality samples. Schmertmann's method can be used on poor quality samples as well. In the present case

NOTES:

(1) *Casagrande A. (1936) "Determination of the Preconsolidation Load and its Practical Significance", Proceedings First International Conf. on Soil Mechanics and Foundation Eng., Vol III.*

(2) *Schmertmann J.H. (1955) "The Undisturbed Consolidation Behavior of Clay", Transitions of the ASCE, Vol 120, pp. 1201-1233.*

the samples would be expected to be of good quality, as they were obtained as block samples with very low sampling disturbance. However, the samples lost moisture during storage. For good quality samples, both methods should yield comparable results. Casagrande's method for disturbed or poor quality samples should yield lower values of preconsolidation pressure and also lower values of compression index (C_c') than the in situ values. Schmertmann's method improves the results for poor quality samples and yields higher values of P_c and C_c' than Casagrande's method, values which should be closer to the in situ values.

TEST RESULTS

Plate 1 shows the results of mechanical analysis conducted on Block Samples I-2 and I-4. It may be seen that both the specimens have almost identical grain size distribution. The results of consolidation tests are presented on Plates 2 through 4. Time vs. compression data for representative load increments, along with the strain vs. pressure (log scale) data, are shown for all three tests.

A summary of the consolidation characteristics of the undisturbed and slurry materials, along with the index properties, is presented in Table 1. From the index properties and results of mechanical analysis tests, the materials from the two block samples appear to be almost identical. The compression index values are also similar. However, the preconsolidation pressure for specimen I-2 is estimated to be 8.0 to 12.0 tsf and for specimen I-4 to be 4.5 to 6.0 tsf.

If you have any questions concerning this report, please do not hesitate to contact us.

Very truly yours,

WOODWARD-CLYDE CONSULTANTS

Frank S. Waller, P.E.
Project Manager

FSW/p

cc: Dr. Lane Schultz
Mr. William J. Santamour
Dr. Barry Voight
Master Files 1.2/5.5

TABLES

TABLE 1
SUMMARY OF CONSOLIDATION TEST RESULTS

Sample	Type	Pc (tsf)		C'_c (Unit Strain Basis)	PL%	LL%	G_s	W_i (%)	W_f (%)
		Casagrande	Schmertmann						
I-2	Undisturbed	8.0	12.0	0.110	18	27	2.80	2.2	9.7
I-2	Slurry	-	-	0.110	18	27	2.80	29.8	16.7
I-4	Undisturbed	4.5	6.0	0.112	19	28	2.76	2.2	6.6

NOTATION:

P_c - Preconsolidation Pressure

C'_c - Compression Index (Unit Strain Basis)

PL - Plastic Limit

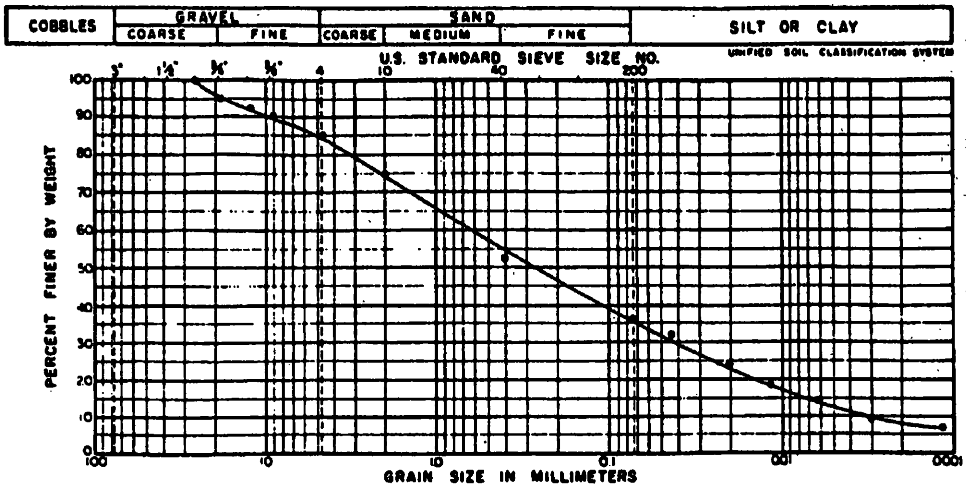
LL - Liquid Limit

W_i - Initial Water Content

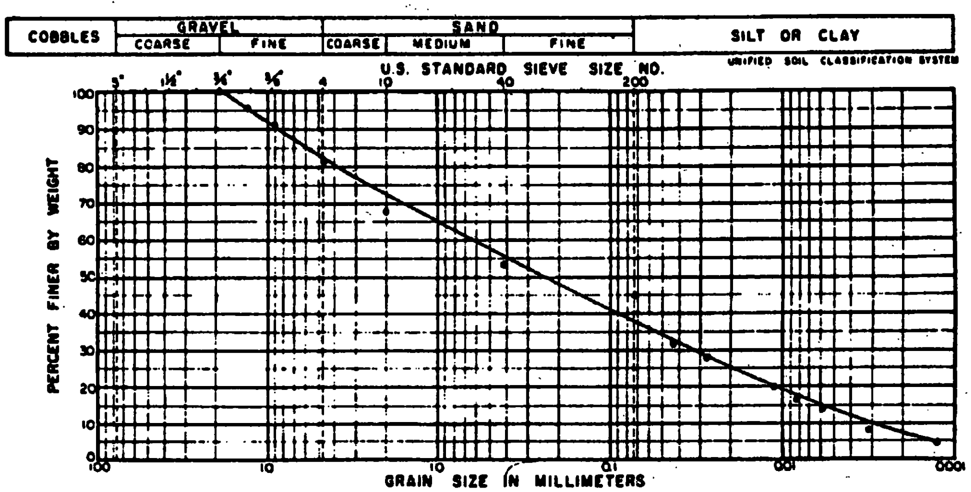
W_f - Final Water Content

PLATES

MECHANICAL ANALYSIS

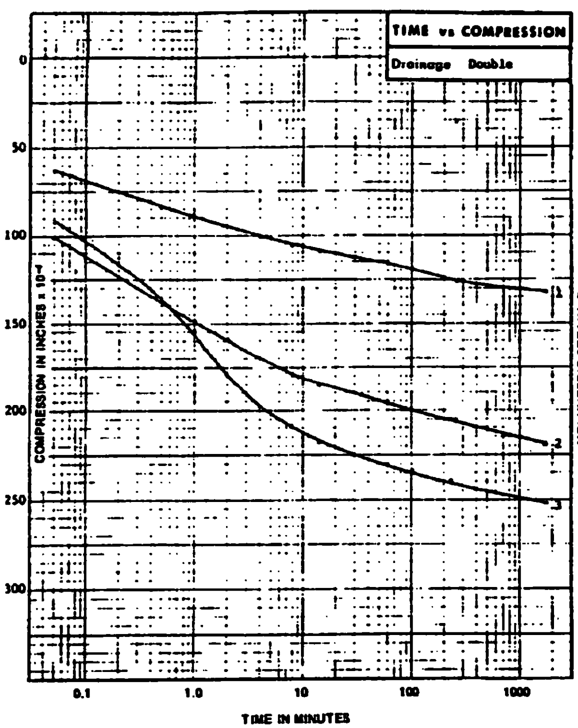


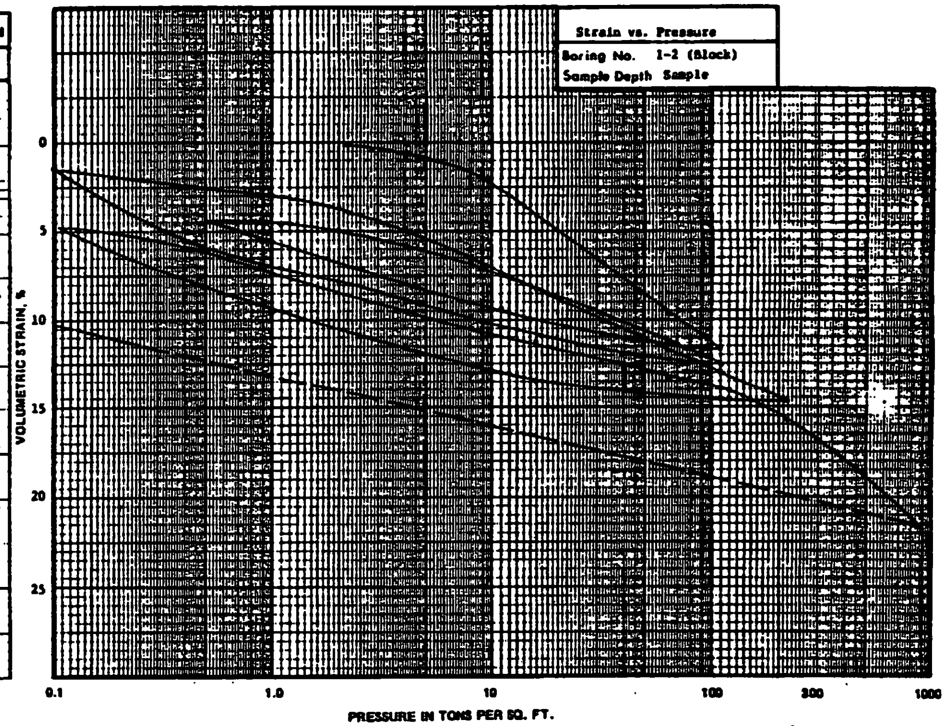
BORING	SAMPLE	DEPTH	SYMBOL	CLASSIFICATION	MC	LL	PL
Block	I-2		•	Fault Gouge	2.2	27	18



BORING	SAMPLE	DEPTH	SYMBOL	CLASSIFICATION	MC	LL	PL
Block	I-4		•	Fault Gouge	2.2	28	19

PLATE 1





CURVE No.	PRESSURE INCREMENT FROM(tsf)	TO(tsf)	COEFFICIENT of CONS. (ft²/DAY)
1	4	8	
2	8	16	
3	16	32	

PRESSURE INCREMENTS OF TIME COMPRESSION CURVES

DESCRIPTION OF SPECIMEN: Fault Gouge

CONSOLIDATION PROPERTIES	
COMPRESSION INDEX	0.110
RECOMPRESSION INDEX	0.032
SWELLING INDEX	–
PRECONSOLIDATION STRESS, tsf	–
EXISTING OVERBURDEN STRESS, tsf	–
FROM VOLUMETRIC STRAIN	

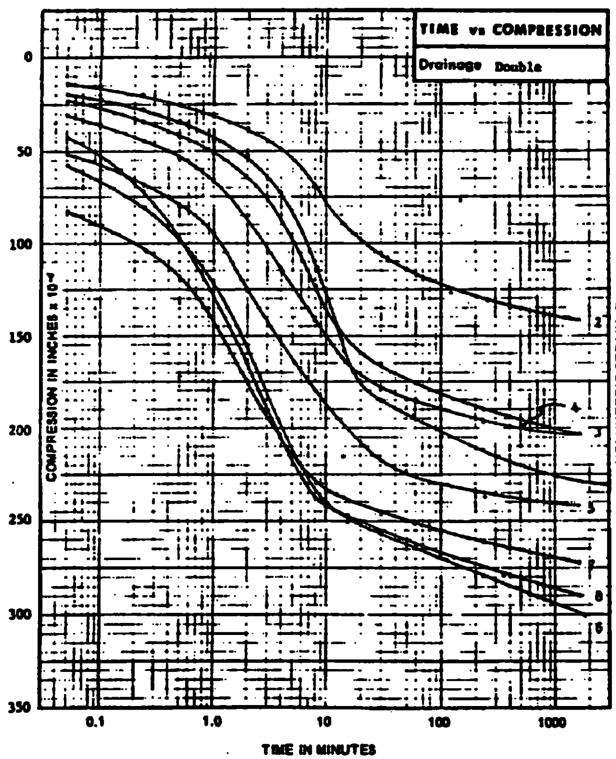
TEST SPECIMEN PROPERTIES	INITIAL	FINAL
WATER CONTENT, %	2.2	5.82
VOID RATIO	.290	.156
SATURATION, %	21.3	100.0
SAMPLE HEIGHT, in.	.969	.851
SAMPLE DIAMETER, in.	2.125	–
UNIT DRY WEIGHT, pcf	129.2	
LIQUID LIMIT, %	27	
PLASTIC LIMIT, %	18	
SPECIFIC GRAVITY	2.80	

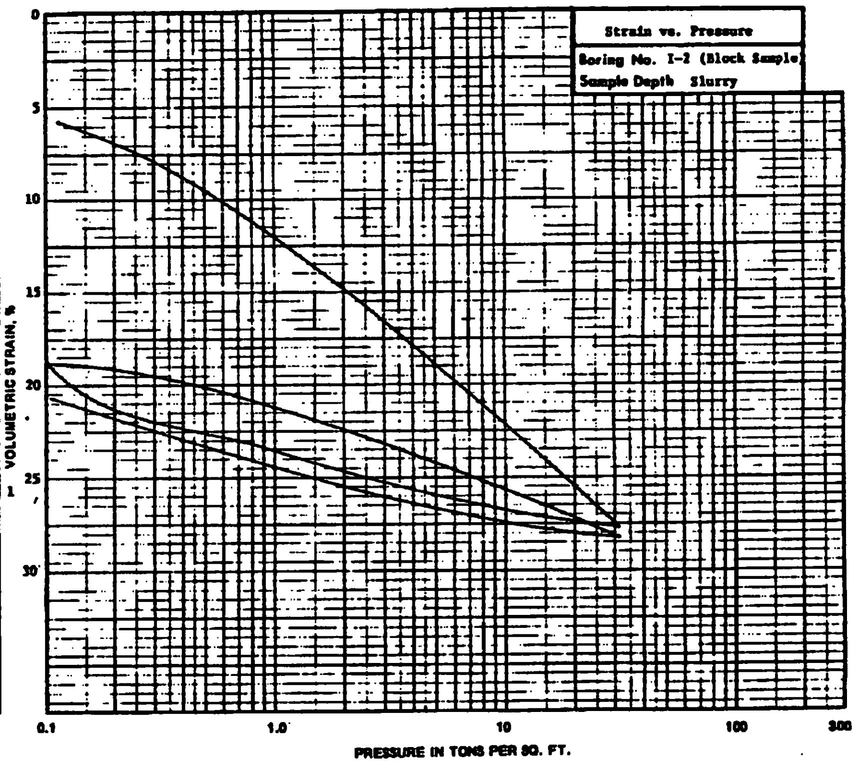
CONSOLIDATION TEST

WOODWARD-CLYDE CONSULTANTS

TESTED BY EDM	DATE 5/29/79
CHKD.BY RDS	JOB No. 74 C 62

PLATE 2





PRESSURE INCREMENTS OF TIME COMPRESSION CURVES

CURVE No.	PRESSURE INCREMENT FROM(tsf)	PRESSURE INCREMENT TO(tsf)	COEFFICIENT of CONS.(FT²/DAY)
1	0	1/8	
2	1/8	1/4	
3	1/4	1/2	
4	1/2	1	
5	1	2	
6	2	4	
7	4	8	
8	8	16	

DESCRIPTION OF SPECIMEN: Fault gouge slurry

CONSOLIDATION PROPERTIES	
COMPRESSION INDEX	0.110
RECOMPRESSION INDEX	0.038
SWELLING INDEX	0.035
PRECONSOLIDATION STRESS, tsf	-
EXISTING OVERBURDEN STRESS, tsf	-
FROM VOLUMETRIC STRAIN	

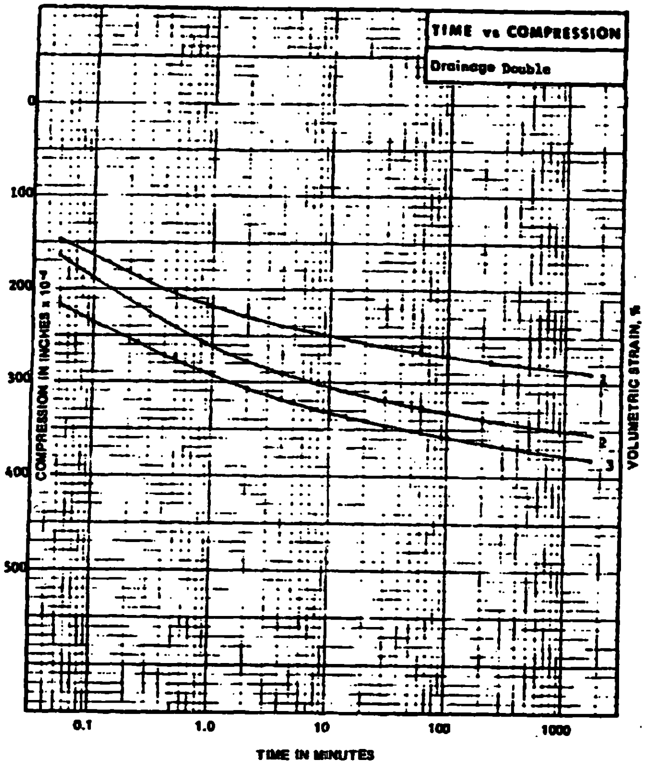
TEST SPECIMEN PROPERTIES	INITIAL	FINAL
WATER CONTENT, %	29.8	16.7
VOID RATIO	.870	.471
SATURATION, %	95.8	99.2
SAMPLE HEIGHT, in.	.877	.690
SAMPLE DIAMETER, in.	2.495	-
UNIT DRY WEIGHT, pcf	83.6	
LIQUID LIMIT, %	27	
PLASTIC LIMIT, %	18	
SPECIFIC GRAVITY	2.80	

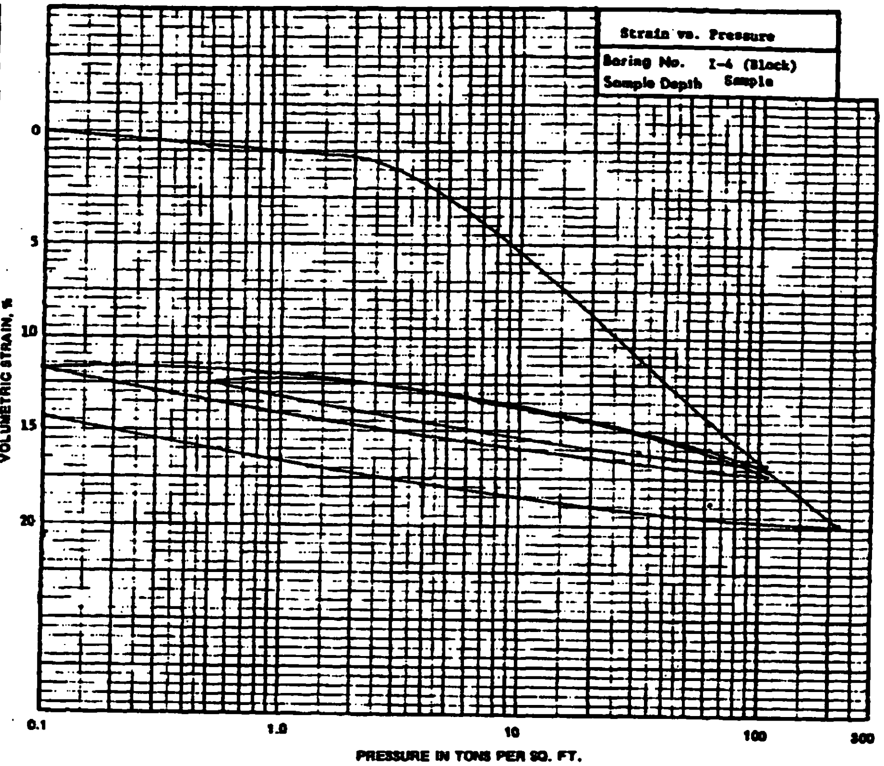
CONSOLIDATION TEST

WOODWARD-CLYDE CONSULTANTS

TESTED BY	EMM	DATE	5/16/79
CHKD. BY	RDS	JOB No	74 C 62

PLATE 3





PRESSURE INCREMENTS OF TIME COMPRESSION CURVES: CURVE No.	PRESSURE INCREMENT FROM(tsf)	PRESSURE INCREMENT TO(tsf)	COEFFICIENT of CONS. (ft²/DAY)
1	4	8	
2	8	16	
3	16	32	

DESCRIPTION OF SPECIMEN: Fault gouge

CONSOLIDATION PROPERTIES	
COMPRESSION INDEX	0.112
RECOMPRESSION INDEX	0.018
SWELLING INDEX	-
PRECONSOLIDATION STRESS, tsf	-
EXISTING OVERBURDEN STRESS, tsf	-
FROM VOLUMETRIC STRAIN	

TEST SPECIMEN PROPERTIES	INITIAL	FINAL
WATER CONTENT, %	3.2	6.6
VOID RATIO	.391	.180
SATURATION, %	22.9	100.0
SAMPLE HEIGHT, in.	1.160	.984
SAMPLE DIAMETER, in.	2.125	-
UNIT DRY WEIGHT, pcf	125.5	
LIQUID LIMIT, %	28	
PLASTIC LIMIT, %	19	
SPECIFIC GRAVITY	2.80	

CONSOLIDATION TEST

WOODWARD-CLYDE CONSULTANTS

TESTED BY	ERK	DATE	5/24/79
CHKD. BY	RDS	JOB No.	74 C 62

PLATE 4

<APPENDIX 2E>

SOIL AND ROCK BORINGS

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 6

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio

DRILL HOLE NO. 1-1

CONTRACTOR: Herron Testing Lab, Inc. COORDINATES N 780,718.9 E 2,370.068

ELEVATION 622.8

DRILLER: Larry Humphrey

GWL 0 HRS 1.9

CLASSIFIED BY: D.B.S. DATE: 4-11-72

24 HRS 2.1

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE SEDIMENTS					
2.5	1	3	6	6	2.5 / 4.0		Mottled gray & or-brn v.f.sand, moist,med.consist., some black organics,v.low plastic,clay interbedded	SC				
5	SHELBY				6.0	5.5						
7.5	2	3	5	5	7.5		Gray silty clay,v.moist-wet,soft and brn,v.f.sand (85% sand)	CL				
10.0	SHELBY				8.0 / 10							
	3	10	12	14	11.5		Gray silty sand (75% sand),wet, med.-stiff	SC				
12.5	4	6	4	4	12.0 / 13.5		Med.gray silty sand,wet w/ interbedded seams of hard moist silty clay;slightly plastic	ML/CL				
15.0	SHELBY				15.0 / 17.0							
17.5	5	3	3	5	18.5		Gray silty clay,firm,mod.plastic, interbedded w/gray silty sand (non-plastic),loose,wet	SC/CL				
20.0	6	3	7	7	20.0		Same					
22.5					23.5							
25.0	7	6	13	24	25.0		Dense gray silt & v.f.sand interbedded,moist,slightly plas.	ML				

GAI - 237 12/68

2E-2

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 6

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio

DRILL HOLE NO. 1-1

CONTRACTOR: Herron Testing Lab.,Inc. COORDINATES

ELEVATION 622.8

DRILLER: Larry Humphrey

GWL 0 HRS 1.9

CLASSIFIED BY: D.B.S. DATE: 4-11-72

24 HRS 2.1

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% REC.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25												
27.5					28.5	29.0	Gray,moist clayey silt,m.plas.stiff	ML				
30.0	8	8	7	7	30.0		UPPER TILL Gray sandy clay;less moist,hard 5% sand & gravel size shale RF, angular	CL				
32.5					33.5							
35.0	9	4	6	8	35.0		Gray moist sandy clay (plastic;sand size frags are gray shale (10° sand) angular	CL				
37.5					38.5	38.5						
40.0	10	18	27	36	40.0		LOWER TILL V.hard slightly moist gray silty clay & gray shale (calcareous) fragments (10%) coarse sand size angular w/some gravel size	CL				
42.5					43.5							
45.0	11	16	20	29	45.0		Same but only slightly damp	CL				
47.5					48.5							
50.0	12	19	20	23	50.0		Same as above	CL				

GAI - 237 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 6
DRILL HOLE NO. 1-1
ELEVATION 622.8
GWL 0 HRS. 1.9
24 HRS. 2.1

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4569-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing Lab., Inc. COORDINATES
DRILLER: Larry Humphrey
CLASSIFIED BY: D.B.S. DATE: 4/13/72

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color, Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50												
52.5												
55	13	31	44	80	54.5 / 56	56	Hard dry gray clay w/ 30% gravel size shale frags-broken, angular	66		56		
57.5							Hard gray shale; broken in zones; clay & shale frags in zones; jointing normal to run & at about 50	48	.19	8.0	3.8	
60.0												
62.5										64.0		
65.0							Same hard gray shale; massive but very thinly laminated; partings and hairline fractures generally normal to run; lt. gray v.f. sands & silts appear in stringers less than 3/4" wide. Some jointing at angles to 60° from normal may be locally controlled by undulating current action on shale (mud) surface-silt stringers show undulating current bedding associated w/some fractures		.92	10.0	7.0	
67.5												
70.0												
72.5										74.0		
75.0												

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 6
DRILL HOLE NO. 1-1
ELEVATION 622.8
GWL 0 HRS. 1.9
24 HRS. 2.1

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4569-00 SITE AREA North Perry, Ohio
CONTRACTOR: Herron Testing Lab., Inc. COORDINATES
DRILLER: Larry Humphrey
CLASSIFIED BY: D.B.S. DATE: 4-13/72

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color, Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75.0												
77.5							Same					
80.0								98	.96	10.0	9.8	
82.5										84.0		
85.0												
87.5							Same	94	.84	10.0	9.4	
90.0												
92.5										94.0		
95.0												
97.5												
100.0												

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio
CONTRACTOR: Herron Testing Lab., Inc. COORDINATES
DRILLER: L. Humphrey
CLASSIFIED BY: D.B.S. DATE: 6-19-72

SHEET 5 OF 6
DRILL HOLE NO. 1-1
ELEVATION 622.8
GWL 0 HRS 1.9
24 HRS 2.1

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Coarse Granular Soils: Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
100.0										
102.5					Same	100	.90	10.0	10.0	
								104.0		
105.0					Same					
107.5						97	.10	10.0	9.7	
110.0										
112.5								114.0		
115.0					Same					
117.5										
120.0						98	.27	10.0	9.8	
122.5								124.0		
125.0										

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: L.H.
CLASSIFIED BY: D.B.S. DATE: 6-19-72

SHEET 6 OF 6
DRILL HOLE NO. 1-1
ELEVATION 622.8
GWL 0 HRS 1.9
24 HRS 2.1

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Coarse Granular Soils: Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
125.0					Same - some hairline bedding fractures normal to core about 1/8-1/4" apart					
127.5						98	.66	10.0	9.8	
130.0										
132.5								134.0		
135.0					Same					
137.5						99	.77	10.0	9.9	
140.0										
142.5								144.0		
145.0					Total Depth 144'					
147.5										
150.0										

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio

SHEET 1 OF 6

DRILL HOLE NO. 1-2

CONTRACTOR: Herron

COORDINATES N 780,971 E 2,370,027.6

ELEVATION 620.3

DRILLER: Ed

GWL 0 HRS 3.3'

CLASSIFIED BY: D.B.S.

DATE: 4-26-72

24 HRS Piez

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE SEDIMENTS					
2.5	1	3	6	6	4.0		Mottled or-brn. & gray silty clay & f.clayey sand;med.-stiff, moist	SC/CL				
5.0	SHELBY				6.0							
	2	1	1	2	7.5		Or-brn & gray sandy clay &clayey sand;soft-med.,wet-saturated	CL/SC				2" ID thin-wall Shelby tube samples used only on this hole
7.5					9.0							
	SHELBY				10.0							
10.0					10.5							
	3	2	4	5	12.0		V.F.gray sand & silt,poorly sorted,non-plastic,wet,loose	SM				
12.5					13.5							
	4	2	3	4	15.0		Interbedded v.f.gray silty sands & slightly plastic clayey sands & mod.plastic silty clays; wet-moist	SM/SC/CL				
15.0	SHELBY				17.0							
17.5					18.5							
	5	2	4	4	20.0		Gray sandy,silty clay;low-mod. plastic,moist,med.-stiff;angular shale RF (3%) mostly 1/16"; some red mottling in layers	CL				Glacial Till? Has RF, but is layered Melting glacial ice blocks deposit rock debris in lake sediments
20.0												
22.5					23.5							
	6	5	6	13	25.0		Same as above;stiff	CL				
25.0												

GAI - 227 12/65

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio

SHEET 2 OF 6

DRILL HOLE NO. 1-2

CONTRACTOR: Herron

COORDINATES

ELEVATION

DRILLER: Ed

GWL 0 HRS

CLASSIFIED BY: D.B.S.

DATE: 4-26-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0						26	? — — — — — — ? UPPER TILL					
27.5					28.5							
	7	4	5	8	30.0		Gray silty clay, w/ 5% shale RF angular & was sorted;med.sand-½";med.-stiff,moist	CL				
30.0												
32.5					33.5							
	8	3	5	8	35		Same;soft-med.	CL				
35.0												
37.5						37.5	? — ? LOWER TILL					
					38.5							
	9	7	14	21	40		Same;hard,dry;some pebbles 1" D. 10% RF;subrounded-angular	CL				
40.0												
42.5					43.5							
	10	11	22	25	45.0		Gray silty clay;10-15% well sorted subrounded,ang.sand & gravel size shale RF to 1"	CL				
45.0												
47.5												
	11	15	19	21			Same;moist,hard	CL				
50.0												

GAI - 227 12/65

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 6

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-2

CONTRACTOR: Herron COORDINATES

ELEVATION

DRILLER: Ed

GWL 0 HRS.

CLASSIFIED BY: D.B.S. DATE: 4-28-72

24 HRS.

Depth Ft.	Profile	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	% Rec.	R.Q.D.	Core Run	Rec. Core	Remarks
50	51.5				51.5		
	52.0	Quartzite Boulder					
52.5		Glacial till; gray clay, w/50% coarse sand&gravel size shale-angular RF; some 3" boulder size shale cores; gravel size shale RF (3/4" D.) subrounded; no recovery 54.8-61.5	33	.28	10	3.3	
55.0 – 60.0	61.5				61.5		
62.5		CHAGRIN SHALE - med.gray shale w/thin silty laminations; slightly broken in upper 1 ft., hairline fractures to core & 11 to bedding	96	.63	10.0	9.6	
65.0 – 70.0	71.5				71.5		
72.5	74.0	Med.gray shale w/soft clay seams & broken zones; esp.broken 71.5-74.0 and 75.5-76.5; no recovery; Layers of soft unrecoverable clay & shale	50	.07	10.0	5.0	
75.0							

GAI-227 12/63

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 6

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio

DRILL HOLE NO. 1-2

CONTRACTOR: Herron COORDINATES

ELEVATION

DRILLER: Ed

GWL 0 HRS.

CLASSIFIED BY: D.B.S. DATE: 4-28-72

24 HRS.

Depth Ft.	Profile	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	% Rec.	R.Q.D.	Core Run	Rec. Core	Remarks
75.0	75.5 – 76.5	See sheet 3					
77.5 – 80.0					81.5		
82.5		Med.gray shale; incipient hairline fractures develop w/release of pressure 1/4" apart, numerous lt.gray f.sand interbedded	93	.71	10.0	9.3	
85.0 – 90.0					91.5		
92.5		Same shale w/f.interbedded sands, broken on bedding planes into pieces 2"-3"	92	.04	10.0	9.2	Changed to BX core at 91.5' to avoid loss of run due to obstructi[ng] boulders near base of augers at 51'
95.0 – 100							

GAI-227 12/63

2E-11

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 5 OF 6
DRILL HOLE NO. 1-2A
CONTRACTOR: Herron COORDINATES
ELEVATION
DRILLER: Ed
GWL 0 HRS. 3.6
CLASSIFIED BY: D.B.S. DATE: 5-5-72
24 HRS.

Depth Ft.	Soil Description	% Rec.	RQD	Core Run	Rec. Core	Remarks
101.5	Same as above; some thin clay seams & zones of weathered-broken shale RF; drilled soft in zones	90	.08	10.0	9.0	Hole 1-2A is a relocation 9' from 1-2 toward 1-1. Attempted to avoid boulders. New coring began at 101.5'. Roller bit used on relocated hole 68.5-101.5
111.5	Med. gray shale; w/lt. gray sandstn. siltstn. seams 1/16-1½" thick; exhibit crossbedding, rippling, and cut-fill sedimentary characteristics. Broken slightly around 113'; bedding horizontal w/some bedding fractures	79	.36	10.0	7.9	* Recovery poor due to core barrel complications estimated recovery near 100%
121.5	Same as above	93	.4	10.0	9.3	

GAI-227 12/65

2E-12

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio
SHEET 6 OF 6
DRILL HOLE NO. 1-2A
CONTRACTOR: Herron COORDINATES
ELEVATION
DRILLER: Ed
GWL 0 HRS. 3.6
CLASSIFIED BY: D.B.S. DATE: 5-8-72
24 HRS.

Depth Ft.	Soil Description	% Rec.	RQD	Core Run	Rec. Core	Remarks
131.5	Gray shale w/lt. gray crossbedded sand & siltstone shale well indurated w/few thin clay seams shale appears "varved" w/dk. gray and med. gray bands; some lt. brn. shale bands "varves" 1/8"-4"	98	.94	10.0	9.8	
141.5	Same as above	88	.53	8.5	7.5	
150	Total Depth 150'					

GAI-227 12/65

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio
SHEET 1 OF 3
CONTRACTOR: Herron COORDINATES N 780,487.7 E 2,369,172.7
DRILL HOLE NO. 1-3
DRILLER: H. Humphrey
ELEVATION 619.4
GWL 0 HRS 2.0
CLASSIFIED BY: D.L.R. DATE: 4-4-72
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	R.Q.D	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0.0												
2.5	1	1	2	2			Lacustrine deposits, silty sand, brown, mostly f. sand, moist, loose, non plastic	SM				
5.0						5.5						
	2	1	3	5			Silty sandy clay, gray, mostly very fine sand (est 45%) med. stiff, moist, low plasticity	CL				Water sample taken for water quality testing
7.5	3	SHELBY										
10.0	4	2	3	4			Same as above, except v.f. sand estimated 20%; considerable silt size, moist to saturated	CL				
12.5												
	5	3	4	7			Same as above	CL				
15.0												
17.5												
	6	12	12	11			Same as above	CL				
20.0												
22.5												
	7	4	7	9			Same as above	CL				
25.0												

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio
SHEET 2 OF 3
CONTRACTOR: Herron COORDINATES
DRILL HOLE NO. 1-3
DRILLER: H. Humphrey
ELEVATION
GWL 0 HRS
CLASSIFIED BY: D.L.R. DATE: 4-4-72
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	R.Q.D	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0												
27.5	8	SHELBY										22" recovery water sample for water quality testing taken 26'-30'
30.0	9	5	9	11			Same as above except increase in clay size; stiff, mod. plastic	CL				
32.5						33.5						
	10	8	17	19			Glacial till, clayey sand, gray, dense, mostly f.-med. sand, (shale particles), est. clay size 45%	CL				
35.0												
37.5	11	23	44	54			Same as above, except v. dense, mostly med.-crse. sand size shale particles (est. 30%), damp, low plasticity	CL				
40.0												
42.5	12	14	23	25			Same as above	CL				
45.0												
47.5	13	140	45	50			Same as above	CL				
50.0												

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: L. Humphrey
CLASSIFIED BY: D.L.R. DATE: 4-7-72

SHEET 3 OF 3
DRILL HOLE NO. I-3
ELEVATION
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0						50.6				50.6		
52.5	14					52.5	Boulder-Eratic-Hornblende Gneiss w/garnet & pyrite	43		5'-0"	26"	
55.0							Gray clay w/sand & gravel size shale frags (20%) angular			55.6		
	15	104	85/12				V. poor recovery			57.3		
57.5	16						Subrounded-angular shale & trap rock? frags	87		3'-10"	4"	
60.0	17	197/3				60.5	Gray shale;partially broken & weathered zone @ 61.0-61.5			61.0		Shale
62.5	18						Lt.gray seams of current bedded v.f.sand			4'-0"	46"	
65.0								98	11	65.0		
67.5	19									5'-0"	53½"	
70.0										70.0		
72.5	20						Same but broken and weathered zone near 74'	100	24	5'-0"	62"	Installed 53.0' of 2" dia.perforated plastic pipe for water level measurements
75.0						74.0				75.0		

GAI-327 12/63

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio
CONTRACTOR: Herron COORDINATES N 780,855 E 2,371,155
DRILLER: Larry
CLASSIFIED BY: D.B.S. DATE: 4-26-72

SHEET 1 OF 3
DRILL HOLE NO. I-4
ELEVATION 623.5
GWL 0 HRS 7.3
24 HRS 2.0

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0.0							Topsoil - sandy loam					
2.5	1	3	5	5	2.5–4.0		Or-brn silty clay,moist,med.-stiff					Lacustrine sands,silts, clays
5.0	2	3	6	6	5.5–7.0	5.0	Med.-gray silty clay;med.-stiff, moist and mixed w/or-brn.silt & v.f. sand					
7.5	3	4	10	6	8.5–10.0		Same;less silt & sand, stiff					
10.0	4	3	4	5	10.5–12.0		Same as above					
12.5	5	6	7	9	13.5–15.0		Same as above					
15.0												
17.5	6	6	5	8	18.5–20.0		Same as above Gray clayey f.v.f.sand;soft,wet-saturated					Water sample take from seepage here
20.0												
22.5	7	5	7	11	23.5–25.0		Less of above and soft-med.silty clay					
25.0												

GAI-327 12/63

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 3

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio

DRILL HOLE NO. 1-4

CONTRACTOR: Herron COORDINATES

ELEVATION

DRILLER: Larry

GWL 0 HRS

CLASSIFIED BY: D.B.S. DATE: 4-26-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
27.0						27	———— ? ———— ? ———— UPPER TILL					
27.5												
	8	4	6	8	28.5 / 30.0		Med.-gray silty clay w/50% coarse sand & gravel size shale RF; moist & stiff					
30.0												
32.5												
	9	8	8	11	33.5 / 35.0		Same w/10% gravel size RF mostly 1/8" subangular-subrounded; stiff-hard & moist					
35.0												
37.5												
	10	14	19	25	38.5 / 40.0		LOWER TILL Same; but hard & dry					
40.0												
42.5												
	11	16	22	28	43.5 / 45.0		Same as above w/some rounded RF 1/2-3/4"					
45.0												
47.5												
	12	60	104		48.5 / 49.5		No recovery; boulder ricochet					
50.0												

GAI-227 12/68

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 3

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio

DRILL HOLE NO. 1-4

CONTRACTOR: Herron COORDINATES

ELEVATION

DRILLER: Larry

GWL 0 HRS

CLASSIFIED BY: D.B.S. DATE: 4-26-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50.0	13	32	45	50	51.5		Med.gray clay-v.hard & dry w/various rock frags, rounded to angular 15% RF well graded between sand, gravel & pebbles - boulders(?)					
52.5												
55.0	14	22	150/3		54.0 / 55.3		Same as above w/larger shale RF 15%					55.0
							CHAGRIN SHALE Med.gray shale; slightly broken, some bedding fractures to run and some fracturing at 20° to run			56.0		
57.5								98	.4	5	4.9	
60.0										61.0		
62.5												

GAI-227 12/68

2E-19

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio
CONTRACTOR: Herron Testing Lab., Inc. COORDINATES N 779,598.3 E 2,370,382
DRILLER: Larry Humphrey
CLASSIFIED BY: D.L.R. DATE: 4-7-72

SHEET 1 OF 4
DRILL HOLE NO. 1-5
ELEVATION 626
GWL 0 HRS Piez Obs.
24 HRS Tube

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	qu	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							Lacustrine deposits, lt.brn.silty sand, mostly f.sand (est 85%), moist, med.dense, non plastic, thin streaks of chiefly silt	SM				Hollow stem auger Outer Dia. 9" Inner Dia. 4¼"
2.5	1	5	6	6								
5.0	2	2	2	2			Same as above except sand is saturated, somewhat less silt					
7.5												
10.0	3	5	6	9			Silty clayey sand, gray, mostly v.f. sand (est 80%) saturated med.dense, slightly plastic	SC				
12.5	4	4	5	10			Silty sand, gray, mostly poorly graded f.sand (est 85%) saturated med.dense, non plastic	SM				
15.0	5	2	6	6			Silty clayey sand, gray, mostly f.sand (est 80%) saturated med. dense, interspersed w/minor thin streaks of silty clay, slightly plastic	SC/SM				
17.5												
20.0	6	2	3	4			Same as above except increase in silty clay (est 25%) w/v.f.sand	SC				
22.5												
25.0	7	SHELBY					Same as above					

GAI-227 12/68

2E-20

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: L. Humphrey
CLASSIFIED BY: D.L.R. DATE: 4-7-72

SHEET 2 OF 4
DRILL HOLE NO. 1-5
ELEVATION
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	qu	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0	8	3	5	6			Silty clay, gray, moist, stiff, minor thin streaks of v.f.sand, low plasticity	CL				
27.5												
30.0	9	4	7	10			Same as above except very stiff	CL				
32.5												
35.0	10	10	17	22			Glacial till, sandy clay, gray, dense, moist, mostly med. subangular shale sand particles (est 20%) low plasticity	CL				
37.5												
40.0	11	28	39	61			Same as above, except v.dense, includes some coarse sand size shale particles	CL				
42.5												
45.0	12	19	23	27			Same as above except damp to dry includes also angular shale fragments up to 3/4"					
47.5												
50.0	13	29	31	49			Same as above except without shale frags; f.size mostly silt; slightly plastic	ML				?

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio
CONTRACTOR: Herron COORDINATES ______
DRILLER: L. Humphrey
CLASSIFIED BY: D.L.R. DATE: 4-7-72

SHEET 3 OF 4
DRILL HOLE NO. 1-5
ELEVATION ______
GWL 0 HRS ______
24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% REC.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
	14	27	45	54			Same as above except dry, (est 40%) highly weathered & decomposed angular shale fragment ¼" to 1" dia., very dense					
						59.0	CHAGRIN SHALE Gray shale, some moist clay & frags near top of run, broken & partially weathered in upper 2'; generally massive, seams of lt.gray v.f.sand which exhibits current bedding	96	.50	8.5	8.1	
							Same	98	.75	10.0	9.8	

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio
CONTRACTOR: Herron COORDINATES ______
DRILLER: L.H.
CLASSIFIED BY: D.B.S. DATE: 4/19/72

SHEET 4 OF 4
DRILL HOLE NO. 1-5
ELEVATION ______
GWL 0 HRS ______
24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% REC.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75.0–80.0						80.0	Same	92	.91	2.4	2.2	
							Total Depth 80'					

GAI-227 12/68

2E-23

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio
CONTRACTOR: Herron COORDINATES N 780,077.9 / E 2,369,886.6
DRILLER: John
CLASSIFIED BY: D.B.S. DATE: 5-10-72

SHEET 1 OF 3
DRILL HOLE NO. 1-6
ELEVATION 624.0
GWL 0 HRS. 2.5'
24 HRS. 2.5

Sample No.	SPT Blows/6 in. 6	12	18	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	U.S.C.S.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
				LACUSTRINE SEDIMENTS		* indicates paraffin sealed sample jar
1	2	4	4	Or-brn clayey sand; soft, moist, slight plastic, interbedded gray silty clay	[illegible]	Water seepage @ 3'
2	1	2	3	Or-brn v.f. sand & silty clay, soft & v.moist-wet, gray silty clay interbedded	[illegible] *	Water seepage @ 5'
3	3	4	4	Interbedded gray v.f. sand, clayey sand and silty clay; soft-med, wet	[illegible]	
4	2	2	2	Same as above, but mostly non-plas. v.f. wet sand, firm	[illegible] *	
5	4	8	6	Same as above, firm to dense	[illegible]	
6	3	5	6	Interbedded layers of clayey sand & silty clay, some red clay seams & less than 1% m.sand sizes have RF, moist, med.-stiff	[illegible] *	
7	2	4	5	Same as above	[illegible]	

GAI-227 12/68

2E-24

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: John
CLASSIFIED BY: D.B.S. DATE: 5-10-72

SHEET 2 OF 3
DRILL HOLE NO. 1-6
ELEVATION
GWL 0 HRS.
24 HRS.

Sample No.	SPT Blows/6 in. 6	12	18	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	U.S.C.S.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
				— ? — — — ? —		
				UPPER TILL		
8	2	4	5	Gray silty clay w/5-10% angular-subrounded shale RF; coarse sand to gravel size - max ¼", stiff, moist	CL	
9	2	2	4	Gray silty clay and interbedded v.f. gray clayey sand; v.moist, soft-med. less than 3% coarse sand size RF	CL *	38'-48' drilling was variable v.hard-med. blow counts may not reflect consistency of material between spoon samples: small boulders suspected
				LOWER TILL		
10	14	17	25	Gray silty clay w/ 15-20% fine gravel size shale RF, mostly subangular to angular, hard, dry. RF to ¼"	CL *	
11	14	19	27	Same as above	CL	Possible water seepage between 45-49'
				Boulder; est. 8"-12" — ? —		Augered past boulder

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA North Perry, Ohio
SHEET 3 OF 3
DRILL HOLE NO. 1-6
CONTRACTOR: Herron COORDINATES
ELEVATION
DRILLER: John
GWL 0 HRS
CLASSIFIED BY: D.B.S. DATE: 5-10-72
24 HRS

Sample No.	SPT Blows/6 In. (6)	(12)	(18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% REC.	RQD	Core Run	Core Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
12	25	30	36	51.5		Same as before; size to ½", side of sample moist; damp-dry inside					
					52.0	——— ? ——— ——— ? ———					
						CHAGRIN SHALE Broken shale, not weathered, fractures, pieces ½"-2", possibly some clay	20	0	5.0	1.0	Irregular coring technique - Low RQD (Shale & clay in broken & weathered zone 52' to 63')
						Same as above	20	0	2.5	0.5	
						Same as above	60	0	5.0	3.0	
					63.0	——— ? ——— ——— ? ———					
						Gray shale w/thin lt. gray sandstone seams, numerous tensional bedding joints - bedding horizontal	95	17	4.0	3.8	
					68.0	Total Depth 68'					

Core run depth marks: 51.5, 56.5, 59.0, 64.0, 68.0

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 1 OF 3
DRILL HOLE NO. 1-7
CONTRACTOR: Herron COORDINATES N 780,514 E 2,369,801.8
ELEVATION 621.6
DRILLER: Larry
GWL 0 HRS 3'
CLASSIFIED BY: D.B.S. DATE: 5-5-72
24 HRS 4'

Depth Ft.	Sample No.	SPT Blows/6 In. (6)	(12)	(18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	*	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0										* indicates parafin sealed sample jar
2.5	1	2	3	5	2.5–4.0		Or-brn, silty clay w/gray mottled; some f. sand; soft-med., moist	CL	*	Water seepage around 4'
5.0	2	4	4	5	5.5–7.0	6.0	Same as above, but med-stiff w/more silt Gray silty clay, soft-med, v. moist	CL/ML CL	*	
7.5	3	4	5	7	8.5–10.0		Same as above; but wet; interbedded non-plastic, f. gray sand	CL/SM		Water seepage around 8.5'
10.0	4	5	3	7	10.5–12.0		Gray f. sand; non to v. slight plasticity, soft-med., wet; interbedded sandy clay	SM/CL	*	
12.5	5	3	3	4	13.5–15.0		Gray f. sand & silty clay interbedded soft to stiff, moist	SM/CL		
15.0										
17.5	6	6	7	7	18.5–20.0	18.5	Gray silty clay, stiff, moist; w/fine gray sand, wet. Less than 1% subrounded shale RF ⅛-¼". Dk. red clay seams interbedded w/gray clay. Laminated	CL/SM		
20.0										
22.5	7	6	7	7	23.5–25.0	25.0	Same as above, but no f. sand; 5% gray shale RF, 1/16"-1/4", angular to subrounded, dk. red & brown mottling	CL	*	Glacial Till @ 25'
25.0										

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio SHEET 2 OF 3
CONTRACTOR: Herron COORDINATES DRILL HOLE NO. 1-7
DRILLER: Larry ELEVATION
CLASSIFIED BY: D.B.S. DATE: 5-5-72 GWL 0 HRS. 24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	Q	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp. Geologic Data, Ground Water, Construction Problems, etc.
25.0							UPPER TILL					
27.5												
30.0	8	5	6	8			Same as above	CL				
32.5												
35.0	9	5	7	9			Same as above; 5-10% RF, no red & brown mottling	CL				
							———?———————?———					
							LOWER TILL					Percentage of the large sizes of rock frags seems to increase w/ depth range; fine sand to ½"
37.5												
40.0	10	19	22	30			Gray silty clay; 20-25% RF, hard, v.slightly moist - dry	CL				
42.5												
45.0	11	27	39?	25			Same as above	CL	A			
47.5												
50.0	12	17	28	30			Same	CL				

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio SHEET 3 OF 3
CONTRACTOR: Herron COORDINATES DRILL HOLE NO. 1-7
DRILLER: Larry ELEVATION
CLASSIFIED BY: D.B.S. DATE: 5-5-72 GWL 0 HRS. 24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp. Geologic Data, Ground Water, Construction Problems, etc.
50.0												
52.5												
55.0	13	19	27	45		54.0	———?———————?——— Same as above; 50-60% RF-mostly broken & weathered shale, dry & slightly friable					Weathered Shale Zone 54-65.5
57.5												
60.0	14	17/4"					Gray shale, fissile, poorly indurated and slightly weathered to clay; wet					Water seepage in shale @ 59.5
62.5												
65.0												
						65.5	——— ——— ——— ———			65.5		Auger refusal
							Gray shale w/lt.gray & lt.brn. sandstone & siltstone seams. Horizontal bedding, bedding fractures					
67.5												
70.0								100	77	9.0	9.0	
72.5												
75.0							TOTAL DEPTH 74.5'			74.5		Coring discontinued - silt buildup in cored hole

GAI-227 12/68

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 1 OF 4
DRILL HOLE NO. 1-8
CONTRACTOR: Herron COORDINATES N 780,910.2 E 2,369,718.3
ELEVATION 616.1
DRILLER: Larry
GWL 0 HRS ____ 24 HRS ____
CLASSIFIED BY: D.B.S. DATE: 4-27-72

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	*	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												* indicates parifin seal on sample jar
2.5	1	3	4	5	2.5–4.0		Or-brn.f.sand;moist Or-brn&gray silty clay moist,med-stiff	SM/CL	*			Same material but lower sand has more moisture.
5.0	2	1	2	4	5.5–7.0	7.5	Same;wet clayey sand,less silty clay,gray silty sand near base wet,soft-med. ——?—— ——?——	ML	*			
7.5	3	2	4	6	8.5–10.0		Gray silty clay;med.consistency; moist-wet	CL	*			
10.0	4	2	3	5	10.5–12.0		Same as above w/interbedded f. sandy clay & some f.clayey sands of slight plasticity	CL/ML				
12.5	5	5	6	6	13.5–15.0		Same as above;v.moist,med.-stiff	CL/ML	*			
15.0												
17.5	6	3	9	11	18.5–20.0		Same as above;moist	CL/ML				
20.0												
22.5	7	4	6	7	23.5–25.0	23.0	——?—— ——?—— UPPER TILL Gray clay w/well sorted,moist shale R.F.,angular-subrounded RF 5% f.sand size to ¼"	CL	*			
25.0												Glacial Till

GAI-227 12/66

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 2 OF 4
DRILL HOLE NO. 1-8
CONTRACTOR: Herron COORDINATES ____
ELEVATION ____
DRILLER: Larry
GWL 0 HRS ____ 24 HRS ____
CLASSIFIED BY: D.B.S. DATE: 4-27-72

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0												
27.5	8	4	6	10	28.5–30.0		Same as above	CL	*			
30.0												
32.5	9	13	20	30	33.5–35.0	34.0	Same as above LOWER TILL Gray silty clay,w/ 15% shale RF; well graded between silt & ¼" size;hard,v.slightly moist	CL				
35.0												
37.5	10	16	20	25	38.5–40.0		Same;v.hard	CL	*			
40.0												
42.5	11	12	19	25	43.5–45.0		Same as above;hard,slightly moist					
45.0												
47.5						47.5 48.5	Garnet granite gneiss boulder 2" recovery of gravely clay(till) and shale RF	16	.1	47.5 5.0	0.8	Auger refusal @ 47.5
50.0												

GAI-227 12/66

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES ______
DRILLER: Larry
CLASSIFIED BY: D.B.S. DATE: 4-27-72

SHEET 3 OF 4
DRILL HOLE NO. 1-8A
ELEVATION ______
GWL 0 HRS ______
24 HRS 3.0

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	%Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0										
52.5	14	120	52.5 / 53.0		Gray silty clay;v.hard & dry,50% broken shale R.F.			52.5		Resumed split spoon sampling
55.0										Relocated hole due to boulder complications. Set augers to refusal and began coring. Hole;second hole locate 6' south (1-8A)
57.5				56.5 / 57.0 / NO REC. / 59.0	Boulders;andesite & quartzite 5" total recovery			56.5		
60.0					Gray shale w/interbedded seams of lt.gray sandstone. Some lt.brn. varves of more dense shale (mudstone?) bedding fractures not as extensive as in most other cores, but some fractures along sandstone-shale interface	76	.4	10.0	7.6	Unrecovered material 57-59',possible weathered shale
62.5										
65.0								66.5		
67.5					Same as above;but some jointing 30 to 45° to the horizontal bedding plane					
70.0										Longest piece 14"
72.5						95	.8	10.0	9.5	
75.0										

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES ______
DRILLER: Larry
CLASSIFIED BY: D.B.S. DATE: May 1972

SHEET 4 OF 4
DRILL HOLE NO. 1-8A
ELEVATION ______
GWL 0 HRS ______
24 HRS 3.0

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	%Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75.0								76.5		
77.5					Same as above	90		5.0	4.5	Longest piece 14"
80.0								81.5		
82.5					TOTAL DEPTH 81.5'					
85.0										
87.5										
90.0										
92.5										
95.0										
97.5										
100.0										

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 1 OF 3
DRILL HOLE NO. 1-9
CONTRACTOR: Herron COORDINATES N 781,257.1 E 2,369,601.4
ELEVATION 618.8
DRILLER: Larry
GWL 0 HRS 7.0
CLASSIFIED BY: D.B.S. DATE: 5-22-72
24 HRS 6.4

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.		Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												* Paraffin sealed
2.5	1	3	6	7	2.5–4.0		Or-brn.&gray silty clay w/lenses of sandy clay;firm-stiff,moist	CL	*			
5.0	SHELBY ▲				5.0–7.0	7.0	Same as above;wet-lost most of sample	CL				▲Shelby failed! Water seepage 6.5'
7.5	SHELBY #1				7.0–9.0		Gray silty clay interbedded w/ fine sand;moist	CL/ML				24" Rec.
10.0	2	3	4	6	10.5		Same as above,firm,varved in zones;some rounded RF 1/8-1/4"	CL/ML	*			
12.5												
15.0	SHELBY #2				15.0–17.0		Same as above;soft,moist	CL/ML				21" Rec.
17.5	3	3	3	5	18.5		Stratified gray silty clay & clayey sand;stringers of red & black clay soft-firm;moist	CL/SC	*			
20.0	4	3	3	7	20.0–21.5		Same as above	CL/SC	*			
22.5												
25.0												

GAI-227 12/69

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 2 OF 3
DRILL HOLE NO. 1-9
CONTRACTOR: Herron COORDINATES
ELEVATION
DRILLER: Larry
GWL 0 HRS.
CLASSIFIED BY: D.B.S. DATE: 5-22-72
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.		Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0	5	5	9	11	25.0–26.5		Same as above;stiff,moist,more red clay,trace of plant frags	CL/SC	*			
27.5						28.0	UPPER TILL					
30.0	SHELBY #3				30.0–32.0		Gray silty clay;1-5% RF,mostly coarse sand to 1/4",moist,soft-firm	CL				22" Rec.
32.5	6	4	9	12	33.5?		Same as above;traces of red clay max. 1";ang-subround 5% RF	CL	*			
35.0	SHELBY #4				35.0–37.0	37.0	Same as above					21" Rec.
37.5	7	12	18	21	38.5?		LOWER TILL Gray silty clay,5-10% RF,ang-subround,coarse sand to 1/4"; damp-moist,hard	CL	*			Lower Till
40.0	SHELBY #5				40.0–40.9?		Same as above; 10% rF					10" Rec./11" pushed
42.5	8	16	26	31	42.5?			CL	*			
45.0	● 9	40	74	122	45.0–46.5?		Same as above	CL	*			● 3½"O.D. spoon sample 2-7/8" ID Resumed standard 2" OD 1-3/8" ID spoon
47.5	10	17	18	24	48.0?		Same as above		*			
50.0						49.5 / 50.0	Boulder - less than 0.5'			49.5		

GAI-227 12/69

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 3 OF 3
DRILL HOLE NO. 1-9
CONTRACTOR: Herron COORDINATES
ELEVATION
DRILLER: Larry
GWL 0 HRS
CLASSIFIED BY: D.B.S. DATE: 5-22-72
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	Soil Description: Density (or Consistency), Color, Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
30.0							Gray gravely clay;40-50% RF, angular-subrounded,max.2",mostly fine gravel size shale RF	94	.94	3.5	3.3	
32.5										33.0		
	11●	41	111	–			Same as above, hard & dry		*			● 2-3/8" O.D. spoon sample
35.0	12	38	54	102			Same as above		*	33.5		Standard split spoon sample (2" OD)
37.5						38.0	Same as above	43	.4	3.0	1.3	
	13	107/5"					Weathered shale some clay			38.5		
40.0						40.0				40.0		
42.5							Gray shale,thin lt.gray sandstone seams,some fracturing normal & 30° to nearly horizontal bedding plane; appears fresh & unbroken					
45.0								97	.86	10.0	9.7	
47.5												
70.0										70.0		
72.5							TOTAL DEPTH 70'					Used 20' casing (3") to seal upper saturated zone (recovered casing)
75.0												

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 1 OF 3
DRILL HOLE NO. 1-10
CONTRACTOR: Herron COORDINATES N 781,190.3 E 2,369,237.8
ELEVATION 607.1
DRILLER: Larry
GWL 0 HRS 5.0
CLASSIFIED BY: D.B.S. DATE: 5-15-72
24 HRS 4.1

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	Soil Description: Density (or Consistency), Color, Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0.0							LACUSTRINE SEDIMENTS					* indicates sample jar sealed in paraffin
2.5	1	3	5	5	2.5	3.5	Or-brn silty clay,stiff,moist, gray mottling,unstratified	CL	*			
					4.0		Or-brn silty clay & f.clayey sand, gray mottling,med-stiff,moist, stratified	SM-CL				
5.0					5.5	6.0	F.brn.sand,nat-saturated,loose, non-plastic	SM				5.5 Water Seepage
	2	1	2	4	7.0		Gray silty clay;firm,moist	CL	*			
7.5					8.5	9.0	Gray v.f.sand,saturated,loose-firm,non-plastic					
10.0	3	3	5	8	10.0 / 10.5		Interbedded w/red&gray silty clay, med.-stiff,v.moist,less than 3% coarse sand size shale RF,max.size 1",subrounded	SM/CL	*			
	4	7	11	15	12.0		Same as above,few RF,stiff	SM/CL	*			
12.5					13.5		Gray v.f.sand,saturated,firm,non plastic,interbedded f.sand & silty clay,stiff,moist	SM				
15.0	5	7	9	14	15.0	14.5		CL	*			UPPER TILL 14.5
							UPPER TILL					
							Gray silty clay,5% coarse sand-f. gravel shale RF,max.¼",stiff-hard, slightly moist					
17.5					19.5							
20.0	6	4	6	6	20.0		Gray silty clay,5% coarse sand-f. gravel size RF,sub-rounded to subangular;max ¼",some red clay, moist,med.-stiff	CL	*			
22.5					23.5							
25.0	7	4	7	9	25.0		Same as above	CL	*			

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Harron COORDINATES

DRILLER: Larry

CLASSIFIED BY: D.B.S. DATE: 5-15-72

SHEET 2 OF 3

DRILL HOLE NO. 1-10

ELEVATION

GWL 0 HRS.

24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25												
					28.5		LOWER TILL					
30	8	16	24	30	30.0		Gray silty clay, 5-10% shale RF, mostly coarse sand-f. gravel, max. 1", hard, damp-dry	[illegible]	[illegible]			Augers jumped @ 28.5
35	9	11	21	28	35.0		Same as above	[illegible]	[illegible]			Augers jumped @ 32.5
40	10	21	48	52	40.0	39.5	Same as above; f. hard	[illegible]	[illegible]			
							Cobble Zone					
						41						Augered hard
	11						No recovery			44.0		Auger refusal
45							Boulder - quartzite 2" rec.					
							Shale Boulders & cobbles in clayey till	8.0	0	4.0	.5	
										48.0		
						49	? ?					CHAGRIN SHALE
50							Weathered shale suspected					

GAI - 237 12/65

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Harron COORDINATES

DRILLER: Larry

CLASSIFIED BY: D.B.S. DATE: 5-16-72

SHEET 3 OF 3

DRILL HOLE NO. 1-10

ELEVATION

GWL 0 HRS.

24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50	12						Gray shale, hard, dry, fissile			51.0		
							Gray shale w/thin interbedded seams of lt. gray sandstone; numerous tensional bedding fractures 1/8-1/4" apart; bedding horizontal	100	.6	5.0	5.0	
										56.0		
							Same as above	92	.3	5.0	4.6	
										61.0		
							TOTAL DEPTH 61.0'					

GAI - 237 12/65

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-39

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Rexron

DRILLER: John

CLASSIFIED BY: D.R.S.

COORDINATES N 780,832.8 E 2,369,312.6

DATE: 5-2-72

SHEET 1 OF 4
DRILL HOLE NO. 1-11
ELEVATION 619.4
GWL 0 HRS 9'
24 HRS 7.5'

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0.0							LACUSTRINE SEDIMENTS					
2.5	1	3	3	2	2.5–4.0		Or-brn.silty clay,gray mottle, soft-med.,moist	CL				
5.0	2	2	2	4	5.5–7.0		Same as above,med.compt. Fe oxidation stains and organic frags	CL				
7.5	3	2	1	3	8.0–9.5	9.5	Or-brn.f.sandy clay & clayey sand, soft-med., moist					
10.0	4	2	1	2	10.5–12.0		Gray f.sand & silt;moist,non plastic,some interbedded gray silty clay					
12.5	5	2	2	3	13.5–15.0		Gray clayey f.sand & silty clay, some dk.red clay mottling,moist					
17.5	6	2	3	6	18.5–20.0		Same as above					
22.5	7	2	3	4	23.5–25.0		——— ? ——— ——— ? ——— Same as above w/some organics & few RF (sand & 1/4" dia.)					

GAI - 237 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-40

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Rexron

DRILLER: John

CLASSIFIED BY: D.R.S.

COORDINATES

DATE: 5-2-72

SHEET 2 OF 4
DRILL HOLE NO. 1-11
ELEVATION
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0						27.0	——— ? ——— ——— ? ——— UPPER TILL					
27.5	8	2	3	5	28.5–30.0		Gray silty clay,soft-med.,moist w/some sand size RF shale some of angular-subrounded gravel & broken shale	CL				
32.5	9	2	5	8	33.5–35.0		Gray silty clay w/ 10% shale RF 1½" dia.subrounded shale pebble, moist	CL				
37.5	10	12	16	25	38.5–40.0	38.0	——— ? ——— ——— ? ——— LOWER TILL Gray gravely clay;15-20% angular-subrounded shale RF,size range coarse sand to ½",hard,dry	CL				
42.5	11	15	22	24	43.5–45.0		Same as above	CL				Water seeped in hole over night,making this sample moist
47.5	12	17	33	79	48.5–50.0		Gray silty clay;20-25% RF,mostly shale,angular-subangular,slightly damp;avg.size 1/8-1/4"					
50.0							Boulder					

GAI - 237 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant	W.O. 4549-00	SITE AREA N. Perry, Ohio	SHEET 3 OF 4
CONTRACTOR: Herron	COORDINATES		DRILL HOLE NO. 1-11
DRILLER: John			ELEVATION
			GWL 0 HRS 3.0'
CLASSIFIED BY: D.B.S.	DATE: 5-3-72		24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Core Run	Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0												
52.5												
	13	[illegible]			53.5 / 54.0		Saturated silty clay - no cohesion; Boulder?			55.0		
55.0							Boulders in till	15	0	2.0	.3	
					57.0	57.0				57.0		57.0
57.5	14	33			57.5		Gray shale & clay, weathered; hard, damp					
					59.5							WEATHERED ZONE
60.0	15	50	55		60.5		Gray weathered shale; till (clay&RF) pebbles of LS & Sandstone					
62.5												
	16	81	[illegible]		63.5 / 64.0		Gray shale RF w/sandy gray clay					
65.0												
67.5												
	17	128			68.5 / 69.0		Gray shale; fissle, poorly indurated, some weathering to gray clay			69.5		
70.0							Gray shale & lt. gray silt & sand seams, bedding fractures numerous about 1/8-1/4" apart. Broken & slightly weathered	18	0	5.0	.9	
72.5												
						74.5				74.5		74.0
75.0												

GAI - 327 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant	W.O. 4549-00	SITE AREA N. Perry, Ohio	SHEET 4 OF 4
CONTRACTOR: Herron	COORDINATES		DRILL HOLE NO. 1-11
DRILLER: John			ELEVATION
			GWL 0 HRS
CLASSIFIED BY: D.B.S.	DATE: 5-5-72		24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Core Run	Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75.0							Same as above; not weathered or broken					
77.5								94	.28	5.0	4.7	
										79.5		
80.0							Same as above; bedding fractures seem to be tensional, due to release of confining pressure					
82.5								100	.34	5.0	5.0	
										84.5		
85.0							Same as above					
87.5								100	.08	5.0	5.0	
										89.5		
90.0							Same as above					
92.5								98	.26	5.0	4.9	
										94.5		
95.0							Same as above					
97.5								100		5.0	5.0	
										99.5		9 May 72
100												

GAI - 327 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-43

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES N 780,460.3 E 2,369,403.2

DRILLER: Larry

CLASSIFIED BY: D.B.S. DATE: 5-2-72

SHEET 1 OF 4
DRILL HOLE NO. 1-12
ELEVATION 619.8
GWL 0 HRS 3.0
24 HRS 3.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Core Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0.0							LACUSTRINE SEDIMENTS					
2.5	1	2	2	3	3.5 / 4.0		Or-brn clayey sands,moist,soft, f.grained; Or-brn & gray mottling silty clay,stiff,moist	SC/CL				
5.0						5.0	——— ? ——— ——— ? ———					
	2	3	5	9	5.5 / 7.0		Gray silty clay w/or-brn mottling v.stiff,moist	CL				
7.5	3	4	3	4	8.5 / 10.0		Interbedded;gray silty clay,med. consistency,moist,low plasticity, gray clayey sand;wet,non-plastic	CL/SC				
10.0	4	3	4	4	10.5 / 12.0		Gray silty clay,med.consistency, low-med.plasticity;layered black organics in zones;f.sandy clay zones	CL				
12.5	5	4	7	8	13.5 / 15.0		Gray silty clay;stiff,moist,layered w/black organics & frags of brown woody material	CL				
15.0												
17.5	6	8	11	13	18.5 / 20.0		Interbedded gray silty and sandy clays and f.grained clayey sands, stiff and moist;some thin seams of red clay	CL/SC				
20.0												
22.5	7	5	7	10	23.5 / 25.0		Gray silty clay w/red mottling; med.stiff,moist,less than 3% coarse sand size gray shale frags	CL				Glacial till suspected because of RF
25.0												

GAI-237 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-44

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES

DRILLER: Larry

CLASSIFIED BY: D.B.S. DATE: 5-2-72

SHEET 2 OF 4
DRILL HOLE NO. 1-12
ELEVATION
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Core Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0						26.0	——— ——— ——— ———					
							UPPER TILL					Probable Lacustrine-Till Interface
27.5	8	5	7	10	28.5 / 30.0		Same as above;w/some subrounded gravel 1/4" dia.,total RF 5%	CL				
30.0												
32.5						33.0	——— ? ——— ——— ? ———					
	9	8	19	24	33.5 / 35.0		LOWER TILL Gray silty clay;slightly moist, hard; 10% RF of gray shale, angular-subround mostly coarse sand to coarse gravel 1/4" dia.	CL				LOWER TILL
35.0							Some boulders between 35 & 40'					
37.5	10	26	32	100/4	38.5 / 39.9		Same as above;dry,w/some weathered shale rock	CL				
40.0												
42.5	11	21	31	35	43.5 / 45.0		Same as above, 15-20% RF					
45.0												
47.5						48.5	——— ——— ——— ———					
	12	35	34	42	48.5 / 50.0		Gray shale & clay,decomposed & broken shale,pieces ¼-½",65-75% RF	RF				
50.0												

GAI-237 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-45

PROJECT: CEI - Perry Nuclear Power Plant	W.O. 4549-00
SITE AREA: N. Perry, Ohio	SHEET 3 OF 4
CONTRACTOR: Barron	DRILL HOLE NO. 1-12
COORDINATES:	ELEVATION:
DRILLER: Larry	GWL 0 HRS.
CLASSIFIED BY: D.B.S.	24 HRS.
DATE: 5-2-72	

Depth Ft.	Sample No.	SPT Blows/6 in. (6)	SPT Blows/6 in. (12)	SPT Blows/6 in. (18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Coarse Granular Soils: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0												40.5
52.5												Weathered Shale Zone
	13	65	50/2		53.5 / 54.2		Broken gray shale & some gravely clay, hard, dry	0C				
55.0										55.5		56.0
							Slightly weathered gray shale broken irregularly in ½-2" frags in first 6" of run					
57.5							Gray shale w/lt. gray silty seams numerous hairline bedding fractures normal to run	84	.74	5.0	4.2	
60.0										60.5		
							Same shale, bedding nearly horizontal; fracturing parallel; normal & 60° to bedding; broken in zones					F. sand & till frags in excess in washings at approx. 70' Unexplained loss of Rec.
62.5												
65.0								73	.20	10.0	7.3	
67.5												
70.0										70.5		70.5
							Gray shale w/lt. gray silt seams. Pieces mostly ½-1½"; appears weathered in zones					Started coring w/Bx core barrel
72.5												
								80	.14	5.0	4.0	
75.0												

GAI - 327 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-46

PROJECT: CEI - Perry Nuclear Power Plant	W.O. 4549-00
SITE AREA: North Perry, Ohio	SHEET 4 OF 4
CONTRACTOR: Barron	DRILL HOLE NO. 1-12
COORDINATES:	ELEVATION:
DRILLER: Larry	GWL 0 HRS.
CLASSIFIED BY: D.B.S.	24 HRS.
DATE: 5-4-72	

Depth Ft.	Sample No.	SPT Blows/6 in. (6)	SPT Blows/6 in. (12)	SPT Blows/6 in. (18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Coarse Granular Soils: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75.0										75.5		
							Same as above; fissle & easily broken in zones; bedding nearly horizontal					When Bx core barrel was used here and on hole 1-2, the RQD was much lower than on any other shale at similar depths
77.5								90	0	5.0	4.5	
80.0										80.5		
							TOTAL DEPTH 80.5					
82.5												
85.0												
87.5												
90.0												
92.5												
95.0												
97.5												
100												

GAI - 327 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-47

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES N 780,010 E 2,369,515

DRILLER: Larry

CLASSIFIED BY: D.B.S. DATE: 5-10-72

SHEET 1 OF 4 DRILL HOLE NO. 1-13 ELEVATION 620.8 GWL 0 HRS 4.5 48 HRS 3'-9"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
0.0							LACUSTRINE SEDIMENTS					* indicates sample sealed in paraffin
2.5	1	5	7	8	2.5–4.0		Interbedded or-brn V.F.clayey sand,v.f.sand,sandy clay;gray clay seams,firm,moist	%	*			Gray clay & mottling appears around fractures & is probably asst. w/leaching Water seepage at 5.1'
5.0	2	1	2	2	5.5–7.0	6.5	Same as above w/limonite concretions,soft,wet	%				
							Gray v.f.sand;loose,wet					
7.5	3	3	4	4	8.5–10.0		Interbedded v.f.gray sand & silty clay layers 1/8-1/4";sand;loose-firm clay;mod.-stiff,wet	%	*			
10.0	4	3	4	5	10.5–12.0		Same as above	%				
12.5	5	8	7	8	13.5–15.0		Same as above but less clay, wet - saturated	SM				
15.0 / 17.5	6	6	8	9	18.5–20.0		Gray silty clay w/thin seams of red clay;some organic silts and clayey v.f.sand,low plas., med-stiff,moist	CL				Suspected start of till, but no RF
20.0 / 22.5	7	6	8	11	23.5–25.0		Same as above, but less than 5% subrounded-angular shale RF	CL	*			

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-48

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES

DRILLER: Larry

CLASSIFIED BY: D.B.S. DATE: 5-10-72

SHEET 2 OF 4 DRILL HOLE NO. 1-13 ELEVATION 620.8 GWL 0 HRS 24 HRS 3.8'

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	% Rec.	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
25.0						26.0	UPPER TILL					
27.5	8	13	16	19	28.5–30.0		Gray silty clay w/less than 5% angular-subrounded shale RF. Mostly coarse sand-fine gravel, max.½";v.stiff,moist	CL	*			
30.0 / 32.5	9	15	18	20	33.5–35.0	33.5	LOWER TILL Gray silty clay w/10-15% RF;some v.f. sand w/less than 5% RF hard,damp	CL				
35.0 / 37.5	10	18	26	37	38.5–40.0		Same as above,RF gray silty clay w/20-15% shale RF;angular-sub rounded,max. ½";damp to dry, v.hard	CL	*			
42.5					43.5	43.0	Boulder Zone					
45.0	11	75	21	27	43.5–45.0	43.8	Same as before	CL				
47.5	12	[illegible]			48.5	48.5	Boulder - Granite 5"-6"			48.5		Set up for coring thru boulders @ 48.5'
50.0							Gray clayey gravel (broken shale RF 1/8"-1")	GC				

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 3 OF 4
DRILL HOLE NO. 1-13 & 1-13A
ELEVATION
CONTRACTOR: Herron COORDINATES
GWL 0 HRS
DRILLER: Larry
24 HRS
CLASSIFIED BY: D.B.S. DATE: 5-11-72

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Core Run	Core Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50						30	0	5.0	1.5	
52.5					Gray shale; slightly weathered numerous bedding fractures, silt stone seams bedding near horizontal, piece 3" long			53.5		Tryed "Boulder Buster" at 48.5' but failed
55.0		23 / 104/.4	55.0 / 55.8		Gray shale, weathered, slightly friable near horizontal bedding. Soft material, clayey shale gravel			56.0		Hole 1-13A - Moved hole about 6' west to avoid Boulder - another boulder re-encountered at 49.0'. Augered past boulder to 55' & took S.S. sample.
					Granite Gneiss Frag 2"; fell from upper zone?					
57.5					Gray shale & thin seams of lt. gray sandstone, nearly parallel bedding, tensional bedding joints 1/8-1/2" apart; broken & slightly weathered zones; some fractures 60-75° to bedding	58	0	5.0	2.9	Weathered zone 53-61
60.0										
				61.0				61.0		
62.5					Gray shale w/lt. gray seams of sandstone 1/16-1/4" thick generally unbroken; numerous bedding fractures as above - tensional					
65.0						91	.60	10.0	9.1	
67.5										
70.0								71.0		
72.5					Same as above, sandstone seams 1/16-1½" thick	100	.76	10.0	10.2	
75.0										

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 4 OF 4
DRILL HOLE NO. 1-13A
ELEVATION
CONTRACTOR: Herron COORDINATES
GWL 0 HRS
DRILLER: Larry
24 HRS
CLASSIFIED BY: D.B.S. DATE: 5-14-72

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Core Run	Core Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75.0										
77.5					Same					
80.0								81.0		
					TOTAL DEPTH 81.0'					
82.5										
85.0										

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-51

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 1 OF 3
DRILL HOLE NO. 1-14
CONTRACTOR: Herron COORDINATES N 780,259.9 E 2,370,682.9
ELEVATION 624.8
DRILLER: John
GWL 0 HRS 5.5
CLASSIFIED BY: D.B.S. DATE: 5-17-72
24 HRS 2.5

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	Soil Description: Density (or Consistency), Color, Soil Type - Accessories	U.S.C.S.	*	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE SEDIMENTS					* indicates sample sealed in parafin
2.5	1	4	6	8	2.5 / 4.0		Or-brn sandy clay, firm, moist, gray mottling (leaching) interbedded or-brn. med. sand loose-firm, non plastic	CL/SM				
5.0	2	3	5	7	5.5 / 7.0		Same as above, more sand, wet sandy clay; slight plasticity	SM/SC	*			Water seepage 5.5'
7.5	3	4	4	5	8.0 / 9.5	8.8	Same as above, saturated; ¼" laminations sand & silty clay	SM/CL				
10.0					10.5		Gray silty clay, firm, wet, 2" lenses of fine grained sand	CL				
	4	3	4	6	12.0		Gray fine grained sand, loose-firm, saturated. ¼" laminations w/ silty clay	SM/CL	*			
12.5	5	1	3	4	13.5 / 15.0		Gray silty clay, firm, saturated, unstratified	CL	*			
15.0 / 17.5	SHELBY #1				16.0 / 18.0							24" REC
	6	2	2	6	19.5		Gray laminated (¼") silty clay and non plastic f.sand. Firm, wet 1" angular LS RF, some red clay	CL/SM				
20.0												
22.5	7	3	6	12	23.5 / 25.0		Same as above, more sand, saturated	SM/SC				
25.0												

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-52

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 2 OF 3
DRILL HOLE NO. 1-14
CONTRACTOR: Herron COORDINATES
ELEVATION
DRILLER: John
GWL 0 HRS
CLASSIFIED BY: D.B.S. DATE: 5-17-72
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	Soil Description: Density (or Consistency), Color, Soil Type - Accessories	U.S.C.S.	*	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0												
27.5						27.5	——— ? ——— ——— ? ——— UPPER TILL					
	8	3	5	6	28.5 / 30.0		Gray silty clay, soft-firm, wet. 5-10% subangular shale RF, mostly coarse sand size, max. 1"	CL	*			
30.0 / 32.5												
	SHELBY #2				33.0 / 35.0		Same as above					23" REC
35.0	9	3	3	5	36.5		Same as above; soft	CL				
37.5						38.5	——— ? ——— ——— ? ——— LOWER TILL					
40.0	10	9	13	20	40.0 / 41.5		Gray silty clay, hard, slightly moist 15-20% RF, mostly shale, coarse sand to ¼", subang-subround.	CL	*			
42.5	SHELBY #3				42.0 / 44.0		Same as above; RF to 1"					19" of 21" REC
45.0	11	10	20	35	45.5		Same as above; dry - slightly damp					
47.5					48.5							
50.0	12	19	25	46	50.0		Same as above; 25-30% RF					

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-53

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 3 OF 3
DRILL HOLE NO. 1-14
CONTRACTOR: Herron COORDINATES
ELEVATION
DRILLER: John
GWL 0 HRS.
CLASSIFIED BY: D.B.S. DATE: 5-18-72
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0												
52.5						53.0	CHAGRIN SHALE					
	13	20	36	48	53.5		Gray shale frags, mostly ¼"-1", interspersed clay & weathered shale; hard, damp-dry					Glacial origin suspected but uncertain
55.0					55.0							Weathered shale zone 53-63
57.5												
	14	89			58.5 / 59.0		Gray clay (weathered shale frags) hard, moist-damp					
60.0												
	15	[illegible]			[illegible]		Gray shale, weathered, fissle. Some clay. Dry			61.0		
62.5						63.0						
65.0												
67.5							Gray shale w/lt. gray sandstone seams. Generally unbroken. Horizontal bedding. Bedding fractures 1/8-1/4" apart, fractures normal, 60° & 30° to bedding	85	.6	10.0	8.5	
70.0												
72.5										72.0		
75.0												

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-54

PROJECT: CEI Perry Nuclear Plant 4549-00 SITE AREA N. Perry, Ohio
SHEET 1 OF 3
DRILL HOLE NO. 1-15
CONTRACTOR: Herron COORDINATES N 780,653.1
ELEVATION 621.9
DRILLER: John E 2,370,594.5
GWL 0 HRS. 5.0
CLASSIFIED BY: D.B.S. DATE: 5-20-72
24 HRS 3.3

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	*	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							Lacustrine Sediments					* Indicates samples sealed in parafin
2.5	1	4	5	7	2.5 / 4.0		Or.-brn. & gray silty clay, fine sandy clay, soft-firm, moist	CL	*			
5.0					5.0							Water seepage @ 5'
	SHELBY #1				7.0		ST3-1 discarded - 6" rec					
7.5	2	2	2	4		8.2	Or-brn. f. sand, non plastic, loose, saturated w/some sandy clay	SM/CL				
					8.5 / 9.5		Gray silty clay & non plastic varves, f. sand, soft-firm, moist	SM/CL				Broundary appears sharp probably a weathering or oxidation horizon
10.0	3	1	2	5	11.0		Same as above, sand loose & saturated	SM/CL	*			
12.5					13.5							
15.0	4	1	1	3	15.0		Same as above, more clay, wet, soft	CL/SM				
	SHELBY #2				17.0		ST3-2 - 24" rec.					
17.5	5	1	2	2	18.5		Same as above	CL/SM				
20.0												
22.5					23.5							
25.0	6	1	1	2	25.0		Same as above w/V.F. sand & silt loose, saturated, some red clay strings	SM/CL	*			

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Pwr.Plt W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron
DRILLER: John
CLASSIFIED BY: D.B.S.
COORDINATES
DATE: 5-20-72

SHEET 2 OF 3
DRILL HOLE NO. 1-15
ELEVATION 621.9
GWL 0 HRS 5.0
24 HRS 3.3

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.	‰	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0												
						27.0	— ? — — ? —					
27.5							UPPER TILL					Glacial Till ? is red clay an indicator of upper till?
					28.5							
30.0	7	2	4	4	30.0		Gray silty clay;5% angular-sub angular coarse sand size shale RF max ½"	CL	#			
					31.0							
32.5	SHELBY #3				33.0		Same as above,subrounded,max 1½", firm-stiff	CL				
	8	2	5	8	34.5		Same as above;5-10% RF,moist, firm-stiff	CL				
35.0												
37.5						38.0	— ? — — ? —					
					38.5		LOWER TILL					
40.0	9	20	26	31	40.0		Gray sandy clay,hard,damp-moist 20-25% RF mostly coarse sand	CL	#			
42.5					43.0							
45.0	10	13	21	33	44.5		Same as above;V.Hard damp more fine gravel size RF to ½"	CL				
47.5					48.0							
50.0	11	11	19	37	49.5		Same as above,slightly more moist	CL	#			

GAI - 227 12/65

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron
DRILLER: John
CLASSIFIED BY: D.B.S.
COORDINATES
DATE: 5-20-72

SHEET 3 OF 3
DRILL HOLE NO. 1-15
ELEVATION 621.9
GWL 0 HRS 5.0
24 HRS 3.3

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0					51.0							
52.5	12	15	32	55	52.5		Gray silty clay;20-25% shale RF angular-subrounded mostly coarse sand - fine gravel max. 1"	CL				
										53.6		
						54.0	Clayey gravel, mostly shale RF					
55.0							— ? — — ? — CHAGRIN SHALE					Weathered shale 54-58.5
57.5						58.0	— ? — — ? —					
							Gray shale w/lt. gray sandstone seams	59	.26	10.0	5.9	5' good shale
60.0												
62.5										63.5		
65.0												
67.5												
70.0												
72.5												
75.0												

GAI - 227 12/65

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

CEI - Perry Nuclear
PROJECT: Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron
DRILLER: John
CLASSIFIED BY: D.B.S.
COORDINATES N 781,060 E 2,369,515
DATE: 5-23-72
SHEET 1 OF 3
DRILL HOLE NO. 1-16
ELEVATION 618.7
GWL 0 HRS.
24 HRS. 5.0

Sample No.	SPT Blows/6 in. (6)	(12)	(18)	Soil Description: Density (or Consistency), Color, Soil Type - Accessories	U.S.C.S.	Remarks: Chemical Comp., Geologic Dsn., Ground Water, Construction Problems, etc.
				LACUSTRINE SEDIMENTS		
1	4	4	6	Gr-brn. silty clay w/interbedded clayey sand & non plastic f. sand, firm, moist, gray mottling		Water (see page 5.5')
2	2	1	3	Same as above, more f. sand, laminated, wet, soft		
ATTEMPTED SHELBY ▲				Gray, same as above, more silty clay & clayey sand		▲ Made two attempts; first try - 14" second try - 19" Probably disturbed; discarded
3	3	2	2	Same as above, nearly saturated		
4	3	4	6	Same, firm and moist		
SHELBY #1						
5	2	4	5	Same, firm-stiff, moist, trace of red clay		
6	1	2		Gray silty clay, sandy clay. Laminated soft-firm, moist, trace of red clay		

GAI-227 12/65

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

CEI - Perry Nuclear
PROJECT: Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron
DRILLER: John
CLASSIFIED BY: D.B.S.
COORDINATES
DATE: 5-23-72
SHEET 2 OF 3
DRILL HOLE NO. 1-16
ELEVATION
GWL 0 HRS.
24 HRS.

Sample No.	SPT Blows/6 in. (6)	(12)	(18)	Soil Description: Density (or Consistency), Color, Soil Type - Accessories	U.S.C.S.	Remarks: Chemical Comp., Geologic Dsn., Ground Water, Construction Problems, etc.
SHELBY #2				Same		23" Rec. Upper till w/1 Shelby
				UPPER TILL		
7	3	4	6	Gray silty clay, 5% shale RF, size mostly coarse sand, max. 1/4", soft-firm, moist angular - subrounded	CL	
8	5	12	14	Same as above, max. 3/4", firm-hard, 5-10% RF	CL	
				LOWER TILL		
				Same as above, hard, damp-dry 10-15% RF		
SHELBY ▲						9" pushed hit boulder ▲ Discarded 3"/9" of sample disturbed by boulder
9	10	21	24	Same as above; v. hard, 15% RF, mostly f. gravel size	CL	
10	14	24	25	Same as above, hard, moist 20-25% RF, mostly 1/8-1/4"	CL	
11	15	20	28	Same as above, 25-30% RF, max 1/2"	CL	
12	16	24	26	Same as above	CL	

GAI-227 12/65

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 6549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES ______

DRILLER: John

CLASSIFIED BY: D.B.S. DATE: 5-25-72

SHEET 3 OF 3

DRILL HOLE NO. 1-16

ELEVATION ______

GWL 0 HRS ______

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% REC.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0					Gravely clay & clayey gravel?	CL-GC				Drilled hard then soft in short intervals Weathered shale 50-53.5
52.5		[illegible]	52.0							
				53.5	**CHAGRIN SHALE** Gray shale, lt. gray f. sandstone seams, numerous horizontal & parallel bedding fractures 1/8-1/2" apart. Appears unweathered and unbroken	92	.64	53.0 10.0	9.2	
55.0										
57.5										
60.0										
62.5				63.0	TOTAL DEPTH 63'			63.0		
65.0										
67.5										
70.0										
72.5										
75.0										

GAI-327 12/68

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 6549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES N 781,345 E 2,370,374.5

DRILLER: Larry

CLASSIFIED BY: D.B.S. DATE: 5-17-72

SHEET 1 OF 3

DRILL HOLE NO. 1-17

ELEVATION 625.3

GWL 0 HRS 4.0

24 HRS 3.0

Depth Ft.	Sample No.	SPT 6	SPT 12	SPT 18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.		Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							**LACUSTRINE SEDIMENTS**					
2.5	1	3	1	1	2.5 / 4.0		Or-brn. med. grain sand, wet, loose, non-plastic, well sorted, some well rounded f. gravel 1/2"	SM				
5.0	SHELBY #1				5.0 / 7.0	6.2	——— ? ——— ——— ? ———					23" rec.
7.5	2	3	6	9	8.5		Gray silty clay; firm, wet, lens (or pipe?) of or-brn. med. sand	CL				
	3	3	3	6	10.0		Laminated gray silty clay & f. sand (non plastic); soft to firm, saturated	CL/SM				
10.0	4	2	4	6	10.5 / 12.0		Same as above	SP/SM				
12.5					13.5							
	5	2	2	4	15.0		Same as above	SP/SM				
15.0	SHELBY #2				17.0							23" rec.
17.5	6	2	3	4	18.5 / 20.0		Gray silty clay, soft-firm, wet, unstratified	CL				
20.0												
22.5					23.5							
25.0	7	2	2	3	25.0		Laminated (1/8") gray silty clay & f. well sorted sand, moist-wet, firm	CL/SM				

GAI-327 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-61

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 2 OF 3
DRILL HOLE NO. 1-17
CONTRACTOR: Herron COORDINATES
ELEVATION
DRILLER: Larry
GWL 0 HRS
CLASSIFIED BY: D.B.S. DATE: 5-17-72
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	qu	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
28.5–30.0	8	6	9	12			Same, but less laminated & more fine sand	SC/CL				
33.5–35.5	SHELBY #3						Reddish gray silty clay, varved, moist, firm 1-3% coarse sand size RF	CL				
35.5–37.0	9	4	4	6			Same as above, soft, v. moist lens of fine sand, thin stringers of red clay	CL/SC				
37.5						37.5	— ? — UPPER TILL					
38.5–40.0	10	5	7	10			Gray silty clay; firm-stiff, moist, 5-10% shale RF, mostly coarse sand, max. 1/4"	CL				
43.5–45.0	11	9	17	22		44.0	Same as above w/interbedded silty clay and f. sand	CL				
45.0							LOWER TILL					
							Gray silty clay 5-15% RF, coarse sand to max 1/4"; hard, moist					
48.5–50.0	12	23	38				Gray silty clay w/10-15% RF as above, hard & dry @ 50'	CL				

GAI-237 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-62

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 3 OF 3
DRILL HOLE NO. 1-17
CONTRACTOR: Herron COORDINATES
ELEVATION
DRILLER: Larry
GWL 0 HRS
CLASSIFIED BY: D.B.S. DATE: 5-18-72
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0–50.5				51	50.5							Auger refusal 51'
51.0–61.0							Gray gravely clay; 35-45% assorted rock frags, mostly shale; coarse sand to 1/2", max. 1"	58	[illegible]	10.0	5.8	
61.0–65.0							Gray gravely clay; 45-55% RF, mostly f. gravel sizes, max. 1½" gray shale boulder 3" thick (bedding about 10^0-15^0 to core axis	55	.2	4.0	2.2	
65.5						65.5	CHAGRIN SHALE:					
65.0–71.0							Gray shale w/thin sandstone and siltstone lenses. Horizontal bedding, numerous bedding fractures	90	.71	6.0	5.4	Weathered zone v. thin or absent
71.0						71.0	TOTAL DEPTH 70'					

GAI-237 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-63

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Raymond Int.
DRILLER: Don Sugers
CLASSIFIED BY: D.B.S.
COORDINATES N 781,108.1 E 2,369,887.7
DATE: 5-25-72
SHEET 1 OF 3
DRILL HOLE NO. 1-18
ELEVATION 602.1
GWL 0 HRS.
24 HRS 1.5'

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE SEDIMENTS		CHE 55
2.5	1	2	2	2	2.5–4.0		Brown & gray silty clay, trace of organics, soft, moist, unstratified	CL	
5.0	SHELBY #1				5.0–7.0	5.5	Gray interbedded f.clayey sand & silty clay, soft-firm, moist, stratified	SC/CL	20" rec.
7.5	2	3	4	6	7.0–8.5		Gray silty clay, firm, moist, trace of red clay & coarse sand size RF (1%) stratified clay	CL	
10.0					10.0	10.0	——?—— ——?——		Upper Till
	3	4	8	11	11.0–12.5		UPPER TILL Gray silty clay, firm-stiff, moist trace of red clay, 5% RF, mostly coarse sand; max. 1", ang-subround	CL	
15.0	SHELBY #2				15.0–17.0			CL	
17.5	4	6	9	12	17.0–18.5		Same as above, 10-15% RF, stiff		
20.0	5	11	20	32	20.0–21.5	20.5	LOWER TILL Same as above, more f.gravel sizes 15-20% RF, HARD, damp-dry	CL	Lower Till
22.5						23.0–24.0	Boulder Zone		
25.0									

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-64

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Raymond Int.
DRILLER: Don
CLASSIFIED BY: D.B.S.
COORDINATES
DATE: 5-25-72
SHEET 2 OF 3
DRILL HOLE NO. 1-18
ELEVATION
GWL 0 HRS.
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	% Rec.	RQD	Core Run	Core Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0													
27.5	6	21	38	48	27.5–29.0		Same as above, 25% RF, damp	CL					
30.0	DENISON #1				30.0								24" Rec.
32.5	7	23	34	60	32.5–34.0		Same as above, 30-35% RF	CL					
35.0	DENISON #2				35.0								6" Rec.
37.5	8	38	43	90	37.5–39.0		Same 35-40% RF	CL					
40.0	DENISON #3				40.0		Same as above				42.0		24" Rec. Excess moisture due to careless preparation of recovered Sample 4 or malfunction of Denison sampler
42.5					42.8–43.0	43.0	Gray gravely clay-clayey gravel, broken shale 50% RF						
45.0							CHAGRIN SHALE Gray shale w/thin sandstone seams slightly broken & weathered, horizontal bedding fractures w/ some fracturing 30° & 90° to horizontal bedding		95	.39	5.5	5.2	Inaccurate depths. Driller in error probably in unconsolid material. Depth error less than 1 ft.
47.5						47.5	Same as above, fresh				47.5		
50.0									98	.35	4.0	3.9	

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-65

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. 1-18

CONTRACTOR: Herron

COORDINATES

ELEVATION

DRILLER: Don

GWL 0 HRS

CLASSIFIED BY: D.B.S.

DATE: 5-26-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	qu	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0												
							Total Depth 51.5			51.5		
52.5												
55.0												
57.5												
60.0												

GAI - 327 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-66

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio

SHEET 1 OF 3

DRILL HOLE NO. 1-19

CONTRACTOR: Herron

COORDINATES N 780,714.4 E 2,369,953.1

ELEVATION 622.3

DRILLER: Ed

GWL 0 HRS 4.0

CLASSIFIED BY: D.B.S.

DATE: 5-19-72

24 HRS 3.5

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	qu	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE SEDIMENTS					
2.5	1	2	2	5	2.5 – 4.0		Or.-brn.&gray silty clay,sandy clay,med.grained clayey sand, moist,soft	CL/SC				
5.0	SHELBY #1				5.0 – 7.0		Or-brn.f.-med.grained sand, saturated;loose	SM				14" rec. in Shelby loose,saturated sand lost
7.5	2	1	2	3	7.0 – 8.5		Gray silty clay;soft-firm,wet	CL				
10.0												
12.5	3	3	3	5	11.0 – 12.5		Gray silty clay,f.sandy clay, non-plastic,f.sand,firm,wet	CL/SM				
15.0	SHELBY #2				15.0 – 17.0		Gray silty clay,some assorted RF (Till?)	CL				Till or washed RF from above or RF in lacustrine sediments? (24" rec.)
17.5	4	2	2	3	17.0 – 18.5		Gray clayey sand Laminated gray f.clayey sand & silty clay,saturated,soft some red clay	SC SC/CL				
20.0	5	3	5	5	20.0 – 21.5	21.0	Same as above,mostly f.sand Laminated red&gray silty clay, firm,moist,1% coarse sand - f. gravel RF	SC/CL CL				
22.5												20'-8" casing (5") installed
25.0												

GAI - 327 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-67

PROJECT: Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: Ed
CLASSIFIED BY: D.B.S. DATE: 5-20-72

SHEET 2 OF 3
DRILL HOLE NO. 1-19
ELEVATION
GWL 0 HRS.
24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	%	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0	6	8	10	16	26.5		Gray clayey v.f.sand non to slightly plastic, unstratified, poorly graded, dense, wet	SC				
27.5						27.5	——— ? ——— ——— ? ——— UPPER TILL					
30.0					30.0		13" rec/20" pushed					
	SHELBY #3				31.6		Gray silty clay 5-10% shale RF, moist, firm-stiff					Shelby pushed hard at 31'
32.5	8	7	20	11	33.1		Same as above, lost most of sample					
35.0					35.0							
	SHELBY #4				36.0	36.5	LOWER TILL					18" Rec. Shelby quit at cobble
37.5	9	14	18	29	38.3		Gray silty clay w/clayey fine sand lenses; damp, hard, 5% RF mostly coarse sand to 1/8" max. 1/4"					
40.0	SHELBY #5				40.0 / 41.0							
	10	18	33	43	42.5		Gray silty clay; hard, dry 5-10% coarse sand size RF, max. ½"					12" rec.
42.5												
45.0	SHELBY #6				45.0 / 45.8							7" Rec.
47.5	PITCHER #1				48.0							0" Rec.
	PITCHER #2				49.0		Same as above					9" rec
50.0	11	13	22	28			Same 15% RF, more f.gravel					

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-68

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: Ed
CLASSIFIED BY: D.B.S. DATE: 5-22-72

SHEET 3 OF 3
DRILL HOLE NO. 1-19
ELEVATION
GWL 0 HRS. 6.0
24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0					50.5	51.0 / 51.7	Some coarse gravel-boulder matl. noted when rolling to 51', boulder 51-51.7					
					52.0							
52.5	PITCHER #3				53.0							
	12	31	59	15	54.5		Gray gravelly clay & clayey gravel - hard, dry, 40-60% shale RF to 2"					
55.0					55.0							
	19	125	45	62	56.5		Same as above					Rods broke w/increase torque - lost sampler Lost: 1 pitcher sample 1 Nx-AW adapter 15' AW rods Moved hole 5' north, re-augered 55' took spoon sample
57.5						57.0	——— ? ——— ——— ? ——— CHAGRIN SHALE Weathered shale zone (57-65)					
60.0										60.0		Auger refusal
62.5							Gray shale w/thin lt.gray sandstone seams, horizontal bedding, numerous bedding fractures & some normal to bedding. Slightly broken & weathered in first five feet					
65.0						65.0	——— ——— ——— ———	94	26	10.0	9.4	Lost in hole: 1 pitcher sampler 1 Nx-AW adapter 15' AW rod
67.5												
70.0										70.0		T.D. 70'
72.5												
75.0												

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES N 780,326.2 E 2,370,041.4
DRILLER: Ed
CLASSIFIED BY: D.B.S. DATE: 10 May 1972

SHEET 1 OF 3
DRILL HOLE NO. 1-20
ELEVATION 623.6
GWL 0 HRS. 3.0
24 HRS 1.8

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.		Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												
2.5	1	3	3	5	2.5 – 4.0		Or-brn. sandy clay; mottled gray, low plasticity;med.-stiff, moist	SC				
5.0	2	2	3	5	5.5 – 7.0		Same as above;lenses of soft gray plastic clay. Stringers of black organics	SC				
7.5	SHELBY #1				9.0	9.0	Same as above	SC/SM				
							Or-brn. v.f. sand & silt, poorly graded					Rec 9"
10.0	SHELBY #2				11.0		Gray v.f. sand;non-plastic,v.moist	SM				Rec. 24"
							Gray v.f. sand w/lenses of gray silty clay, moist	SM/CL				
12.5	3	2	3	5	12.5		Same as above - saturated, soft mostly v.f. sand	SM/CL				
15.0	4	2	6	7	[illegible] – 17.0		Gray v.f. sand and silty clay interbedded med. plastic,med-stiff, moist,"varved" clay & sand ½-¼"	SM/CL				
17.5	SHELBY #3				18.0 – 20.0		Same as above	SM/CL				Rec. 17"
20.0												
22.5	5	6	12	11	23.5 – 25.0		Gray v.f. sand, slightly plastic, v.moist to saturated	SC				
25.0												

GAI-327 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: Ed
CLASSIFIED BY: D.B.S. DATE: 20 May 1972

SHEET 2 OF 3
DRILL HOLE NO. 1-20
ELEVATION
GWL 0 HRS. 3.0
24 HRS 1.8

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0												
27.5	SHELBY #4				28.0 – 30.0	29.0	UPPER TILL					16" Rec.
							Gray clay w/ 1% med-coarse sand size shale R.F.;v. moist					
30.0	6	2	3	4	31.5		Gray clay w/less than 5% coarse sand and gravel shale R.F.;v. soft & wet					
32.5	7	2	6	6	33.5 – 35.0		Gray silty clay w/5% coarse sand & gravel RF (size to 1" - sub rounded to angular) soft-med.; moist					
35.0												
37.5	SHELBY #5				38.0 – 39.2	39.0	LOWER TILL					Rec. 11"
40.0	8	17	33	39	40.7		Gray silty clay w/20-25% angular-subangular shale RF;coarse sand to gravel size - max ¼";hard, slightly damp to dry;slightly friable					
	PITCHER #1				41.0 – 41.9		Same as above; damp-moist					Pitcher sample 41-41.92 8" Rec.
42.5										42.0		
45.0							Gray gravely clay;less than 50% gravel;v.hard,dry					
47.5							Zones of coarse sand and clay max. size 1" mostly coarse sand to ¼",angular-subangular	78	91	100	7.8	
50.0												

GAI-327 12/68

GILBERT ASSOCIATES, INC.

SOIL CLASSIFICATION SHEET

2E-71

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES:

DRILLER: Ed

CLASSIFIED BY: D.B.S. DATE: 20 May 1972

SHEET 3 OF 3

DRILL HOLE NO. 1-20

ELEVATION

GWL 0 HRS 3.0

24 HRS 1.8

Sample No.	SPT Blows/6 in. 6	12	18	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	% Rec.	RQD	Core Run	Core Rec.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
				Boulder - 3"					Hawthorn used to widen Nx core hole but boulder encountered at 53'
9	53	82	—	Gray shale RF, weathered, broken, some clay; moist due to					Roller bit to 58.5
									Weathered shale 53.5-62
10	191	—	—	Gray shale, fissle, bedding nearly paralle, slightly friable, dry					
				Gray shale, fissile, weathered, interbedded clay seams		0	3.0		
				Gray shale, more massive appearance - not weathered but broken in zones: 63.8-64.5 & 68.5-69 Numerous tensional bedding fractures 1/8-1/4" apart Some fracturing normal to bedding & 60° to bedding Thin interbedded seams of lt. gray sand stone	100	34	7.0	10.0	
				TOTAL DEPTH 69'					

GAI - 237 12/68

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-72

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio

CONTRACTOR: Herron COORDINATES N 781,325.4 E 2,370,007.3

DRILLER: Ed Sezwyck

CLASSIFIED BY: R.P.V. DATE: 6-22-72

SHEET 1 OF 3

DRILL HOLE NO. 1-21

ELEVATION 619.3

GWL 0 HRS 2.5'

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	U.S.C.S.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
0							1.5 TSF
2.5-4.0	1	3	6	8	Orange brown & gray mottled clay and silt trace fine sand - moist stiff	CL	
5.5-7.0	2	2	5	6	Gray silt, little clay w/pockets of orange brown silt, wet, stiff	ML	
8.5-10.0	3	2	3	3	Gray silt, trace clay, w/interbedded seams of fine sand - stiff, wet	ML	
10.5-12.0	4	2	5	5	Gray silt, trace clay, w/interbedded layers of fine sand & clay, soft, wet, stiff	ML	
13.5-15.0	5	1	3	3	Gray silt & clay, trace fine sand soft, wet, m. stiff	CL	
18.5-20.0	6	2	4	4	Gray interbedded layers of f. sand & silty clay w/black streaks m. stiff, moist	SC/CL	
23.5-25.0	7	10	15	22	UPPER TILL Gray f. sand & silt - dense	SC/ML	

GAI - 237 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-73

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio

SHEET 2 OF 3

DRILL HOLE NO. 1-21

CONTRACTOR: Herron COORDINATES

ELEVATION

DRILLER: Ed S.

GWL 0 HRS.

CLASSIFIED BY: R.P.V. DATE: 6-23-72

24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	U.S.C.S.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
25.0–28.5									
28.5–30.0	8	5	7	9	28.5–30.0		Gray clay, little silt ±10% R.F. V.stiff	CL	
33.5–35.0	9	8	10	14	33.5–35.0		Gray clay, little silt	CL	Lower Till
							Tr. fine sand 40-50% R.F. (m.sand-f.gravel size)v.stiff		
38.5–40.0	10	14	21	27	38.5–40.0		Same - hard	CL	
43.5–45.0	11	19	29	37	43.5–45.0		Gray clay, little silt, ±30% F.F. (c.sand-f.gravel size) hard-dry	CL	
48.5–50.0	12	19	28	32	48.5–50.0				

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-74

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio

SHEET 3 OF 3

DRILL HOLE NO. 1-21

CONTRACTOR: Herron COORDINATES

ELEVATION

DRILLER: E.S.

GWL 0 HRS. 2.5'

CLASSIFIED BY: R.P.V. DATE: 6-26-72

24 HRS. 1'

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	% Rec.	RQD	Core Run	Rec. Core	Remarks
50.0							Gray clay, little silt ±30% R.F. (c.sand-f.gravel size) dry, hard	CL				
53.5–55.0	13	36	50	68	53.5–55.0		Same, w/fissle shale particles	CL				
57.0–57.5						57.0–57.5	Shale layer					
58.5–59.3	14	46	100/2		58.5–59.3	59.3	Gray clay, tr. silt, ±20% R.F., v.hard	CL				
59.3–64.3							Gray shale, horizontal bedding w/ clay seam @ 60.0', weak zone w/fract rock @ 63.3', some cross bedding, occasional seam of fine sandstone	84	32	5.0	4.2	

GAI - 227 12/68

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-75

CEI - Perry Nuclear

PROJECT: Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 1 OF 3

DRILL HOLE NO. 1-22

CONTRACTOR: Herron

COORDINATES N-781,839.4
E-2,370,071.3

ELEVATION 606.8

DRILLER: John

GWL 0 HRS. ____

24 HRS ____

CLASSIFIED BY: D.B.S.

DATE: 6-13-72

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	%	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–50								49.0		Hole not soil sampled - 50' of core taken for seismic survey. Soil samples 0-50' from 1-22A (approx. 20 feet west of 1-22 and 100' east of 1-30)

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-76

CEI - Perry Nuclear

PROJECT: Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 2 OF 3

DRILL HOLE NO. 1-22

CONTRACTOR: Herron

COORDINATES ____

ELEVATION ____

DRILLER: John

GWL 0 HRS. ____

24 HRS ____

CLASSIFIED BY: D.B.S.

DATE: 6-12-72

Depth Ft.	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Core Run	Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0–59.0	Gray shale & clay, weathered & broken; fractures mostly along & to bedding	20	0	10.0	2.0	Weathered shale & clay at 49' Run appears more broken possibly due to rock wedged in barrel - no elevation into barrel
59.0–64.0	Gray shale w/some lt. gray sandstone seams, some fractures to bedding; fractures unweathered & unbroken	94	.48	5.0	4.7	
64.0–67.5	Same; pieces 2-3" (tensional bedding fractures develop after a few hours about 1/8-1/4" apart)	74	.23	3.5	2.6	Lost part of core possible picked up in next run
67.5–74.0	Same; broken in zones (possibly due to drilling procedure)	84	.04	6.5	5.5	

Depth scale: 50.0, 52.5, 55.0, 57.5, 60.0, 62.5, 65.0, 67.5, 70.0, 72.5, 75.0

GAI - 227 12/68

GILBERT ASSOCIATES, INC.

SOIL CLASSIFICATION SHEET

2E-77

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio

SHEET 3 OF 3

DRILL HOLE NO. 1-22

CONTRACTOR: Herron COORDINATES

ELEVATION

DRILLER: John

GWL 0 HRS

CLASSIFIED BY: R.P.V. DATE: 6-24-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils Range Size / Core Run	Grain Shape / Core Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75.0												
77.5							Gray shale w/numerous hor. & 60° fractures - weak zone w/silty clay and shale fragments from 77.0-77.5' (± 10% of core w/vertical fract.) longest pc. 0.55'	82	.21	10.0	8.2	
80.0												
82.5										84.0		
85.0							Gray shale w/0.5" thick banded tan siltstone - badly fractured shale @ 84'-85', 90-91', 91.5-92.0' - some cross bedding					
87.5								94	.25	10.0	9.4	
90.0												
92.5										94.0		
95.0							Gray shale w/½" to 3/4" bands of tan siltstone, & a 3/4" layer of lt.gray sandstone, some crossbedding					
97.5								94	.47	5.0	4.71	
100.0										99.0		

GAI-227 12/66

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-78

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 1 OF 3

DRILL HOLE NO. 1-22A

CONTRACTOR: Raymond Int'l. COORDINATES N 781,147.6 E 2,370,055.8

ELEVATION 606.2

DRILLER: Don Suggs

GWL 0 HRS

CLASSIFIED BY: R.V. DATE: 6-16-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.		Coarse Granular Soils Range Size / Core Run	Grain Shape / Core Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							Orange-brown w/gray mottled clay, little silt, few fine sand seams	CL				
2.5	1	4	8	4	3.5 4.0		Same, stiff	CL				
5.0	SHELBY #1				5.0 7.0		Gray silt & fine sand, moist	SC/ML				24" rec
7.5	2	5	9	11	8.5		Gray silt & fine sand, few clay seams, moist, med.dense	SC/ML				
10.0	3	8	8	9	10.0 11.5		Gray silt & fine sand, moist, med.dense	SC/ML				
12.5												
15.0	SHELBY #2				15.0 17.0		Gray varved clay, little silt, firm	CL				20" rec
17.5	4	3	5	6	18.5	17.5	Gray clay, tr. silt, occ. pocket of red brown clay, tr. coarse sand particles, stiff	CL				Upper till 1.25 TSF
20.0	SHELBY #3				20.0 22.0		Gray clay & silt-tr. little f.sand some RF	CL/ML				18" rec
22.5	5	7	11	14	23.5		Gray clay & silty, some m-f.sand size R.F.; v.stiff	CL/ML				4.25 TSF
25.0												

GAI-227 12/66

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-79

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Raymond Int'l. COORDINATES
DRILLER: Don Suggs
CLASSIFIED BY: R.V. DATE: 6-16-72

SHEET 2 OF 3
DRILL HOLE NO. 1-22A
ELEVATION
GWL 0 HRS.
24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0					25.0		Gray clay & silt, little shave fragments					
							LOWER TILL					LOWER TILL 4.5 TSF
27.5							Same - hard					
					27.9							
30.0					30.0							
	PITCHER #1						Same					12" Rec.
32.5					32.5							
	7	18	32	38			Gray clay & silt, w/coarse sand size RF - hard					
					34.0							
35.0	PITCHER #2											
					36.5							
37.5	8	25	32	42			Gray clay, little silt, 50% R.F. dry, hard					24" Rec.
					38.0							
	PITCHER #3						Same w/friable shale fragments					
40.0												
					40.5							
	9	47	75		41.1		Same w/m.gravel size R.F.					
	PITCHER				41.5							
						41.9	- - - - - - - -			42.0		
42.5												
45.0							Gray shale w/1.5' of clay seam w/shale fragments (42.5-44.0') Shale w/hor.bedding ½"-3/4" clay seams @ 45.3 & 49.0'					
47.5								60	0	10.0	6.0	
50.0												

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-80

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Raymond Int'l. COORDINATES
DRILLER: Don Suggs
CLASSIFIED BY: R.V. DATE: 6-16-72

SHEET 3 OF 3
DRILL HOLE NO. 1-22A
ELEVATION
GWL 0 HRS.
24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0												
										52.0		
52.5												
										53.9		
55.0							Gray shale, Hor. bedding w/o cc ½" clay seam, longest pc. 2", some cross bedding	98	0	5.0	4.9	
57.5												
										58.75		
60.0												
62.5												
65.0												
67.5												
70.0												
72.5												
75.0												

GAI-227 12/68

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-81

PROJECT: Perry Nuc. Power Plt. W.O. 4549-00 SITE AREA: Perry, Ohio
CONTRACTOR: Herron COORDINATES: N 781,127.9 / E2,370,055.9
DRILLER: L. Humphrey
CLASSIFIED BY: RPV DATE: 7-24-72 to 7-29-72

SHEET 1 OF 5
DRILL HOLE NO. 1-22-P-
ELEVATION 607
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Recovery	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					No Sampling Req'd From 0' To 51.5'			51.5		Boring Added By Woodward - Gardner Assoc. For Pressure Meter Testingin Rock -
54				54.0	Grey Shale, Weathered, Badly Fractured		0	2.5 (54.0)	0	
55					Grey Shale, Horiz Bedding, Some Cross Bedding, of Fine Grained Sandstone Seams, occ. 60° Fracture	100	.48	2.5 (56.5)	2.5	
56 / 60					Grey Shale, w/ Extensive Cross Bedding, 60° & 90° Serrated Fract.	99	.66	5.0 (61.5)	4.95	Pressure Meter Test @ 61.0'
65					Grey Shale, Horiz Bedding, Some Cross Bedding, Few Fine Grained Sandstone seams, Extensively Fractured (60° & 90°.)	84	.49	5.0 (66.5)	4.17	Pressure Meter Test @ 66'
70					Grey Shale w/ Extensive Cross Bedding, Few Fine Grained Sandstone Seams, Some 60° Fract.	100		6.0 (72.5)	6.6	Recovered 7" From Previous Run.
75										

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-82

PROJECT: Perry Nuc. Power Plt. W.O. 454900 SITE AREA: Perry Ohio
CONTRACTOR: Herron COORDINATES:
DRILLER: L. Humphrey
CLASSIFIED BY: RPV DATE:

SHEET 2 OF 5
DRILL HOLE NO. 1-22P-2
ELEVATION 607
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Recovery	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75 / 76					Grey Shale, - Some Cross Bedding, Few Fine Grained Sand Stone Seams - w/Clay Layer Betw. 78.0 & 79.0'	96	.70	6.5 (78.0)	6.25	
79					Grey Clay, 40% RF			(79.0)		
80 / 84					Grey Shale, Few Fine Grained Sand Stone Seams, Clay seam @ 83.5'. Some 60° Fractures.	77	.47	5.0 (84.0)	3.8	
85 / 89					Grey Shale, Few Tan Silt Seams, some Cross Bedding - (1"-3" Lyrs)	85	.47	5.0 (89.0)	4.25	
90 / 94					Grey Shale, Some Cross Bedding & Fine Grained Sand Seams. OCC. 60° Fractures.	100	.90	5.0 (94.0)	5.18	Recovered 2" From Previous Run. Pressure Meter Test @ 94'
95										

GAI-227 12/68

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-83

PROJECT: Perry Nucl. Power Plt. W.O. 4549-00 SITE AREA: Perry, Ohio

CONTRACTOR: Herron COORDINATES:

DRILLER: L. Humphrey

CLASSIFIED BY: RPV DATE:

SHEET 3 OF 5

DRILL HOLE NO. 1-22p-2

ELEVATION 607-

GWL 0 HRS.

24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% RECOVERY	RQD	Coarse Granular Soils: Range Size / Core Run	Coarse Granular Soils: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
94 – 99					Grey Shale, Few Fine Grained Sandstone Seams, Badly Fractured From 94.0 - 95.01	93	.78	5.0	4.7	Pressure Meter Test @ 99'
99 – 108.5					Grey Shale, Some Cross Bedding w/ Fine Grained Sandstone Seams (May 2")	96.5	.89	9.5	9.1	
108.5 – 118.5					Grey Shale, Some Cross Bedding; Fine Grained Sand Seams ½"-2" Thick	100	.67	10.0	10.6	Recovered 7" From Previous Run

GAI-227 12/66

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-84

PROJECT: Perry Nucl. Power Plt. W.O. 454900 SITE AREA: Perry Ohio

CONTRACTOR: Herron COORDINATES:

DRILLER: L. Humphrey

CLASSIFIED BY: RPV DATE:

SHEET 4 OF 5

DRILL HOLE NO. 1-22-P-2

ELEVATION 607 -

GWL 0 HRS.

24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% RECOVERY	RQD	Coarse Granular Soils: Range Size / Core Run	Coarse Granular Soils: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
118.5 – 128.5					Grey Shale, Some Cross Bedding, of OCC Fine Grained Sandstone Seams OCC Seams of Tay Shale	100	.72	10.0	10.0	
128.5 – 138.5					Grey Shale, w/ Cross Bedding, Some Fine Grained Sandstone seams	100	.68	10.0	10.0	
138.5 –										

GAI-227 12/66

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-85

PROJECT: Perry Nucl. Power Plt. W.O. 45-49-00 SITE AREA Perry, Ohio
CONTRACTOR: Buxton
DRILLER: L. Bumpf...
CLASSIFIED BY: RPV
COORDINATES:
DATE:

SHEET 5 OF 5
DRILL HOLE NO. 122P-2
ELEVATION 607
GW. 0 HRS.
24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	In. Rec.	Profile	Soil Description: Density (or Consistency), Color, Soil Type - Accessories	% Recovery	RQD	Core Run	Core Rec.	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
140					Grey Shale, Some Cross Bedding - Few Fine Grained Sandstone seams	100	68	10.0	10.0	Pressure Meter Test @ 147.5'
148.5	5							148.5		
150					Grey Shale Horiz. Bedding Some fine grained sandstone seams	100	82	3.5	3.5	
152								152.0		Pressure Meter Test @ 152.5'
155					End of Boring					

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-86

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Raymond
DRILLER: Don
CLASSIFIED BY: D.B.S.
COORDINATES: N 781,006.9 E 2,370,301.9
DATE: 5-31-72

SHEET 1 OF 3
DRILL HOLE NO. I-23
ELEVATION 613.9
GW. 0 HRS. 5.0
24 HRS. 2.8

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	In. Rec.	Profile	Soil Description: Density (or Consistency), Color, Soil Type - Accessories	U.S.C.S.	%	Range Size	Grain Shape	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
2.5	1	3 / 4 / 8	2.5 – 4.0		Or-brn. w/gray silty clay & interbedded f.sand, soft-firm, moist	CL/SM				Limonite concretions filling worm burrows!
5.0	SHELBY #1		5.0 – 7.0		Brn. v.f. sand, loose, moist	SM				18" Rec.
7.5	2	1 / 2 / 2	– 9.0	8.0	Same as above					
					Grey silty clay, soft, wet					
10.0	3	3 / 5 / 9	10.5 – 12.0		Grey silt & silty clay, soft-firm, moist, unstratified	ML/CL				
12.5										
15.0	SHELBY #2		15.0 – 17.0		Grey silty clay & interbedded v.f.sand; stratified, firm, moist, traces of red clay	CL/SM				24" Rec.
17.5	4	3 / 7 / 10	– 19.0		Same as above, less sand, more red clay	CL/SM				
				19.0	———?——— ——— ———?———					Upper Till
20.0	SHELBY #3		20.0 – 22.0		Grey silty clay & interbedded v. fine sand; stratified, firm, moist, traces of red clay; 5% coarse sand size RF, max ¼-½"	CL				20" Rec.
22.5	5	4 / 5 / 7	– 24.0		Same as above, moist-wet, firm-stiff	CL				
25.0										

GAI-227 12/68

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Raymond Int'l. COORDINATES ______

DRILLER: Don

CLASSIFIED BY: D.B.S. DATE: 5-31-72

SHEET 2 OF 3

DRILL HOLE NO. 1-23

ELEVATION ______

GW. 0 HRS. ______

24 HRS. ______

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	Soil Description Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	[illegible]	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	Remarks Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
	SHELBY #4						Same as above, no red clay	CL				Rec. 20"
	6	5	7	14			Same, 5-10% RF coarse sand (1/16") max ½", firm-stiff-moist	CL				
	SHELBY #5						Same as above	CL				18" Rec.
							LOWER TILL					
	7	22	32	41			Same as above, 10-15% RF, hard moist-damp	CL				
	SHELBY #6						Same as above 15-20% RF, max. 4"	CL				10" Rec. Discarded
	PITCHER #1											
	8	27	35	45			Same as above	CL				19" Rec.
	PITCHER #2						Same as above 20-25% RF, dry					24" Rec.
	9	34	64	78				CL				
	PITCHER #3						Same as above					18" Rec. Thin wall of tube ripped
	10	[illegible]						CL / SH				

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Raymond COORDINATES ______

DRILLER: Don

CLASSIFIED BY: D.B.S. DATE: 6-1-72

SHEET 3 OF 3

DRILL HOLE NO. 1-23

ELEVATION ______

GW. 0 HRS. 5.0

24 HRS. ______

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	Soil Description Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	Remarks Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
	DENISON #1						Clayey silt w/fine gravel RF					
							6" gray shale					
	[illegible]						No recovery					
							Gray shale, lt. gray siltstone seams, horizontal bedding, numerous horizontal parallel bedding fractures, some normal to bedding	95	87	10.0	9.5	
							TOTAL DEPTH 62.4'					

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET — 2E-89

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES N 781,025 E 2,370,300
DRILLER: John
CLASSIFIED BY: D.B.S. DATE: 6-5-72
SHEET 1 OF 2
DRILL HOLE NO. 1-23B
ELEVATION 113.9
GWL 0 HRS 18'
24 HRS 5.5

Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	U.S.C.S.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
						Hole 18' north of stake. Intended as pressure meter hole, but deleted
1	3 / 4 / 4	2.5–4.0		Or-brn. & gray silty clay, firm, moist, trace of organics & roots	CL	
2	2 / 4 / 4	5.5–7.0		Brn. & gray laminated v.f. sand & silty clay,	SM/CL	
		8.0		V.f. non plastic sand, wet-saturated, firm		Water seepage @ 6'
3	2 / 4 / 4	9.5		Same as above, wet	SM/CL	
				——— ? ——— ——— ——— ? ———		
4	2 / 3 / 5	10.5–12.0		Gray, silt-silty clay, unstratified moist, firm, lens of v.f. non plastic sand	SM/CL	
5	2 / 3 / 7	13.5–15.0	14.5	Gray v.f. sand, saturated, loose	SC	Water seepage @ 13'
				Laminated silty clay, some sand & red clay, firm, moist-wet	CL/ML	
6	2 / 3 / 6	18.5–20.0		Same as above, moist, trace of RF (1/8")	CL/SC	
7	2 / 3 / 4	23.5–25.0		Same as above, lens of v.f. non plastic sand - saturated	CL/SC	

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET — 2E-90

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: John
CLASSIFIED BY: D.B.S. DATE: 6-5-72
SHEET 2 OF 2
DRILL HOLE NO. 1-23B
ELEVATION
GWL 0 HRS
24 HRS

Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	U.S.C.S.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
			26.5	——— ? ——— ——— ——— ? ——— UPPER TILL		
8	5 / 8 / 15	28.5–30.0		Gray silty clay 5-10% RF, mostly coarse sand (1/8-1/4") max. 1", angular - subround		30' auger - pulled out after 2 hrs.
				Total Depth - 30'		

Core Run: 30.0

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-91

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Raymond COORDINATES N 780,533.1 E 2,370,362
DRILLER: Don
CLASSIFIED BY: D.B.S. DATE: 6-2-72

SHEET 1 OF 3
DRILL HOLE NO. 1-24
ELEVATION 622.1
GWL 0 HRS. 4.5
24 HRS 4.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	Soil Description: Density (or Consistency), Color, Soil Type - Accessories	U.S.C.S.	qu	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE SEDIMENTS					
2.5	1	4	6	7	2.5 / 4.0		Or-brn. silty clay & fine sand, firm, moist	ML/SC				
5.0	SHELBY #1				5.0 / 7.0		Same as above, wet-saturated, loose	ML/SC				22" Rec.
7.5	2	1	5	6	8.5	8.0	Same as above, mostly f. non-plastic sand, clay interbeds Same as above, but gray	SC/CL				
10.0	3	5	9	9	10.5 / 12.0		Same as above, moist, slightly more dense	SC/CL				
12.5												
15.0	SHELBY #2				15.0 / 17.0		Same as above	SC/CL				24" Rec.
17.5	4	4	8	11	18.5		Same as above, wet	SC/CL				
20.0	5	4	13	17	20.0 / 21.5		Same as above, mostly v.f. sand moist	SC/CL				
22.5												
25.0												

GAI - 227 12/65

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-92

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Raymond COORDINATES
DRILLER: Don
CLASSIFIED BY: D.B.S. DATE: 6-2-72

SHEET 2 OF 3
DRILL HOLE NO. 1-24
ELEVATION 622.1
GWL 0 HRS. 4.5
24 HRS 4.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	Soil Description: Density (or Consistency), Color, Soil Type - Accessories	U.S.C.S.	qu	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0	SHELBY #3				25.0 / 27.0		Gray silty clay, moist, soft-firm, varved, some red clay	CL				26" Rec.
27.5	6	4	5	7	28.5		Same as above					
30.0	SHELBY #4				30.0 / 32.0	31.0	Same as above UPPER TILL Gray silty clay 3-5% RF, max. ½" mostly coarse sand	CL CL				22" Rec. Upper Till
32.5	7	5	7	10	33.5		Same as above, firm, moist					
						34.0	LOWER TILL					Lower Till
35.0	SHELBY #5				35.0 / 36.7		Same as above, stiff-hard, 10% RF, max ½"	CL				
37.5	8	21	24	34	38.7		Same; hard 15% RF					
40.0	PITCHER #1				40.0 / 42.5		Same as above	CL				26" Rec
42.5	9	29	43	55	44.0		Same as above, 20% RF	CL				
45.0	PITCHER #2				45.0 / 47.5		Same	CL				30" Rec.
47.5	10	33	66	84	49.0		Same, 20-25% RF, max. 1", damp-dry	CL				
50.0												

GAI - 227 12/65

GILBERT ASSOCIATES, INC. 2E-93

SOIL CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 3 OF 3

DRILL HOLE NO. 1-24

CONTRACTOR: Raymond COORDINATES ______ ELEVATION ______

DRILLER: Don GWL 0 HRS 4.5

CLASSIFIED BY: D.B.S. DATE: 6-2-72 24 HRS 4.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	%REC.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0	PITCHER* 3				51.7		Same as above, limestone cobble	CL/GC				18" Rec.
	11	71	48	52			Same, v.hard & dry, 30-35% RF					
55.0	PITCHER* 4				57.5/57.6		Gray clayey gravel/gravely clay 40-60% RF	CL/GC				21" Rec.
							Weathered gray shale, fissle			57.6		
							Gray shale w/lt.gray sandstone seams. Horizontal bedding & tensional bedding fractures 1/16-1/4" apart, some fractures normal, 75 to bedding	92	47	10.0	9.2	
										67.6		
							T.D. 67.6					

GAI-227 12/68

GILBERT ASSOCIATES, INC. 2E-94

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 1 OF 4

DRILL HOLE NO. 1-25

CONTRACTOR: Herron COORDINATES N 780,181.5 E 2,370,289.5 ELEVATION 625.6

DRILLER: Ed GWL 0 HRS 4.0'

CLASSIFIED BY: D.B.S. DATE: 5-16-72 24 HRS 0.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.		Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												* indicates sample jar sealed in parafin
2.5	1	3	5	5			Or-brn. v.f.sand, non-plastic, wet, firm; interbedded w/or-brn. & gray silty clay, moist, stiff	SM/CL	*			
5.0						6.0	Same as above; laminated, saturated	[illegible]				
	2	3	5	5			Same as above, gray	[illegible]				
7.5	3	2	2	2			Same as above; more clay, soft-med. wet	[illegible]	*			
10.0	4	3	5	8			Gray silty clay w/v.f. sand; v. moist, soft-med., unstratified	[illegible]				
12.5	5	2	3	5			Same as above	[illegible]	*			
17.5	SHELBY* 1											
20.0												
22.5	6	3	4	5			Laminated v.f. gray sand w/red & gray silty clay, soft-stiff, v. moist	[illegible]				

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-95

PROJECT: CEI - Perry Nuclear Power Plant   W.O. 4549-00   SITE AREA N. Perry, Ohio
CONTRACTOR: Herron   COORDINATES
DRILLER: Ed
CLASSIFIED BY: D.B.S.   DATE: 5-16-72

SHEET 2 OF 4
DRILL HOLE NO. 1-25
ELEVATION
GWL 0 HRS.
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	ω	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0												
						27.0	———?——— ——— ———?———					
27.5							UPPER TILL					
					28.5							
	7	3	5	8			Gray sandy clay;soft-med.wet 1-5% shale RF; coarse sand to ¼", subangular	CL	#			
30.0					30.0							
32.5												
					33.0							
	SHELBY #2											24" Rec.
35.0					35.0	34.8	——— ——— ———					
							LOWER TILL					Shelby pushed hard last 2" of run
37.5												
					38.5							
	8	12	22	28			Gray sandy clay;hard,dry;15% shale RF; coarse sand to 1", subangular-subrounded	CL	#			
40.0					40.0							
42.5												
					43.5							
	9	20	29	34			Same as above;red-brn.clay zone	CL				
45.0					45.0							
47.5												
					48.5							
	10	18	43	70			Same as above w/more red clay	CL				
50.0					50.0							

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-96

PROJECT: CEI - Perry Nuclear Power Plant   W.O. 4549-00   SITE AREA N. Perry, Ohio
CONTRACTOR: Herron   COORDINATES
DRILLER: Ed
CLASSIFIED BY: D.B.S.   DATE: 5-16-72

SHEET 3 OF 4
DRILL HOLE NO. 1-25
ELEVATION
GWL 0 HRS.
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0												
52.5												
					53.5	53.5	CHAGRIN SHALE					
	11	37	129/5		54.3		Gray shale,fissile,dry,slightly friable,v.slightly weathered					
55.0										55.0		
							Claystone boulder					
							Interbedded clayey till(?) and shale boulders					
57.5												
60.0								10	0	10.0	1.0	Estimated weathered zone 53.5- 65
62.5												
65.0										65.0		
							Gray shale & interbedded clay zones;broken,weathered zones; bedding @ 5°,bedding fractures and some fractures 90° & 45° to bedding					
67.5								88	.18	4.5	4.0	
										69.5		
70.0							Gray shale w/thin lt.gray sandstone seams;broken soft & weathered in zones					
72.5												
								80	.3	10.0	8.0	
75.0												

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-97

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: Ed
CLASSIFIED BY: D.B.S. DATE: 5-16-72

SHEET 4 OF 4
DRILL HOLE NO. 1-25
ELEVATION
GW.L 0 HRS.
24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
79.5							Total depth 79.5			79.5		

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-98

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES N 781,556.3
DRILLER: Larry E 2,369,537.5
CLASSIFIED BY: D.B.S. DATE: 5-23-72

SHEET 1 OF 3
DRILL HOLE NO. 1-26
ELEVATION 620.5
GW.L 0 HRS. 5'-8"
24 HRS. 3.0'

Sample No.	SPT Blows/6 in. 6	12	18	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
				LACUSTRINE SEDIMENTS		Hole 15' north of approximated location
1	3	4	4	Or-brn & gray silty clay w/interbedded clayey sand & non plastic f. sand; firm-stiff, moist, somewhat stratified	CL/SC	
2	2	3	7	Same as above; firm	CL/SC	
SHELBY ▲				Same as above		▲ Shelby failed (1" Rec.)
3	6	9	9	Gray silty clay, stiff, moist unstratified	CL	
SHELBY #1				Same as above		24" Rec.
4	6	14	13	Same as above, some interbedded f. sand	CL/SC	
5	6	9	11	Same as above, trace of red clay	CL/SC	
SHELBY #2				Same as above		
6	5	6	10	Stratified silty clay & f. non-plastic sand (1/8" varves) moist-wet, soft-firm	CL/SC	
7	4	9		Same as above, wet, loose sand	SC/CL	

GAI - 227 12/68

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-99

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: Larry
CLASSIFIED BY: D.B.S. DATE: 5-23-72

SHEET 2 OF 3
DRILL HOLE NO. 1-26
ELEVATION
GWL 0 HRS.
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0				10	25.5						
27.5					28.5						
30.0	8	4	10	13	30.0		Same as above, more red clay, less sand but stratified w/1-3% coarse sand size RF (1/16")	CL/ML			Stratified clay w/RF probably not till but related to glacial outwash into lake
32.5	SHELBY #3				32.0 / 34.0	33.5					15" Rec.
							UPPER TILL				
35.0	9	18	13	16	35.5		No recovery				
	10	6	11	18	37.0		No recovery				
37.5	11	9	13	16	37.5 / 39.0		Gray silty clay, 5% RF, mostly shale, coarse sand-f. gravel, max ¼", angular-subround, stiff-moist	CL			
40.0	12	7	10	13	40.0 / 41.5		Same as above, 5-10% RF				
42.5					43.5						
45.0	13	15	20	29	45.0	44.5	Same as above 15-20% RF Max 2" more f. gravel size	CL			
							LOWER TILL Stiff-hard, moist-damp				
47.5					48.5						
50.0	14	26	25	25	50.0		Same as above, hard, dry-damp 20-25% RF	CL			

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-100

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: Larry
CLASSIFIED BY: D.B.S. DATE: 5-25-72

SHEET 3 OF 3
DRILL HOLE NO. 1-26
ELEVATION
GWL 0 HRS. 5'-8"
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0												
52.5						52.5 / 53.5	Boulder Zone					
55.0	15	33	88	51	54.5 / 56.0		Gray gravely clay, 30-35% RF, mostly f. gravel, max. 2", hard, moist-dry			56.0		
57.5							Gray gravely clay, 40-50% RF mostly broken shale, angular, coarse sand to 1½"	95	.3	6.0	5.7	
60.0						61.0	Gray clayey gravel 50-60% RF, max. greater than 2"					
62.5							Gray shale w/lt. gray sandstone seams, pieces 2-3", appears unweathered			62.0		
65.0							Same as above, unbroken	104	.9	5.0	5.2	
67.5							TOTAL DEPTH 67.0'			67.0		
70.0												
72.5												
75.0												

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-101

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA: Perry, Ohio
CONTRACTOR: Herron COORDINATES N 781,509.8 E 2,369,186.2
DRILLER: Ed Sezwyck
CLASSIFIED BY: R.P.V. DATE: 6-20-72

SHEET 1 OF 2
DRILL HOLE NO. 1-27
ELEVATION 575.6'
GWL 0 HRS
24 HRS 2.5'

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												
2.5					2.5		Misc. poorly sorted beach sand, med.dense, moist	SM				
	1	1	6	19	4.0							
5.0					5.5		Same, becoming	SM				
	2	4	8	12	7.0	6.0	Gray clay, little silt, grace-little sub-rounded med.coarse gravel, v.stiff, moist	CL				3.5 TSF
7.5					8.5							
	3	11	15	30	10.0	9.0	Gray clay little silt, some coarse gravel, v.stiff, dry					4.5 TSF
10.0					10.5			CL				
	4	31	62	112	12.0		Same					
12.5					13.5							
	5	16	36	42	15.0		Lt.gray clay, little silt & med.-coarse gravel, hard, dry	CL				
15.0												
17.5					18.5							
	6	110	-	-	19.0		Gray clay, little silt, 50% shale RF	CL				
20.0						20.0	Lt.gray f.grained Sandstone (25.5) becoming gray shale, hor. bedding badly fract. @ 21.0' w/numerous seams of sandstone & a 1.5" layer of tan siltstone @ 22.5'			20.0		
22.5								63	26	5.0	3.15	
25.0										25.0		

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-102

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: Ed Swyzack
CLASSIFIED BY: R.V. DATE: 6-21-72

SHEET 2 OF 2
DRILL HOLE NO. 1-27
ELEVATION
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0							Gray shale, hor. bedding, some cross bedding, sandstone seams			25.0		
27.5								99	88	5.0	4.95	
30.0							TOTAL DEPTH 30'			30.0		
32.5												
35.0												

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-103

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 1 OF 2
CONTRACTOR: Herron COORDINATES N 781,381.5 E 2,368,881
DRILL HOLE NO. 1-28
DRILLER: Larry
ELEVATION 576.9
CLASSIFIED BY: D.B.S. DATE: 5-31-72
GWL 0 HRS 2.1
24 HRS 1.5

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	Soil Description: Density (or Consistency), Color, Soil Type - Accessories	% Rec.	RQD	Core Run	Core Rec.	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							Beach Deposits					
2.5	1	4	7	10	2.5–4.0		Beach gravel, brown, loose, wet, poorly sorted, subround-round	GW				
5.0	2	8	11	10	5.5–7.0		Same as above	GW				
8.0						8.0	LOWER TILL					
	3	24	57	48	8.5–10.0		Lt.brn. & gray sandy clay 20-25% RF max. 1" coarse sand & fine gravel, moist, hard	CL				
	4	27	37	42	10.5–12.0		Gray gravely clay 35-40% RF max 1½", poorly sorted sand & gravel, moist, firm-hard	CL				
	5	23	33	31	13.5–15.0		Same as above	CL				
	6	11	27	99	19.0–20.5	20.0	Gray gravely clay-clayey gravel 40-50% Rf, moist, hard	CL/GC				
20.5							CHAGRIN SHALE Gray shale, fissile, dry			20.5		Weathered zone 20'-41'

GAI-237 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-104

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
SHEET 2 OF 2
CONTRACTOR: Herron COORDINATES
DRILL HOLE NO. 1-28
DRILLER: Larry
ELEVATION
CLASSIFIED BY: D.B.S. DATE: 5-31-72
GWL 0 HRS 2.1'
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	Soil Description: Density (or Consistency), Color, Soil Type - Accessories	% Rec.	RQD	Core Run	Core Rec.	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0							Gray shale w/lt.gray sandstone seams, slightly weathered and broken probably mixed w/clayey gravel	16	0	9.5	1.5	Most shale has horizontal bedding, no clay recovered, one 4" piece has bedding 5° to normal
30.0	7	12/3"					Gray shale & clay, weathered, fissile			30.0		Cored w/single tube core barrel
							Gray shale (Boulders) and gravel (subround-round metamorphic RF & angular shale RF) mostly ¼" 7" of good shale recovered above broken shale & gravel. Probably boulders & gravel in silty clay	5	0	10.0	0.5	Abundant silty clay/clayey silt cuttings
40.0							Weathered shale, fissile			40.0		
41.0						41.0	Gray sahle & lt.gray siltstone seams. Horizontal bedding w/ bedding fractures 1/8-1/4" apart. unweathered	82	38	4.5	3.7	Two ¼x¼" pebbles (metam) at top of run. Core appears abraided - sand & gravel?
44.5							TOTAL DEPTH 44.5			44.5		

GAI-237 12/68

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-105

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 1 OF 4

CONTRACTOR: Herron COORDINATES N 781,083.6 E 2,369,963.8

DRILL HOLE NO. 1-30

DRILLER: Ed

ELEVATION 608.3

CLASSIFIED BY: D.B.S. DATE: 5-31-72

GWL 0 HRS

24 HRS Cased off

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	ω	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE SEDIMENTS					
2.5	1	4	4	5	2.5 – 4.0		Or-brn. & gray interbedded f.loose sand & silty clay, moist-wet, firm, stratified 1/8-1/4"	SC/CL				
5.0							——— ? ——— ——— ——— ? ———					
	2	3	3	4	5.5 – 7.0		Same as above, gray, more f.wet sand, trace of red clay	SC/CL				
7.5	3	4	6	7	8.5 – 10.0		Same as above, less sand, more red clay, firm-stiff, moist	CL/SC				Lost spoon sample but recovered w/auger
10.0	4	4	8	17	10.5 – 12.0		Same as above, trace of shale RF	CL/SC				
12.5	5	6	10	13	13.5 – 15.0		Zone of f. clayey sand	SC				
15.0							Gray silty clay, some red clay & interbedded f.sand, 3-5% RF, max. ¼", stratified, moist, firm	CL				
17.5	6	3	6	7	18.5 – 20.0		Gray clayey sand, lenses of clay loose wet-saturated, unstratified	SC/CL				
20.0						21.5	——— ? ——— ——— ——— ? ——— UPPER TILL					
22.5	7	4	6	7	23.5 – 25.0		Gray silty clay; 5-10% RF mostly coarse sand & f.gravel (1-3 mm) max.1", stiff, moist	CL				
25.0												

GAI-227 12/66

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-106

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549 SITE AREA N. Perry, Ohio

SHEET 2 OF 4

CONTRACTOR: Herron COORDINATES

DRILL HOLE NO. 1-30

DRILLER: Ed

ELEVATION

CLASSIFIED BY: D.B.S. DATE: 5-31-72

GWL 0 HRS

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	ω	Coarse Granular Soils Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0												
27.5						27.0	——— ? ——— ——— ——— ? ——— LOWER TILL					
30.0	8	11	16	20	28.5 – 30.0		Gray silty clay, 10-15% RF, mostly f.gravel, max. 1½" hard, dry-damp					
32.5	9	10	15	21	33.5 – 35.0		Same as above, 15-20% RF					
35.0												
37.5	10	11	21	12½/5	38.5 – 40.0	40.0	Gray-brn. silty clay, zones of RF 5-10% & 25-30%, latter appears slightly decomposed & friable, hard, damp					
40.0							Boulder Zone					Boulder zone 40-41 used roller bit therefore moisture added to samples
42.5	11	18	31	43	43.5 – 45.0		Gray silty clay, 30-35% RF, max. 1", hard, moist & dry zones					
45.0												
47.5	12	51	38	100/1	48.5 – 49.6	49.6	Gray gravely clay - 40-45% RF hard					
50.0							Gray shale, weathered, fissle, broken					Chagrin Shale

GAI-227 12/66

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-107

SHEET 3 OF 4

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
DRILL HOLE NO. 1-30
CONTRACTOR: Herron COORDINATES
ELEVATION
DRILLER: Ed
GWL 0 HRS
CLASSIFIED BY: D.B.S. DATE: 6-2-72
24 HRS Cased

Depth Ft.	Soil Description	% Rec.	RQD	Core Run	Core Rec.	Remarks
50.0–60.0	Gray shale & lt.gray siltstone, horizontal bedding & bedding fractures, some 45&90° to bedding broken in zones	82	.45	10.0	8.2	
60.0–70.0	Same as above	98	.51	10.0	9.8	

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-108

SHEET 4 OF 4

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
DRILL HOLE NO. 1-30
CONTRACTOR: Herron COORDINATES
ELEVATION
DRILLER: Ed
GWL 0 HRS
CLASSIFIED BY: D.B.S. DATE: 6-2-72
24 HRS

Depth Ft.	Soil Description	% Rec.	RQD	Core Run	Core Rec.	Remarks
70.0–80.0	Same as above	98*	.54	10.0	9.8*	* Lost 18" of run, obtained poor re-drill recovery-recovered 8.3 + 1.5 - 9.8'
80.0–90.0	Same as above	85	.56	10.0	8.5	Low recovery;ran out of H_2O while coring therefore ground up shale at 85-86'
90.0–100.0	Same as above; 2" weak zone - fissle at 91'	98	.45	10.0	9.8	Remaining in Hole: 50' Nx casing 3' Nx saw tooth bit Estimated casing depth - 49'-9"

Total Depth 100'

GAI - 227 12/68

Revision 12
January, 2003

2E-109

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 5

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
DRILL HOLE NO. 1-31
CONTRACTOR: Herron COORDINATES N 780,986 E 2,370,024.7
ELEVATION 619.9
DRILLER: Larry
GWL 0 HRS
CLASSIFIED BY: D.B.S. DATE: 6-2-72
24 HRS 4.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	qu	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE SEDIMENTS					Location: 25' from 1-2 toward original 1-30 coordinates. Approx. 10' east of line 1-32, 1-2, & actual 1-30.
2.5	1	4	7	7	2.5–4.0		Or-brn. & gray silty clay, moist, stiff	CL				
5.0	2	1	2	2	5.5–7.0		Or-brn. clayey sand & v.f. non plastic sand, loose & soft, wet-saturated	SC/SP				Water seepage
7.5	3	7	5	5	8.5–10.0	9.5	Same as above	SC/SP				
10.0							Gray silty clay & interbedded clayey sand & non-plastic fine sand, firm, wet, stratified	CL/SC/SP				
	4	1	2	1	10.5–12.0		Same as above					
12.5	5	2	3	3	13.5–15.0		Same as above, moist, soft-firm	CL/SC/SP				
15.0												
17.5	6	4	6	7	18.5–20.0		Same as above, less f. sand, trace of red clay	CL/SC				
20.0												
22.5	7	5	6	8	23.5–25.0		Gray silty clay, some red clay, varved, trace of RF, moist, firm	CL				
25.0												

GAI - 227 12/68

2E-110

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 5

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
DRILL HOLE NO. 1-31
CONTRACTOR: Herron COORDINATES
ELEVATION
DRILLER: Larry
GWL 0 HRS
CLASSIFIED BY: D.B.S. DATE: 6-2-72
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	qu	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0						26.0	UPPER TILL					
27.5	8	3	5	6	28.5–30.0		Gray silty clay, 5-10% RF, max. 1" angular-subrounded, mostly coarse sand, firm, v. moist	CL				
30.0					31.5							
32.5	SHELBY #1					33.0	Same as above	CL				24" Rec.
					33.5		LOWER TILL	CL				Did not elevate rig on sump
	9	10	19	27	35.0		Gray silty clay, 20-25% RF, max. 2" coarse sand & fine gravel, hard, moist-damp					
35.0					35.5							Shelby #2 depth undetermined-pushed thru spoon hole - jar sample
	SHELBY #3				36.5		Same as above					Shelby #3 - pushed 9" lost 3" - discarded
37.5	10	14	24	25	38.0		Same, 15-20% RF, mostly coarse sand size, v. stiff-hard, moist	CL				
	11	15	23	29	38.5–40.0		Same as above	CL				
40.0												
42.5	12	16	19	28	43.5–45.0		Same as above, hard, damp 20-25% RF	CL				
45.0												
47.5	13	14	24	31	48.5–50.0		Same as above, dry, 25-30% RF	CL				
50.0												

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-111

CEI - Perry Nuclear

PROJECT: Power Plant W.O. 4569-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES

DRILLER: Larry

CLASSIFIED BY: D.B.S. DATE: 6-5-72

SHEET 3 OF 5

DRILL HOLE NO. 1-31

ELEVATION

GWL 0 HRS.

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0–58.0										
58.0–64.0					Gray shale frags some v.f. sandstone, mostly f.gravel size, broken, probably in silty clay	20	0	5.0	1.0	
64.0					——?—— —— ——?——					
64.0–69.0					Gray shale w/interbedded sandstone seams, tensional bedding jointing, some jointing normal to horizontal bedding	96	.58	6.0	5.8	Driller had difficulty retaining water. Repeated augers
69.0–74.0					Same as above; appears more broken	80	.22	5.0	4.0	Gravel from above seems to occupy top of run
74.0–75.0										

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-112

CEI - Perry Nuclear

PROJECT: Power Plant W.O. 4569-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron

COORDINATES Located 25' from 1-2 toward original 1-30 site. Now approx. 10' east of line joining 1-32, 1-2 & 1-30 (Actual Location)

DRILLER: Larry

CLASSIFIED BY: D.B.S. DATE: 6-5-72

SHEET 4 OF 5

DRILL HOLE NO. 1-31

ELEVATION

GWL 0 HRS.

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75.0–84.0					Same shale	92	60	10.0	9.2	
84.0–94.0					Same shale; joints in addition to horizontal, at 15° to bedding. Some fractures associates w/ sandstone interbeds	96	.76	10.0	9.6	
94.0–100.0					Same; fracture 45° to bed	93	76	10.0	93	

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-113

SHEET 5 OF 5
DRILL HOLE NO. 1-31
ELEVATION
GWL 0 HRS.
24 HRS

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Hetzer
COORDINATES
DRILLER: Larry
CLASSIFIED BY: D.B.S. DATE: 6-5-72

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Coarse Granular Soils: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
										Boulder Zone 50-53
					Same as above					
								9.0	8.4	70' plastic 4" casing installed

GAI-237 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-114

SHEET 1 OF 5
DRILL HOLE NO. 1-32
ELEVATION 620.9
GWL 0 HRS.
24 HRS

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Hetzer
COORDINATES N 780,921.1 E 2,370,056.8
DRILLER: Ed
CLASSIFIED BY: D.B.S. DATE: 6-6-72

Sample No.	SPT Blows/6 in. (6 / 12 / 18)	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
		LACUSTRINE SEDIMENTS		
1	4 / 6 / 8	Or-brn. & gray silty clay, stiff, moist	CL	
2	2 / 2 / 4	Or-brn, v.f. non plastic sand & interbedded silty clay, soft & loose - firm, wet-saturated, stratified	SM/CL	Seepage at 5.3'
3	3 / 7 / 6	Gray silty clay, lens of f.sand firm-stiff, moist	CL/SM	
4	3 / 4 / 7	Same as above, moist-wet, thin seam of or-brn. clay	CL/SM	
5	3 / 4 / 5	Same, more wet sand	SM/CL	
6	3 / 7 / 10	Gray silty clay w/interbedded v.f. sand; stiff (dense), moist, trace of red & black clay, disturbed strata	CL/SM	
7	5 / 8 / 11	Gray silty clay, laminated w/red clay, moist, firm-stiff	CL	

GAI-237 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-115

SHEET 2 OF 5
PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
DRILL HOLE NO. 1-32
CONTRACTOR: Herron COORDINATES
ELEVATION
DRILLER: Ed
GWL 0 HRS.
CLASSIFIED BY: D.R.S. DATE: 6-7-72
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	qu	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0												
27.5	8	3	4	5	28.5 – 30.0		Same as above, trace of RF, stratified	CL				
30.0						31.5	——?—— ——?—— UPPER TILL					
32.5	9	6	8	10	33.5 – 35.0		Gray silty clay, 5-10% Rf, ang-subang., mostly coarse sand, max. 3/4", stiff, moist	CL				
35.0	SHELBY				36.5	36.5						16" Rec.
37.5	10	12	21	35	38.0		LOWER TILL Gray silty clay, 15-20% RF, hard, damp	CL				Rig lifted when Shelby pushed to 36.5
	11	13	24	33	38.5 – 40.0		Same, hard, moist-damp, 20-25% RF, coarse sand & f.gravel, max. 3/4"	CL				
40.0												
42.5	12	15	26	32	43.5 – 45.0		Same as above	CL				
45.0												
47.5	13	14	28	48	48.5 – 50.0		Same, v.hard, 25-30% RF	CL				
50.0												

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-116

SHEET 3 OF 5
PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
DRILL HOLE NO. 1-32
CONTRACTOR: Herron COORDINATES
ELEVATION
DRILLER: Ed
GWL 0 HRS.
CLASSIFIED BY: D.R.S. DATE: 6-8-72
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0						50.5	Boulder Zone					
52.5	14	17	31	147	53.5 – 55.0		Same as above	CL				
55.0							Gray clayey gravel 50% RF, mostly f.gravel size (shale)					
57.5	15	77	154		58.5 – 59.5		Same as above	CL				
60.0							——?—— CHAGRIN SHALE ——?——			62.0		
62.5							Gray shale, broken & weathered zones					
65.0 – 70.0								80		10.0	8.0	
						71.0				72.0		
72.5							Soft shale zone (gravelly clay?)					
75.0												

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-117

SHEET 4 OF 5

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-32

CONTRACTOR: Barron COORDINATES

ELEVATION

DRILLER: Ed

GWL 0 HRS.

CLASSIFIED BY: D.B.S. DATE: 6-8-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Coarse Granular Soils: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
					Gray shale, thin lt. gray sandstone seams & weak clayey shale seams; bedding fractures horizontal ¼-½" apart, some normal to bedding	95	.4	10.0	9.5	
					Same, no weak clay seams	98	40	10.0	9.8	
					Same as above	98	40	10.0	9.8	

GAI-287 12/65

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-118

SHEET 5 OF 5

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-32

CONTRACTOR: Barron COORDINATES

ELEVATION

DRILLER: Ed

GWL 0 HRS.

CLASSIFIED BY: D.B.S. DATE: 6-10-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Coarse Granular Soils: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
					Same as above			102.0		65' Nx casing + Nx driving shoe
						100	80	10.0	10.0	
					TOTAL DEPTH 112.0			112.0		

GAI-287 12/65

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-119

CEI - Perry Nuclear

PROJECT: Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR Herron COORDINATES N 780,797.7 E 2,370,116.8

DRILLER: Ed

CLASSIFIED BY: D.B.S. DATE: 6-10-72

SHEET 1 OF 9
DRILL HOLE NO. 1-33
ELEVATION 622.9
GWL 0 HRS 4.0 around
24 HRS casing

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	qu	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
2.5–4.0	1	3	5	6	2.5–4.0		Or-brn.&gray intrbdd silty clay & clayey fine sand, stiff, moist	CL/SC				
5.5–7.0	2	2	2	5	5.5–7.0		Same as above, saturated, soft	CL/SC				
7.5						7.5						
8.5–10.0	3	2	2	2	8.5–10.0		Gray interbedded clayey silt & v.f.sand, soft, saturated	SC				
10.5–12.0	4	3	5	4	10.5–12.0		Gray interbedded clayey silt, silty clay & v.f.sand, firm, wet-saturated	ML/CL/SM				
13.5–15.0	5	1	1	2	13.5–15.0		Same, mostly clayey silt soft-firm, wet	ML				
18.5–20.0	6	2	2	5	18.5–20.0		Same as #4, more V.F.sand laminated, trace of red clay	SM/CL/ML				
23.5–25.0	7	2	5	6	23.5–25.0	24.5	Gray silty clay w/some red clay laminations, firm, moist	CL				UPPER TILL
							Gray silty clay 5-10% RF, max ½", med-coarse sand					

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-120

CEI - Perry Nuclear

PROJECT: Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES

DRILLER: Ed

CLASSIFIED BY: D.B.S. DATE: 6-10-72

SHEET 2 OF 9
DRILL HOLE NO. 1-33
ELEVATION
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	qu	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
28.5–30.0	8	2	4	6	28.5–30.0		No rec.					
33.5–35.0	9	5	7	11	33.5–35.0		Gray silty clay, stiff w/coarse sand frags(10%) max 1½"	CL				
35.0–36.0	SHELBY #1				[illegible]	36.0	SAME					U.D. SHELBY - 20" push, 17" recovery lifted up truck
							LOWER TILL					
37.5	10	23	29	35	[illegible]		Same, hard, moist	CL				
							Same as above					
38.5–40.0	11	13	29	38	[illegible]–40.0		Same, hard, moist, w/pc fine gravel					
43.5–45.0	12	30	34	40	43.5–45.0		Same, max ½"					
48.5–50.0	13	21	33	41	48.5–50.0		Same, damp-moist, max. 1½"					

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-121

CEI - Perry Nuclear

PROJECT: Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES

DRILLER: Ed

CLASSIFIED BY: D.B.S. DATE: 6-12-72

SHEET 3 OF 9

DRILL HOLE NO. 1-33

ELEVATION

GWL 0 HRS.

24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50.0					Boulder zone					
		28 40 52			Gray clayey gravel-gravelly clay 40-60% coarse sand-gravel HF					
55.0					Gray shale & some clay, weathered & broken					Weathered zone 54.5-60.0
					Same; fissle					
					———?——— ———?———					
60.0					Gray shale w/thin lt. gray sandstone seams, thin weaker zones & breaks associated w/sandstone lenses, horizontal bedding fractures & some 90° & 30° to bedding	98	[illegible]	10.0	9.8	
70.0					Same w/o 30° fracture	100	98	10.0	10.0	
75.0										

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-122

CEI - Perry Nuclear

PROJECT: Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES

DRILLER: Ed

CLASSIFIED BY: D.B.S. DATE: 6-13-72

SHEET 4 OF 9

DRILL HOLE NO. 1-33

ELEVATION

GWL 0 HRS.

24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75.0										
80.0					Shale w/numerous breaks, pieces 1-3", soft weathered shale zone 3" thick @ 89', bedding fractures & some 30° & 60° to bedding	94	.98	10.0	9.4	
90.0					Gray shale w/few weak zones, occ 30° & 5° fractures, some cross bedding 1" & 2" pc. between 62.5 & 64.0'	97.5	60	10.0	9.75	
100.0										

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-123

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: Ed Secvyk
CLASSIFIED BY: R.P.V. DATE: 6-14-72

SHEET 5 OF 9
DRILL HOLE NO. 1-33
ELEVATION
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100.0–110.0					Gray shale w/sandstone seams w/ weak zone from 103.5-103.9' (crossbedded w/f.sandstone seams)	99	.71	10.0	9.9	
110.0–120.0					Gray shale w/weak zone 17.2-17.4' (soft gray clay w/shale frags) Few sandstone seams	98.25	.73	10.0	9825	
120.0–130.0					Gray shale w/14 sections from ½"-1½" thick of weak,crossbedded shale layers @ 124' and 1½" thick layers of tan sandstone was observed	99	.65	10.0	99	

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-124

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: Ed S.
CLASSIFIED BY: R.P.V. DATE: 6-14-72

SHEET 6 OF 9
DRILL HOLE NO. 1-33
ELEVATION
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
130.0–140.0					Gray shale w/sandstone seams & layers,extensively fractured, some crossbedding,weak zones between 137 & 138 (silty clay w/ shale fragments)some vert. fractures, 60°	93	.45	10.0	9.3	
140.0–150.0					Gray shale - weak zones of gray silty clay w/shale frags @ 140.5' 143', 143.8' & 147.0' shale fractured horizontally	96.5	.56	10.0	9.65	

GAI - 227 12/68

GILBERT ASSOCIATES, INC. 2E-125

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio

SHEET 7 OF 9

DRILL HOLE NO. 1-33

CONTRACTOR: Herron COORDINATES ______

ELEVATION ______

DRILLER: Ed S.

GWL 0 HRS. ______

CLASSIFIED BY: R.V. DATE: 6-15-72

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Core Run	Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
160.0–165.0					Gray shale,50% crossbedded w/clay seams ± 1/8-1/2",some tan bands of sandstone	98	.44	10.0	9.8	
165.0–170.0					Gray shale w/lt.gray sandstone seams,gray clay seam 1/4" thick @ 168.5. Horizontal bedding fractures, but not extensively developed on the 1/4-1/2" scale	99	.73	10.0	9.9	Clay appears lensatic & in sharp contact w/ unweathered shale surface. Clay does not seem to be remenant of weathered shale. Clay is mod-high plas not silty. Has slightly briny taste.
170.0–175.0					Same as above 1/4" clay lens @ 175 slight petroliferous odor on fresh breaks	100	.65	10.0	10.0	

GAI - 227 12/68

GILBERT ASSOCIATES, INC. 2E-126

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 8 OF 9

DRILL HOLE NO. 1-33

CONTRACTOR: Herron COORDINATES ______

ELEVATION ______

DRILLER: Ed

GWL 0 HRS. ______

CLASSIFIED BY: D.B.S. DATE: 6-17-72

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Core Run	Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
175.0–180.0										
180.0–190.0					Same,sandstone zones up to 1' thick (40-50% SS) clay seams: ½" @ 180.1; 2" @ 180.3-180.5; 1" @ 180.65-180.75; ½" @ 181.35-181.38; 2½" @ 181.6-181.8	100	.46	10.0	10.0	
190.0–200.0					Gray sahle w/layers of greywhite fine grained sandstone (thickness 3/16 to 3") 10% crossbedding - 2" clay seam @ 197.5', longest pc. 0.85'	99	.85	10.0	9.9	

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-127

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: Ed Sezwyck
CLASSIFIED BY: R.V. DATE: 6-17-72

SHEET 9 OF 9
DRILL HOLE NO. 1-33
ELEVATION
GWL 0 HRS.
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
							Gray shale, ± 13" crossbedding w/ fine grained sandstone seams. Weak clay seams @ 200.6' & 202.2' Longest pc. 0.7'			10.0	9.8	
												Boring completed

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-128

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES N 780,784.5 E 2,370,123.9
DRILLER: John
CLASSIFIED BY: D.B.S. DATE: 5-17-72

SHEET 1 OF 1
DRILL HOLE NO. 1-34
ELEVATION 622.2
GWL 0 HRS.
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.		Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
												Casing (-64' of 3½" 80g) Installation for Seismic Study. No rock core 60 soil-redrill rate. Base of casing 60' Casing installation time: 3½ hrs. 7:30-11

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-129

SHEET 1 OF 3

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
DRILL HOLE NO. 1-35
CONTRACTOR: Raymond Int. COORDINATES N 780,658.8 E 2,370,152.4
ELEVATION 622.1
DRILLER: Don
GWL 0 HRS. 5.6
CLASSIFIED BY: D.B.S. DATE: 6-5-72
24 HRS 4.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.		Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE SEDIMENTS					1-35 - added by W/G approx. 100' from 1-1 toward 1-24
2.5	1	4	5	7	2.5 / 4.0		Or-brn & gray interbedded silty clay & v.f. sand(non plastic), firm,moist	CL/SM				1-35P - added 17.5' east from 1-35 for pressure meter work. No samples - Harron T.L
5.0	SHELBY #1				5.0 / 7.0		Same as above;more clay,wet	CL/SM				16" Rec
7.5	2	3	5	6	8.5		Same as above	CL/SM				
							——— ? ——— ——— ——— ? ———					
10.0	3	2	2	4	10.0 / 11.5		Gray v.f. sand & interbedded silty clay,stratified,soft, saturated	SM/CL				
12.5												
15.0	SHELBY #2				15.0 / 17.0							24" Rec
17.5	4	6	7	7	18.5		Gray sandy silt & clay	ML				
20.0	5	3	4	6	20.0 / 21.5		Gray v.f.sand & interbedded silty clay,stratified,soft,wet,trace of red clay	SM/CL				
22.5						24.0	——— ? ——— ——— ——— ? ———					
25.0							UPPER TILL					1

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-130

SHEET 2 OF 3

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
DRILL HOLE NO. 1-35
CONTRACTOR: Raymond Int. COORDINATES
ELEVATION
DRILLER: Don
GWL 0 HRS. 5.6
CLASSIFIED BY: D.B.S. DATE: 6-5-72
24 HRS 4.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.		Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25.0	SHELBY #3				25.0 / 27.0		Gray silty clay,5% RF,mostly coarse sand size(1/16-1/4") firm-stiff,moist	CL				19" Rec
27.5	6	3	4	7	28.5			CL				
30.0	SHELBY #4				30.0 / 32.0		Same as above	CL				17" Rec
32.5	7	5	7	9	33.5		Same as above,5-10% RF	CL				
35.0	SHELBY #5				35.0 / 36.0	35.5	Same as above Rf max 1½"	CL				Pushed 21" 18" Rec
							LOWER TILL - same but hard,moist, 10-15% RF					
37.5	8	28	36	39	38.5		Same as above but zones of 90% v.f.sand,and zones of 65-70% coarse sand					
40.0	PITCHER #1				40.0 / 42.2		Same as above, more RF 1/8-1/4"; hard,moist-damp,15-20% RF	CL				
42.5	9	26	39	42	43.7		Same					41' - drilled hard (tube sheared at end) 15" Rec
45.0	PITCHER #2				45.0		Same					19" Rec
47.5	10	16	23	31	47.5 / 49.0		Same, more Rf at ¼-½"	CL				
50.0												

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-131

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Raymond
DRILLER: Don
CLASSIFIED BY: D.B.S.
COORDINATES
DATE: 6-7-72
SHEET 3 OF 3
DRILL HOLE NO. 1-35
ELEVATION
GWL 0 HRS 5.6
24 HRS 4.0

Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	% Rec.	RQD	Core Run	Core Rec.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
PITCHER #3							Rec 26"
11	26 / 125						
		Gray clayey gravel & gravelly clay 45-65% HF					
		CHAGRIN SHALE Gray shale w/lt.gray sandstone, broken in some zones; fractures 11 & to horizontal bedding	81	34	10.0	8.1	Partially weathered zone 59'-64'
		Same as above, unbroken, some thin weak clayey shale zones	104	46	5.0	5.2	
		TOTAL DEPTH					

GAI-XXX 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-132

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Raymond
DRILLER: Don
CLASSIFIED BY: D.B.S.
COORDINATES N 780,210
E 2,369,763.1
DATE: 6-7-72
SHEET 1 OF 3
DRILL HOLE NO. 1-36
ELEVATION 622.8
GWL 0 HRS
24 HRS 3.8

Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	U.S.C.S.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
		LACUSTRINE SEDIMENTS		
1	5 / 6 / 7	Gr-brn. silty clay & fine non-plas sand, moist-wet, soft-firm	CL/ML	
		——— ? ——— ——— ——— ? ———		
SHELBY #1				24" Rec.
2	5 / 5 / 6	Interbedded gray v.f. sand & some silty clay, wet, sat. soft-firm	SM/CL	
3	5 / 7 / 5	Gray clayey silt, unstratified, firm, saturated	ML	
SHELBY #2		Gray silty clay & v.f. sand, interbedded, firm, moist	CL/SM	23" Rec.
4	11 / 18 / 20	Gray clayey silt & v.f. sand, hard, dense, wet	ML/SM	
5	8 / 8 / 11	Same as above, moderately dense	ML/SM	

GAI-XXX 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-133

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Raymond COORDINATES ______
DRILLER: Don
CLASSIFIED BY: D.B.S. DATE: 6-7-72

SHEET 2 OF 3
DRILL HOLE NO. 1-36
ELEVATION ______
GWL 0 HRS ______
24 HRS ______

Sample No.	SPT Blows/6 in. 6	12	18	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	U.S.C.S.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
SHELBY #3				——?—— ——?—— UPPER TILL		22" Rec.
6	8	10	14	Gray silty clay, 5-10% RF, mostly med-coarse sand, max ¾", stiff, moist, trace red clay	CL	
SHELBY #4				Same as above		19" Rec.
7	6	7	11	Same as above	CL	
				LOWER TILL		
SHELBY #5				Same as above, hard, moist-damp 10-15% RF, max ½"	CL	16" Rec.
8	19	30	43	Same, 15% RF damp - dry		
PITCHER #1				Same		16" Rec.
9	28	38	48	Same, dry	CL	
PITCHER #2				Same, 20% RF		26" Rec. (Time ½ hr.)
10	19	32	44	Same 20-25% RF, max 1"	CL	

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-134

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Raymond COORDINATES ______
DRILLER: Don
CLASSIFIED BY: D.B.S. DATE: 6-8-72

SHEET 3 OF 3
DRILL HOLE NO. 1-36
ELEVATION ______
GWL 0 HRS ______
24 HRS 3.8

Sample No.	SPT Blows/6 in. 6	12	18	Soil Description (Density (or Consistency), Color, Soil Type - Accessories)	% Rec.	RQD	Core Run	Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
11	47	64	108						
PITCHER #3				Gray sandy clay, gravely clay, v. hard, dry					17" Rec.
12	19	39	58	Same as above, max 1½"					
PITCHER #4				Gray clayey gravel, 50-60% RF					10" Rec.
13	160								
PITCHER #5				Same, max. 3"					
14	100/2"			CHAGRIN SHALE					
				Gray shale, slightly weathered to 64', horizontal bedding joints some normal to bedding	97	.59	10.0	9.7	
				Same, thin SS seams, horizontal bedding joints & some 75° and 10° to bedding, weak, soft shale zone 74-75	98	.5	5.0	4.9	

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-135

PROJECT: CEI, Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio
CONTRACTOR: Herron COORDINATES N 780,224 E 2,369,808
DRILLER: L. Humphrey
CLASSIFIED BY: R.P.V. DATE: 7-29-72

SHEET 1 OF 4
DRILL HOLE NO. 1-36P 2
ELEVATION 622.8
GWL 0 HRS.
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% RECOVERY	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–58.5								585		Pressuremeter hole - no sampling from 0-58.5' Pressuremeter tests in soil @ 45', 50', 55'
58.5–63.5 (60)					Gray shale, extensively crossbedded some fine grained sandstone seams fractured clay seam @ 60.2'	40	0	5.0 635	2.0	Longest core section 2"
63.5–68.5 (65)					Gray shale, some cross bedding w/fine grained sandstone seams	100	.51	5.0 685	5.0	L.C.S. 12"
68.5–73.5 (70)					Same	100		5.0 735	5.0	L.C.S. 10"
75										

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-136

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: L. Humphrey
CLASSIFIED BY: R.P.V. DATE: 7-29-72

SHEET 2 OF 4
DRILL HOLE NO. 1-36-P2
ELEVATION 622.8
GWL 0 HRS.
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% RECOVERY	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75					Gray shale, crossbedded, few fine grained sandstone seams	100	.38	5.0 78.5	5.0	Longest Core Section 10"
80					Gray shale, some cross bedding w/fine grained sandstone seams-massive	100	.76	5.0 835	5.0	L.C.S. 12"
85					Same	99		5.0 885	495	L.C.S. 12"
90–95					Gray shale, some crossbedding, occasional fine grained sandstone seams, few 90° fractures	90		10.0 985	9.0	L.C.S. 10"
100										

GAI - 227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio

CONTRACTOR: Herron COORDINATES

DRILLER: L. Humphrey

CLASSIFIED BY: R.P.V. DATE: 7-29-72

SHEET 3 OF 4
DRILL HOLE NO. 1-36-P2
ELEVATION 622.8
GWL 0 HRS.
24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% RECOVERY	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100								97	.82	5.0 (103.5)	4.9	L.C.S. 10"
105							Gray shale, horiz. bedded, w/fine grained sandstone seams	100	.70	5.0 (108.5)	5.0	L.C.S. 9½" Recovered 1" from previous run
110							Same	98		10.0 (118.5)	9.9	L.C.S. 10"
115												
120							Gray shale, Horiz. bedded, occ. crossbedding w/few fine grained sandstone seams - some 90° fractures	100		10.0	5.0	L.C.S. 10.5
125												

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio

CONTRACTOR: Herron COORDINATES

DRILLER: L. Humphrey

CLASSIFIED BY: R.P.V. DATE: 7-29-72

SHEET 4 OF 4
DRILL HOLE NO. 1-36-P2
ELEVATION 622.8
GWL 0 HRS.
24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% RECOVERY	R.Q.D.	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
125										(128.5)		
130							Gray shale, few layers of tan siltstone, some crossbedding w/ fine grained sandstone seams up to 2" thick	97	.78	10.0 (138.5)	8.1	L.C.S. 9"
135												
140							Gray shale, some fine grained sandstone seams, massive	100	.67	5.0 (143.5)	5.0	L.C.S. 10"
145							Gray shale, some fine grained sandstone seams, massive	95	.73	5.0 (148.5)	4.7	L.C.S. 105"
150							End of Boring					

GAI-227 12/68

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-139

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. 1-37A

CONTRACTOR: Herron COORDINATES ______

ELEVATION 621.3

DRILLER: Ed Sezwyck

GWL 0 HRS ______

CLASSIFIED BY: ______ DATE: 11-13-72

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in.	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil or Rock	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–13.0									Moved 3' east after completion of boring to take shell by tube samples
13.0–15.0	ST	3-1	13.0 / 15.0						
20.0–22.0	ST	3-2	20.0 / 22.0						
28.0–30.0	ST	3-3	28.0 / 30.0						
30.0–32.0	ST	3-4	32.0						

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-140

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 3

DRILL HOLE NO. 1-37

CONTRACTOR: Herron COORDINATES N 780,545 E 2,369,875

ELEVATION 621.3

DRILLER: Ed Sezwyck

GWL 0 HRS 4.0

CLASSIFIED BY: D.B.S. DATE: 11-1-72

24 HRS 2.0

Depth Ft.	Sample No.	SPT 6	SPT 12	SPT 18	Profile	Description	U.S.C.S.	R.Q.D.	Remarks
2.5–4.0	1	3	4	4		Or-Brn. v.f.sandy silty clay, firm, moist	CL		* Waxed split sample
5.5–7.0	2	1	1	1	8.0	Layers or.brn.f.sand & brn-grey silty clay, soft wet-saturated	SP/CL		Roller bit used to advance hole
8.5–10.0	3	2	3	4		Grey clayey silt w/layers f.sand & silty clay, firm, wet	ML/SP/CL		
11.5–13.0	4	1	2	3		Grey clayey silt, 3" f.sand, wet, soft	ML/SP		
14.5–16.0	5	3	2	4		Same, w/1/8" layers sand interspersed	SP/CL		
17.5–19.0	6	4	5	9		Grey f.sand, clayey silt, silty clay, w/tr.blk.organics, laminated, stiff, moist			
20.5–22.0	7	5	6	7		Same as above w/red silty clay			
23.5–25.0	8	3	5	7		Same as above, less sand	CL	*	
26.5–28.0	9	3	6	8	27.5	Same, w/tr.crse.RF	CL		
29.5–31.0	10	3	5	9		Grey silty med.sandy clay; 5% RF stiff moist, tr.red clay	CL	*	
32.5–34.4	SHELBY								ST3-1 Push 2' Rec. 9' Pushed 32.5-34.5
34.9	11	10	14	20	35.0	Same; v.stiff 2" layer of silty crse.sand			
37.5–39.0	12	17	43	57		Grey clayey med.-crse.sandy silt; hard, damp; 20-25% RF, max. 1/2"	ML	*	
40.5–42.0	13	21	33	38		Same as above			
43.5–45.0	14	15	25	28		Same			
46.5–48.0	15	20	27	37		Same; except damp-moist & v.stiff-hard; 1" silty crse.sand layer		*	

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET 2E-141

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio
SHEET 2 OF 3
DRILL HOLE NO. 1-37
CONTRACTOR: Herron COORDINATES ______
ELEVATION 621.3
DRILLER: Ed Sezwyck
GWL 0 HRS 4.0
CLASSIFIED BY: D.B.S. DATE: 11-1-72
24 HRS 2.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50	16	20	38	142	51.0		Same;25-30% RF,damp-moist,hard cobble 51-51.5					
					52.5							
	17	23	50	85	54.0	54.2	Grey f.gravelly-red sandy clayey silty clay 40-50% RF,max. 1", hard,damp	silt/ ML-CL				
55					55.5 / 55.6					56.0		
60							Grey shale w/lt.grey SS seam, broken & clayey weathered shale zones thruout run;approx. 1.3' of solid shale in run	41		10.0	4.1	L.P. 0.4 S.P. N/A Avg. .15 Methane 0.25%
65						66.0				66.0		
70							Grey shale,massive,no fractures or weak zones (core broken to fit in box),lt.grey thin SS seams, a few dense tan zones (aphantic, not fissile,denser than shale, unsiliceous,in gradational contact w/shale,1/4-3/4" thick; mud stone?)	100		10.0	10.0	L.P. 3.87' S.P. 0.16 Avg. 1.0 Methane 0.1%
75										76.0		
80							Same as above; 1/4" weak shale zone w/30' hairline fracture & v.thin clay parting at 77.9	96		10.0	9.6	L.P. 1.20 S.P. 0.03 Avg. 0.60
85										86.0		
90							Same;seams of sandstone up to 2" thick at 90.8, 91.7, 93.0; hairline fracture 20° at 95.0', no apparent weak zones [A M-402 Methanometer was used to detect concentration of methanometer (CH_4) gas. Generally the boring was bailed down to the detection depth.]	96		10.0	9.6	L.P. 2.8 S.P. 0.09 Avg. 0.90
95										96.0		
100												

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET 2E-142

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio
SHEET 3 OF 3
DRILL HOLE NO. 1-37
CONTRACTOR: Herron COORDINATES ______
ELEVATION 621.3
DRILLER: Ed Sezwyck
GWL 0 HRS 4.0
CLASSIFIED BY: D.B.S. DATE: 11-1-72
24 HRS 2.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100 / 105							Same; est. 10-15% sandstone seams slightly broken & clayey at 97.3-97.5; near vertical fracture 98.7-99.1,102.2-102.4,104.0-104.2; broken & clayey zone 105.1-105.2	100		10.0	10.0	L.P. 1.15
										106.0		
110 / 115							Same;est. 10-15% sand seams; suspected zone of clay seams between 111.9-112.9 (slight oxidation in a sand seam & 0.02' clay seam at approx. 112)	96		10.0	9.6	L.P. 1.52 S.P. 0.04 Avg. 0.8 Clay is slightly silty & in sharp contact w/shale
										116.0		
120 / 125							Same; est. 15-20% sandstone seams max. thickness of sand 0.2' irregular fracture 125.2-125.4 @ 60°, near vertical fracture 125.9-126.	- 99		10.0	9.9	L.P. 3.10 S.P. 0.10 Avg. 0.90
										126.0		
130 / 135							Same;broken at 126, clay seams 0.1' thick at approx. 129, 135, some minor clay seams between, slightly broken at approx. 132.	86		10.0	8.6	L.P. 0.95 S.P. 0.02 Avg. 0.50
										136.0		
140 / 145							Same; est. 20-25% SS thruout max. SS thickness 0.2',small 60° fracture at approx. 142	100		10.0	10.0	L.P. 2.42 S.P. 0.02 Avg. 1.0
										146.0		
150							Same as above;methane 5% after bailed dry - open flame, no odor			4.0		L.P. 2.2 S.P. .35 Avg. .8
										150.0		

T.D. 150' - hole bailed dry

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-143

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 2

DRILL HOLE NO. 1-38

CONTRACTOR: Herron

COORDINATES N 780,490 E 2,369,915

ELEVATION 622.1

DRILLER: Ed Sezwcyk

GWL 0 HRS 4.5'

CLASSIFIED BY: D.B.S.

DATE: 10-17-72

24 HRS 3.5'

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D. % Rec.	Soil Or Rock Range Size / Core Run	Grain Shape / Core Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												* split & waxed dample
	1	3	4	6			Or-brn.&grey V.F.sand & clayey silt,firm,moist	SM-ML				
5												4.5 Flowing Water
	2	3	3	3			Same, saturated					
10	3	3	4	7			Grey V.F. sand & silt,firm-dense, saturated	SM-ML				
	4	2	4	3			Same,mostly of sand,wet, laminated,tr.clay					
15	5	4	4	7			Same as above					
	6	[illegible]	[illegible]	10			Same,stiff,tr.organic clay					
20												
	7	8	9	12			Same					
25	8	4	7	8			Grey silty clay w/some v.f. sand, thinly laminated,moist,firm-stiff, red laminae,tr.sub-round pebbles	CL				
	9	3	5	7		27.5	Same	CL				
							Grey silty clay w/5-10% med.sand RF.,moist,stiff					
30	10	2	4	4			Same,max.½",angular-subround, soft-firm					
	11	4	6	7			Same,stiff, 10-15% RF					
35						36.0						
	12	3	9	12			Grey clayey silt,10-15% RF,v. stiff-hard,moist,max. ½"	ML/SC				
40	13	12	19	30			Same,appears dry-damp,hard, increase in coarse fraction, 15-20% RF					
	14	14	17	21			Same as above					
45	15	14	17	24			Same as above					
	16	14	24	25			Same					
50												

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-144

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 2 OF 2

DRILL HOLE NO. 1-38

CONTRACTOR: Herron

COORDINATES

ELEVATION

DRILLER: Ed Sezwcyk

GWL 0 HRS

CLASSIFIED BY: D.B.S.

DATE: 10-17-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D. % Rec.	Soil Or Rock Range Size / Core Run	Grain Shape / Core Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50	17	24	27	32			Same; 20-25% RF; max 1"			52.0		
							Grey clayey gravel	GC				
55												* sample 56.5
						56.5	Grey shale,shale frags & clay, weathered,fractured & broken zones,fractures 45°,60°,90°			10.0		L.P. 0.7 S.P. 0.04 Avg. .4
60						60.3	Grey shale w/thin lt.grey siltstone seams,horizontal bedding, and weathered		70	62.0	7.0	L.P. 0.4 S.P. 0.2 Avg. 0.3
65							Same;unweathered except at 71.3 - weathered shale lens (appears like clayey f.gravel - due to redrill over weak zone?)			10.0		Core fall out thru retainer, had to redrill therefore poor recovery
70									92	72.0	9.2	L.P. 1.5 S.P. .05 Avg. .6
							Same;no broken or weathered zones			5.0		
75									98	77.0	4.9	L.P. 2.7 S.P. .2 Avg. 1.5
							T.D. 77.0'					
80												

GAI - 227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

CEI - Perry Nuclear

PROJECT: Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio SHEET 1 OF 2
CONTRACTOR: Herron COORDINATES N 780,600 DRILL HOLE NO. 1-39
DRILLER: Larry Humphrey E 2,369,870 ELEVATION 621.3
CLASSIFIED BY: R.E.L. DATE: 10-16-72 GWL 0 HRS 5.3' @ 13:30
24 HRS 3.6'

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	% Rec. / R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0	1	2	5	5			Brown mottled v.f. sandy silt, damp to moist, v.thin horizontal layering	ML				
5	2	5	8	10		6.5	Gray silty v.f. to fine sand and gray brown silt w/little clay in approx. ½" alternating layers moist to wet	SM to ML				
10	3	4	4	6		11.0						
	4	2	3	3		14.0	Gray clayey silt w/few thin silty sand layers, moist-wet, soft sl. to mod.plas., mod.dry breaking strength	ML				
15	5	2	2	2			Gray fine sandy silt, soft to med. moist to wet	ML				
20	6	4	5	8			Grey silty fine sand to f.sandy silt w/tr.clay, moist, layered	SM-ML				
25	7	4	6	9		27.0	Gray silt w/tr.clay & gray silty f.sand in approx. 2" layers, moist to wet tr. of reddish colored streaking	SM to ML				
30	8	2	6	7			Gray silty clay w/est. 15% c.sand size pcs shale, damp to moist slightly to mod.plas., med.cons.	CL				
35	9	5	8	9		36.0	Gray silty clay w/est. 15-20% c. sand size pcs shale, damp to wet, soft to med.stiff, red colored streaks	CL				Two variaties of material
	10	13	19	26			Gray sandy silt w/est. 30% coarse sand & f.gravel, mostly sh.pcs. dry to damp, v.stiff	ML				
40	11	16	24	31			Gray sandy silt w/some fine gravel, sand vanes from f.to c.gr. dry to damp, v.stiff					
45	12	16	22	30			Same as above					
50	13	15	21	27			Gray sandy silt w/some gravel up to ½", est. 5-10% gravel, est. 20% sand, dry to damp, v.stiff					

GAI - 227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

CEI - Perry Nuclear

PROJECT: Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio SHEET 2 OF 2
CONTRACTOR: Herron COORDINATES DRILL HOLE NO. 1-39
DRILLER: Larry Humphrey ELEVATION
CLASSIFIED BY: R.E.L. DATE: 10-16-72 GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	% Rec. / R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50							Gray gravelly sandy silt w/a few cobbles up to 3", v.hard glacial till. Shale boulders up to 1 ft. thick interspersed in gravelly till - exhibit only slight weathering and horizontal bedding		56	5.0 / 55.0	2.8	
55							Same as above		71	5.0 / 60.0	3.55	
60							Gray glacial till - weathered bedrock contact between 60 & 62.5		40	2.5 / 62.5	1.0	
65							Gray shale w/thin fine grained sandstone layers, some grinding of core through spinning masks any zones of weakness		77	6.0 / 68.5	5.9	L.P. .62' SP .05' Avg. .20'
70							Same as above w/a few weak zones up to .05' and a weathered zone from 72.5 to 73.05		100	9.0 / 77.5	9.0	L.P. .9' S.P. .02' Avg. .35'
75												
80							Boring terminated @ 77.5' in gray shale					

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 046549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES N 780,480 E 2,369,990

DRILLER: Lynn Lease

CLASSIFIED BY: D.B.S. DATE: 10-31-72

SHEET 1 OF 2 DRILL HOLE NO. 1-40 ELEVATION 622.2 GWL 0 HRS 4.0 24 HRS 1.8

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					2.5							* Waxed split samples
	1	2	3	4	4.0		Or-Brn. w/grey mottling, clayey silt & layers silty f.sand, moist, firm	ML/SM				
5					5.5							
	2	5	7	9	7.0	7.0	Same; Or.-Brn., tan, Brn.mottling, wet					
					8.5							
10	3	3	4	4	10.0		Same as above; grey					
					11.5							
	4	7	6	7	13.0		Same as above					
15					14.5							
	5	5	10	11	16.0		grey clayey v.f.sandy silt, stiff moist-wet					
					17.5							
	6	3	10	8	19.0		grey clayey silty v.f.cond., dense moist-wet					
20					20.5							
	7	12	23	28	22.0	21.5	Grey silty f.sand, v-dense, moist-wet, well carted: grey w/red laminae silty clay; 1-3% med.-crse. sandy RF stiff moist	CL				
					23.5							
25	8	3	4	6	25.0				*			
					26.5							
	9	3	5	8	28.0		Same as above, Max. RF 1/2"		*			
30					29.5		Same, retains laminations, 5% med.-crse.					
	10	5	7	9	31.0	30.5			*			
					32.5		Grey silty med.-v.crse. sand clay; unlaminated; 5-10% RF, max. 1/2", sub. ang.-sub. rnd; firm-stiff moist-wet	CL				
	11	2	3	3	34.0				*			
35					35.5							
	12	4	7	16	37.0		Same; 10-15% RF, stiff-v.stiff, moist max. RF 3/4"		*			
					38.5	37.5		ML				
40	13	22	29	36	40.0		Grey clayey crse.-verse sandy silt; damp-dry, hard, 20-25% sub. ang. RF		*			
					41.5							
	14	25	39	39	45.0		Same		*			
45					44.5							
	15	9	16	25	46.0		Same		*			
					47.5							
	16	13	24	44	49.0		Same		*			
50												

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 046549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES

DRILLER: Lynn Lease

CLASSIFIED BY: D.B.S. DATE: 11-1-72

SHEET 2 OF 2 DRILL HOLE NO. 1-40 ELEVATION 622.2 GWL 0 HRS 4.0 24 HRS 1.8

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50	17	24	100	–	50.5		Same, 25-35% RF		*	51.5		
						54.2	till & gneiss cobble			3.75	1.0	
55							Grey shale, weathered, broken			55.25		L.P. 0.3
							Same, Clay seams, fractured			5.25	2.3	L.P. 0.3
60										60.5		
							Grey shale & SS; numerous fractured zone & weathered clayey shale zones			5.5	2.2	L.P. 0.3' Methane 0.0%
65										66.0		
							Same as above	50		3.0	1.5	L.P. 0.84
70										69.0		
							Same			2.5	0.4	Suspected defect in core barrel- silty cuttings accumulate around core causing plugging of barrel.
										71.5		
							Same			4.0	1.4	
75						75.0				75.5		
							Grey shale & SS seams appears fresh & generally unweathered, no broken zones, methane 0.15%; L.P. .60, S.P. .05, Avg. .40	100		5.0	5.0	Unprecedented poor recovery- discovered that remaining shell was missing from barrel!
80										80.5		
							Same as above; a few, hairline clay partings. L.P. .65, S.P. .03, Avg. .40	100		4.5	4.5	
85										85.0		
							Same as above;	100		4.5	4.5	L.P. .65 S.P. .06 Avg. .30 Methane 0.1%
90										89.5		
							T.D. 89.5'					
95							[A M-402 Methanometer was used to detect concentration of methanometer (CH_4) gas. Generally the boring was bailed down to the detection depth.]					
100												

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-149

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES N 780,410 E 2,369,930

DRILLER: Larry Humphrey

CLASSIFIED BY: D.B.S. DATE: 10-17-72

SHEET 1 OF 2

DRILL HOLE NO. 1-41

ELEVATION 622.9

GWL 0 HRS 7.5

24 HRS 6.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D. % Rec.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												* Samples split and sealed in wax
	1	2	2	5			Or-brn&grey mottled f.sand & some clay, firm-stiff, moist to wet in lower portion	SM/SC?				
5	2	4	5	7		7.0	Brn.&org-brn & sand lenses, silt & clay layers, stiff-moist	SM/ML?				
10	3	5	4	5			Grey v.f.sand w/interbedded thin layers of silt & clay; saturated, dense	SM/ML/CL?				
	4	2	2	4			Same; soft, less sand					
15	5	3	3	5			Same, mostly clayey silt but inter-bedded v.f. sand, saturated					Higher blow counts here appear to reflect more v.f. sand
	6	6	9	15			Same, mostly v.f. sand					
20	7	3	8	8			Same, mostly v.f. sand & silt, saturated					
25	8	6	7	6			Same; moist-wet, dense, thin layers 1/16"					
	9	4	6	7		29.0	Same, moist, some red clay laminae					
30	10	4	6	8			Grey silty clay, 5% med-crse. shale RF, firm, moist	CL				
	11	4	5	7			Same, 10-15% RF max 1/4"					
35						36.0	Same; max. 1/2"					
	12	5	15	19			Grey v.dense silt, no RF; thin v. dense c.sandy clay; max. ¼" approx. 8-12" thick, appears almost homogeneous	CL/ML				marker horizon also seen on beach cliffs
40	13	13	18	21			Grey clayey silt, 10-15% RF hard, damp					
	14	19	25	29			Grey v.dense f.sand & silt lens @ 42; then till w/20-25% RF, hard, dry					
45	15	13	20	28			Grey hard c.-med. sandy clayey silt; 10-15% RF, max. 1/4"					
	16	12	18	28			Same as above; sub-ang. to sub-round RF					
50												

GAI - 227 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-150

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES

DRILLER: Larry Humphrey

CLASSIFIED BY: D.B.S. DATE: 10-17-72

SHEET 2 OF 2

DRILL HOLE NO. 1-41

ELEVATION 622.9

GWL 0 HRS 7.5

24 HRS 6.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D. % Rec.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50							Grey clayey gravelly sand 60-70% coarse sand-f.gravel, hard, damp, cohesive			52.0 / 53.0		L.P. .15'
55						57.5				5.0 / 58.0		
60						64.0	Grey shale & clay - weathered and broken in zones		58	6.0 / 64.0	3.5	L.P. 0.25 S.P. .03 Avg. .20
65							Grey shale & lt.grey siltstone 0.2' vertical fracture @ 66.0' 45° fractures at 66.4, 68.7, 68.8, 60° fracture at 70' weathered and broken zone 0.1' at 67.0		81	10.0 / 74.0	8.1	Lost some in hole, slipped thru retainer L.P. 0.65 S.P. 0.04 Avg. 0.4
75							Same, unweathered, unbroken		115	6.0 / 80.0	6.9	Recovered approx. 0.9' from run 64-74
80							T.D. 80.0' [A M-402 Methamometer was used to detect concentration of methanometer (CH_4) gas. Generally the boring was bailed down to the detection depth.]					Methane 1.15%

GAI - 227 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 3

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-42

CONTRACTOR: Herron COORDINATES N 780,347 E 2,369,947

ELEVATION 623.4

DRILLER: Ed Sezwyck

GWL 0 HRS See hydrologic data sheet 1-42

CLASSIFIED BY: D.B.S. DATE: 10-24-72

24 HRS 2.4'

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D. % rec.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												
	1	4	4	6			Or-brn w/grey mottle,f.sandy silty clay & clayey f.sand;firm moist-wet	CL/SC				
5	2	2	3	2			Greyish brn. f.sandy,clayey silt, firm,wet	ML				
10	3	3	1	2			Same as above-grey;w/some layers f.sand	ML/SM				
	4	5	6	8			Grey layers silty clay,f.sand, silt,firm,wet	CL/SP/ML				
15	5	SHELBY		#1			Same					3" Shelby-24" REC
	6	4	6	6			Same					
20	7	4	5	6			Same					21' of 5" casing installed
25	8	8	9	6			Same					
	9	1	2	2			Grey laminated v.f. sand & clay silt some red clay,wet,soft					3" Shelby pushed 2' REC 1.3'
30						30.5						
	10	SHELBY		#2								
	11	3	5	7			Grey silt clay,5-10% med.-crse. sand size RF,moist-wet,firm-stiff	CL				
35	12	5	8	14			No recovery					3" Shelby pushed 12" rig stood up Rec. 12"
		SHELBY		#3		37.5						
	13	12	21	28			Grey med.-v.crse.sandy clay/silt, v.stiff-hard 15-20% RF,damp,max. 1/2"	CL/ML				
40	14	23	31	33			Same; 20% RF					
45	15	19	29	30			Same 20-25% RF hard					
	16	21	29	34			Same as above					
50	17	9	30	40			Same as above					

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 3

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-42

CONTRACTOR: Herron COORDINATES

ELEVATION 623.4

DRILLER: Ed Sezwyck

GWL 0 HRS See hydrologic data sheet 1-42

CLASSIFIED BY: D.B.S. DATE: 10-24-72

24 HRS 2.4'

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D. % rec.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50												
	18	32	43	64			Grey v.crse-f.gravelly silty clay, moist-damp,v.stiff-hard;35-45% RF,max.1½"	CL/GC				
55						55.5				55.5		
							Grey shale,weathered,relatively soft,damp					L.P. .45
60							Grey shale,broken & weak shale zones		92	5.0 / 60.5	4.0	S.P. - Avg. .25
65							Grey shale,recovered 1.1' of solid shale;(9' weak clayey shale, inclined 20°,broken,weathered		40	5.0 / 65.6	2.0	L.P. .50 S.P. - Avg. .3
70							Grey shale w/lt.grey siltstone seams,also lt.brn-grey layers of v.dense v.fg.sandstone 1/2" thick; thin clay partings at 66.5,71.6, 72.0,72.1,70.1. Moderately weathered shale zone at 75-75.5 (weak clayey shale) Hairline fracture 75° at 67'		73	10.0 / 75.6	9.3	L.P. 0.55 S.P. 0.02 Avg. 0.35 Methane 0.2%
75						78.1	Some shale,vertical fracture 86.5-87.5,broken & weak shale zones 75.5-76.3 also 76.8-77.1 and 77.8-78.1					
80							Fresh shale		95	10.0 / 85.5	9.5	L.P. 1.4 S.P. 0.03 Avg. .6 Black oily foam in drill wash
85							Grey shale;fresh,thin weak shale 92.8-92.9,lt.grey siltstone seams					L.P. 2.3'
90							[A M-402 Methanometer was used to detect concentration of Methanometer (CH_4) gas. Generally the boring was bailed down to the detection depth.]		98.5	10.0 / 95.5	9.85	S.P. 0.1 Avg. 0.9 Methane 0%
95												
100												

GAI-227 8/72

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.

CEI - Perry Nuclear SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES
DRILLER: Ed Serwyck
CLASSIFIED BY: D.B.S. DATE: 10-20-72

SHEET 3 OF 3
DRILL HOLE NO. 1-42
ELEVATION 623.4
GWL 0 HRS See hydrologic data sheet 1-42
24 HRS 2.4'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	% R.Q.D. / % Rec.	Core Run	Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100					Grey shale, unweathered, unbroken w/lt.grey SS & siltstone seams, soft shale zone 0.1' thick @ 99', ½" clay seam at 89'		94	10.0 / 105.5	9.4	L.P. 2.2 S.P. 0.1 Avg. 0.5 Clay seam appears to be bedded and in sharp contact w/shale
105					Same; 2" sandstone at 107.5 60° fracture 108.7-109.2 (irregular) sharp 45° fracture at 111.3-111.5 vertically fractured 111.5-112.8		98.5	10.0 / 115.5	9.85	L.P. 0.95 S.P. 0.04 Avg. 0.3 Seems to be definite cleavage or fracture zone closed joints
115					Same; broken 115.5-115.9 &119.6-119.8; slight weak zone @ 116.2-116.3; sandstone/siltstone seams numerous - 15% of run although no thicker than 0.1'		97	10.0 / 125.5	9.7	L.P. 0.75 S.P. 0.03 Avg. 0.035
125					Same; est. 20% sandstone/siltstone, v.thin clay seam 126.1, fractured 60-90° @ 132.5-133.1		97.5	10.0 / 135.5	9.75	L.P. 0.6 S.P. 0.02 Avg. 0.40
135					Same; est. 20-25% sandstone; clay seam 142.05-142.12 (med-hi plastic non silty clay)		94.5	10.0 / 145.5	9.45	L.P. 0.95 S.P. 0.04 Avg. 0.60 No petroliferous odor on freshly broken shale
145					Same; thin weak shale zone 145.5-145.6; v.dense shale, 20-25% sandstone/siltstone.		100	4.5 / 150.0	4.5	Methane 0.0% L.P. 0.65 S.P. 0.03 Avg. 0.35
150					T.D. 150.0'					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

CEI - Perry Nuclear SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron COORDINATES N 780,285 E 2,369,950
DRILLER: Ed Serwyck
CLASSIFIED BY: D.B.S. DATE: 10-19-72

SHEET 1 OF 2
DRILL HOLE NO. 1-41
ELEVATION 623.6
GWL 0 HRS 9.0
24 HRS 3.5

Depth Ft.	Sample No.	SPT 6	SPT 12	SPT 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0	1	3	4	4			Or-brn. w/grey mottling silty f. sand and clayey silt, wet, dense, 2" layers					* Sample split and sealed in wax
5	2	5	7	9		4.5	Or-brn grading to grn/grey, mostly silt & f.sand, wet, dense					
10	3	4	5	6			Same; grey	ML				
	4	5	10	12			Grey f.sand, wet-moist, v.dense					
15	5	4	5	5			Grey v.f.sand & clayey silt, saturated, dense					
	6	7	8	8			Same; moist-wet					
20	7	4	5	7			Same as above; thin layers ½", tr. organics and red clay					
25	8	5	12	15			Grey f.sand; some silt & clayey silt; saturated, dense, unstratified; tr.red clay					
	9	4	13	21			Red & grey laminated silty clay & some f.sand, moist, v.stiff					
30	10	4	7	10		31.0	Same; little or no f.sand at top; f.sand & RF 5-10% near 31'					
	11	4	8	10			Grey med.-crse.sandy silty clay; v.stiff, moist, 10% subang-subrnd. RF, max. ½"					
35	12	8	12	16		37.0	Same as above, stiff-v.stiff					
40	13	14	25	25			Grey med.-v.crse.sandy clayey silt, hard, dry-damp, 15-20% sand & RF: 1/8-1/2"					
	14	25	27	34			Same; slightly greater % of coarse fraction, damp, v.stiff-hard					
45	15	18	24	35			Same					
50	16	16	27	34			Same; RF mostly 1/8-1/4"					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 2 OF 2

DRILL HOLE NO. 1-43

CONTRACTOR: Herron COORDINATES ______

ELEVATION 623.6

DRILLER: Ed Sezwyck

GWL 0 HRS 9.0

CLASSIFIED BY: D.B.S. DATE: 10-20-72

24 HRS 3.5

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50	17	27	37	95			Same;increase in % & size of coarse fraction; max. 2"			52.0		
55											0.6	Poor recovery in till & weakh shale
						57.0	— ? — ? — ?		52	10.0		Little or no weath. shale
60							Grey shale & thin lt. gray silt-stone seams,generally unbroken & unweathered weak shale zone .2' thick at 59.0			62.0	4.6	L.P. 0.9 S.P. 0.03 Avg. 0.4
65							Same; 1" weak clayey shale zone @ 62.85 & a 1/4" zone at 63.55 and thin clay partings at 65.90		72.5	10.0		L.P. 1.55 S.P. .08
70										72.0	9.35	
75							Same;broken zone 72.5-72.7; vertical fracturing between 73.3 and 76.0,tr. of clay along fracture between 74.3 & 75.0		98	5.0 77.0	4.9	L.P. .95 S.P. .10 Avg. .5
							T.D. 77.0'					Methane: 0.11%
80							[A M-402 Methamometer was used to detect concentration of methanometer (CH_4) gas. Generally the boring was bailed down to the detection depth.]					

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 2

DRILL HOLE NO. 1-44

CONTRACTOR: Herron COORDINATES ______

ELEVATION 623.2

DRILLER: Ed Sezwyck

GWL 0 HRS. 15.0

CLASSIFIED BY: D.B.S. DATE: 10-21-72

24 HRS 1.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0.0					2.5							* Sample sealed in wax
	1	3	4	4			Or.brn. & mottled grey layers clayey f.sand and silty clay, firm,stiff,moist					Water @ 4.1'
5.0					5.5							
	2	2	4	5		6.5						
					8.5		Grey f.sand w/layers clayey silt, 1/4-1" layers,firm-moist-wet					
10.0	3	2	3	6			Same, saturated					
					11.5							
	4	2	3	4			Same, mostly clayey silt & silty clay, little f.sand					
					14.5							
15.0	5	2	2	5			Same					
					17.5							
	6	5	13	14			Grey silty f.sand, saturated,v. dense					
20.0					20.5							
	7	3	6	10			Grey silty clay/clayey silt;some f.sand layered,wet firm;tr. red clay					
					23.5							
25.0	8	4	10	19			Grey f.sand, some layers silty clay, wet, dense/firm					
					26.5							
	9	4	3	4			Grey silty clay; tr. red clay & RF, laminated, soft, wet		*			
					29.5	28.0						
30.0	10	3	4	6			Grey silty clay 3-5% med.-crse. sand size RF, soft-firm,wet		*			
					32.5							
	11	3	5	4			Same as above; max 1/2" RF					
35.0					35.5	36.5	Same as above					
	12	6	11	20			Grey clayey, med.-v.crse.sandy silt,hard,damp-moist		*			This sample split - boundary
					38.5							
40.0	13	14	23	30			Same; 15-20% RF - max. 3/4"					
					41.5							
	14	20	26	41			Same; 20-25% RF - max 1"					
					44.5							
45.0	15	20	30	50			Same as above					
					47.5							
	16	23	28	35			Same as above - max. 1½"					
50.0												

GAI - 227 12/68

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-157

PROJECT:	CEI - Perry Nuclear Power Plant
W.O.	044549-000
SITE AREA	N. Perry, Ohio
CONTRACTOR:	Herron
COORDINATES	
DRILLER:	Ed Sezwyck
CLASSIFIED BY:	D.B.S.
DATE:	10-21-72
SHEET	2 OF 2
DRILL HOLE NO.	1-44
ELEVATION	623.2
GWL 0 HRS	15.0
24 HRS	1.0

Depth Ft. (50)	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
	17	32	37	63	50.5 – 52.0		Same;25-30% RF			52.0		
55						56.0	Same 30-40% sand-f.gravel	30		5.0	1.5	Coarse till probably not recovered 16" till sample wrapped & sealed
							Grey shale;fractured 57-59',soft clayey shale zones numerous up to 61.3'			57.0		
60								90		5.0	4.5	
						60.9	Gray shale & lt.grey siltstone seams,unbroken,unweathered,thin clay seam at 67'			62.0		L.P. 1.95 S.P. .05 Avg. .8
65								97		10.0	9.7	
70										72.0		
75							T.D. 72'					40' plastic perforated pipe installed
80												
85												
90												
95												
100												

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-158

PROJECT:	CEI - Perry Nuclear Power Plant
W.O.	044549-000
SITE AREA	N. Perry, Ohio
CONTRACTOR:	Herron
COORDINATES	N 780,490 E 2,369,725
DRILLER:	Lynn Lease
CLASSIFIED BY:	D.B.S.
DATE:	10-30-72
SHEET	1 OF 2
DRILL HOLE NO.	1-45
ELEVATION	621.5
GWL 0 HRS	6.0
24 HRS	1.7

Depth Ft. (0)	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
	1	2	3	4	2.5 – 4.0		Or.brn. w/grey mottling clayey f. sand & silt,firm,moist	ML/SM				
5	2	8	6	5	5.5 – 7.0		Brn.clayey silt & some v.f.sand, firm-stiff,moist	ML/SM				
10	3	7	9	13	8.5 – 10.0		Grey silt & v.f.sand,some silty clay layers,saturated,med.-dense	ML/SP/CL				
	4	2	4	5	11.5 – 13.0		Grey clayey silt,wet,firm	ML				
15	5	4	7	9	14.5 – 16.0		Grey laminated silty clay & silty f.sand,firm-stiff,moist	CL/SM				
	6	2	3	6	17.5 – 19.0		Same,wet					
20	7	5	10	9	20.5 – 22.0		Grey f.sand,some layers silty clay saturated,mod.dense	SP/CL				
25	8	2	3	5	23.5 – 25.0		Grey silty clay,some red clay laminae,firm,wet	CL				
	9	2	3	5	26.5 – 28.0	26.5	Grey silty med.-crse.sandy clay, firm-stiff,moist,15% sand RF,max. 1/4"	CL				
30	10	3	4	6	29.5 – 31.0		Same;10% RF,moist-wet,firm					
	11	3	4	8	32.5 – 34.0		Same as above;moist,stiff					
35	12	12	13	22	35.5 – 37.0	35.0	Grey clayey crse.sandy silt,v. stiff,moist,15% RF,max. 1/2"	ML				
40	13	16	24	29	38.5 – 40.0		Same;15-20% RF, (Shear plane @ 60°)					
	14	17	17	29	41.5 – 43.0		Same, max. 1",hard,damp-dry					
45	15	15	24	55	44.5 – 46.0		Same as above 20-25% RF,damp					
	16	18	20	39	47.5 – 49.0		Same, 20% RF, damp					
50												

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-159

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 2 OF 2

DRILL HOLE NO. 1-45

CONTRACTOR: Herron COORDINATES

ELEVATION 621.5

DRILLER: Lynn Lease

GWL 0 HRS 6.0

CLASSIFIED BY: D.B.S. DATE: 10-30-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Core Run (Range Size)	Rec. Core (Grain Shape)	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50	17	29	49	50/0.5	51.5		Grey clayey crse.sandy-f.gravelly silt, max. 1¼" 30-40% RF	[illegible]		51.5		
55								10		5.0	0.5	L.P. 2"
						57.0				56.5		
60							Grey shale & clayey shale, mod. weath. & broken to approx. 60'	84		5.0	4.2	L.P. .45
										61.5		
65							Grey shale sly weath. in zones (clayey shale zones presumably washed out and not recovered) fractured 61.5-62 & 64 thru 71.5	66		10.0	6.6	L.P. .45
70										71.5		
75							Grey shale generally fresh fractured 45° @ 73; broken zone 74.3-74.8	96		5.0	4.9	L.P. .70 S.P. .04 Avg. .30
										76.5		
80							Grey shale & lt. grey SS seams, sly broken at 76.5, 80.3-80.7, weak shale 81 to 81.5; fracture 60° at 77.9-78.3, 78.8-79.5	89		5.0	4.45	L.P. .45 Avg. .30 Methane 0.13%
										81.5		
85							Same; fracture 45° at 82, 80° @ 83-83.3, 75° at 84.5-84.7, 75° at 86.2	89		5.0	4.45	L.P. .65 S.P. .05 Avg. .40 Methane 0.0%
										86.5		
							T.D. 86.5'					
90							[A M-402 Methamometer was used to detect concentration of methanometer (CH_4) gas. Generally the boring was bailed down to the detection depth.]					
95												
100												

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-160

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 2

DRILL HOLE NO. 1-46

CONTRACTOR: Herron COORDINATES E 780,605 N 2,369,770

ELEVATION 620.5

DRILLER: Lynn Lease

GWL 0 HRS 3.5

CLASSIFIED BY: D.B.S. DATE: 10-21-72

24 HRS 1.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Core Run (Range Size)	Rec. Core (Grain Shape)	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												* Split samples wax sealed Sand is brn. clay grey
	1	2	3	3	2.5–4.0		Or-brn. f.sand w/layers of silty clay, wet, soft-firm	[illegible]				
5	2	4	6	7	5.5–7.0		Same, less oxidized, more silty clay					
10	3	1	2	1	8.5–10.0		Grey clayey f.sand & silty clay, 1/8-1/4" layers, soft, saturated	[illegible]				
	4	1	2	2	11.5–13.0		Grey clayey silt, soft, wet	ML				
15	5	1	3	5	14.5–16.0		Grey f.sand & silty clay, 1/16-1/8" layers, tr. red clay & black organic clay laminae	[illegible]				
	6	12	9	12	17.5–19.0		Grey f.sand; some layers of silty clay, clayey silt, tr. red & black clay dense, saturated					
20	7	4	5	9	20.5–22.0		Laminated red & grey silty clay; some v.f.sand, stiff, moist, tr. med.sand size RF	CL				
25	8	3	6	9	23.5–25.0		Same as above					
	9	4	5	6	26.5–28.0	29.0	Same as above, 1-3% med.sand RF	CL	*			
30	10	4	6	8	29.5–31.0		Grey clayey silt 5% med.-crse.sand size shale RF, v.stiff, moist	ML	*			
	11	3	5	6	32.5–34.0	35.0	Same 5-10% crse.-v.crse.sand, RF, max. 3/4"		*			
35	12	21	20	24	35.5–37.0		Same; 10-15% RF - max. 1", hard, dry-damp	ML	*			
40	13	14	50/0.3		38.5–39.3		Same; cobble or boulder at 39.3 (no rec.)					
	14	35	33	34	41.5–43.0		No recovery					Probably encountered pebble which blocked material from entering spoon
45	15	14	23	29	44.5–46.0		Same 15-20% RF					
	16	15	20	25	47.5–49.0		Same as above			49.0		
50												

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES

DRILLER: Lynn Lease

CLASSIFIED BY: D.B.S. DATE: 10-21-72

SHEET 2 OF 2

DRILL HOLE NO. 1-46

ELEVATION 620.5

GWL 0 HRS 3.5

24 HRS 1.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50	17	78	55	51	50.5 / 52.0		Grey med.-crse.sandy f.gravelly silt & clay 30-40% RF			52.5		
55							Clayey f.gravel & crse.sand, cobbles			3.5 (56.0)	.8	
60							Grey shale, weathered & broken, numerous fractures (high angle) and clayey weathered shale zones	94		5.0 (61.0)	4.7	L.P. 0.4 S.P. — Avg. 0.2
65							Grey shale, unweathered, unbroken, some thin clay seams	100		5.0 (66.0)	5.0	L.P. .50 S.P. .03 Avg. .30
70							Same as above			6.0 (72.0)	5.2	L.P. .60 S.P. .08 Avg. .40 Lost some in last pull
75							T.D. 72'					
80												
85												
90												
95												
100												

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, OHIO

CONTRACTOR: Herron COORDINATES N 780,385 E 2,369,763

DRILLER: Lynn Lease

CLASSIFIED BY: D.B.S. DATE: 10-24-72

SHEET 1 OF 2

DRILL HOLE NO. 1-47

ELEVATION 622.1

GWL 0 HRS 7.5'

24 HRS 1.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0	1	3	4	6	2.5 / 4.0		Brn.Or.brn.&mottled grey f.sandy silty clay, stiff, moist	CL/SM				
5	2	4	4	6	5.5 / 7.0	6.5	Brn.or.-brn.layers, f.sand, clayey silt, moist	SM/ML				
					8.5		Grey layers silt, f.sand, silty clay firm, wet					
10	3	2	2	4	10.0		Same, mostly f.sand; saturated, soft/loose					
	4	2	3	2	11.5 / 13.0		Same as above					
15	5	2	6	9	14.5 / 16.0		Grey f.sand, some silty clay layers med.dense, saturated	SM/CL				
	6	6	9	10	17.5 / 19.0		Grey v.f.sand & silt, little clay, dense, wet	SM/ML				
20	7	1	2	3	20.5 / 22.0		Grey laminated f.sand, silty clay, red and black clay, firm, moist	SM/CL				
25	8	5	7	7	23.5 / 25.0		Same as above, moist-wet					
	9	1	2	1	26.5 / 28.0		Same as above, unusually wet & cohesive					
30	10	2	4	7	29.5 / 31.0	30.0	No recovery ?					
	11	3	5	6	32.5 / 34.0		Gry.silt clay 5-10% med.-crse.sand size RF, stiff, moist	CL				
35	12	8	11	13	35.5 / 37.0	36.0	v.f.sand & well sorted c.sand @ 36.0 No recovery					
40	13	17	22	29	38.5 / 40.0		Grey clayey crse.sandy silt, 15-20% subang-subrd RF, damp, v.stiff-hard	ML				
	14	19	25	28	41.5 / 43.0		Grey c.sandy-f.gravelly silt/clay 20-25% RF, moist, v.stiff	ML/SC				
45	15	10	18	100/5	44.5 / 45.8		Grey med.crse.sandy silty clay 15-25% RF, max 1", moist, v.stiff					
50	16	45	48		47.5		Grey gravelly clay, hard damp max 2"	GC				

GAI - 227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-163

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio SHEET 2 OF 2
CONTRACTOR: Herron COORDINATES DRILL HOLE NO. 1-47
DRILLER: Lynn Lease ELEVATION
CLASSIFIED BY: D.B.S. DATE: 10-26-72 GWL 0 HRS 24 HRS

Depth Ft.	Profile	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	Range Size / Core Run	Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
50	51.0	No recovery		51.0		
	52.2	Granite greiss boulder 1.2'				Mineralogy: qtz biotite, orthoclase, native copper pyrite
	53.7	Grey crse, sandy silt/clay, 25-35% RF, Rec. 1.0'	92	5.0	4.6	
55		Grey shale, weathered, fractured, broken in zones, several clayey shale zones & clay in fractures		56.0		L.P. 0.8 S.P. 0.03 Avg. .4
60		Shale; grey clayey silty v.crse sand & f.gravel cobbles & boulder of weathered to only slightly weathered shale	40	5.0	2.0	C.sand size frags in clay; however run retains distorted relic bedding
				61.0		
65		Weathered grey shale, shale gravel & sandy silt, clay shale bedding 25° "C" horizon or boulder in till, clay matrix in gravelly zone	48	5.0	2.4	Methane @ 61' .34%
				66.0		
		Same as above	36	5.0	1.8	
70				71.0		
75	75.0	Grey shale, horizontal bedding, numerous weak clayey shale zones, broken in zones	91	5.0	4.55	L.P. 0.5 S.P. 0.03 Avg. 0.2
				76.0		
80		Grey shale w/lt.grey siltstone seams, appears fresh w/few thin (0.1') broken & clayey shale zone	92.8	7.0	6.5	L.P. 0.65 S.P. 0.03 Avg. 0.3
				83.0		
85		Same as above	39.6	3.0	1.2	L.P. .50 Redrill over lost core
				86.0		
		Same	92	2.5	2.3	L.P. .25 S.P. .05 Avg. .20
				88.5		
90		Same, weak shale zone 91.9-92.0 broken & slightly weath. @ 89.0	98	4.0	3.9	L.P. .60 S.P. .06 Avg. .25
				92.5		
95		T.D. 92.5				
		[A M-402 Methamometer was used to detect concentration of methanometer (CH_4) gas. Generally the boring was bailed down to the detection depth.]				
100						

GAI - 227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-164

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio SHEET 1 OF 2
CONTRACTOR: Herron COORDINATES N 780,780 E 2,369,850 DRILL HOLE NO. 1-48
DRILLER: Lynn Lease ELEVATION 620.5
CLASSIFIED BY: D.B.S. DATE: 11-15-72 GWL 0 HRS 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Remarks
0					2.5					* Indicate: waxed split sample
	1	4	6	8	4.0		Or-Brn. w/grey mottling, clayey silt & Clayey f. sand, firm, moist, laminated	ML/SC		
5					5.5					
	2	2	2	3	7.0		Or-Brn. silty f.sand w/some layer clayey silt, loose, med., saturated	SM		
					8.5					
10	3	1	5	5	10.0		Grey layers clayey silt, silty clay f.sand firm, saturated	ML/CL		
					11.5					
	4	2	2	3	13.0		Grey clayey silt, wet, firm	ML		
15					14.5					
	5	2	3	3	16.0		Grey layers, f.sand, clayey silt w/some thin strings, black organic clay (on) firm, moist wet	SM/ML		
					17.5					
	6	3	4	19	19.0		Grey w/some red silty clay & f. sand stiff, moist, disturbed bedding	CL/SM		
20					20.5					
	7	6	10	12	22.0		Grey & red laminated silty clay stiff, moist	CL		
					23.5					
25	8	6	8	11	25.0	25.0	Same as above, 1-3% med. sand size RF firm-stiff, moist	CL	*	
					26.5					Reworked till zone?
	9	5	7	10	28.0		Grey silty med.-crse. sandy clay, some red clay faintly bedded, 5-10% RF max. 1/4"; firm-stiff, moist	CL	*	
30					29.5					
	10	4	5	7	31.0		Same as above, stiff-firm, moist-wet	CL	*	
					32.5					
	11	4	6	9	34.0		Same, 15-20% med.crse, sandy RF	CL	*	
35					35.5	35.0				
	12	11	18	18	37.0		Grey clayey med.-crse. sandy silt v.stiff recovering hard, damp 10-15% RF, 2" zone clayey f.sand	ML	*	
					38.5	38.7				
40	13	20	24	26	40.0	39.7	Grey silty, clayey med.-crse. sand v.dense, moist	SM	*	Abblation till? coarsens upward in zone
					41.5					
	14	18	22	30	43.0		Grey clayey med.-verse sandy silt hard, damp-15-20% RF	ML	*	
45					44.5					
	15	14	21	30	46.0		Same, but w/more clay (soft-firm zone)	CL	*	
					47.5					
	16	35	34	40	49.0		No Recovery			
50										

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-165

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 2 OF 2

DRILL HOLE NO. 1-48

CONTRACTOR: Herron COORDINATES

ELEVATION 620.5

DRILLER: Lynn Lease

GWL 0 HRS

CLASSIFIED BY: D.B.S. DATE: 11-16-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50	17	39	85		51.5		Grey clayey, silty C-coarse sand & gravel max. 2 1/2"	SW/GM	#	52.0		
55						57.5	Same as above		#	5.0	3.6	
										57.0		
60							Grey shale, unweathered, 30° fracture at 59'; clay seam 0.02' thick at 60.5; vertical fracture at 61.5		88	5.0	4.4	L.P. 0.4' S.P. 0.05 Avg. 0.2
										62.0		
65							Same: 30° fracture at approx. 63.5		90	10.0	9.0	L.P. 0.5' S.P. 0.03 Avg. 0.30
70										72.0		
75							T.D. 72.0'					Attempted to bail hole for Methane observation failed.
80												
85												
90												
95												
100												

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-166

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 2

DRILL HOLE NO. 1-49

CONTRACTOR: Herron COORDINATES N 780,720 E 2,369,710

ELEVATION 620.0

DRILLER: Lynn Lease

GWL 0 HRS 8.5

CLASSIFIED BY: D.B.S. DATE: 11-21-72

24 HRS 1.7

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					3.5							* waxed split sample
	1	8	8	8			Or.brn. w/grey mottling silty v.f.sandy clay & silty v.f. sand; stiff,moist					
5					5.5							
	2	5	5	6		6.5	Or-brn.clayey silt,stiff,wet					
					8.5		Same but grey					
10	3	3	6	9			Same, w/some layers silty f.sand					
					11.5							
	4	3	4	6			Same as above; moist					
15					14.5							
	5	2	4	6			Grey layers,f.sand & silty clay, 1" layer firm red clay,moist-wet					
					17.5							
	6	4	6	8			Same, mostly f.sand					
20					20.5							
	7	4	6	9			Reddish grey silty clay;little f.sand,laminated;stiff moist,tr. rock frags					
					23.5							
25	8	5	6	8			Same; max RF 1/4"					
					26.5							
	9	4	8	10		28.0	Same as above 1-3% RF					
					29.5		Grey silty med.crse.sandy clay, tr.red,faintly laminated 5% RF, stiff,moist					
30	10	4	7	11								
					32.5		Same;stiff-v.stiff;5-10% RF,max.1/8					
	11	6	9	13			Grey clayey f.-crse.sandy silt; 5-10% RF,max.1/8",stiff-v.stiff, moist					
35					35.5	35.						
	12	21	16	40			Same;10-20% RF,v.stiff-hard,moist 2" layer clayey silty med.-crse. sandy RF					
					38.5							
40	13	20	26	43			Same as above, but no 2" layer sandy RF					
					41.5							
	14	15	30	36			Same					
45					44.5							
	15	19	20	25			Same;but moist-wet,v.stiff					
					47.5							
	16	20	28	62			Same as before;hard,damp,20-25% RF,max. 1/2"					
50												

GAI - 227 9/72

2E-167

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES

DRILLER: Lynn Lease

CLASSIFIED BY: D.B.S. DATE: 11-21-72

SHEET 2 OF 2

DRILL HOLE NO. 1-49

ELEVATION 620.0

GWL 0 HRS 8.5

24 HRS 1.7

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50	17	20	54	64			Same, 30-40% RF, max. 3/4", grey clayey crse.sand-gravel/gravelly clay			52		
55						55.5				5.0	4.9	L.P. 4.0'
							Weathered grey shale & clay bedding 15-20°			57		
						58.7						
60							Grey shale & lt. grey SS seams, unweathered, some thin clay partings 30° fracture at 63.7 vertical fracture 63.4-64.0			5.0	5.0	L.P. 0.75' S.P. 0.05' Avg. 0.30
										62		
65										9.5	8.9	L.P. 1.1' S.P. 0.03 Avg. 0.3
70										71.5		Methane greater than 5% after bailing
							T.D. 71.5'					
75							[A M-402 Methanometer was used to detect concentration of methanometer (CH_4) gas. Generally the boring was bailed down to the detection depth.]					Barrel plugged at 71.5'

GAI - 227 9/72

2E-168

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES N 780,670 E 2,369,570

DRILLER: Lynn Lease

CLASSIFIED BY: D.B.S. DATE: 11-24-72

SHEET 1 OF 2

DRILL HOLE NO. 1-50

ELEVATION 619.8

GWL 0 HRS 3.0

24 HRS 1.2

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					3.5							* Waxed split samples Selected for Testing
	1	2	2	4			Or-brn.clay silt & silty f.sand, soft-firm, saturated					
5					5.5							
	2	6	7	6			Or-brn.&grey-brn.silt w/some layers f.sand, limonite nodules 1/8" Firm-stiff, moist					
					8.5	8.0						
10	3	3	2	3			Grey silty f.sand, loose, saturated					
					11.5							
	4	2	3	4			Grey clayey silt, some layers f. sand, firm, wet, laminated					
15					14.5		Grey clayey silt & layers f.sand, laminated, firm-stiff, moist					
	5	5	9	7								
					17.5							
	6	7	12	12			Same as above; shale pebble-subrd. 3/4", v.stiff, tr.red clay, bedding slightly crenulated					
20					20.5							
	7	9	8	8			Same as above; stiff					
					23.5	23.0						
25	8	5	5	10			Grey clayey f.-v.crse.sandy silt, stiff-v.stiff, moist, 10% RF, max 1/4", some red clay					Upper Till
					26.5							
	9	6	7	11			Same as above					
30					29.5							
	10	4	5	7			Same; stiff					
					31.5							
	11	5	7	11			Same; stiff-v.stiff, 10-15% RF, no red clay					
35					35.5	36.0						
	12	14	27	75			Same; v.stiff-hard, 20-25% RF, moist					Lower Till
					38.5							
40	13	34	98	64			Same; greater % of sizes over 1/4", hard, damp					
					41.5							
	14	65	122	65			No recovery					
45					44.5							
	15	23	28	40			Same as above					Rock frag assemblag appears to be more Ign.-metamo: color may suggest Illinoian Age
					47.5							
	16	109	-	-	49.0		Red-brn.silty clayey f.-v.crse. sand, hard, dry, friable					
50												

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI- Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Barton COORDINATES

DRILLER: Lynn Lasse

CLASSIFIED BY: D.B.S. DATE: 11-26-72

SHEET 2 OF 2

DRILL HOLE NO. 1-50

ELEVATION 619.8

GWL 0 HRS 3.0

24 HRS 1.2

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50	17	38	56	[illegible]	0.6		Grey silty crse.sandy clay;30-40% RF,hard,dry			51.6		
							Grey clayey v.crse.sandy gravel, gravelly silt & clay,igneous & metamorphic cobbles			4.5	1.0	
55						56.1				56.1		
							Grey shale w/lt.grey SS seams; mostly weathered & broken w/ clayey shale zones 0.2' thick, vertically fractured thru most of run			2.5 / 58.6	2.5	L.P. 0.40; S.P. 0.01; Avg. 0.15
60							Grey shale w/lt.grey SS seams, unweathered,unbroken			7.0	6.4	L.P. 0.74; S.P. 0.03; Avg. 0.20
65										65.6		
							Same as above			8.0	7.9	L.P. 0.80; S.P. 0.03; Avg. 0.30
70										73.6		
75							T.D. 73.6'					

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Barton COORDINATES N 780,130 E 2,370,030

DRILLER: Lynn Lasse

CLASSIFIED BY: D.B.S. DATE: 11-6-72

SHEET 1 OF 2

DRILL HOLE NO. 1-51

ELEVATION 624.4

GWL 0 HRS 0.0

24 HRS 0.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0	1	4	5	5			Or.-Brn.w/grey mottling,clayey silt w/f.sand,soft-firm,wet	ML				
5	2	5	6	7	7.0	7.5	Or-brn.clayey silt,f.sand,firm, wet	ML/CL				
10	3	3	3	3	10.0		Grey silty f.sand,loose,saturated	SM				
	4	2	2	2			Grey clayey silt,w/some silty clay & f.sand layers,soft,wet,tr. organics	ML				
15	5	3	4	4			Grey clayey silt,firm,wet,tr. organics	ML				
	6	3	5	5			Grey clayey silt w/layers f.sand & clay,firm,moist-wet	ML/CL				
20	7	4	5	6			Same as above;tr.red clay & crse. sand,laminated	ML/CL				
25	8	5	8	8			Same as above, firm-stiff	ML/CL				
	9	1	3	2			Grey w/red silty clay,tr.organics & crse.sand,laminated,soft-wet	CL	#			
30	10	2	3	4	31.0	29.5	Grey silty,med.-crse.sandy clay, soft-firm,moist-wet,faintly laminated,5% RF	CL	#			
	11	2	3	5	34.0		Same;firm,not laminated,10% RF, max. 1/2",wet					
35	12	4	7	13	37.0	36.2	Grey med.-crse.sandy silt/clay 10-15% RF,stiff-v.stiff,moist	ML/CL	#			
40	13	7	15	19	40.0		Grey clayey med.-crse.sandy silt, hard,damp,15-20% RF	ML	#			
	14	19	22	30			Same,25-30% RF		#			
45	15	18	25	30			Same		#			
	16	16	27	44			Same; 30-35% v.crse.sandy RF		#			
50												

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 2 OF 2

DRILL HOLE NO. 1-51

CONTRACTOR: Herron COORDINATES ______

ELEVATION ______

DRILLER: Lynn Lease

GWL 0 HRS ______

CLASSIFIED BY: D.B.S. DATE: 11-6-72

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50	17	36	48	50			Same as above		*	52.0		
55							Grey gravelly clay/clayey gravel cobbles up to .35', v.dense			5.0	2.5	
						57.1 / 58.1	Grey weath.shale, some clay; sly broken			57.0		
60							Grey shale, lt.grey thin SS seams, appears fresh unbroken, except for thin sly weath.& broken zones between 59.0-59.3			5.0	4.7	L.P. 0.55 S.P. .03 Avg. .30
65							Grey shale, unweathered, unbroken, thin (0.03') clayey shale zones at 68.5, 69.3, slightly broken at 66.0, 68.6, 67.0			62.0 / 10.0	9.3	L.P. 0.70 S.P. 0.02 Avg. 0.30
70										72.0		
75							T.D. 72.0'					
80												
85												
90												
95												
100												

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 2

DRILL HOLE NO. 1-52

CONTRACTOR: Herron COORDINATES N 780,050 E 2,369,790

ELEVATION 623.6

DRILLER: Lynn Lease

GWL 0 HRS 3.0

CLASSIFIED BY: D.B.S. DATE: 11-10-72

24 HRS 0.0

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					2.5							
	1	3	4	4	4.0		Or.brn.w/grey mottle clayey f.sand & silt, firm, moist-wet	[illegible]				Water at 2.0'
5					5.5							
	2	3	3	4	7.0		Brn.-tan silty f.sand; med.-dense, wet	SM				
					8.5							
10	3	2	2	5	10.0		Grey layers f.sand & silt, saturated firm	[illegible]				
					11.5							
	4	2	2	3	13.0		Grey clayey silt, soft-firm, wet	ML				
15					14.5							
	5	4	3	4	16.0		Grey silty f.sand, loose-mod.; saturated	SM				
					17.5							
	6	2	2	3	19.0		Grey clayey v.f.sandy silt, soft-firm, wet	ML				
20					20.5							
	7	4	9	9	22.0		Grey layers f.sand & clayey v.f. sandy silt, firmwet-sat., tr.red clay	[illegible]				
					23.5							
25	8	2	5	7	25.0		Grey silty v.f. sandy clay, some red clay, 1-3% med. RF (max 1/2")	CL				Possibly re-worked material
					26.5	27.0						
	9	3	5	7	28.0		Grey silty, med.-crse.sandy clay, firm, moist, 5-10% RF, tr.red clay	CL	*			Red clay sticky v.soft-high plas.
30					29.5							
	10	5	7	9	31.0		Same as above		*			Vt. seems to show faint but disturbed bedding
					32.5							
	11	4	5	7	34.0		Same; max 3/4", soft zone 1" thick		*			
35					35.5	36.0						
	12	5	12	15	37.0		Grey clayey med.-crse.sandy silt, v.stiff, moist, 10-15% RF	ML	*			
					38.5							
40	13	13	19	27	40.0		Same; med.-v.crse, 15-20% RF, hard, damp	ML	*			
					41.5							
	14	18	23	30	43.0		Same as above		*			
45					44.5							
	15	18	25	36	46.0		Same as above, 20-25% RF		*			
					47.5							
	16	21	35	62	49.0		Same as above, 25-30% RF		*			
50												

GAI - 227 9/72

2E-173

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 2

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-52

CONTRACTOR: Herron COORDINATES ______

ELEVATION 623.6

DRILLER: Lynn Lease

GWL 0 HRS 3.0

CLASSIFIED BY: D.B.S. DATE: 11-10-72

24 HRS 0.0

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50	17	25	38	49	50.5 / 52.0		Same; 30-40% RF			52.0		
55							Grey clayey gravel/gravelly clay, cobbles of shale, some metamorphic gravel	33		3.0 (55.0)	1.0	0.4' SS bedding @ 20-30°
								0		57.0	0	No recovery
60							Grey shale & lt.grey SS seams, v. slightly weath., soft clayey shale zone 59.9-60.0, vertical irregular fracture 60.4-60.9	92		5.0 (62.0)	4.6	
65							Grey shale w/lt.grey SS seams, thin clay seams (0.03') at 62.8, 63.3, 64, 67.5; tight 60° fracture at 62.5	[illegible]		5.5 (67.5)	5.3	L.P. 0.50 S.P. 0.02 Avg. 0.30
70							Same, no fractures or weathered zones			4.5 (72.0)	4.3	L.P. 0.72 S.P. 0.05 Avg. 0.40
							T.D. 72.0'					
75												
80												
85												
90												
95												
100												

GAI - 227 9/72

2E-174

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 2

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-53

CONTRACTOR: Herron COORDINATES N 780,987 E 2,369,124

ELEVATION 616.8

DRILLER: Ed Sezwyck

GWL 0 HRS ______

CLASSIFIED BY: D.B.S. DATE: 11-16-72

24 HRS 3.75

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												Located 4' west of staked location
	1	4	5	6	2.5		Or.brn.silty f.sand, frim, moist-wet					
5	2	2	3	4	5.5		Or-brn.silty clay w/layers f.sand, firm, moist					
					8.5	9.0						
10	3	2	3	5			Grey silty f.sand, some thin clay layers, firm, saturated					
	4	4	5	9	11.5		Same as above					
15	5	2	3	5	14.5		Same w/silt layer					
	6	3	4	7	17.5		Grey layers f.silty sand, silty clay & some red & black clay strings, firm, moist, horz.bedding					
20	7	4	7	10	20.5		Same as above, disturbed bedding					Installed 22' of 5" casing, advanced hole w/roller bit
					23.5	24.5	Same, more silt than clay					
25	8	4	7	12	26.5		Grey silty med.-crse.sandy clay, some red clay, laminated - 5-10% RF. max. 1/4", moist firm-stiff					Reworked till-upper till starts at approx. 24.5, i.e., where not laminated
	9	9	13	18	29.5		Grey clayey med.-v.crse.sandy silt, tr.red clay, unlaminated 10-15% RF max. 1", v.stiff, moist					
30	10	11	13	18		30.0	Same as above					
	11	7	10	15	32.5		Grey silty med.-crse.sandy clay, red tinge & faintly laminated, 5-10% RF, max.1/4", stiff-v.stiff, moist					Possibly a till of different age
35	12	6	9	18	35.5	37	Same as above, not laminated					
					38.5		Lower Till					
40	13	17	25	32			Same as above, v.stiff-hard					Poor recovery (3")
	14	16	30	36	41.5		Grey clayey med.-v.crse.sandy silt, hard, moist, 15-20% RF, max. 1"					
45	15	15	25	39	44.5		Same as above					
	16	17	40	60	47.5		Same; 20-25% RF					
50												

GAI - 227 9/72

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.

2E-175

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, OHIO

SHEET 2 OF 2

DRILL HOLE NO. 1-53

CONTRACTOR: Herron COORDINATES

ELEVATION 616.8

DRILLER: Ed Sezwyck

GWL 0 HRS

CLASSIFIED BY: D.B.S. DATE: 11-16-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50	17	[illegible]			[illegible]	[illegible]	Same as above w/red-grey color					
							Boulder 11' thick					
					53.5							
55	18	45	45	68			Red-grey clayey silt w/5-10% crse-v.crse.sand size shale frags; hard,moist					Seems to be a till of different age;brn.color & diff.consistency from lower till (Illinoian?)
					56.5							
	19	[illegible]/5"					Grey clayey silty c-v.crse.sand & f.gravel,v.hard,damp-moist; 20-25% silt,clay					
					58.5	59						
60	20	[illegible]					Grey clayey shale,weathered			60.0		Installed 20' of 2" plastic perforated pipe
							T.D. 60.0'					
65							Discontinued 17 Nov. 72					

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

2E-176

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 2

DRILL HOLE NO. 1-54

CONTRACTOR: Herron COORDINATES N 781,310 E 2,369,360

ELEVATION

DRILLER: Ed Sezwyck

GWL 0 HRS Bailed Dry

CLASSIFIED BY: D.B.S. DATE: 11-22-72

24 HRS 6.0

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0												* Waxed split samples
					2.5							
	1	4	6	6			Or-brn.w/grey mottling clayey silt&f.sand,firm-stiff,moist					
5					5.5							
	2	6	8	9			Or.brn. w/lt.grey mottling silty clay & some clayey f.sand,firm-stiff,moist					
					8.5	9.0						
10	3	2	3	5			Grey clayey silt,firm,wet					
					11.5							
	4	3	2	3			Grey clayey silt & f.sand,disturbed bedding,tr.red clay;wet,soft-firm					
					14.5							
15	5	2	4	5			Same as above,moist-wet					
					17.5							
	6	5	8	8			Reddish grey silty clay,laminated, tr.RF.(max.1/4"),stiff,moist, little f.sand					
20					20.5							
	7	3	5	7			Same as above					
					23.5	23.						
25	8	3	5	8			Grey silty f-crse.sandy clay, 5-10% RF,max.1/4",stiff,moist					Upper Till
					26.5							
	9	5	6	9			Same as above, 10% RF					
30					29.5							
	10	6	8	10			Same,but w/red tinge,faintly layered					Diff. Till suspected
					32.5	33	Same as above,v.stiff,cobble of igneous rock					
	11	5	20	27								Lower Till
35					36.5							
	12	18	25	31			Grey clayey med.-v.crse.sandy silt 15-20% RF,max.1",hard, damp					
					38.5							
40	13	63	50	50			Same,cobble of dolomite					V.poor recovery (2")
					41.5							
	14	30	37	32			Same					V.poor recovery (1")
45					44.5							
	15	18	28	38			Same as above					
					48.5							
50	16	36	45	106			Brn.-grey clayey med.-v.crse.sandy silt w/lenses of red silty f.sand, hard,damp					Different type Till

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-177

PROJECT: CEI - Perry Nuclear Power Plant   W.O. 044549-000   SITE AREA N. Perry, Ohio   SHEET 2 OF 2

CONTRACTOR: Herron   COORDINATES ______   DRILL HOLE NO. 1-54

DRILLER: Ed Sezwyck   ELEVATION ______

CLASSIFIED BY: D.B.S.   DATE: 11-24-72   GWL 0 HRS ______   24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50					51.5							
	17	106	56/10	-	52.1		Grey clayey mod.-v.crse.sandy silt, hard,dry,30-40% RF					
					54.5							
55	18	60	92	156			Grey silty,clayey med.-v.crse.sand & F.gravel					
					57.5							
	19	35	56	[illegible]			Grey clayey shale,weathered soft shale,dry			59.0		
60							Grey shale & lt.grey SS seams, vertical fractures 59-61 & 62.3-62.5 and 65-65.4 w/associated clayey & broken zones			7.0	6.5	L.P. 0.55' S.P. 0.02 Avg. 0.25'
65										66.0		
							Grey shale w/lt.grey SS seams; clay seams suspected. Fractures 60° at approx. 67.0-67.5,68.2-68.5, 71.5-71.7			8.0	6.4	L.P. 0.90 S.P. Avg. 0.30
70										74.0		
75							Same; unweathered,unbroken			5.0	4.7	L.P. 0.75 S.P. 0.03 Avg. 0.40
										79.0		
80							Same;weak broken shale zone 81.8-82.0;vertical fractures 79.6-80.2, 82.0-82.1,82.6-82.7; 45° fracture 82.3-82.4,86.8-86.9,87.0-87.1, 87.2-87.3; some clay on horizontal parting surfaces			10.0	9.7	L.P. 0.75 S.P. 0.05 Avg. 0.30
85										89.0		
90							T.D. 89.0' [A M-402 Methanometer was used to detect concentration of methanometer (CH_4) gas. Generally the boring was bailed down to the detection depth.]					Bailed dry; Methane 5%; Low hissing sound but bubbled as water trickled in at 87-89'. No visible flow from casing.

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-178

PROJECT: CEI - Perry Nuclear Power Plant   W.O. 044549-000   SITE AREA N. Perry, Ohio   SHEET 1 OF 1

CONTRACTOR: Herron   COORDINATES ______   DRILL HOLE NO. 1-54A

DRILLER: Ed Sezwyck   ELEVATION ______

CLASSIFIED BY: D.B.S.   DATE: 12-27-72   GWL 0 HRS ______   24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												3' NNE of 1-54
5												
10					14							
15	S	T	3-	1	16		No recovery					
	S	T	3-	2	18		Push 24", Rec 24"					
20					20							
	S	T	3-	3	22		Push 24", Rec 21"					
					24							
25	S	T	3-	4	26		No recovery					
					28							
30	S	T	3-	5	30		Push 24", Rec 14" (1.2')					Cobble obstruction
	S	T	3-	6	32		Push 24", Rec 19" - Discard; disturbed in sampling process by cobble					
35												

GAI - 227 8/72

2E-179

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Kerron

DRILLER: Ed Sezevck

CLASSIFIED BY: J.L.W.

COORDINATES N 781,390 E 2,369,870

DATE: 12-28-72

SHEET 1 OF 5

DRILL HOLE NO. 1-55

ELEVATION 620

GWL 0 HRS

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0						1.0	Topsoil					
							Lacustrine deposits, moist mottled brown & grey clayey silt					
	1	4	6	9								
5							Lacustrine deposits, moist brown interbedded silt & clay					
	2	2	2	4								
10	3	2	3	8			Lacustrine deposits, moist brownish & grey interbedded silty clay & fine sand					
	4	4	6	8			As above					
15	5	2	2	4			As above					
20	6	2	4	8			As above					
25	7	5	5	9			As above					
							Brownish & grey interbedded silt & clay					
30	8	5	11	15			Upper Till					
35	9	6	9	16			Brownish grey clayey silt, trace C/F sand & fine gravel (angular & sub-angular rock frags)					
40	10	10	14	16			As above except color is grey instead of brownish grey					
							Lower Till					
45	11	23	38	39			Grey silt little C/F sand & gravel (angular to sub-angular)					
50	12	15	28	32			As above					

GAI - 20 8/72

2E-180

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Kerron

DRILLER: Ed Sezevck

CLASSIFIED BY: J.L.W.

COORDINATES

DATE: 12-28-72

SHEET 2 OF 5

DRILL HOLE NO. 1-55

ELEVATION 620

GWL 0 HRS

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% Rec.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50												
							Grey silt & C/F sand & gravel angular & sub-angular - hard pan					
55	13	57	[illegible]									
							Grey partly friable weathered shale					
	14	[illegible]	[illegible]							60.0		
60							Grey shale with occ. interbedded siltstone, fine sandstone & brown-grey shale					Bailed hole dry to 70.0 ft. Read 0.1% on Methanometer
65								98	83	10.0		
70										70.0		
							Broken zone at 72'					Bailed hole dry to 80.0 ft. Methanometer was out of charge, thus no reading, but high pitched noise was heard
75							As above	96	88	10.0		
80										80.0		
85							As above Broken zone at 86'	98	92	10.0		Bailed hole dry 100 ft., set hole packer at 82.0 ft. Read greater than 5% methane gas
90							Clay seam at 91'			90.0		
95							As above	98	95	10.0		
100										100.0		

GAI - 20 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES

DRILLER: Ed Serwyck

CLASSIFIED BY: J.L.W. DATE: 12-28-72

SHEET 3 OF 5

DRILL HOLE NO. 1-55

ELEVATION 620

GWL 0 HRS

24 HRS

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	% Rec.	R.Q.D.	Core Run	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
100	Broken at 101'-101.5				
105	As above	95	80	10.0	Bailed hole dry to 120 ft. Set hole packer to 6 ft. Detected greater than 5% methane gas at top of casing. Bled gas to atmosphere for 5 min. then shut-in. Pressure meter read 0.4 psi and flow rate 2.1 cfm.
110	Clay seam at 110.3			110.0	
115	As above	99	90	10.0	
120				120.0	Took two gas samples for laboratory testing. After bleeding gas overnight flow rate was less than 0.2 cfm
125	As above Broken at 126'-127'	97	90	10.0	
130	Broken 131.5 & 139.7			130.0	Bailed hole dry to 140.0 ft., set hole packer at 124.0 ft. Gas pressure 0.6 psi while flowing; flow rate of 1.4 cfm.
135	As above	98	82	10.0	
140				140.0	Collected two gas samples for lab testing
145	As above Broken at 146.5'	100	87	10.0	Bailed hole dry to 160 ft., set packer at 145 ft. Open line read 0.7 psi and flow meter rate of 2.4 cfm.
150				150.0	

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES

DRILLER: Ed Serwyck

CLASSIFIED BY: J.L.W. DATE: 12-28-72

SHEET 4 OF 5

DRILL HOLE NO. 1-55

ELEVATION 620

GWL 0 HRS

24 HRS

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	% Rec.	R.Q.D.	Core Run	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
150					Left gas shut-in overnight; opened gas line for 24 minutes, volume too small to measure, water level built up to 146.2 ft.
155	As above Broken 155.9'-156.1	99	92	10.0	
160				160.0	
165	As above	98	93	10.0	
170				170.0	
175	As above Broken at 177'	100	77	10.0	
180				180.0	
185	As above	99	60	5.0	
				185.0	
		95	72	5.0	
190				190.0	Bailed hole dry to 220 ft. Set hole packer at 158 ft. Flow at start 5.2 cfm (uncorrected) at 2.7 psi. After 30 min. flow 4.0 cfm and pressure 1.9 psi.
195	As above Broken at 198'	98	85	10.0	
200				200.0	

GAI - 227 8/72

2E-183

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 5 OF 5

DRILL HOLE NO. 1-55

CONTRACTOR: Herron COORDINATES

ELEVATION 620

DRILLER: Ed Sezwyck

GWL 0 HRS

CLASSIFIED BY: J.L.W. DATE: 12-28-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	[redacted] Rec.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
200												
205							As above Broken at 205'	98	78	10.0		
210										210.0		
							Bottom of Boring					

GAI - 227 8/72

2E-184

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 5

DRILL HOLE NO. 1-56

CONTRACTOR: Herron COORDINATES N 781,174 E 2,369,386

ELEVATION 608.7

DRILLER: Ed Sezwyck

GWL 0 HRS

CLASSIFIED BY: D.B.S. DATE: 12-6-72

24 HRS 5.15'

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												6' SW of 1-56
	1	4	5	6	2.5		Or-brn w/grey mottling clayey silt & f.sand; layer crse. sand, stiff, moist					
5	2	2	4	5	5.5		Brn. clayey silt w/layers f. sand, moist-wet, firm					
10	3	7	8	9	8.5	9.5	Same as above Grey silty f.sand, wet, mod. dense					
	4	5	7	9	11.5		Grey w/red laminated silty clay, some f. sand; stiff, moist					
15	5	8	11	11	14.5		Grey silty f. sand, unstratified, wet, mod to dense					
	6	5	5	6	17.5	19.0	Grey w/red laminated silty clay, some thin f. sand layers, firm-stiff, moist, tr. crse. sandy RF					Installed 22' of 5" casing
20	7	4	7	8	20.5		Reddish grey clayey f-crse. sandy silt 5% RF, stiff, moist					Upper Till
25	8	7	10	12	23.5		No recovery					
	9	7	16	20	26.5	28.0	Grey clayey med-v.crse.sandy silt, 10-20% RF, stiff-v.stiff, moist					
30	10	12	20	41	29.5		Same 15-20% RF, v. stiff-hard, moist.					Lower Till
	11	21	34	39	32.5		Same w/2" cobble					
35	12	15	19	19	35.5		V. poor recovery, v. stiff, moist					
40	13	25	35	36	38.5		Same; hard					
	14	24	50	60	41.5	41.0	Reddish grey-reddish brn. clayey crse. sandy silt; 5-25% RF (zones), hard, moist					
45	15	40	60	—	44.5	45.0 46.5	Same Grey silt, hard, moist-damp					
					47.5	47.5	Grey clayey crse. sandy silt, 25-35% RF					Installed 52' NX flush joint casing
50	16	150	—	—	48.0		Grey shale, weathered, clayey, fissle					

GAI - 227 8/72

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.

2E-185

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 5

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-56

CONTRACTOR: Herron COORDINATES ______

ELEVATION 608.7

DRILLER: Ed Sezwyck

GWL 0 HRS ______

CLASSIFIED BY: D.B.S. DATE: 12-6-72

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50–60.0							Grey shale w/lt. grey sandstone/ siltstone seams; mostly unweath. and massive; weak shale and clay @ 51'-51.2, 30° fracture and weak shale @ 55.1-55.2	95		10.0	95.0	Fresh Rock at 50' L.P. 3.15 S.P. 0.04 Avg. 0.60
60.0–70.0							Same; sandstone lense up to 01', 30° fracture 61.3, 61.8; vertical fractures 62.0-62.4, 66.8-66.95; slightly broken 61.2-61.3, 62.0-62.2, 67.65-67.75; clay seams (firm, wet) 69.0, 69.25-69.4	100		10.0	10.0	L.P. 0.80 S.P. 0.04 Avg. 0.60
70.0–80.0							Same; massive	98		10.0	9.8	L.P. 1.2 S.P. 0.04 Avg. 0.6
80.0–90.0							Same; thin clay seam 82.25, 85.9, no fractures except usual horizontal partings	99		10.0	9.9	L.P. 1.35 S.P. 0.08 Avg. 0.7
90.0–100.0							Same; clay seam 95.15-95.20, massive	100		10.0	10.0	L.P. 2.25 S.P. 0.03 Avg. 0.00

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

2E-186

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 5

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-56

CONTRACTOR: Herron COORDINATES ______

ELEVATION 608.7

DRILLER: Ed Sezwyck

GWL 0 HRS ______

CLASSIFIED BY: D.B.S. DATE: 12-6-72

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100–110.0							Same; generally massive, no clay seams recovered, est. % sand in run 5-10%; (some grey-brn. mud-stone bands 1/2-3/4" thick in gradational contact w/grey shale may contain sand lenses, appears denser than shale and is generally harder, lacks fissility)	100		10.0	10.0	L.P. 1.9 S.P. 0.04 Avg. 0.8
110.0–120.0							Same; massive, numerous sand lenses up to 0.15 ft. thick, est. 20% sand in run	100		10.0	10.0	L.P. 1.25 S.P. 0.05 Avg. 0.90
120.0–130.0							Same; clay seam (soft, high plas.) 0.03' thick at 120.2, 120.3 and 0.05' thick at 120.35-120.40, fracture 60° @ 125.0-126.0, some clay along break; est. sand 20%, numerous brown bends	100		10.0	10.0	L.P. 1.45 S.P. 0.05 Avg. 0.80 Methane greater than 5% - noticeable flow & odor
130.0–140.0							Same; massive, no clay, no fractures except bedding fractures, but a weak fissile zone 139.8-139.9; est. 10% sandstone	99		10.0	9.9	L.P. 1.75 S.P. 0.02 Avg. 0.70
140.0–150.0							Same as above; est. 20% sandstone	100		10.0	10.0	L.P. 1.50 S.P. 0.04 Avg. 0.60

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-187

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 4 OF 5

DRILL HOLE NO. 1-56

CONTRACTOR: Herron

COORDINATES

ELEVATION 608.7

DRILLER: Ed Sezwyck

GWL 0 HRS

CLASSIFIED BY: D.B.S.

DATE: 12-19-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
150–160					Same; est 10-15% sandstone		100	10.0 (160.0)	10.0	L.P. 1.15' S.P. 0.05 Avg. 0.50 Avg. 0.40 L.P. 1.25' S.P. 0.02
160–170					Same; est. 10-15% sandstone, numerous clay partings, especially between 162-162.5		97	10.0 (170.0)	9.7	163.5 tested gas composition H_2O level approx 161.5 at 9 a.m. Bailed approx. 24 gal. @11 a.m. H_2O level between 5" & NX casing unchanged - therefore, H_2O possibly all from shale.
170–180					Same; est. 20-25% sandstone; some clay partings at 175.7 to 175.9; brown "bands" or lenses, less compressible than grey shale at time of formation as indicated by compaction features in bedding		99	10.0 (180.0)	9.9	L.P. 1.45 S.P. 0.04 Avg. 0.40
180–190					Same; est. 15% sandstone		100	10.0 (190.0)	10.0	179.5 tested gas pressure and flow rate (12/21) water level 28.25 12/26 L.P. .90 S.P. 0.03 Avg. 0.50
190–200					Same; est. 10-15% sandstone; thin slightly broken shale zones 196.1-196.3, 198.0-198.1, 199.5-199.7		99	10.0 (200.0)	9.9	L.P. 1.5 S.P. 0.02 Avg. 0.4 Water level 12/27 - 28.7'

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-188

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

SHEET 5 OF 5

DRILL HOLE NO. 1-56

CONTRACTOR: Herron

COORDINATES

ELEVATION

DRILLER: Ed Sezwyck

GWL 0 HRS

CLASSIFIED BY: D.B.S.

DATE: 12-27-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
200–210					Same; est. 15% sandstone		90	10.0 (210.0)	9.0	L.P. 1.25 S.P. 0.02 Avg. 0.50 Remainder of run not held by core retainer
					T.D. 210.0 Ft.					

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 044549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron COORDINATES N 780,364 E 2,369,853

DRILLER: Ed Sezwyck

CLASSIFIED BY: D.B.S. DATE: 12-1-72

SHEET 1 OF 1

DRILL HOLE NO. 1-57

ELEVATION 622.6

GWL 0 HRS

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50–56						56	Grey clayey crse.sandy gravel and gravelly clay			52.0 / 5.0 / 57.0	1.0	Began core sampling at 52.0'. No soil samples
60							Grey shale;badly weathered clayey and broken zones. Dip 20°			5.0 / 62.0	1.5	L.P. 0.15 Avg. 0.10
65							Grey shale w/lt. grey SS seams, bedding plane inclined 20° from horizontal(dip). Numerous high angle fractures but appears only slightly-moderately weath.over all			4.25 / 66.25	3.8	L.P. 0.6' S.P. Avg. 0.25 Bailed dry 4/12 CH_4 3.5%
70							Same w/clay seams up to 1/2"			5.75 / 72.0	2.8	L.P. 0.5 S.P. - Avg. 0.2
75							Data incomplete - material jammed in barrel but less than 3 ft. rec.			10.0 / 82.0	4.66	Threads on bit failed - core retainer pinched core - did not enter barrel
80–85							Grey shale w/lt. grey SS seams; fresh unweathered,unbroken, no clay			5.0 / 87.0	4.65	* broken shale & clay at base of run (Horz. bedding) L.P. 1.40 S.P. 0.03 Avg. 0.60
90							T.D. 87.0' Footage: 35' coring [A M-402 Methanometer was used to detect concentration of methanometer (CH_4) gas. Generally the boring was bailed down to the detection depth.]					Dense aphanitic brown bands in shale,probably chert w/some clay

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron Testing COORDINATES N 781,030 E 2,368,780

DRILLER: Humphrey

CLASSIFIED BY: Renken DATE: 7/26/73

SHEET 1 OF 3

DRILL HOLE NO. 1-58

ELEVATION 606.3

GWL 0 HRS 6'1"

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
						.33	4 inches topsoil					This boring was drilled for proposed barge unloading channel
	1	5	5	5			Lacustrine sediments Sandy silt, light brown, mottled with some gray very fine sand, firm, moist	ML				GWL after pulling augers @ 9:30 am 7/30/73 is 7'1" 7' GWL @ 11:30 am 7/31/73
5	shelby				20"							
	2	4	6	8			Sandy silt, light brown, firm moist, no plasticity					
10	shelby				24"							
						12.5	Upper till					
	3	5	6	8			Gray silty clay with rock fragments	CL				
15	4	5	6	8			Gray clayey silt and silty clay with trace fine sand and rock fragments					
	shelby				22"		First attempt for Shelby unsuccessful, drilled a hole adjacent to this one to get a comparable Shelby tube					
	5	4	6	7			Gray silty clay, firm, low plasticity with some rock fragments					
20	shelby				23 1/2"		Gray silty pebbly clay					
	6	4	8	11			Moist, silty clay with rock fragments (trace), firm, low plasticity					
25						26.0						

GAI - 227 8/72

2E-191

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 3

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-58

CONTRACTOR: Herron Testing COORDINATES

ELEVATION 606.3

DRILLER: Humphrey

GWL 0 HRS 6'1"

CLASSIFIED BY: Renken DATE: 7/26/73

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S. % Rec.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
	sh	el	by		17"		Lower Till Shelby is hard and dry, silty clay with increasing % rock fragments	CL				GWL after pulling augers was 6'1". Approx. 24 hrs later the level was 7'. The water in this hole is not groundwater, but rather water left from a result of drilling.
	7	13	21	28			Dry, hard, silty gray clay with some rock fragments					
30												
	sh	el	by		11"		Last possible obtainable Shelby					
	8	14	22	26			Same as above with some large fragments ½ in maximum diameter					
35	9	22	31	38			Same as above					
40	10	22	44	55			Same as above with chunks of shale fragments					
						42.5	Shale 4½ in penetration, laminated, gray shale fraturing along bedding planes					
45	14	150						81%	66%	12"	9 3/4"	Max. piece is 2 3/4 ". Several pieces together give a good RQD of 8". Problems with losing H_2O Closed augers farther down.
50												

GAI-227 8/72

2E-192

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 3

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-58

CONTRACTOR: Herron Testing COORDINATES

ELEVATION 606.3

DRILLER: Humphrey

GWL 0 HRS 6'1"

CLASSIFIED BY: Renken DATE: 7/26/73

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
							This is also a laminated dark gray shale horizontal bedding	96%	79%	9'	8'8½"	7½" RQD @ 9" & 4'9" there is a light brown siltstone seam
55								100%	86%	6'	6'	RQD is 5'2" max. core is 14" material is laminated (gray) fracturing along bedding. From 6½ to 11" rock is highly fractured
60						61.0	Td @ 61'					

GAI-227 8/72

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-193

PROJECT: Perry W.O. 064569-000 SITE AREA N. Perry
CONTRACTOR: Herron COORDINATES N 781,260 E 2,368,600
DRILLER: Ed and Larry
CLASSIFIED BY: RAR DATE: 7/24/73

SHEET 1 OF 2
DRILL HOLE NO. 1-59
ELEVATION 576
GWL 0 HRS 3'
24 HRS Filled in

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
							Beach sediments	GP				This boring was drilled for proposed barge unloading channel.
						2.5						
	1	2	2	4			Medium to coarse beach sand, moist					
5												
	2	3	5	5			Medium to coarse grained sand, some gravel, saturated					
						8.5	Upper till					
	3	5	9	11			Gray silty clay with some fragments, dry	CL				
10						10.8						
	4	11	16	28			Lower till Gray silty clay with some fragments, dry, 10% fragments					
	5	14	30	25			Brittle, very dry, silty clay with some fragments (10%) stiff					
15												
	6	69	46			19.5	2" penetration of 116 blows, material is same as above, shale in bottom of spoon					Max. size core is 11", laminated shale with lt & dk gray bands, 2 thin clay seams @22½' & 24'11" One thin band of siltstone @ 21½'
20							Gray shale					
25												

GAI-337 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-194

PROJECT: Perry W.O. 064569-000 SITE AREA N. Perry
CONTRACTOR: Herron COORDINATES
DRILLER: Ed and Larry
CLASSIFIED BY: RAR DATE: 7/24/73

SHEET 2 OF 2
DRILL HOLE NO. 1-59
ELEVATION 576
GWL 0 HRS 3'
24 HRS Filled in

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
												RQD is 110" - most vert. fract occurs at top of core. Material fract occur along horizontal bedding planes
30						30'						
							TD @ 30'					

GAI-337 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-195

SHEET 1 OF 2
PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio
DRILL HOLE NO. 1-60
CONTRACTOR: Herron COORDINATES N 781,650 E 2,370,615
ELEVATION 625.7
DRILLER: Humphrey
GWL 0 HRS 7'6" 11:30 pm
CLASSIFIED BY: Renken DATE: 8/2/73
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
							Topsoil 11"					This boring was drilled for proposed stream diversion channel
	1	5	7	8			Lacustrine sediments Unconsol sample silty brown medium sand, damp, with no plasticity	SM				GWL after pulling augers 3:00 pm 6'3"
5	2	3	4	4			Medium to fine grained dark brown sand, wet, having no plasticity					
	3	3	4	5			Upper till Gray, nearly equal % of silt & clay, having very low plasticity, moist, firm	CL				
10	4	4	6	7			Gray clayey silt and silty clay with streaks of very fine sand					
	5	3	4	7			Gray silty clay with trace very fine sand, low plasticity, moist firm, gray silty clay, moist to wet, low plasticity, firm					
15	6	6	6	8			Gray silty clay, moist to wet, same as above					
20	7	6	8	9			Gray clayey and sandy silt with streaks of very fine sand, moist to wet, firm	ML				
25												

GAI - 227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-196

SHEET 2 OF 2
PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio
DRILL HOLE NO. 1-60
CONTRACTOR: Herron COORDINATES
ELEVATION 625.7
DRILLER: Humphrey
GWL 0 HRS 7'6" 11:30 pm
CLASSIFIED BY: Renken DATE: 8/2/73
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
30	9	7	12	9			Clayey silt (firm) moist with a very fine gray sat sand and clayey silt having very low plasticity and sand having none					
	10	5	9	13			Dryer, trace fragments, silty clay, stiff, low plasticity	CL				
	11	5	6	10		41.5	Same as above, largest fragments is ½" across					
							41½"					

GAI - 227 9/72

2E-197

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 2
PROJECT: Perry W.O. 044549-000 SITE AREA
CONTRACTOR: Herron COORDINATES N 781,980 E 2,370,575
DRILL HOLE NO. 1-61
ELEVATION 625.4
DRILLER: Humphrey
GWL 0 HRS 9'4" hole caved in at completion
24 HRS 16' 13'6 after 3 hrs
CLASSIFIED BY: Renken DATE: 8/1/73

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
						1.6	17" topsoil					This boring was drilled for proposed stream diversion channel.
	1	1	1	1			Light rd brown sand, crumbly, soft, damp, fine grained	SP				
5												
	shelby				15"							
	2	4	4	2			Brown, medium to fine grained sand with some organic material, unconsolidated sample, damp					
	3	2	1	4			Same as above, some silt and clay, damp	SM				
10												
	shelby				17"	11.0						
							Upper till					
	4	5	7	7			Gray silty sand, moist, trace clay in thin streak, firm, no plasticity	SM				
15												
	shelby				23"							
	5	7	9	10			Gray silty sand, moist, trace clay in thin streak, firm, no plasticity					
20												
	shelby				22"		Gray silty clay with st sand	CL				
	6	7	8	9			Gray silty clay with sts of sand firm, moist					
25												

GAI - 227 9/72

2E-198

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 2
PROJECT: Perry W.O. 044549-000 SITE AREA
CONTRACTOR: Herron COORDINATES
DRILL HOLE NO. 1-61
ELEVATION
DRILLER: Humphrey
GWL 0 HRS 625.4
24 HRS
CLASSIFIED BY: Renken DATE: 8/1/73

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
	shelby				19"		Gray silty sand	SM				
	7	4	5	7			Gray sandy silt, with streak of clay, moist to saturated sandy silt also, silty clay, firm					
30												
	shelby				21"							
	8	7	9	11			Gray silty clay, stiff, moist	CL				
	9	7	10	4			Gray silty clay, trace fragments, damp, stiff, low plasticity					
35												
	10	8	10	12			Gray silty clay, low plasticity, damp, stiff					
40												
	11	7	9	10			Same as above, trace fragments (5%), damp					
	12	5	6	7			Same as above, low plasticity, damp					
45												
						46.5	Lower till					
	13	9	18	21			Dry, brittle 15-20% fragments, low plasticity, silty clay	CL				
50	14	13	20	26		50	Same as above TD @ 50'					

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-199

SHEET 1 OF 1

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-62

CONTRACTOR: Herron COORDINATES N 780,486 E 2,368,193

ELEVATION 617.2

DRILLER: Humphrey

GWL 0 HRS hole caved in at 6'11"

24 HRS settled down to 7'11"

CLASSIFIED BY: RAR DATE: 7/30/73 3:00 pm

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
						.5	6" topsoil					This boring was drilled at proposed sludge lagoon basin site.
							Lacustrine sediments Brown, mottled, clayey silt near bottom of sample, brown silty fine sand, dry, no to low plasticity	ML				
	1	5	6	7								
5	2	3	5	5			Sections of fine silty sand and clayey silt in alternating bands firm, dry	SM ML				
						8.5	Moist, brown sand, firm, no plasticity, changing to					
	3	3	3	5			Upper till a gray silty clay with trace fine sand, moist, low plasticity firm	CL				
10												
	4	4	6	7		13.0	Gray silty clay, firm, moist, with some fine sand in thin sections, low plasticity					
							TD @ 13'					
15												

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-200

SHEET 1 OF 1

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-63

CONTRACTOR: Herron COORDINATES N 780,554 E 2,368,381

ELEVATION 620.4

DRILLER: Humphrey

GWL 0 HRS 7'5"

CLASSIFIED BY: Renken DATE: 7/30/73

24 HRS 7'8"

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0						.35	4" topsoil					This boring was drilled at proposed sludge lagoon basin site.
							Lacustrine sediments					
	1	4	6	6			Light brown, mottled with clean white silty sand, sandy silt, sand is fine, firm, no plasticity					#2 sealed for mechanical analysis test
	2	3	4	5			Brown silty clay with some fine sand, firm, dry					
5	sh	el	by		24"							
	3	2	3	3		8.5	Moist, brown, clayey silt, with some very fine sand, soft to firm, low plasticity					#4 sealed for mechanical analysis
	4	4	4	4			Upper till Gray, saturated, clayey silt as well as thin streak of silty fine sand, no to low plasticity, soft					
10	5	1	1	1			Gray, silty fine sand, wet, firm No plasticity					
	6	1	1	2			Gray sandy silt, silty sand, trace clay no plasticity, wet					
	7	2	3	4		14.5	Gray, silty clay, moist, firm, with low to slight plasticity trace fine sand					#7 sealed for mechanical anlysis; WL @ 0 hrs 2:00 pm 7'5" 7/30 9:15 am 7/31 WL 7'4"
15							TD @ 14'.6" Installed 9'6" PVB tube for permeability test					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-201

SHEET 1 OF 1

PROJECT: Perry W.O. 064549-000 SITE AREA N. Perry, Ohio DRILL HOLE NO. I-64

CONTRACTOR: Herron Testing COORDINATES N 780,623 / E 2,368,569 ELEVATION 620.0

DRILLER: Humphrey GWL 0 HRS 10'3"

CLASSIFIED BY: RAR DATE: 7/1/73 11:30 am 24 HRS 6'3"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
						.8	10" topsoil			This hole was drilled at proposed sludge lagoon basin site.		
							Lacustrine sediments					
	1	3	4	5			Brown mottled silty sand, with trace clay, moist, firm, no plasticity					Sample #2 sealed for mechanical analysis
5	2	2	4	4			Brown, clayey silt with layers of very fine sand					
	3	4	5	7		7.5	Brown clayey silt, firm, moist, having low plasticity, with trace fragments					
							Upper till					
10	4	3	5	6			Gray silty clay with est 15-25% very fine sand, firm, moist, low plasticity					
	5	4	6	7			Gray clayey silt with some very fine sand, no plasticity to low plasticity, moist firm					Sample #6 sealed for mechanical analysis
	6	4	4	7		14.0	Gray silty clay, stiff, moist					
15							TD 14					Percolation of H_2O into hole is extremely slow

GAI-237 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-202

SHEET 1 OF 1

PROJECT: Perry W.O. 064549-000 SITE AREA N. Perry, Ohio DRILL HOLE NO. I-65

CONTRACTOR: Herron COORDINATES N 870,450 / E 2,368,422 ELEVATION 618.0

DRILLER: Humphrey GWL 0 HRS 7'6"

CLASSIFIED BY: RAR DATE: 7/31/73 10:20 am 24 HRS hole caved in @ 7'6"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
						.3	3" topsoil					This boring was drilled at proposed sludge lagoon basin site.
							Lacustrine sediments					
	1	4	5	7			Light brown clayey and sandy silt with trace rock fragments, mottled some very fine sand, firm, no plasticity					
5	2	4	6	7			Medium brown, mottled, moist, firm, clayey silt with streaks of sand (very fine)					
	3	5	6	5		8.5	Top of sample, brown silty and soft, moist, no plasticity					
10							Upper till Bottom of sample, gray silty clay with streak of silty sand					
	4	2	3	4		12.5	Gray silty clay with lense of very fine sand, clay having low plasticity, firm, wet					
							Hole td @ 12'6"					
15												

GAI-237 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-203

SHEET 1 OF 1

PROJECT: Perry W.O. 064549-000 SITE AREA N. Perry, Ohio
DRILL HOLE NO. 1-66
CONTRACTOR: Herron COORDINATES N 780,480 E 2,368,610
ELEVATION 619.5
DRILLER: Humphrey
GWL 0 HRS 7'9"
CLASSIFIED BY: RAR DATE: 7/30/73 Moved hole slightly
24 HRS 5'10"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
						.83	10" topsoil					This boring was drilled at proposed sludge lagoon basin site.
							Lacustrine sediments					
	1	4	7	8			Light brown, mottled with gray clay, clayey silt, firm, slightly moist, low plasticity					
5	2	3	5	6			Medium brown, silty clay, mottled, firm slightly moist, low plastic					
	shelby				24"		Top was clayey, silt, bottom sandy silty					
	3	1	3	3		7.75	Brown changing to gray, wet, silty sand					#3 sealed for mechanical, analysis
10							Upper till					
							Gray, wet to saturated, silty clay, firm to soft, low plasticity with very fine sand layers					
	4	1	1	2		12.5						
15							TD @ 12½ ft. installed 4" PVB for permeability, 11'4" of tube					

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-204

SHEET 1 OF 2

PROJECT: Perry W.O. 064549-000 SITE AREA N. Perry, Ohio
DRILL HOLE NO. 1-67
CONTRACTOR: Herron COORDINATES N 780,610 E 2,369,950
ELEVATION 619±
DRILLER: Humphrey
GWL 0 HRS -
CLASSIFIED BY: RAR DATE: 8/1/73 12:00 noon
24 HRS 5'-4"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
						.83	10" topsoil					This boring was drilled for proposed sewage treatment plant site.
							Lacustrine sediments					
	1	2	2	4			Brown mottled, soft, clayey silt with 20% (est) fine sand layer					
5							Brown gray silty clay					
	shelby				24"							
						7.0	Upper till					
	2	2	4	7			Gray clayey silt with trace sand soft, moist, no plasticity					
10	3	8	5	4			Gray silty sand, stiff, moist, no plasticity					
	shelby				21"		Gray silty sand, wet					
	4	2	2	3			Gray silty clay with trace very fine sand					
15												
	shelby				17"		Gray sand to silt, wet					
	5	2	3	4			Gray sandy silt, wet demonstrating dilatancy, no plasticity, soft					
20	6	3	4	6			Gray, silty clay, firm, moist low plasticity, trace rock fragments					
25												

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-205

SHEET 2 OF 2

PROJECT: Perry W.O. 064549-000 SITE AREA N. Perry, Ohio DRILL HOLE NO. 1-67

CONTRACTOR: Herron Testing COORDINATES ELEVATION

DRILLER: Humphrey GWL 0 HRS -

CLASSIFIED BY: RAR DATE: 8/1/73 24 HRS 5'4"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
	7	4	6	9			Gray silty clay, moist, same as above, with streaks of very fine sand					GWL at 0 hrs did not exist. Water did not seep in fast enough after 27 3/4 hrs it rose to 4'10"
30	8	9	11	12			Dryer, firm, silty clay with trace sand to rock fragments, low plasticity, increase in fragments to 5-10%					
35	9	6	9	11			Gray silty clay, dryer, firm to stiff, rock fragments ¼ diameter 5-15% fragments					
						36.5	Lower Till - it became harder to drill at this depth. Dry, hard, brittle, silty clay 15-20% fragments					
40	10	16	27	37		40	TD 40'					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-206

SHEET 1 OF 2

PROJECT: CEI - PNPP W.O. 06-4549-000 SITE AREA N. Perry, Ohio DRILL HOLE NO. 1-68

CONTRACTOR: Herron Testing COORDINATES N 781900 E 2370130 ELEVATION 617.3

DRILLER: L. Humphrey GWL 0 HRS 4.8'

CLASSIFIED BY: JGD DATE: 5/23 - 5/28/74 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE Moist, loose tan silty fine sand.	SM				Topsoil 1'
5	1	4	5	7			Tan ends at 6'					
	2	3	4	5		6.0	Moist					
10	3	1	2	3			Wet, loose, gray silty fine sand, with trace clay	SM				
	4	4	6	11			Moist, medium stiff, gray silty sandy clay	CL				
15	5	8	9	9			Moist, medium dense, gray silty fine sand with trace clay, stratified	SM				
20	6	4	6	6			Moist, medium stiff, gray silty sandy clay with red clay specks, stratified	CL				
						23.0						
25	7	3	4	5			UPPER TILL Moist, soft, gray silty clay with shale fragments (5-10%) stratified					
30	8	3	4	5			Relatively moist, soft, gray silty clay with fine shale fragments (5-10%) and gravel, calcareous	CL				
35	9	7	11	14			Same, medium stiff to stiff					
						37.0						
40	10	14	40	35			LOWER TILL Relatively dry, very stiff, gray silty clay with shale fragments, calcareous					
45	11	30	37	34			Same	CL				
[illegible]	12	[illegible]	[illegible]	[illegible]			Same - trace sand					

GAI - 227 8/72

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-207

PROJECT: CEI - PNPP	W.O. 04-4549-000
SITE AREA	N. Perry, Ohio
CONTRACTOR:	Herron
COORDINATES	N 781900 E 2370130
DRILLER:	Humphrey
CLASSIFIED BY:	JGD
DATE:	5/23 - 5/28/74
SHEET	2 OF 2
DRILL HOLE NO.	1-68
ELEVATION	617.3
GWL 0 HRS	4.8'
24 HRS	

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
	13	21 / 43			Gray silty clay with fine to coarse shale fragments (30%)					
					Hard					
					Cobbles					
					Weathered Shale					
					Gray shale, weathered, soft to medium hard, thin and flat laminae, jointing (45° angle), maximum piece .4'		1			
					Gray shale with thin siltstone lenses, unweathered, medium hard, thin and flat laminae, some jointing, scour and fill structures		2			
					Same No jointing		3			
					T. D. - 78.6'					

GAI - 227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-208

PROJECT: CEI - PNPP	W.O. 04-4549-000
SITE AREA	N. Perry, Ohio
CONTRACTOR:	Herron Testing
COORDINATES	N 781900 E 2370130
DRILLER:	L. Humphrey
CLASSIFIED BY:	JGD
DATE:	5/23-28/74
SHEET	1 OF 1
DRILL HOLE NO.	1-68
ELEVATION	617.3
GWL 0 HRS	4.8'
24 HRS	

PIEZOMETER RESULTS

	Bottom	Water Level	Elev	Top of Pipe
1	63.7'	10.8'	617.3	619.5
2	48.5'	7.4'	617.3	620
PVC	19.0'	5.3'	617.3	620

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-209

PROJECT: CEI - PNPP W.O. 04-4549-000 SITE AREA N. Perry, Ohio SHEET 1 OF 2

CONTRACTOR: Herron Testing COORDINATES N 780,140 E 2,370,440 DRILL HOLE NO. 1-69

DRILLER: L. Humphrey ELEVATION 622.7

CLASSIFIED BY: JGD DATE: 6/28-7/3/74 GWL 0 HRS 5' 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE					Topsoil 10"
	1	3	4	5			Moist, loose, brown silty fine sand with trace clay	SM				
5												
	2	2	5	6		7.0						
10	3	3	5	5			Moist, soft, gray silty (15) sandy (35) clay with sand layer	CL/SM				
	4	3	5	6			Wet, loose gray silty sand					
15	5	3	4	6			Moist, soft gray silty clay with fine gravel, lenticular red clay inclusions					
20	6	5	8	10		21.0	Moist, loose to medium dense alternating gray clayey silt ~~and clayey sand~~	SO				
							UPPER TILL					
25	7	4	4	6			Moist, medium stiff, stratified					
30	8	4	7	8			Gray silty clay with fine to medium grained subrounded shale fragments and lenticular red clay inclusions, calcareous	CL				
35	9	5	9	12		34.5	Dry, very stiff, hard					
							Gray silty clay with 15-20% fine to coarse grained shale frags, calcareous					
40	10	30	35	42								
45	11	28	26	34				CL				
							Boulder - 47'					Hole is bending here
50	12	34	47	63			Hard Cobbles					

GAI-227 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-210

PROJECT: CEI - PNPP W.O. 04-4549-000 SITE AREA N. Perry, Ohio SHEET 2 OF 2

CONTRACTOR: Herron Testing COORDINATES N 780,140 E 2,370,440 DRILL HOLE NO. 1-69

DRILLER: L. Humphrey ELEVATION 622.7

CLASSIFIED BY: J.G. Darabaris DATE: 6/28-7/3/74 GWL 0 HRS 5' 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50							Gray silty clay with 50% shale fragments					
55	13	35	47	106		55.0						
							Gray shale, weathered, broken up soft to medium hard, some jointing, thin and flat lamination, max piece 1"					
60									1	9.0'	2.9'	
65										65		
							Gray shale with clay seams, unweathered, medium hard, no jointing, thin and flat lamina max piece 7"			5'	5'	
70										70		
							Gray shale with trace (5%) thin siltstone lenses, unweathered, medium hard, jointing at 74', flat lamina					Lost core had to redrill
75										5'	3.0'	
							T.D. 75'					

GAI-227 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-211

SHEET 1 OF 1

PROJECT: CEI- PNPP W.O. 04-4549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-69

CONTRACTOR: Herron Testing COORDINATES N 780,140 E 2,370,440

ELEVATION 622.7

DRILLER: L. Humphrey

GWL 0 HRS 5'

24 HRS

CLASSIFIED BY: JGD DATE: 6/28-7/3/74

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.

PIEZOMETER RESULTS

	Bottom	Water Level	Elev.	Top of Pipe
1	73.5'	6.0'	622.7'	625
2	45.5'	12.7'	622.7'	626
PVC	19'	5.0'	622.7'	626

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-212

SHEET 1 OF 2

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-70

CONTRACTOR: Herron Testing COORDINATES N 780282 E 2369667

ELEVATION

DRILLER: L. Humphrey

GWL 0 HRS

24 HRS

CLASSIFIED BY: KH, JGD DATE: 5-20-74

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18
	1	3	3	4
5				
	2	5	9	10
10	3	5	8	16
	4	3	5	5
15	5	2	3	6
20	6	7	9	11
25	7	3	4	4
30	8	2	1	2
35	9	5	7	15
40	10	13	23	37
45	11	14	22	35
50	12	38	43	60

DESCRIPTION (Density (or Consistency), Color, Rock Or Soil Type - Accessories):

LACUSTRINE

Soft to firm orange-brown and gray interlaminated clayey silt/silty clay and silty fine sand

Soft to firm gray varved clayey silt and fine sand

32

UPPER TILL

Firm to stiff gray silty clay, some sand and fine gravel-sized rock fragments

37

LOWER TILL

Stiff to hard gray clayey silt, some sand to boulder-sized rock fragments

REMARKS: Top Soil 17"

GAI - 227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-213

SHEET 2 OF 2

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-70

CONTRACTOR: Herron Testing COORDINATES N 780282 E 2369667

ELEVATION 621

DRILLER: L. Humphrey

GWL 0 HRS

CLASSIFIED BY: KH, JGD DATE: 5/20/74

24 HRS 2.5'

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50												
	13	31	r22									
	14	58	r22									
55												
60							CHAGRIN SHALE Gray shale with irregular laminae of light gray silty sandstone Maximum piece 10½ inches		37 %	7'	4.7'	
										63'		
65									50 %	10'	9'	
70										73'		
75												

GAI - 227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-214

SHEET 1 OF 2

PROJECT: CEI-PNPP W.O. 04-4549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-71

CONTRACTOR: Herron Testing COORDINATES N 780442 E2369609

ELEVATION 620.7

DRILLER: L. Humphrey

GWL 0 HRS

CLASSIFIED BY: KH, JGD DATE: 5/16/74

24 HRS 2.6

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE Soft to firm orange-brown and gray interlaminated clayey silt/silty clay and fine sand					Topsoil 10"
	1	2	3	4								
5	2	4	5	6			Soft to firm varved clayey silt and silty fine sand					
10	3	5	9	15								
	4	2	3	8								
15	5	4	5	7								
20	6	6	7	16								
25	7	3	5	7								
30	8	4	5	6			UPPER TILL Firm to stiff gray silty clay, little sand and gravel-size rock fragments					
35	9	6	8	12								
40	10	10	24	36			LOWER TILL Stiff to hard clayey silt/silty clay, some sand and gravel-size rock fragments					
45	11	15	23	35								
50	12	33	33	60								

GAI - 227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-215

SHEET 2 OF 2
PROJECT: CEI-PNPP W.O. 06-4569-000 SITE AREA N. Perry, Ohio
DRILL HOLE NO. 1-71
CONTRACTOR: Herron Testing COORDINATES N780442 E2369609
ELEVATION 620.7
DRILLER: L. Humphrey
GWL 0 HRS
CLASSIFIED BY: KH, JGD DATE: 5/16/74
24 HRS

Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Core Run	Core Rec.	Remarks
Gray shale with irregular laminae of light gray silty sandstone slightly weathered, broken maximum piece 8½ inches	73%		10'	9.9'	
Same unweathered					
Maximum piece 7½ inches	36%		10'	9.9'	

GAI-237 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-216

SHEET 1 OF 4
PROJECT: CEI - P N P P W.O. 064569-000 SITE AREA N. Perry, Ohio
DRILL HOLE NO. 1-72
CONTRACTOR: Herron COORDINATES N 781 334 E 2 369 616
ELEVATION 619 (Aprx)
DRILLER: F. Sezzick
GWL 0 HRS 17'10"
CLASSIFIED BY: JGD DATE: 10/9/73
24 HRS

Sample No.	SPT Blows/6 in. (6)	(12)	(18)
1	2	8	5
2	9	10	13
3	5	11	13
4	8	10	12
5	5	6	6
6	2	2	3
7	2	2	4
8	4	6	10
9	5	7	7
10	2	2	4
11	2	2	3
12	2	2	4
13	2	3	6
14	5	6	7
15	5	5	7
16	7	7	9
17	5	5	5
18	7	5	5
19	13	13	13
20	5	11	14
21	5	8	13
22	7	10	14
23	8	13	17
24	8	10	18
25	9	12	13
26	8	11	15
27	5	14	21
28	8	17	21
29	15	43	22
30	12	39	40
31	18	2[illegible]	25
32	11	34	31
33	13	20	25

Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	Remarks
Tan silt & wood, dry, loose silt		
Mottled gray-brown sandy silt, dry, medium dense, blocky with trace clay, roots	CL/ML	Lacustrine
Interlaminated lenses of tan fine sand & silt & gray clay, medium dense to stiff, damp	SM/CL	
Gray silty clay with trace fine shale gravel, soft, moist		
Gray clayey silt, laminated, medium dense, moist	ML/CL	
Interlaminated gray clay & silt with trace black organic, moist, soft - loose	CL/ML	
Gray clayey silt with trace black organic lenses, moist, loose to medium dense, laminated	ML	
Same, wet		
Gray silty clay with trace red clay lenses, laminated, moist, stiff	CL	
Gray silty clay with trace fine shale gravel, red clay lenses, laminated, moist, very stiff		Upper Till
Gray silty clay with little fine to medium shale gravel, not laminated	CL	
Gray silty clay with some fine to medium subangular shale gravel, trace red clay & fine to coarse (1" dia) shale gravel		Lower Till
Gray silty clay & coarse platy shale gravel	CL	
Gray silty clay & subangular-subrounded fine to coarse shale gravel, moist, hard		

GAI-237 8/72

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-217

SHEET 2 OF 4

PROJECT: CEI - P.N.P.P. W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-72

CONTRACTOR: Herron Testing COORDINATES N 781 304 E 2 369 616

ELEVATION 619 (appx)

DRILLER: E. Sedgwick

GWL 0 HRS 17'10"

CLASSIFIED BY: JGD DATE: 10/10

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
	34	16	61	40			Gray silty clay & fine to coarse shale gravel & cobbles @ 51.5'					Residual
	35	30	53	23								
	36	13	20	31			Gray silty clay & fine to coarse subangular shale gravel (1-2" dia)					
	37	23	41	52								
	38	131	67	113								
	39	60	54	92		59.5						
	40	65	/..				Weathered Shale			60.0'		
							Dark gray shale with trace (20%) interlaminated gray siltstone, fine grained brown ss, flat & thin lamination, some x lamination in medium hard unweathered, joint 45° at 67.5' max. piece 14"		46%	10'	6.5'	
							Dark gray shale with trace (5%) light gray ss lenses interlaminated unweathered, medium hard, flat & thin lamination, little x lamination, no apparent joints but two busted zones of core @ 71.5 & 78.5. max. piece 21"		66%	70' / 10'	10'	
							Dark gray shale interlaminated with trace (5-10%). light gray siltstone lenses unweathered, medium hard, flat & thin lamination, some x lamination, no jointing. max. piece 1'		61%	80' / 10'	10'	
							Dark gray shale interlaminated with little (10-15%) light gray medium hard, flat & thin lamination, x lamination, jointing 30° @ 97.5' max. piece 15"		65%	90' / 10'	9.8'	
										100'		

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-218

SHEET 3 OF 4

PROJECT: CEI - P.N.P.P. W.O. 04-4549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-72

CONTRACTOR: Herron Testing COORDINATES N 781 304 E 2 369 616

ELEVATION 17'10"

DRILLER: E. Segweick

GWL 0 HRS

CLASSIFIED BY: JGD DATE: 10/17/74

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100							Dark gray shale with little interlaminated thin light gray siltstone lenses & clay seam @ 102.6' medium hard, unweathered, no joints, thin & flat lamina with some x lamination, max piece 9½"		77%	10'	10'	
110							Thick light gray siltstone lenses 109.4-109.7'. Clay seam 1"			110'		
115							Dark gray shale with some interlaminated light gray siltstone lenses predominant from 112.8-113.1', unweathered, medium hard, thin & flat lamination, x lamination, no joints, max. piece 5"		20%	10'	9.7'	
120							Thin clay seams			120'		
125							Dark gray shale with trace (10%) interlaminated siltstone lenses, unweathered, medium hard, thin & flat lamination with little x laminations, jointing 33° @ 128.5' @ 120' @ 129'. max piece 8"		15%	10'	9.4'	
130							Possibly has clay seams (washed out)			130'		
135							Dark gray shale with some interlaminated thin light gray-brown siltstone lenses, unweathered, medium hard, thin & flat lamination with little x lamination, no jointing. max piece 16½"		93%	10'	10'	
140							Same - maximum piece 1'			140'		
145									57%	10'	10'	
150										150'		

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-219

PROJECT: CEI - P.N.P.P. W.O. 04-4549-000 SITE AREA N. Perry, Ohio
SHEET 4 OF 4
CONTRACTOR: Herron Testing COORDINATES N 781 304 E 2 369 616
DRILL HOLE NO. 1-72
DRILLER: E. Segzweick
ELEVATION 619 (appx)
GWL 0 HRS 17'10"
24 HRS
CLASSIFIED BY: JGD DATE: 10/30-11/1/74

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
150										
155					Dark gray shale with little (15%) thin interlaminated light gray-brown siltstone lenses, medium hard, unweathered, no joints, thin & flat lamination with some x lamination. maximum piece 7½"		33%	10'	10'	
160								160'		
165					Dark gray-black shale with trace (10%) interlaminated light gray siltstone lenses, medium hard, unweathered, no joints, thin & flat lamination with some x lamination. maximum piece 10"		47%	10'	9.7'	
170								170'		
175					Interlaminated dark gray to black shale with trace (5%) interlaminated light gray to brown siltstone lenses, medium hard (but softer than upper layer) unweathered, no joints, thin & flat lamination with some x lamination maximum piece 11"		37%	10'	9.6'	
180					Interlaminated black shale & light gray-brown siltstone, medium hard, unweathered, vertical joint @ 180', thin & flat lamination, x lamination, max piece 8"			180'		
185							71%	10'	9.7'	
190					Black shale with some light gray to brown siltstone, medium hard, unweathered, no joints, thin & flat lamination, x lamination. max. piece 5½"			190'		
195							40%	10'	9.8'	
200								200'		

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-220

PROJECT: CEI-PNPP W.O. 04-4549-000 SITE AREA N. Perry, Ohio
SHEET 1 OF 2
CONTRACTOR: Herron Testing COORDINATES N 780,420 E 2,368,920
DRILL HOLE NO. 1-73
DRILLER: E. Sedgewick
ELEVATION 618.3
GWL 0 HRS 5.7'
CLASSIFIED BY: JGD DATE: 6/5/74-6/7/74
24 HRS

Depth Ft.	Sample No.	SPT 6	SPT 12	SPT 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Range Size / Core Run	Grain Shape / Rec. Core	REMARKS
0												Top soil 1'
	1	3	4	5			Moist, loose, tan silty fine sand	SM				
5							Wet-same					
	2	2	2	3		7.0'						
							Wet, loose, gray silty fine sand					
10	3	4	5	6								
	4	3	4	6			Same					
							Moist, loose to medium dense, same					
15	5	5	6	10				SM				
							Same with red lenticular clay inclusions					
20	6	4	5	9								
25	7	3	4	5			Same					
						27.0						
							Relatively dry, stiff to medium stiff gray silty clay with fine shale fragments, stratified, calcareous					
30	8	5	8	10				CL				
35	9	3	6	10								
						37.0						
							Dry medium stiff to stiff gray silty clay with fine to coarse shale fragments (10%), stratified, calcareous	CL				
40	10	19	26	37								
45	11	14	20	23								
							Same					
50	12	24	35	39								

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - PNPP W.O. 04-4549-000 SITE AREA Perry

CONTRACTOR: Herron Testing COORDINATES N 780,420 E 2,368,920

DRILLER: E. Sedgewick

CLASSIFIED BY: JGD DATE: 6/5/74-6/7/74

SHEET 2 OF 2

DRILL HOLE NO. 1-73

ELEVATION 618.3

GWL 0 HRS 5.7'

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50												
							Hard					
55	13	28	39	47			Gray silty clay with 20% shale fragments	[illegible]C				
60	14	41	57	73			30 to 40% shale fragments					
	15	120/5"	[illegible]				Gray shale, weathered, soft, thin and flat lamination					
65							Gray shale with interlaminated thin siltstone lenses (15%) unweathered, medium hard, some jointing at 64', 67', thin and flat lamination, clay seams at about 64', max piece 8" @ 71' 3/4 hr fine grain sandstone lense		1	10.0	7.9	
70										73.0		
75							T.D. 73.0'					

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - PNPP W.O. 04-4549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron Testing COORDINATES

DRILLER: E. Sedgewick

CLASSIFIED BY: JGD DATE: 6/5 - 7/74

SHEET 1 OF 1

DRILL HOLE NO. 1-73

ELEVATION 618.3

GWL 0 HRS 5.7'

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.

PIEZOMETER RESULTS

	Bottom	Water Level	Elev.	Type of Pipe
1	72.0	( )	618.3	621.0
2	54.0	5.3	618.3	621.5
PVC	23.0	3.7	6.8.3	620.5

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-223

PROJECT: CEI - PNPP W.O. 04-4549-000 SITE AREA Perry
CONTRACTOR: Herron COORDINATES N 779 725 E 2369165
DRILLER: E. Sedgewick
CLASSIFIED BY: JGD DATE: 5/23-5/25/74

SHEET 1 OF 2
DRILL HOLE NO. 1-74
ELEVATION 620.2'
GWL 0 HRS 4.6'
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE					Top soil 1'
	1	2	3	2			Moist, loose tan silty fine sand					
5							Oversaturated, very loose, tan silty fine sand	SM				
	2	1	1	1		10						
10	3	1	1	3			Wet, very loose gray silty fine sand	SM				
	4	1	5	5			Moist, same					
15	5	6	14	13			Moist, loose to medium dense, same					
20	6	5	5	5			Relatively moist, soft to medium stiff, gray silty (20) sandy (25) clay stratified	CL				
25	7	6	7	9			Same					
						31.5	UPPER TILL					
30	8	6	9	10			Relatively moist, medium stiff to stiff gray silty clay with fine shale fragments and gravel, calcareous	CL				
35	9	13	14	17			Relatively dry, stiff, same					
						[illegible]	LOWER TILL					
40	10	[illegible]	[illegible]	[illegible]			Dry, medium stiff to stiff gray silty clay with fine shale fragments and gravel (5-10%), calcareous	CL				
45	11	[illegible]	[illegible]	[illegible]			Same					
50	[illegible]	[illegible]	[illegible]	[illegible]			Hard					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-224

PROJECT: CEI - PNPP W.O. 04-4549-000 SITE AREA Perry
CONTRACTOR: Herron COORDINATES N 779 725 E 2369165
DRILLER: E. Sedgewick
CLASSIFIED BY: JGD DATE: 5/23/74-5/25/74

SHEET 2 OF 2
DRILL HOLE NO. 1-74
ELEVATION 620.0'
GWL 0 HRS 4.6'
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50							Relatively dry, hard, gray silty sandy clay with fine shale fragments and gravel (25-50%)					
	13	30	120									
	14	61	157	[illegible]		54						
55							Weathered soft jointing vertical					Refusal @ 54.5
60							Gray silty shale with siltstone lenses (max 3/4", most much smaller, approx 5% of sample) Relatively unweathered, medium hard, thin and flat lamination, no joints, max 5"		1	10'	4.4'	
65										64.5		
70							Same		2	10'	3.3'	
75							Broken			74.5		
							T.D. 74.5'					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-225

SHEET 1 OF 1

PROJECT: CEI - PNPP W.O. 06-4549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron Testing COORDINATES N 779 725 E 2369165

DRILLER: E. Sedgewick

CLASSIFIED BY: JGD DATE: 5/23-25/74

DRILL HOLE NO. 1-74

ELEVATION 620.2

GWL 0 HRS 4.6'

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
							PIEZOMETER RESULTS					

	Bottom	Water Level	Elev.	Tip of Pipe
1	64.7	3.2	620.2	623
2	44.5	3.3	620.2	623.5
PVC	16.5	3.3	620.2	622.5

GAI-337 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-226

SHEET 1 OF 2

PROJECT: CEI - PNPP W.O. 06-4549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron Testing COORDINATES N 779,590 E 2,369,885

DRILLER: E. Sedgewick

CLASSIFIED BY: JGD DATE: 6/7/74-6/11/74

DRILL HOLE NO. 1-75

ELEVATION 621.3

GWL 0 HRS 4'11"

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE					Topsoil 1'
	1	3	4	4			Moist, loose red-tan silty fine sand					
5								SM				
	2	1	1	2		7.0	Wet, same					
10	3	2	2	4			Moist, loose gray silty fine sand	SM				
	4	3	5	10			Same					
15	5	3	3	4			Same					
20	6	2	2	2			Wet, soft gray silty clay with red-tan clay inclusions	CL				
						22.0	UPPER TILL					
25	7	2	3	4			Moist, soft gray silty clay with red-tan clay stringers and black shale fragments, stratified, calcareous					
30	8	3	4	6				CL				
						34.0	LOWER TILL					
35	9	14	18	20			Stiff, relatively moist, gray silty clay with fine to coarse black shale fragments stratified (5-10%), calcareous					
40	10	20	34	42								
45	11	18	39	50			Very stiff	CL				
							Hard shale fragments, subrounded cobbles (¼" - 1")					
50	12	74	67	43								

GAI-337 8/72

2E-227

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 2

PROJECT: CEI - PNPP W.O. 06-4549-000 SITE AREA N. Perry, Ohio DRILL HOLE NO. 1-75

CONTRACTOR: Herron Testing COORDINATES N 779,590 E 2,369,883 ELEVATION 621.3

DRILLER: E. Sedgewick GW. 0 HRS 4'11"

CLASSIFIED BY: JGD DATE: 6/7/74-6/11/74 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Pc. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50										
55	13	84 84 64		56%	Gray silty clay with 25-50% shale fragments					
60	14	216/.3			Gray shale, weathered, soft thin and flat bedding					
65					Gray silty shale with interlaminated thin siltstone lenses (5%) unweathered, medium hard, thin and flat lamination, no joints		1	10	9.4	
70								70.0		
					T.D. @70.0					

GAI-227 8/72

2E-228

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 1

PROJECT: CEI - PNPP W.O. 06-4549-000 SITE AREA N. Perry, Ohio DRILL HOLE NO. 1-75

CONTRACTOR: Herron Testing COORDINATES N 779,590 E 2,369,883 ELEVATION 621.3

DRILLER: E. Sedgewick GWL 0 HRS 4.11'

CLASSIFIED BY: JGD DATE: 6/7-11/74 24 HRS

PIEZOMETER RESULTS

	Bottom	Water Level	Elev.	Top of Pipe
1	66.5	3	621.3	624
2	47.5	2.5	621.3	624.5
PVC	27.5	1.4	621.3	624.5

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-229

SHEET 1 OF 1

PROJECT: CEI - PNPP W.O. 06-4549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-76

CONTRACTOR: Herron Testing COORDINATES N 777 769 E 2369517

ELEVATION 608.3

DRILLER: E. Sedgewick

GWL 0 HRS 4'11"

CLASSIFIED BY: JGD DATE: 6/19-74-6/21/74

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core / Run	Grain Shape / Rec. / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0	1	1	2	3			LACUSTRINE Moist, loose, red-tan silty fine sand					Topsoil 1'
	2	5	3	5				SM				
	3	4	4	4			Wet, loose, tan clayey sand with subrounded gravel					
5	4	2	3	1		6.0						
	5	3	4	6			UPPER TILL Moist, soft to stiff, stratified gray silty clay with subangular fine to medium shale fragments					
	6	7	10	12								
10	7	7	17	23		10.0						
	8	13	20	23			LOWER TILL Relatively moist, very stiff to stiff, calcareous, gray silty clay with subangular shale fragments (10%), stratified					
	9	17	21	30								
15	10	13	30	31								
	11	16	26	25								
	12	13	26	35			Coarse shale fragments					
	13	13	26	41								
20	14	17	29	29			Some sand					
	15	17	35	31								
	16	15	31	42			Dry, very stiff to hard, gray silty clay with 20% fine to coarse grained shale fragments, stratified					
25	17	32	42	55				CL				
	18	25	29	55								
	19	35	61	[illegible]			Cobble size fragments					
30	20	53	103	[illegible]			Gray silty clay with 10-20% fragments fine to medium grained					
	21	20	33	38								
	22	35	42	55								
	23	25	135	[illegible]			25-50% cobble size fragments					
35	24	77	213	[illegible]								
	25	118	143									
	26	[illegible]	62	225		[illegible]	25-50% cobble size fragments					
40	[illegible]	[illegible]	[illegible]				Shale, weathered Gray shale with thin interlaminated light gray siltstone Thin and flat laminated, medium hard joints at 42', 44' (45° angle), max 9½"		1	10.0	9.3	
							3/4" fine grain brown ss layer					
51												Gas was Present

T.D. @ 50'

GAI - 227 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-230

SHEET 1 OF 2

PROJECT: CEI - PNPP W.O. 06-4549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-77

CONTRACTOR: Herron Testing COORDINATES N 781 185 E 2370660

ELEVATION 626.7

DRILLER: E. Sedgwick

GWL 0 HRS 4'9"

CLASSIFIED BY: JGD DATE: 6/25/74-6/27/74

24 HRS 4'1"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core / Run	Grain Shape / Rec. / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
C												Topsoil 1'
	1	4	4	4			Moist, loose tan silty fine sand	SM				
5												
	2	3	4	7		7.5						
10	3	4	3	4			Moist, loose gray sandy silt with trace clay lenticular red clay inclusions					
	4	4	5	6								
15	5	3	5	6			Moist, loose gray clayey silt	ML				
20	6	5	1	1		[illegible]	Same					
							Moist, medium stiff gray, clayey silt with trace shale fragments, lenticular red clay inclusions					
25	7	7	7	8								
30	8	14	14	14			Moist, stiff, stratified gray silty clay with subrounded fine shale fragments (5%) calcareous					
35	9	3	7	7			Soft, to medium stiff	CL				
40	10	5	6	4		[illegible]	Medium stiff - 10% fragments					
45	11	12	14	62			Dry, very stiff to hard gray silty clay with 50% gravel and cobble size fragments					
	[illegible]	[illegible]	[illegible]	[illegible]			Dry, medium stiff 15-20% fragments					

GAI - 227 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-231

PROJECT: CEI - PNPP W.O. 04-4549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron Testing COORDINATES N 781 185 E 2370660

DRILLER: P. Sedgwick

CLASSIFIED BY: JGD DATE: 6/25-6/27/74

SHEET 2 OF 2

DRILL HOLE NO. 1-77

ELEVATION 624.7

GWL 0 HRS 4'0"

24 HRS 4'1"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
							Gray silty clay with 15-20% shale fragments					
55	13	17	25	31								
							Very stiff to hard (50-75%) frags					
60	14	35	45	77			Vertical joints 60-62' Weathered shale to 62'					
65							Gray shale with thin light gray siltstone lenses (5%) unweathered medium to hard, no joints, thin and flat lamina, max 5"		25%	10'	[illegible]	
70												
							TD 70'					

GAI-287 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-232

PROJECT: CEI - PNPP W.O. 04-4549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron Testing COORDINATES N 781 255 E 2 370 535

DRILLER: L. Humphreys

CLASSIFIED BY: JGD DATE: 6/21-6/25/74

SHEET 1 OF 2

DRILL HOLE NO. 1-78

ELEVATION 622.1

GWL 0 HRS 3'6"

24 HRS 3'11"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE					Topsoil 1'
	1	3	4	6			Moist, loose tan silty fine sand	SM				
5							Moist, soft tan silty (15) sandy (35) clay	CL				
	2	4	5	7		7.6						
10	3	3	3	3			Wet, soft gray silty clay. wet, loose gray silty fine sand with trace clay	CL SM				
	4	3	3	4								
15	5	3	5	6			Same					
20	6	1	4	15			UPPER TILL Moist, medium stiff to stiff gray silty clay with trace shale fragments and coal, stratified					
25	7	6	3	7			Moist, medium stiff gray silty clay with lenticular red clay inclusion and (1-5%) shale fragments, calcareous, stratified	CL				
30	8	4	4	5								
35	9	3	3	10			Same					
							LOWER TILL					
40	10	20	27	40			Dry, stiff gray silty clay with 5-10% fine subrounded shale fragments, calcareous	CL				
45	[illegible]	[illegible]	[illegible]	[illegible]			Very stiff					
50	[illegible]	[illegible]	[illegible]	[illegible]			Stiff					

GAI-287 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-233

SHEET 2 OF 2

PROJECT: CEI - PNPP W.O. 04-4549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-78

CONTRACTOR: Herron Testing COORDINATES N 781 255 E 2 370 535

ELEVATION 622.1

DRILLER: L. Humphreys

GWL 0 HRS 3'6"

CLASSIFIED BY: JGD DATE: 6/21-6/25/74

24 HRS 3'11"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50												
55	13	25	43	56			Dry, very stiff hard clayey silt with 25% fine to coarse grain shale fragments	ML				
60	14	21	33	74		[illegible]	Cobbles					
65							Shale weathered Gray shale with trace siltstone lenses unweathered, medium hard, no joints, thin and flat lamination, max piece 9"		1	10	8.6'	
70										70'		
							T.D. 70'					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-234

SHEET 1 OF 2

PROJECT: CEI - PNPP W.O. 04-4549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-79

CONTRACTOR: Herron Testing COORDINATES N 781 175 E 2 370 770

ELEVATION 620.3

DRILLER: L. Humphrey

GWL 0 HRS 5'

CLASSIFIED BY: JGD DATE: 6/25-6/27/74

24 HRS 3'3"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE					Topsoil 12"
	1	4	5	5			Moist, soft tan silty (20) sandy (30) clay	CL				
5	2	5	3	5			Wet, soft					
10	3	4	3	4			Moist, soft gray silty clay, stratified					
	4	3	4	5			Same					
15	5	2	3	4			Moist, loose, gray sandy (10) clayey (30) silt with red lenticular clay specks, loose to medium stiff	CL				
20	6	1	13	14								
							UPPER TILL					
25	7	3	5	5			Moist, soft to medium stiff gray silty clay with 5% fine subround shale fragments, red lenticular clay specks, stratified, calcareous					
30	8	5	7	7								
35	9	4	6	8								
							LOWER TILL					
40	10	12	16	32			Relatively moist, stiff gray silty clay with fine to medium grain shale fragments (15%), dry, very stiff	CL				
45	11	13	24	[illegible]								
[illegible]	12	[illegible]	[illegible]	[illegible]			30% fragments cobbles					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-235

PROJECT: CEI - PNPP W.O. 06-6569-000 SITE AREA N. Perry, Ohio

SHEET 2 OF 2

DRILL HOLE NO. 1-79

CONTRACTOR: Herron Testing COORDINATES N 781 175 E 2 370 770

ELEVATION 620.3

DRILLER: L. Humphrey

GWL 0 HRS 5'

CLASSIFIED BY: JGD DATE: 6/25-6/27/74

24 HRS 3'3"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50							Dry, very stiff, hard gray silty clay with 33% cobbles fragments					
55	13	34	43	[illegible]		620						
							Weathered shale					
							Gray shale with 1% interlaminated light gray siltstone					
60							Unweathered, medium hard, thin and flat lamination, no jointing max piece 10"		30%	10	10	
65							2-3" clay seams at 65'			66		
							T.D. @ 66'					
70												

GAI - 227 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-236

PROJECT: CEI - PNPP W.O. 06-6569-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 2

DRILL HOLE NO. 1-80

CONTRACTOR: Herron Testing COORDINATES N 780 745 E 2 370 920

ELEVATION 623.2'

DRILLER: Ed. Sedgewick

GWL 0 HRS 4'11"

CLASSIFIED BY: JGD DATE: 7/8-7/10/74

24 HRS 3'9"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												Topsoil 13"
	1	3	6	7			Moist, loose tan silty sand with trace clay	SM				
5	2	3	6	6		10						
10	3	5	7	10			Moist, loose gray clayey silt, stratified	ML				
	4	4	7	9								
15	5	7	10	12			Wet, loose gray silty fine sand					
20	6	4	7	12			Wet, loose gray clayey (10) silty (30) fine sand	SM				
25	7	3	6	8		22	Moist, soft gray silty (10) sandy (20 clay, inclusions, stratified	CL				
30	8	5	5	7			Moist, medium stiff gray silty clay with trace fine shale fragments gravel, stratified, calcareous	CL				
35	9	3	5	7		[illegible]						
40	10	14	22	32			Dry very stiff gray silty clay with subround fine to coarse grained shale fragments (20-30%)	CL				
45	11	30	24	34								
50	12	[illegible]	34	47			Hard					

GAI - 227 2/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-237

PROJECT: CPI - PNPP W.O. 04-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 780 745 / E 2 370 920
DRILLER: Ed. Sedgewick
CLASSIFIED BY: JGD DATE: 7/8-7/10/74
SHEET 2 OF 2
DRILL HOLE NO. 1-80
ELEVATION 623.2
GWL 0 HRS 4'11"
24 HRS 3'9"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
55	13	24	30	50		56'	Dry very stiff to hard gray silty clay with 30% coarse shale fragments	CL				
							Weathered shale					
60							Gray shale with 5% thin siltstone lenses interlaminated, unweathered, medium hard, thin and flat lamination, jointing at 60°, max. piece 5½"		28%	50 / 65	4.3'	Lost part of core because a pebble wedged into the slit of the sample tube and widened the tube, allowing the core to slip out when we pulled the sampler up.
65												
70							Gray shale with 5% thin siltstone clay seam at 72', ½" thick brown fine grain sandstone, unweathered, medium hard, thin and very flat lamination, no joints. maximum piece 7"		46%	5 / 73	4.6'	
75							T.D. 73'					

GAI-237 2/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-238

PROJECT: CPI - PNPP W.O. 04-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 780540 / E 2 370 790
DRILLER: E. Sedgewick
CLASSIFIED BY: JGD DATE: 6/28-7/2/74
SHEET 1 OF 2
DRILL HOLE NO. 1-81
ELEVATION 624'
GWL 0 HRS 4'
24 HRS 4'6"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE					1' topsoil
	1	4	6	8			Moist, loose tan silty fine sand					
5	2	1	2	3			Wet	SM				
						8'						
10	3	4	5	4			Moist, loose gray silty fine sand					
	4	5	5	5								
15	5	3	4	5				SM				
20	6	1	3	3			Moist, soft gray silty (20) sandy (30) clay with red clay inclusions, stratified	CL				
25	7	5	6	7		24'	UPPER TILL					
30	8	4	6	5			Moist, medium stiff gray silty clay with 5% fine, subround shale fragments and red clay inclusions, stratified, calcareous	CL				
35	9	6	9	11		37'	LOWER TILL					
40	10	19	22	44			Dry, very stiff gray clayey silt with fine to medium grain shale fragments (10-20%) calcareous					
45	11	22	48	50				CL				
50	12	11	14	15			Gray clayey silt with medium to coarse grained shale fragments (20-40%) calcareous					

GAI-237 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-239

PROJECT: CEI - PNPP W.O. 06-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 780 540 / E 2 370 790
DRILLER: E. Sedgewick
CLASSIFIED BY: JGD DATE: 6/28-7/2/74
SHEET 2 OF 2
DRILL HOLE NO. 1-81
ELEVATION 624'
GRL 0 HRS 6'
24 HRS 4'6"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
							Gray silty clay with coarse shale fragments (25-50%)					
[illegible]	13	25	30	32			Dry, very stiff, cobbles					
						57'	Weathered shale					
							Gray shale with 5% thin siltstone lenses and some evidence of clay seams, relatively unweathered, medium hard, thin and flat lamination, no joints, max. piece 5"		20 %	10.2	1.4	Had to retrieve last half of sample and in the process broke up some of the sample

GAI-227 8/73

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-240

PROJECT: CEI - PNPP W.O. 06-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 780390 / E 2370980
DRILLER: E. Sedgewick
CLASSIFIED BY: JGD DATE: 7/11-7/12/74
SHEET 1 OF 2
DRILL HOLE NO. 1-82
ELEVATION 624'
GRL 0 HRS 5'2"
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LACUSTRINE					11" top soil
	1	2	2	3			Moist, loose brown silty (15) clayey (20), sand	SM				
5	2	3	3	4								
						7.5	Moist, loose gray silty sand	SM				
10	3	2	3	4								
	4	2	3	4			Moist, soft gray silty clay, stratified					
15	5	2	1	2			Same	CL				
20	6	1	2	2			With interlaminated sand layers and red clay inclusions					
25	7	3	5	7								
						28.5	Moist, soft to medium stiff gray silty clay with 5% of fine to coarse shale fragments, stratified, calcareous	CL				
30	8	2	4	6								
35	9	3	6	8								
						44.5	Dry, stiff to very stiff gray silty clay with 10-20% subround fine to coarse shale fragments, stratified, calcareous	CL				
40	10	13	14	21								
45	11	12	14	12								
50	13	11	15	[illegible]								

GAI-227 8/73

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-241

SHEET 2 OF 2

PROJECT: CEI - PNPP W.O. 04-4549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-82

CONTRACTOR: Herron Testing COORDINATES N 780390 E 2370980

ELEVATION 624

DRILLER: E. Sedgewick

GWL 0 HRS 5'2"

CLASSIFIED BY: JGD DATE: 7/11/74-7/12/74

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50							Dry, hard, gray silty clay with 30-40% coarse shale fragments					
55	13	93	71	75								
		[illegible]				59.5						
60							WEATHERED SHALE					
							Gray shale with 5% thin siltstone lenses, ½" thick fine grain sandstone at 61', 1½" and 3/4" gray clay seams at 63-64', unweathered, medium hard, thin and flat lamina, no joints, max. piece 3"		0 %	10'	4.1'	
65												
										64		
70												

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-242

SHEET 1 OF 2

PROJECT: CEI - P.N.P.P. W.O. 064549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-87

CONTRACTOR: Herron Testing COORDINATES N 779 566 E 2 370 054

ELEVATION 622.0

DRILLER: E. Sedgewick

GWL 0 HRS 6'8"

CLASSIFIED BY: JGD DATE: 9/30-10/2/74

24 HRS 6'3-1/2"

Depth Ft.	Sample No.	SPT 6	12	18
0	1	2	5	5
	2	4	9	9
	3	5	6	6
5	4	1	4	6
	5	2	4	5
	6	2	4	6
10	7	2	4	6
	8	1	4	7
	9	2	4	5
15	10	2	4	6
	11	2	4	6
	12	3	6	7
	13	4	6	8
20	14	2	3	4
	15	2	4	6
	16	2	4	4
25	17	1	2	3
	18	2	3	4
	19	3	6	6
30	20	3	6	11
	21	5	18	21
	22	13	26	34
	23	14	32	42
35	24	21	30	46
	25	26	36	43
	26	16	31	28
40	27	16	35	56
	28	16	32	42
	29	21	28	33
45	30	18	31	40
	31	23	36	41
	32	21	34	42
	33	34	41	

DESCRIPTION (Density (or Consistency), Color, Rock Or Soil Type - Accessories) — U.S.C.S. — REMARKS:

- Light brown silt, dry, loose — REMARKS: T.S. = 18" Lacustrine
- Red-light brown-gray mottled sandy silt with subangular fine to med shale gravel, dry, medium dense — ML
- Silty fine sand, wet
- Gray silt, laminated, moist, loose to medium dense
- Same with trace clay, fine sand, and black organic layers — ML
- Gray silty fine-sand, loose, wet — SM
- Gray silt with trace clay, fine sand and black organic layers, moist, loose, medium dense, laminated — ML
- Same with red clay specs — ML
- Gray silt & red & gray clay (interlaminated) with trace black organic layer, moist — ML
- (23.5) Gray clayey silt & red clay lenses
- Interlaminated, moist, soft - med stiff gray silty clay and red clay with trace silt lenses, black organic material and fine shale fragments (>1%) — CL — REMARKS: Upper till
- Gray silty clay with some red clay lenses tr f sh frag, moist, stiff
- (30.5) Gray silty clay with little subangular fine to medium shale fragments, blocky, hard, damp, laminated — CL — REMARKS: Lower Till
- Same with some subangular fine to coarse shale fragments
- Gray sandy silty clay with some fine - coarse shale fragments
- Gray silty clay with some fine - coarse shale fragments, cobbles

GAI - 227 8/72

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-243

PROJECT: CEI - P.N.P.P. W.O. 044549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 779 556 / E 2 370 054
DRILLER: P. Sedgwick
CLASSIFIED BY: IGD DATE: 9/30-10/2/74
SHEET 2 OF 2
DRILL HOLE NO. 1-87
ELEVATION 622.0
GWL 0 HRS 6'8"
24 HRS 6'3-1/2"

Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Core Run	Core Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
	Gray sandy silty clay and cobble size subangular shale fragments	SC				
	Weathered shale					
	Dark gray shale with 5-10% thin interlaminated light gray siltstone, medium hard, unweathered, thin & flat lamina, some vertical jointing, max piece 2½", & some cross lamination		[illegible]%	10'	[illegible]	Lost part of sample (ball bearing got wedged into core retainer slit widening core retainer and allowing part of sample to slip out
	Grey shale with 10% thin interlaminated light gray siltstone & occasional ½ - 1" thick fine brown sandstone, medium hard, unweathered, thin & flat lamination, cross lamination, no jointing. max. piece 15"		[illegible]%	10'	[illegible]	
	Grey shale with 5% thin interlaminated siltstone and occasional thin ½" thick fine brown sandstone, medium hard, unweathered, thin & flat lamination, occasional cross lamination, ½" thick vertical joint at 78½', max. piece 13½"		[illegible]%	10'	[illegible]	
	T.D. 83.0'					

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-244

PROJECT: CEI - P.N.P.P. W.O. 044549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 779621 / E 2370233
DRILLER: E. Sedgwick
CLASSIFIED BY: IGD DATE: 10/4/74
SHEET 1 OF 2
DRILL HOLE NO. 1-88
ELEVATION 625.2
GWL 0 HRS 7'6"
24 HRS 6'9-1/2"

Sample No.	SPT Blows/6 in. 6	12	18
1	1	4	6
2	3	6	6
3	5	4	5
4	3	3	3
5	1	3	5
6	2	3	4
7	1	6	5
8	4	3	5
9	1	5	7
10	4	3	4
11	3	6	[illegible]
12	6	7	11
13	6	8	[illegible]
14	5	7	9
15	4	5	6
16	4	4	5
17	3	5	8
18	4	4	7
19	4	7	8
20	4	7	8
21	3	5	6
22	5	6	10
23	8	14	16
24	9	28	[illegible]
25	14	[illegible]	[illegible]
26	18	[illegible]	[illegible]
27	21	[illegible]	[illegible]
28	[illegible]	[illegible]	[illegible]
29	18	[illegible]	[illegible]
[illegible]	17	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
Tan silt, medium dense, damp		Top soil 8"
Red-brown fine sandy silt, medium dense, damp	ML	Lacustrine Sediments
Mottled red-brown fine sandy silt, loose, moist		
Gray silty fine sand, loose, wet	ML	
Gray fine sandy silt with trace clay, loose, wet		
Gray silt and clay, laminated, stiff, moist	CL-ML	
Gray clayey silt with trace black organic material, stiff to medium dense, moist	ML	
Gray silt and silty clay with trace black organic material interlaminated, stiff to medium dense, moist	CL-ML	
Same with red clay lenses		
Gray silty clay w/some silt lenses	CL	Upper Till
Same with trace subangular shale fragments		
Gray silty clay with some lenticular red clay lenses and trace subangular fine to medium shale gravel, stiff, moist, laminated	CL	
Coarse gravel, siltier, less moist		
Gray silty clay with some fine to coarse subround shale gravel and subround shale cobbles, hard, damp	CL	Lower Till
Gray silty clay and fine to very coarse subangular shale gravel and quartz gravel, hard, damp	SC	

GAI-227 8/72

2E-245

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 2

PROJECT: CEI - P.N.P.P. W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. 1-88

CONTRACTOR: Herron Testing COORDINATES N 779621 E 2370233

ELEVATION 625.2

DRILLER: E. Sedgewick

GWL 0 HRS 7'6"

CLASSIFIED BY: JGD DATE: 10/7/74

24 HRS 6'9-1/2"

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50		[illegible]			Fine to very coarse (2"d) subangular shale gravel and gray silty clay, hard, moist					
					Weathered shale			54.5'		Shale
55					Gray silty shale and interlaminated light gray siltstone (4" thick zone at 54.5') with some fine gray brown sandstone lenses, thin flat lamination and x-lamination, some clay zones - 59'; 59½', medium hard, unweathered, jointing at 60' at 75°, maximum piece 10"		57%	10'	9.6'	
60										
65								64.5'		
					Gray silty shale with trace gray siltstone, fine grained brown sandstone lenses, thin and flat lamination, medium hard, unweathered, no joints, max. piece 1'		57%	10'	9.8'	
70										
75					T.D. 74.5					
80										

GAI-227 8/72

2E-246

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 4

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Lake Erie/N. Perry

DRILL HOLE NO. S-1

CONTRACTOR: Warren George COORDINATES N 784,598 E 2,367,208

ELEVATION Lake Bottom [illegible]

DRILLER: Ed Fritsch

GWL 0 HRS

CLASSIFIED BY: D.B.S. DATE: 9-26-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock or Soil Type - Accessories	% Recovery	R.Q.D.	Soil or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					(USGS) Lake Level 574.05 = 0					
5										
10										
15										
20										
25										
30				[illegible]						
				[illegible]	C-M Sand					
35								37.0		
					Barrel pushed easily thru material, suspected soft weathered zone 546.10					
40					Chagrin Shale - Dk.grey shale, numerous lt.grey sandstone-siltstone seams, some zones of soft clayey shale up to 1" thick ½" clay seam @ 44.0'; numerous horz. bedding joints, most pc. ½-2", 60° fract. @ 42.0'	66		10.0'	6.6'	L.P. 0.5' S.P. 0.03' Avg. 0.2'
45								47.0		
50										

GAI-227 8/72

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-247

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Lake Erie/N. Perry Lake

SHEET 2 OF 4

DRILL HOLE NO. 5-1

CONTRACTOR: Warren George COORDINATES ______ ELEVATION 582.[illegible]

DRILLER: Ed Fritsch GWL 0 HRS ______

CLASSIFIED BY: D.B.S. DATE: 9-26-72 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% Recovery	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50–57.0					Same; soft shale zones 48.5-49.3 and 53.5 to 55, near vertical fracture at 49.5' and 50'	95		10.0'	9.5'	L.P. 0.62' S.P. 0.04'
57.0–67.0					Same; badly broken zone 5" thick at 59.2-59.7, thin soft seams at 60.4, 60.8, 61.8, 63.7, fracture 30° at 61.2, appears generally less weathered, more massive than first two runs	99		10.0'	9.9'	L.P. 0.75 S.P. 0.03 Avg. 0.4
67.0–77.0					Same as above; soft shale zone 72.1-72.6, some horizontal bedding fracture & 20° fractures at 74.1 and 74.4, v. thickey seam at 72.9	94		10.0'	9.4'	L.P. .64' S.P. 0.02 Avg. .4'
77.0–87.0					Same; no weak shale zones, no irregular fractures in horizontal bedding fractures 2"-12" apart; shale unweathered & unbroken - solid appearance; numerous siltstone seams w/some cross bedding	100		10.0'	10.0'	L.P. 0.9' S.P. 0.03' Avg. 0.5'
87.0–97.0					Grey shale, w/cross bedding, weak zones @ 94.3' thru 97.0' w/fine grained sandstone seams - solid up to 94.3'	100		10.0'	10.0'	L.P. 0.7' S.P. 0.03 Avg. 0.45'
97.0–100										

GAI-227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-248

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio

SHEET 3 OF 4

DRILL HOLE NO. 5-1

CONTRACTOR: Warren George COORDINATES ______ ELEVATION ______

DRILLER: Jake Harris GWL 0 HRS ______

CLASSIFIED BY: R.P.V. DATE: 9-28-72 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% Recovery	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100–107.0					Same, with weak zone @ 106.0'	100		10.0'	10.0'	L.P. 0.8' S.P. 0.03' Avg. 0.3'
107.0–117.0					Same, with weak zones @ 108.5, 112.0, & 115.3	97.5		10.0'	9.75	L.P. 1.08 S.P. 0.02'
117.0–127.0					Grey shale, massive, w/occ. weak zones, little cross bedding, 2"-3" thick layers of fine grained sandstone	96		10.0'	9.6'	L.P. 1.6 S.P. 0.02 Avg. 0.7
127.0–137.0					Grey shale w/fine grained sand layers, some weak zones 128.5, 130.5, occ. dark brown banding - some vert. fract.	95		10.0	9.5	L.P. 1.05' S.P. 0.03'
137.0–147.0					Same; weak clayey shale zones 140.9, 141.2, 144.1, 145.1, fracture zone (60°) at 145.1-145.4	97		10.0	9.7	L.P. 0.90' S.P. 0.15 Avg. 0.40
147.0–150										

GAI-227 9/72

2E-249

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Lake Erie/ N. Perry, Ohio

SHEET 4 OF 4

DRILL HOLE NO. S-1

CONTRACTOR: Warren George COORDINATES

ELEVATION

DRILLER: Jake Harris

GWL 0 HRS

CLASSIFIED BY: D.B.S. DATE: 9-28-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% Recovery	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
150					Same, solid run, weak zones 149.4, 152.8	100		10.0'	10.1'	L.P. 2.20' S.P. .25 Avg. .80
155								157.0		
160					Same; zone of .05' pieces 160.9-161.3	94		10.0'	9.4'	L.P. 1.20' S.P. .04' Avg. 0.30 Approx. 2.0' of core remained-picked up in 167-177 run
165								167.0		
170					Grey shale w/sandstone layer 167.8-168.2 and numerous other interspersed layers of SS; weak zone 175.0', very "sound" appearance	99		10.0'	9.9'	L.P. 1.85' S.P. .07 Avg. 1.0'
175								177.0		
180					Same; no apparent weak zones	97		3.0 180.0	2.9'	L.P. 1.30'

GAI-237 8/72

2E-250

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 1 OF 4

DRILL HOLE NO. S-2

CONTRACTOR: Warren George COORDINATES N 782,507 E 2,368,433

Lake Bottom ELEVATION 555.1

DRILLER: Jake

GWL 0 HRS 19.0' W.L.

CLASSIFIED BY: R.P.V. DATE: 10-3-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color (USCS) Rock Or Soil Type - Accessories	% Recovery	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					Lake Level 574.1 = 0					
5										Drove 5" casing 2' into bottom w/600# hammer 17/89
10										
15										
20				19.0	Dk. grey shale w/clay seams - w/pcs of boulder			21.0		Used 140# hammer for first 6" then 300# hammer
25					Boulder sections over dark grey shale, extensively cross bedded, w/fine grained sandstone seams - weak zones (clay w/shale frags @ 23.5 and 25.0')	78%		6.0'	4.7'	L.P. 0.5' S.F. 0.02' Ave. 0.3'
								27.0		
30					Dark grey shale, some cross bedding, w/fine grained sandstone seams - weak zone @ 28.0'	85		10.0'	8.45'	L.P. 0.8' S.P. 0.04' Ave. 0.4'
35								37.0		
40					Dark grey shale - extensively cross bedded; 5" clay & fract. shale seam @ 40.9'; a 1" soft seam @ 46.8' w/fine grained sandstone seams	100		10.0'	10.0'	Lost water @ 38' L.P. 0.77' S.P. 0.02' Ave. 0.3
45								47.0		
50										

GAI-237 8/72

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-251

CEI - Perry Nuclear

PROJECT: Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 2 OF 4

DRILL HOLE NO. S-2

CONTRACTOR: Warren George COORDINATES ______

ELEVATION ______

DRILLER: Jake Harris

GWL 0 HRS ______

CLASSIFIED BY: D.B.S. DATE: 10-4-72

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% RECOVERY	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50–56.0					Grey shale w/cross bedded SS; no fractures on recovered soft shale zones	90%		9.0'	8.6'	L.P. 0.70' S.P. 0.04' Avg. 0.3'
56.0–66.0					Same but 1/4" clay seam @ 56.1	94		10.0'	9.4'	L.P. 0.9' S.P. 0.2' Avg. 0.5'
66.0–76.0					Same;w/near horizontal irregular fracture & soft shale @ 74.9,broken solid shale & some clay near base of run; fracture & thin layer of soft shale @ 68.4	99		10.0	9.9	L.P. 1.10' S.P. .04' Avg. .50'
76.0–86.0					Grey shale w/cross bedded SS; fairly massive run, no apparent fractured or soft shale zones	100		10.0'	10.0'	L.P. 1.30' S.P. 0.05' Avg. 0.50'
86.0–96.0					Same as above; a few very thin weaker shale partings between 89 and 90	96		10.0'	9.6'	.2' lost recovered in next run
96.0–100										

GAI-227 8/71

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-252

CEI - Perry Nuclear

PROJECT: Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 3 OF 4

DRILL HOLE NO. S-2

CONTRACTOR: Warren George COORDINATES ______

ELEVATION ______

DRILLER: Jake Harris

GWL 0 HRS ______

CLASSIFIED BY: D.B.S. DATE: 10-4-72

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% RECOVERY	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100–105.8					Grey shale & SS soft & broken shale 1" thick @ 98.85, thin soft shale layer @ 100.4, 104.55 run appears generally massive	100		9.8'	10.0'	2' of this run belongs w/previ run L.P. 1.35' S.P. .08' Avg. .80'
105.8–115.8					Grey shale w/sandstone seams - soft & broken shale (±0.1') @ 113.8'	90		10.0'	9.0'	L.P. 1.0' S.P. 0.06' Ave. 0.5'
115.8–125.8					Same - badly fractured zones 118.9 to 119.0, 121.5 to 121.8 and 122.1 to 122.3	98.5		10.0'	9.85'	L.P. 1.2' S.P. 0.07' Ave. 0.4'
125.8–135.1					Sound grey shale & fine grained sandstone	86		9.3'	8.0'	L.P. 0.9' S.P. 0.07' Ave. 0.4'
135.1–145.1					Same	100		10.0'	10.0'	L.P. 2.2' S.P. 0.25' Ave. 0.7'
145.1–150										

GAI-227 8/71

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-233

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

CONTRACTOR: Warren George

DRILLER: Jake Harris

CLASSIFIED BY: D.R.S. DATE: 10-5-72

SHEET 4 OF 4

DRILL HOLE NO. S-2

ELEVATION

GWL 0 HRS

24 HRS

COORDINATES

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% Recovery	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
150					Dark grey shale & sandstone fractured zone @ 153.6'	98%		10.0'	9.8'	L.P. 1.3'; S.P. 0.03'; Ave. 0.4'
155								157.5		
160					Dark grey shale & fine grained sandstone badly fractured @ 159 thru 163.5	100		10.0'	10.0'	L.P. 1.1'; S.P. 0.05'; Ave. 0.3'
165					Sound grey shale & sandstone			165.5		
						100		5.0'	5.0'	L.P. 1.4'; S.P. 0.04'; Ave. 0.6'
170					End of hole 10-5-72 0435 a.m.			170.5		
175										

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-234

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549 SITE AREA Perry, Ohio

CONTRACTOR: Warren George

DRILLER: Jake

CLASSIFIED BY: R.P.V. DATE: 10-1-72

COORDINATES N 783,614 E 2,369,005

SHEET 1 OF 5

DRILL HOLE NO. S-3

ELEVATION Lake Bottom 553.00

GWL 0 HRS

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color (USGS) Rock Or Soil Type - Accessories	% Recovery	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					Lake Level 574.05					Drove 5" casing to 21.5' - Reamed Drove NX flush joint to 26.0'
5										
10										
15					... at 570.3					
20				20.8						
				22.5	C - M - Sand					
25				26.0				26.0		
30					Boulder frags - probably pushed down w/casing - Dk. grey shale, fissile, w/weak clayey zones @ 27.0' & 30.5' - heavily cross bedded few fine grained sandstone seams	77		7.6'	5.8'	L.P. 0.6'; S.P. 0.07'; Ave. 0.31; Could not compl 10' run, barrel plugged up
35					Dark grey shale, fissile, w/weak clayey zones @ 33.5, 38.5 & 42.0'. Heavily cross bedded w/occ. fine grained sandstone seams	100		33.6 / 10.0'	10.0'	L.P. 0.73'; S.P. 0.03'; Ave. 0.4'
40										
45					w/zones @ 46.0', 49.0' & 52.0'	100		43.5 / 10.0'	10.0'	L.P. .95'; S.P. 0.04'; Ave. 0.4'
50										

GAI-227 8/72

GILBERT ASSOCIATES, INC.

2E-255

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549 SITE AREA Perry, Ohio

SHEET 2 OF 5

DRILL HOLE NO. 5-3

CONTRACTOR: Warren George COORDINATES

ELEVATION

DRILLER: Jake

GWL 0 HRS

CLASSIFIED BY: R.P.V. DATE: 10-1-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% RECOVERY	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50										
53.5–63.5 (55, 60)					Dark grey shale - extensively crossbedded from 62.0-63.5 - Some fine grained sandstone seams	100		10.0'	10.0'	L.P. .97' S.P. .05' Ave. 0.5' Core looks massive
63.5–73.5 (65, 70)					Same - some crossbedding, few sandstone seams	97.5		10.0'	9.75'	L.P. .75' S.P. 0.09' Ave. 0.4'
73.5–83.5 (75, 80)					Weak Zone @ 78.0'	100		10.0'	10.0'	L.P. 1.4' S.P. 0.04' Ave. 0.4'
83.5–93.5 (85, 90)					Dk.grey shale, w/fine grained sandstone seams (0.35' seam @ 87.0') weak zone @ 87.4' & 92.5'	100		10.0'	10.0'	L.P. 0.95' S.P. 0.04' Ave. 0.4'
93.5–100 (95)					Same - weak (clayey) seam @ 93.7' very little crossbedding w/fine grained sandstone seams	93.5		10.0'	9.35'	L.P. 0.95' S.P. 0.07' Ave. 0.35'
100										

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

2E-256

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549 SITE AREA Perry, Ohio

SHEET 3 OF 5

DRILL HOLE NO. 5-3

CONTRACTOR: Warren George COORDINATES

ELEVATION

DRILLER: Jake

GWL 0 HRS

CLASSIFIED BY: R.P.V. DATE: 10-1-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% RECOVERY	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100										
103.5–113.5 (105, 110)					Dark grey shale, some crossbedding, fine grained sandstone seams vert. fract. @ 112.0'	97.5		10.0'	9.75'	L.P. 0.45' S.P. 0.05' Ave. 0.2'
113.5–123.5 (115, 120)					Same; soft clayey shale zones @ 120, 120.5, 123.0	98.5		10.0'	9.85'	L.P. 1.2' Avg. .3' S.P. 0.01'
123.5–133.5 (125, 130)					Same grey shale & crossbedded S.S., strong petroliferous odor & pressure in spurts displaced water up NX casing 10'; no apparent soft shale zones, petroliferous odor on some fresh breaks	95		10.0'	9.5'	L.P. 1.5' S.P. .1' Avg. .6' Gas pocket encountered - odor detected when rods pulled water jetted up hole approx. 8' above deck
133.5–143.5 (135, 140)					Same; soft shale @ 134.0, & 143; w/3" section of two vertical fractures @ 143.0-143.2, no	96		10.0'	9.6'	L.P. 1.70' S.P. .05' Avg. .6' Gas detected - pressure on water w/i casing reduced
143.5–150 (145)					Grey shale & S.S.; no soft or broken shale zones but pieces unusually short - v.thin clay seams? however some breaks along SS-shale interfaces	95		10.0'	9.5'	No gas pressure no odor L.P. 0.4' S.P. 0.05' Avg. 0.15'
150										

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-257

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549 SITE AREA Perry, Ohio

SHEET 4 OF 5

DRILL HOLE NO. S-3

CONTRACTOR: Warren George COORDINATES

ELEVATION

DRILLER: Jake

GWL 0 HRS

CLASSIFIED BY: R.P.V. DATE: 10-2-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% Recovery	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
150–155								153.5		
155–163.5					Grey shale & SS, broken & weak shale 160.0, 160.7, 162-162.5, 163.3-163.5	96		10.0'	9.6'	L.P. 0.80' S.B. 0.05' Avg. 0.30'
163.5–173.5					Grey shale & SS, apparently unbroken & unweathered, core barrel hammered to free core - possibly accounting for smaller pieces, esp. in bottom 5' of run	97		10.0'	9.7'	L.P. 0.90' S.P. 0.03' Avg. 0.20'
173.5–183.5					Same, no broken or weathered zones, however abundant SS seams perhaps associated w/breaks	100		10.0'	10.0'	L.P. 0.50' S.P. 0.02' Avg. 0.20' 2 samples
183.5–193.1					Same as above	98		9.6'	9.4'	L.P. 0.30' S.P. 0.03' Avg. 0.20' Too short for sampling
193.1–200					Same as above	99		10.0'	9.9'	L.P. 0.45' S.P. 0.03' Avg. 0.20'

GAI - 327 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-258

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549 SITE AREA Perry, Ohio

SHEET 5 OF 5

DRILL HOLE NO. S-3

CONTRACTOR: Warren George COORDINATES

ELEVATION

DRILLER: Jake

GWL 0 HRS 17' of water

CLASSIFIED BY: R.P.V. DATE: 10-2-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% Recovery	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
200–203.1								203.1		
203.1–213.1					w/120' of rod in hole gas & water started coming out in excess of 45 psi. Start @ 10:45. Stopped drilling - dk.grey shale, broken into 2-4" lengths, w/fine grained sand seams, little crossbedding - started drilling @ 13:30	[illegible]		10.0'	9.35'	L.P. 0.32' S.P. 0.04' Avg. 0.2' 128"
213.1–223.1					Same, with 0.2'-0.4' of fine grained sandstone layers	95		10.0'	9.5'	L.P. 0.92' S.P. 0.02' Avg. 0.4'
223.1–233.1					Dark grey shale & fine grained sandstone	97		10.0'	9.7'	L.P. 1.15' S.P. 0.1' Avg. 0.55'
233.1–243.1					Same - fractured zones @ 233.3; 234.4; & 237.0'	93		10.0'	9.3'	L.P. 1.2' S.P. 0.15' Avg. 0.5'
243.1–250					This hole should have stopped @ 171.5'; thru misinterpretation of instruction sheet it was taken down to 243.1'. Over-drilled by 71.6'					Grouted using 14 bags of Dusommer air entrained cement

GAI - 327 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-259

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio SHEET 1 OF 4
CONTRACTOR: Warren George COORDINATES N 784,492 DRILL HOLE NO. S-4
DRILLER: Jake Harris E 2,368,699 Lake Bottom ELEVATION 547.64
CLASSIFIED BY: D.B.S. DATE: 10-10-72 GWL 0 HRS ______ 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color (USCS) Rock Or Soil Type - Accessories	% RECOVERY	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					Lake Level 574.04 = 0					
20					El[illegible] [illegible]					
25				26.4	El. 547.64'					Total Depth below lake level 176.4'
30					Dk. grey soft shale, horiz. bedding, some 60° jointing, very weak zones @ 27.2', 29.5', 30.5' & 32.2' - crossbedded, not suitable for preserving a sample	76		27.2 / 8.2'	6.25'	L.P. 0.4'; S.P. 0.02'; Avg. 0.2'
35					Grey shale, w/sandstone seams	67		35.0 / 3.0' / 38.0	2.0'	L.P. 0.55'; S.P. 0.03'; Avg. 0.2'
40–45					Dark grey shale, w/extensive cross bedding, numerous weak zones (41.0', 42.5, & at 45.5') a 2' clay zone w/shale frags, w/ sandstone seams	93		10.0' / 48.0	9.3'	L.P. 0.6'; S.P. 0.06'; Ave. 0.25'
50										

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-260

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio SHEET 2 OF 4
CONTRACTOR: Warren George COORDINATES ______ DRILL HOLE NO. S-4
DRILLER: Jake Harris ELEVATION 574.04
CLASSIFIED BY: D.B.S. DATE: 10-10-72 GWL 0 HRS ______ 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% RECOVERY	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50–55					Grey shale w/f. grained sandstone seams - w/60° fractured between 49.3 & 50.3, clay zone @ 55.0'	93		10.0' / 58.0'	9.3'	L.P. 0.75'; S.P. 0.03'; Ave. 0.2'
60					Grey shale w/f. grained sandstone seams	[illegible]		3.25' / 61.25	2.[illegible]'	L.P. 0.7'; S.P. 0.07'; Ave. 0.4
65–70					Same - badly fractured @ 61.5' & 71.0'; soft clay seams @ 66.5 & 70.8'	96.5		10.0' / 71.25	9.65'	L.P. 0.88'; S.P. 0.03'; Ave. 0.4'
75					Numerous fractured zones @ 72.0 74.7; 8" clay seam @ 76.25' & 99.6'	95		8.75' / 80.0	8.3'	L.P. 0.6'; S.P. 0.04'; Ave. 0.3'
80–85					Dark grey shale & sandstone - horizontal jointing - soft zones @ 85.0 to 85.4' & at 87.8'	94		10.0' / 90.0	9.4'	L.P. 0.85'; S.P. 0.02'; Ave. 0.25'
90–95					Fractured zone @ 97.5'	96.5		10.0' / 100	9.65'	L.P. 0.9'; S.P. 0.1'; Ave. 0.4
100										

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

2E-261

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 3 OF 4

DRILL HOLE NO. S-4

CONTRACTOR: Warren George COORDINATES ____

ELEVATION 574.04

DRILLER: Jake Harris

GWL 0 HRS ____

CLASSIFIED BY: D.B.S./R.E.L. DATE: 10-11-72

24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% Recovery	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
100, 105					Dark grey shale,w/fine grained sandstone seams,w/weak zone from 102.8' to 103.1' - and @ 1078'	94		8.0' 108.0	7.5'	L.P. 0.7' S.P. 0.07' Ave. 0.35'
110, 115					Same; no apparent fractures or weak shale zones	98		10.0' 118.0	9.8'	L.P. 2.7' S.P. 0.03' Ave. 0.7'
120, 125					Dark grey shale w/thin seams of fine grained sandstone gray clay seams in zone from 118.4 to 120.55. Measurable clay seams 118.6 to 118.78 & 119.15 to 119.22. All pieces of core in this zone less than 0.2, weak zone 125.7 to 125.8	100		10.0' 128.0	10.0'	L.P. 0.95' S.P. 0.03' Ave. 0.5
130, 135					Dark grey shale w/thin seams of fine grained sandstone Broken zone 136.15 to 136.25	100		10.0' 138.0	10.0'	L.P. 1.32' S.P. 0.1' Ave. 0.7
140, 145, 150					Weak zone - clay & shale frags @ 138.0' Dark gray shale w/thin seams of fine grained sandstone Slightly broken zones from 138.8 to 138.95 and 146.37 to 146.46	95		10.0 148.0	9.5'	L.P. 1.07' S.P. .04' Ave. 0.65

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

2E-262

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 4 OF 4

DRILL HOLE NO. S-4

CONTRACTOR: Warren George COORDINATES ____

ELEVATION 574.04

DRILLER: Jake Harris

GWL 0 HRS ____

CLASSIFIED BY: D.B.S./R.E.L. DATE: 10-11-72

24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% Recovery	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
150, 155					Dark gray shale w/thin seams of fine grained sandstone. weak zones 148.90 to 148.92, 150.50 to 150.55, 151.84 to 151.87, 152.04 to 152.10; and 156.98 to 157.14; thin horizontal laminations and moderately broken	96		10.0' 158.0	9.65'	L.P. 0.9' S.P. 0.02' Ave. 0.6'
160, 165					Same; pieces not over .3' in 164-168, unbroken but thin seams of clay and soft shale suspected	97		10.0' 168.0	9.7'	L.P. 1.2' S.P. .04' Ave. .25 As rods were being pulled they jammed @ 146';back press. created artesian like condition
170, 175					Dark gray shale w/thin seams of fine grained sandstone; finely fractured zone 176.5 to 176.6; weak zone 175.4 to 175.6 & 177.25 to 177.27	99		10.0' 178.0	9.9'	4.6' matl. caved on bottom of 168' @ re-entry of core barrel L.P. .12' S.P. .03' Ave. .06'
180					Terminated boring @ 178.0 10-11-72 in gray shale					

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Lake Erie N. Perry, Ohio SHEET 1 OF 4

CONTRACTOR: Warren George COORDINATES N 782,741 E 2,369,272 DRILL HOLE NO. S-5

DRILLER: Jake Harris Lake Bottom ELEVATION 561.0

CLASSIFIED BY: D.R.S. DATE: 10-5-72 GWL 0 HRS ____ 24 HRS ____

(USGS) Lake Level 574.1 = 0

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	Description (Density (or Consistency), Color; Rock Or Soil Type - Accessories)	% Recovery	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
0–12.6					[illegible]					5" casing bounded immediately on solid "rock" bottom. Surveyed elev. of bottom step w/landing plat. @ 577.6. 6" shale recovered by NX flush joint casing (3" ID) solid
12.6–19.8					Grey shale & SS (in shale from casing) slightly weathered on partings (¼-½" apart) traces of clay near top of run	57		6.4'	2.0'	L.P. 0.68'; S.P. 0.05'; Avg. 0.2'
19.8–25.0					Grey shale & SS, broken at 21.3, 21.5, 22.5, 23.7; thin soft shale zone at 20.0, 21.8, 22.8, 23.2. The later is a clayey shale 1" thick appearing as though filling a fracture zone but retains relic bedding	[illegible]		6.0'	5.85'	Several near vertical fracs. L.P. 0.60'; S.P. 0.02'; Avg. 0.20'
25.0–35.0					Grey shale & SS; soft shale zones @ 26.4, 26.7, 28.4, 28.9, 29.4, 30.6, 31.0, 34.8; broken @ 34.0 & 35.0	94.9-99		10.0'	9.8'	L.P. 0.80'; S.P. 0.02'; Avg. 0.40'
35.0–45.0					Grey shale & SS, closely broken fracture 45° @ 36'; parallel fractures 30° at 44.5, 44.7, soft shale @ 44.0 (all fracture angles WRT normal to core run angle bedding plane)	93		10.0'	9.3'	L.P. .85'; S.P. .03'; Avg. .50'
45.0–50										

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio SHEET 2 OF 4

CONTRACTOR: Warren George COORDINATES ____ DRILL HOLE NO. S-5

DRILLER: Jake Harris ELEVATION 574.1

CLASSIFIED BY: D.R.S. DATE: 10-5-72 GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	Description (Density (or Consistency), Color; Rock Or Soil Type - Accessories)	% Recovery	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
50–55.0					Same; clay seam ½" @ 47.4' a zone 1' thick 49.4-50.4 of highly weathered & broken shale & clay; 25° fracture at 53.7	93		10.0'	9.3'	L.P. 0.7'; S.P. 0.06'; Avg. 0.3'
55.0–65.0					Dark grey shale, some crossbedding w/fine grained sandstone seams - weak clayey zones @ 61.3; 62.8	98		10.0'	9.85'	L.P. 0.9'; S.P. 0.04'; Avg. 0.35'
65.0–75.0					Massive - ¼" clay seam @ 71.2	[illegible]		10.0'	9.85'	L.P. 1.2'; S.P. 0.05'; Avg. 0.5'
75.0–85.0					Same w/1" clay seam @ 82'	[illegible]		10.0'	9.85'	L.P. 1.5'; S.P. 0.07'; Avg. 0.3'
85.0–95.0					Weak zones @ 85.2, 87.1, 89.4, & 94.7	[illegible]		10.0	9.78	L.P. 0.68'; S.P. 0.1'; Avg. 0.3'
95.0–100										

GAI-227 8/72

GILBERT ASSOCIATES, INC.

CEI - Perry Nuclear SOIL AND ROCK CLASSIFICATION SHEET

2E-265

PROJECT: Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 3 OF 4

DRILL HOLE NO. S-5

CONTRACTOR: Warren George COORDINATES

ELEVATION

DRILLER: John Harris

GWL 0 HRS

CLASSIFIED BY: D.R.S. DATE: 10-6-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% RECOVERY	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100–105					Dk.grey shale, w/fine grained sandstone seams - badly fractured @ 97.3, 101.3, clay seams @ 98-98.4	98		10.0' (105.0)	9.8'	L.P. 0.6' S.P. 0.03' Avg. 0.3'
105–115					Sound dark grey shale & sandstone	97.5		10.0 (115.0)	9.75	L.P. 1.20' S.P. 0.06' Avg. 0.6'
115–125					Horizontal jointed	97.5		10.0' (125.0)	9.75'	L.P. 0.65' S.P. 0.06' Avg. 0.2'
125–135					Dark grey shale & fine sandstone sound	96.5		10.0' (135.0)	9.65'	L.P. 1.1' S.P. 0.1' Avg. 0.7'
135–145					Same	93		10.0' (145.0)	9.3'	L.P. 1.9' S.P. 0.22' Avg. 0.8
145–150										

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

CEI - Perry Nuclear SOIL AND ROCK CLASSIFICATION SHEET

2E-266

PROJECT: Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 4 OF 4

DRILL HOLE NO. S-5

CONTRACTOR: Warren George COORDINATES

ELEVATION

DRILLER: John Harris

GWL 0 HRS

CLASSIFIED BY: D.R.S. DATE: 10-6-72

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% RECOVERY	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
150–155					Dark grey shale & fine grained sandstone badly fractured @ 147.5, 149.4, 153.9	100		10.0' (155.0)	10.0'	L.P. 1.6' S.P. 0.05' Avg. 0.5'
155–165					No fractured zones	96.0		10.0' (165.0)	9.6'	L.P. 0.95' S.P. 0.05' Avg. 0.2'
165–175					Grey shale & SS (sandstone from strings to 0.2') soft shale at approximately 165.2, 168.5; slightly broken zone @ 165.5-165.7	95		10.0 (175.0)	9.5	

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-267

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

SHEET 1 OF 7

DRILL HOLE NO. S-6

CONTRACTOR: Warren George

COORDINATES 783,307.SN 2,367,270.0E

ELEVATION 574±

DRILLER: Ed Fritsch

GWL 0 HRS 574±

CLASSIFIED BY: LDS

DATE: 7/7/75

24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												4" casing L = 35½" Tunnel ℄ @ elevation 460' Water depth - 25'8" Platform H above lake 9'1" Platform elev. 583'1" NWX casing L = 35'6"
5												
10							LAKE					
15												
20												
25												

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-268

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

SHEET 2 OF 7

DRILL HOLE NO. S-6

CONTRACTOR: Warren George

COORDINATES 783,307.SN 2,367,278.0E

ELEVATION 574±

DRILLER: Ed Fritsch

GWL 0 HRS 574±

CLASSIFIED BY: LDS

DATE: 7/7/75

24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25							Lake Bottom			26.8		
30						538' 4" elevation	No lake bottom sediments save for a few cobbles and boulders. Typical Chagrin shale, light gray (N3-N4) thinly bedded. Most fractures smooth, planar and parallel to bedding which is horizontal. From 1'3¼" - 2'3¼" some vertical fractures and rock overall is fairly well fragmented (pieces 1½"-½"). First 5' medium soft while latter 5' more competent. A few thin (1/16-1/8") siliceous (silt-sand) beds (N8) interlayered with gray shale		95 %	10	9.96	Poor return on drilling water; NWX casing turned down during drilling No gas detected
35										35.8		
40						528' 10"	Considerable increase in siliceous sandy-silty beds from 1¼"-1/16" thick. Fractures parallel to bedding planes. Cross laminae in siliceous sandy-silty beds at approximately 2½'. Oxidized 1" thick sandy bed at approximately 3', irregular contact shows scour effects on underlying light gray (N8) siliceous bed		83 %	9.5	9.5	Drill water returning at start of run but lost again Core (4-5") apparently fell out of barrel. Faulty core catcher
45										45.8		
50–60							Competent shale generally. 3" of cross laminae (N8) at 4' and trace elsewhere of same. 2" near vertical fracture at approximately 8' and 3'9"					Good return on drilling water. At least 4" of core fell into Lake

GAI-227 8/72

2E-269

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

CONTRACTOR: Warren George

DRILLER: Ed Fritsch

CLASSIFIED BY: LDS

COORDINATES 783,307.5N 2,367,278.0E

DATE: 7/7/75

SHEET 3 OF 7

DRILL HOLE NO. 5-6

ELEVATION 574±

GWL 0 HRS 574±

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50–55.3				512' 10" elevation	Core generally harder than before although fractures are typically smooth, planar and clean occasionally weathered shale debris can be found along a few. It is not unusually for partings to occur along shale-siliceous sandy-silty bed interfaces		80 %	10'	9.3'	No gas detected Runs rather irregular
55.3–65.3				502' 10" elevation	Same as before with more abundant fractures parallel to bedding in lower 5'. A three inch long piece at 9' is highly fractured with irregular vertical migration. Cross bedded siliceous N8 beds present but not abundant		53 %	10'	10'	Return on drilling water
65.3–75				492' 10" elevation	Very unusual run, although rock appears at least as competent as previous there are numerous fractures parallel to bedding resulting in low RQD. No abundant cross laminated bed sets, however, micro lenticulated N8 siliceous-silty-sandy laminae may induce partings.		0 %	10'	9.95'	Return on drilling water

GAI - 227 8/72

2E-270

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

CONTRACTOR: Warren George

DRILLER: Ed Fritsch

CLASSIFIED BY: LDS

COORDINATES 783,307.5N 2,367,278.0E

DATE: 7/7/75

SHEET 4 OF 7

DRILL HOLE NO. 5-6

ELEVATION 574±

GWL 0 HRS 574±

24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
75–85.3				488' 10" elevation	Same as previous run abundant light gray N8 lenticular and small scale cross bed sets. Poor RQD could be attributed to this or to poor core catcher shoes. First 3" could be overcored. Voids highly unlikely in this unit. It could be due to some wearing of rock during drilling		0 %	10'	9.75'	A lot of rod vibration. No gas detected
85.3–95.3				478' 10" elevation	Same as previous, abundant fractures somewhat rough but parallel to horizontal bedding Not a particular abundance of cross bed laminae but more lenticular type (N8) siliceous sandy-silty beds		0 %	10'	9.66'	Considerable wobble in rod item No methane detected Drilling speed reduced for last 2' but still some RQD
95.3–100					With respect to fracturing same as before, more small scale cross bed sets and a few ¼-3/8" oxidized bands although of same lithic character as shale. Some evidence for cutting out of small sandy-silty casts (N6) calcareous					No gas detected 10' of NWX added total 45'6"

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-271

SHEET 5 OF 7

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie
CONTRACTOR: Warren George
DRILLER: Ed Fritsch
CLASSIFIED BY: LDS
COORDINATES 783,307.5N 2,367,278.0E
DATE: 7/7/75
DRILL HOLE NO. 5-6
ELEVATION 574±
GWL 0 HRS 574±
24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100–105						468' 10" elevation	debris along fractures although could have been removed by drill water.		0 %	10' (105.3')	9.7'	
105–115						458' 10" elevation	Rock is same general character as before, approximately 3" of N8 siliceous silty-sandy cross laminae at 6½' and thick dark gray (N2) shale 4" thick at approximately 7'. Vertical fracture 3" long at 9½' followed fragments. Throughout run N3-N4 shale interlayered with N2 shale		7 %	10' (115.3')	10'	No gas detected
115–125						448' 10" elevation	Dark gray shale with 10-15% light gray interlaminated siltstone lenses medium hard, unweathered, relatively flat, wavy thin lamination, no joints, several bedding fractures. Maximum piece 1½"		10 %	10'	9.7'	No gas detected

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-272

SHEET 6 OF 7

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie
CONTRACTOR: Warren George
DRILLER: Ed Fritsch
CLASSIFIED BY: LDS/JGD
COORDINATES 783,307.5N 2,367,278.0E
DATE: 7/7/75
DRILL HOLE NO. 5-6
ELEVATION 574±
GWL 0 HRS 574±
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
125–135						438' 10" elevation	Interlaminated dark gray and black shale with 15% light gray siltstone lenses, cross lamination relatively flat, wavy thin laminae, medium hard, unweathered no joints, couple bedding faces		49 %	10'	9.4'	No gas detected
135–145						428' 10" elevation	Same. Maximum piece 9½"		33 %	10'	9.8'	No gas detected
145–150							Improvement in RQD index. Most fractures parallel to horizontal bedding (clean, smooth, and planar). Vertical fractures at 7'2"-7'4" and at 8'7"-9'1". Last ½' of run is very highly fractured. Most rock as before, inter-					See note on gas

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

CONTRACTOR: Warren George COORDINATES 783,307.5N 2,367,278.0E

DRILLER: Ed Fritsch

CLASSIFIED BY: LDS DATE: 7/8/75

SHEET 7 OF 7

DRILL HOLE NO. S-6

ELEVATION 574±

GWL 0 HRS 574±

24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
150				418'10" (elevation)	layered with cross bed sets 1" thick. Some darker shale (N2) at 3'2"			10'	10'	
155								155.5'		
					BOTTOM OF HOLE @ 418'10"					
160					0030 8 July - large volume of gas encountered during retrieval of last core run. 1000 ft³ measured during a 20 minute interval of monitoring. Shut in pressure recorded at 20 psi. However considerable quantities were leaking around casing-rock interface. Water and gas rose 50 ft above lake surface prior to attaching gas monitoring equipment to casing					
165					8 bags of grout					
170										
175										

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

CONTRACTOR: Warren George COORDINATES 782,791.7N 2,367,278.0E

DRILLER: Ed Fritsch

CLASSIFIED BY: LDS DATE: 6/24/75

SHEET 1 OF 7

DRILL HOLE NO. S-7

ELEVATION 574±

GWL 0 HRS 574±

24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					Lake surface elevation 574 ft					Lake elevation fluctuates. Drilling platform extends approx. 7'6" above water level; it will be raised and lowered as needed. Casing (HX)
5					LAKE					
10										
15										
20					Lake Bottom					
		34 / 15 / 38 R			Clay and gravel lake bottom sediments, some angular rock fragments	GC-SC				
25				548'5"	No sample recovered/suspect weathered rock & gravel or boulders					Roller bit fell through this interval

GAI-227 8/72

GILBERT ASSOCIATES, INC.

2E-275

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

CONTRACTOR: Warren George COORDINATES 782,791.7N 2,367,278.0E

DRILLER: Ed Fritsch

CLASSIFIED BY: LDS DATE: 6/24/75

SHEET 2 OF 7

DRILL HOLE NO. S-7

ELEVATION 574±

GWL 0 HRS 574±

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25–35				538'5" elevation	Soft weathered shale with calcareous debris in fractures. Typical thinly bedded Chagrin shale with horizontal bedding. All fractures parallel to bedding; one fracture inclined 60° from vertical 4' from top. Interlaminated beds (N5-N4 color). Core tends to part parallel to bedding. One piece from 3'10"-4'4" has tight, near vertical fracture. Upon drying parts parallel to bedding fractures		52 %	10'	9.7'	No gas detected
35–45				528'5" elevation	Rock same as before except shale is more competent and does not part parallel to bedding as readily. Bedding planes generally planar with occasional small scale ripples. Closed vertical fracture (1½" long) at 3' similar occurrence at 5'1". Some limy clay material fills fracture at 5'2". Small scale cross laminae in beds ¼" thick occur intermittently (1' to inches)		90 %	10'	9.9'	No gas detected
45–50					Rock description as before for first 6'. Last 4' characterized by small scale cross laminae generally siliceous and light gray N5-N6. Particle size of siliceous rock is silt. These					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

2E-276

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

CONTRACTOR: Warren George COORDINATES 782,791.7N 2,367,278.0E

DRILLER: Ed Fritsch/Jake Harris

CLASSIFIED BY: LDS/JGD DATE: 6/24-25/75

SHEET 3 OF 7

DRILL HOLE NO. S-7

ELEVATION 574±

GWL 0 HRS 574±

24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50–55				518'5" elevation	beds 0.5-1" thick, occurring every 0.5-1 ft and are very competent. Occasional bedding plane fractures, but always smooth and clear. Oxidized siliceous silt at 8'; thin band		85 %	10'	10'	No gas detected
55–65				508'5" elevation	Same as before except at 9'-9.5' interval a soft shale interval with some fracturing and small rock fragments. Otherwise fractures are typically smooth, tight, and parallel to bedding.		97 %	10'	9.9'	No gas detected
65–75				498'5" elevation	Dark gray-black shale with trace of interlaminated light gray siltstone to fine sandstone, medium-hard, unweathered, no joints, trace siderite brown lenses.		71 %	10'	10'	Shift change No gas detected

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 7
PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4569-000 SITE AREA Lake Erie
DRILL HOLE NO. S-7
CONTRACTOR: Warren George COORDINATES 782,791.7N 2,367,278.0E
ELEVATION 574±
DRILLER: Ed Pritsch/Jake Harris
GWL 0 HRS 574±
CLASSIFIED BY: LDS/JGD DATE: 6/24-25/75
24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75–85						488' 6" elevation	Dark gray to black shale with 10% interlaminated light gray siltstone, medium hard, unweathered, thin and flat laminations, cross laminations, no joints		39 %	10'	9.8'	No gas detected
85–95						478' 5" elevation	Same as before		86 %	10'	9.9'	No gas detected
95–100							Chagrin shale as before, fractures parallel to bedding but not clean and smooth as before. At 2'2" a 3" fine sand bed, light gray with irregular and scoured base. Considerable cross laminae at					No gas detected 5' casing added total casing - 39'6"

GAI - 327 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 5 OF 7
PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4569-000 SITE AREA Lake Erie
DRILL HOLE NO. S-7
CONTRACTOR: Warren George COORDINATES 782,791.7N 2,367,278.0E
ELEVATION 574±
DRILLER: Ed Pritsch
GWL 0 HRS 574±
CLASSIFIED BY: LDS DATE: 6/25/75
24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100–105						468' 5" elevation	approximately 4', interlayered (sets: 1-3" thick) with shale. More cross beds of similar nature at 7'. At 6' two ½" thick oxidized beds (scratch like shale and doesn't appear silty or sandy. Possibly some limey debris along several fractures		53 %	10'	9.7'	
105–115						458' 6" elevation	Rocks are considerably more fractured than previous but still parallel to horizontal bedding. Cross bed sets not very abundant nor are they thick or conspicuous No calcareous clay along fractures however drill water may have washed this out. No oxidized beds.		17 %	10'	10'	No gas detected P.T. Test
115–125						448' 5" elevation	Generally, core is quite fractured parallel to bedding. A few vertical fractures (2" long) at 4' and in last 6" of core run. Some cross beds (2-3" thick) at 8', a ½" thick oxidized bed. Last 2 core runs have identical physical properties. Fractures have some clay material but none is calcareous. Fractures <1/16" where filled		7 %	10'	10'	5' casing added total - 44'6" No gas detected Good P.T. interval

GAI - 327 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-279

PROJECT: Stage II Offshore Drilling, PNPP W.O. 06-4549-000 SITE AREA Lake Erie
SHEET 6 OF 7
DRILL HOLE NO. S-7
CONTRACTOR: Warren George
COORDINATES 782,791.7N 2,367,278.0E
ELEVATION 574±
DRILLER: Ed Fritsch
GWL 0 HRS 574±
CLASSIFIED BY: LDS
DATE: 6/25/75
24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
125–135				438'8" elevation	As before fracturing is parallel to bedding. A 2" vertical fracture (clean) in first 6". The abundance of cross bed sets as described previously is conspicuous. Interlayered thin (1/16") dark carbonaceous, competent beds; these are slightly darker (N3) and between 5-6½" dark beds are thick 1-2" with scoured top and interbedded with cross bed sets		15 %	10'	10'	
135–145				438'5" elevation	As before, no change, cross bed sets are abundant. 3" thick very hard grey bed at approximately 4'8"		15 %	10'	9.6'	RQD not completely reliable since 2' of core fall on drilling deck
145–150					Rock as before, vertical fractures clean in last 1½'; thin parted beds, ¼" thick, at 4'10"-5'. Vertical fracture at 8"					

GAI-327 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-280

PROJECT: Stage II Offshore Drilling, PNPP W.O. 06-4549-000 SITE AREA Lake Erie
SHEET 7 OF 7
DRILL HOLE NO. S-7
CONTRACTOR: Warren George
COORDINATES 782,791.7N 2,367,278.0E
ELEVATION 574±
DRILLER: Ed Fritsch
GWL 0 HRS 574±
CLASSIFIED BY: LDS
DATE: 6/25/75
24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
150–155				440'5" elevation			15 %	10'	10'	
155–175					BOTTOM OF HOLE @ 4:30 p.m. 6/25/75 10 bags of cement used to grout hole.					

GAI-327 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-281

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Lake Erie/ N. Perry, Ohio SHEET 1 OF 4

CONTRACTOR: Western Geophysical COORDINATES N 783,455 DRILL HOLE NO. 5-8

DRILLER: Jake Harris E 2,367,672 Lake Bottom ELEVATION 549.3

CLASSIFIED BY: D.R.S. DATE: 10-5-72 GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color (USCS) Rock Or Soil Type - Accessories	% RECOVERY	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					Lake Level 574.1					39.5' 4" casing from deck
25.0					Dk. grey shale & interbedded seams of sandstone; slightly weathered & broken in first 1.0' (due to driving of casing); soft shale zones @ 27.4, 28.2-28.3, 30.2-30.3, fracture 30° to bedding at 27.8	96		10.0'	9.6'	L.P. .85 S.P. 0.03 Avg. .4
35.0					Same; vertical fracture 41-41.6; weak shale 42.0-42.2 and 43.3	98		10.0'	9.8'	L.P. .65 S.P. .04 Avg. .40
45.0										
50										

GAI-237 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-282

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio SHEET 2 OF 4

CONTRACTOR: Western Geophysical COORDINATES ____ DRILL HOLE NO. 5-8

DRILLER: Jake Harris ELEVATION ____

CLASSIFIED BY: D.R.S. DATE: 10-6-72 GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% RECOVERY	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50					Same, generally solid except weak zone .2' at base of run	99		10.0'	9.9'	L.P. .85 S.P. .07 Avg. .55
55.0					Same as above	93		10.0'	9.3'	L.P. .70 S.P. .06 Avg. .50
65					Sound grey shale & sandstone becoming thinly jointed (0.2'-0.3') @ 67.5'	100		10.0'	10.0'	L.P. 0.85' S.P. 0.03 Avg. 0.2
75.0					Vertical fract. @ 75.5-76.0, weak clayey zone @ 78.5' becoming massive @ 79.0'	100		10.0'	9.76'	L.P. 1.87 S.P. 0.07 Avg. 0.4
85.0					Sound grey shale & fine grained sandstone	96		10.0'	9.6'	L.P. 1.8 S.P. 0.06 Avg. 0.85
95.0										
100										

GAI-237 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-283

PROJECT: CEI- Perry Nuclear Power Plant W.O. 4549-00 SITE AREA L. Erie/N.Perry,O.

SHEET 3 OF 4

DRILL HOLE NO. S-8

CONTRACTOR: Warren George COORDINATES ________

ELEVATION ________

DRILLER: Jake Harris

GWL 0 HRS ________

CLASSIFIED BY: D.R.S. DATE: 10-6-72

24 HRS ________

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% Recovery	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100					Sound dark grey shale & sandstone Fractured from 103.5 to 104.0	100		10.0'	10.0'	L.P. 1.7 S.P. 0.11 Avg. 0.6
105								105.0		
110					Same; fractured 113.5-114.0	[illegible]		10.0'	9.75'	L.P. 2.3 S.P. 0.05 Avg. 0.5
115								115.0		
120					Sound dark grey shale & sandstone	[illegible]		10.0'	9.6'	L.P. 1.08 S.P. 0.04 Avg. 0.6
125								125.0		
130					Same except for vertical fractures 131.4 to 131.6 and 133.0 to 133.6	100		10.0'	10.0'	L.P. 1.6 S.P. 0.06 Avg. 0.6
135								135.0		
140					Same	[illegible]		10.0'	9.75'	L.P. 1.83 S.P. 0.04 Avg. 0.7
145								145.0		
150					Same					L.P. 1.73 S.P. 0.09 Avg. 0.7

GAI - 337 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-284

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA L.Erie/N.Perry,O.

SHEET 4 OF 4

DRILL HOLE NO. S-8

CONTRACTOR: Warren George COORDINATES ________

ELEVATION ________

DRILLER: Jake Harris

GWL 0 HRS ________

CLASSIFIED BY: D.R.S. DATE: 10-7-72

24 HRS ________

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	% Recovery	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
150					Dark grey shale & sandstone - sound	100		10.0'	10.0'	L.P. 1.75 S.P. 0.09 Avg. 0.71
155								155.0		
160					Same	100		9.5'	9.5'	L.P. 1.25 S.P. 0.08 Avg. 0.6
165								164.5		
170					Same	[illegible]		5.5'	4.6'	L.P. 2.3 S.P. 0.9 Avg. 0.7
								170.0		

GAI - 337 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-285

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

CONTRACTOR: Warren George Drilling Co. COORDINATES 783,177.3N 2,368,756.0E

DRILLER: Ed Fritsch

CLASSIFIED BY: JGD DATE: 6/30, 7/1/75

SHEET 1 OF 7

DRILL HOLE NO. 5-9

ELEVATION

GWL 0 HRS 574±

24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					Platform +7.9'					
					Lake surface elevation 574'					A. For NX coring platform elevation - 582'11"
										B. Water depth - 25'
5					L A K E					
10										
15										
20				549' elevation						
25								25.0		bottom of lake

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-286

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

CONTRACTOR: Warren George COORDINATES 783,177.3N 2,368,756.0E

DRILLER: Ed Fritsch

CLASSIFIED BY: JGD DATE: 6/30, 7/1/75

SHEET 2 OF 7

DRILL HOLE NO. 5-9

ELEVATION

GWL 0 HRS 574±

24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
25					Sediment					Elevation of RX @ 548'2½"
					Slightly weathered dark gray shale					
							51 %	10'	9.2'	
30					Dark gray shale with trace siltstone medium hard, unweathered, thin and flat lamination, no joints					
				539' elevation	Trace light gray clay fills seams maximum piece 14½"					
35								35.0		No gas
					Dark gray shale with trace light gray siltstone and brown siderite lenses, medium hard, unweathered, thin and flat lamination, cross lamination, one joint 30°@38' maximum piece 9"					
40							79 %	10'	10.3'	
				529' elevation						
45								45.0		No gas
					Dark gray shale with littal (10-20%) gray siltstone and brown siderite, interlaminated, medium hard, unweathered, thin and flat lamination, cross lamination, no joints					
50										

GAI - 227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-287

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie
SHEET 3 OF 7
DRILL HOLE NO. S-9
CONTRACTOR: Warren George
COORDINATES 783,177.3N 2,368,756.0E
ELEVATION
DRILLER: Ed Fritsch
GWL 0 HRS 574±
CLASSIFIED BY: JGD
DATE: 7/1/75
24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50				519' elevation	Stiff light gray clay fills seams minute thickness 2-3" broken zone — 53.0'		63 %	10'	9.7'	Not calcareous No gas bubbles
55				509' elevation	Dark gray shale with 20% light gray siltstone and siderite interlaminated with it, medium hard, unweathered, no joints, thin and flat laminae, cross lamination with trace clay Maximum piece 9½"		58 %	10'	9.8'	Not calcareous No gas
60										
65				499' elevation	Dark gray shale with 25% interlaminated light gray siltstone, brown siderite lenses, medium hard, unweathered, thin and flat lamination, cross lamination, no joints Maximum piece 16"		53 %	10'	9.6'	
70										
75										

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-288

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie
SHEET 4 OF 7
DRILL HOLE NO. S-9
CONTRACTOR: Warren George
COORDINATES 783,177.3N 2,368,756.0E
ELEVATION
DRILLER: Ed Fritsch
GWL 0 HRS 574±
CLASSIFIED BY: JGD
DATE: 7/1/75
24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/4 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75				489'6"	Dark gray shale with 20% interlaminated light gray siltstone and brown siderite lenses, medium hard, unweathered, thin and relatively flat lamination, cross lamination, no joints Maximum piece 12"		67 %	9.5'	9.5'	
80								84.5		
85				479'6"	Interlaminated dark gray, black shale with 25% light gray siltstone and brown siderite lenses, medium hard, unweathered, thin and relatively flat lamination, cross lamination, no joints, possible bedding fractures Maximum piece 6"			10'	9'	After core run bailed hole to test for gas concentrations. Can not bail hole, no seal. 4½% CH_4 detected No bubbling. 39' total casing 4'8½" casing turned in; platform 8½" above H_2O Zone may take water
90								94.5		
95					Interlaminated medium light gray shale with occasional medium-dark gray beds up to 4", generally fractures parallel to bedding but several 9-3" intervals to vertical fractures also (at approximately 3½-4 and 9'. Excellent turbidite sequence at					
100										

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-289

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

SHEET 5 OF 7

DRILL HOLE NO. 5-9

CONTRACTOR: Warren George COORDINATES 783,177.3N 2,368,756.0E

ELEVATION

DRILLER: Ed Fritsch

GWL 0 HRS 574±

CLASSIFIED BY: LDS DATE: 7/1/75

24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100						469'6"	6' with silicious reds showing flame like structure (ripped beds) at 2.5' (approximately) several oxidized beds approximately ½-1" thick. Silicious beds lighter and typically displaying small scale cross laminations		80 %	10' 99.5	9.7'	No gas bubbling Might P.T.
105 / 110						459'6"	Same interlaminated light gray and medium gray thinly bedded shale with occasional cross bedded siliceous silt, latter not so abundant as before. Most fractures smooth and parallel to bedding although some vertical fractures at 3.5 and 8'. Silty beds probably do not exceed 15% of rock. Fractures almost always appear tight and without weathered surface or fill material		18 %	much 10' bailing below	10'	Added casing Total casing-44' Would test but cannot develop gas bubbling; detected (CH_4 <5%) after WL 15' lake level
115 / 120 / 125							Fairly competent rock and less fractured than previous. Vertical fractures (7" long) at 5'4" and at 9'8" (4" long). Other fractures smooth and parallel to horizontal bedding laminae. Greater frequency of medium gray shale beds with corresponding decrease in silty, small scale cross laminae. No weathered clay materials or calcareous material on fractures. No apparent tendency to form poker chip fragments		47 %	10'	10'	Vertical fractures occur at end of run and may not be representative of run

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-290

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

SHEET 6 OF 7

DRILL HOLE NO. 5-9

CONTRACTOR: Warren George COORDINATES 783,177.3N 2,368,756.0E

ELEVATION

DRILLER: Ed Fritsch

GWL 0 HRS 574±

CLASSIFIED BY: JGD/LDS DATE: 7/1/75

24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
126 / 130						439'6" elevation	Dark gray to black shale with 20-30% light gray siltstone lenses interlaminated, medium hard, unweathered, thin and flat lamination, cross lamination, no joints, bedding fractures Maximum piece 5"		19 %	10'	10'	5' casing added total casing length - 49'
135 / 140						429'6" elevation	Black shale with 20% light gray siltstone, medium hard, unweathered, thin, relatively flat, wavey lamination, cross lamination, possible bedding fracture, one joint at 434' el, 60° angle Maximum piece 7"		37 %	10'	9.5'	
145 / 150							Dark gray to black shale with 35% light gray siltstone interlaminated with it, medium hard, unweathered, thin, relatively flat wavy lamination, cross lamination, no joints, bedding fractures Maximum piece 6"					Retrieved rest of sample on next run; stuck in core barrel

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-291

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

SHEET 7 OF 7

CONTRACTOR: Warren George COORDINATES 783,177.3N 2,368,756.0E

DRILL HOLE NO. 5-9

DRILLER: Ed Fitsch

ELEVATION

CLASSIFIED BY: JGD/LDS DATE: 7/1/75

GWL 0 HRS 574±

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
150						420'3" elev			76 %	9.2'	9.2'	
155						410'9" elevation	Dark gray to black shale with 20% interlaminated light gray siltstone, medium hard, unweathered, no joints, few bedding partings-fractures, thin, flat, wavy lamination		37 %	9.5'	9.5'	
160												
165							TOTAL CORE DEPTH 138'2" Considerable gas emitted after hole was bailed down 80'; seal was not effected. 8 bags of cement used to grout hole					
170												
175												

GAI-227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-292

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

SHEET 1 OF 6

DRILL HOLE NO. 5-10

CONTRACTOR: Warren George COORDINATES 782,613.4N 2,369,045.7E

ELEVATION 574±

DRILLER: Ed Fritsch

GWL 0 HRS 574±

CLASSIFIED BY: LDS DATE: 7/4/75

24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0							LAKE ERIE SURFACE (574')					
5						555'6" elevation	LAKE			18.5'		Platform lies 11'3" above lake surface. Casing 30'6" Have lowered NX inside 4" which was seated into bottom Tunnel ℄ - 453' Water depths anticipated Can't sample sediments with spoon since adaptor is lost
10												
15												
20							Approximately 1' of O.B. sand and gravel Upper 1'7" consists of weathered shale typical Chagrin. Thinly bedded with horizontal laminae; considerable clay debris some of which could be grout left in rod. Balance of core is fairly well preserved. Interlaminated N4-N3 color with little cross laminae		57 %	10'	9'	Estimated Receiving very little drill water out of NX No gas detected Total casing L 32'6"
25												

GAI-227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-293

PROJECT: Stage II Offshore Drilling, PNPP W.O. 06-4549-000 SITE AREA Lake Erie

SHEET 2 OF 6

DRILL HOLE NO. S-10

CONTRACTOR: Warren George COORDINATES 782,613.4N 2,369,045.7E

ELEVATION 574±

DRILLER: Ed Fritsch

GWL 0 HRS 574±

CLASSIFIED BY: LDS DATE: 7/4/75

24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
26						545'6" elev.	present. One fracture at 2'4" at 50° from horizontal (1" long). other fractures generally smooth, planar and parallel to bedding. Overall shale is slightly weathered and slightly soft			28.5'		
30						535'6" elevation	As before, several oxidized bands (¼-1") occur intermittently at 2.5', 5.5', and 6'. One siliceous and silt-sand, N-7 grey set of small-scale, cross beds occurs at 9'5". In general core appears to be competent and not particularly overly fractured		63 %	10' / 38.5'	9.75'	Drilling water returning. A small piece fell into hole presumably 3" No gas detected
35												
40						525'6" elevation	Slight change in rock to more small scale cross laminations (i.e. @ 2" set @ 4'9"; however, usually thinner i.e. ½") and occur every ft or so. ½" silty oxidized bed at 5'. Also vertical fracture at 4'11", most fractures are typically smooth, planar, and parallel to bedding, some debris but none is calcareous.		[illegible] %	10' / 48.5'	10'	Overcored 2-3" and therefore missed previous piece No loss of drilling water No gas detected
45												
50												

GAI - 227 6/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-294

PROJECT: Stage II Offshore Drilling, PNPP W.O. 06-4549-000 SITE AREA Lake Erie

SHEET 3 OF 6

DRILL HOLE NO. S-10

CONTRACTOR: Warren George COORDINATES 782,613.4N 2,369,045.7E

ELEVATION 574±

DRILLER: Ed Fritsch

GWL 0 HRS 574±

CLASSIFIED BY: LDS DATE: 7/4/75

24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50						515'6" elevation	Very typical Chagrin shale, fairly free of fractures and competent except for last 8" which has vertical fracture 3½" long and is fairly soft, more abundant interlaminated N-7, siliceous, small scale cross bed sets (½-2") (Representative set at 7.5', note some of which is referred to as cross bed sets actually disturbed beds, tendency to crack when dried		[illegible] %	10' / 58.5'	10'	No gas detected
55												
60						505'6" elevation	Competent shale as before, first 6' is extremely competent, however within last 4' the pieces are usually 4". It is apparent that many of the fractures occur at siliceous cross bed sets and dark shale (not atypical). Some pitting in initial 3½" but voids do not appear continuous. Siderite or oxidized bands are not present		60 %	10' / 68.5'	9.4' imperfect RCS	Drilled water isn't coming up and out of casing No gas detected Note: either there is a seal or else are taking water
65												
70							Abundant siliceous, sandy small scale cross bed sets. Thickness same as before however the thicker sets are far more abundant. All fractures planar, smooth and parallel to horizontal bedding planes. In a sense it can be interpreted as the "C" unit of a typical Bouma sequence		31 %	10'	9.2'	Good return on drilling water. No gas detected Appears to be a good seal. Core catcher is malfunctioning and will be replaced.
75												

GAI - 227 - 6/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-295

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

SHEET 4 OF 6

DRILL HOLE NO. 5-10

CONTRACTOR: Warren George COORDINATES 782,613.4N 2,369,045.7E

ELEVATION 574±

DRILLER: Ed Fritsch

GWL 0 HRS 574±

CLASSIFIED BY: LDS DATE: 7/4/75

24 HRS 574±

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75								78.5'		
80, 85				485'6" elevation	Considerable cross bedding with obvious truncated foreset beds. Much more fracturing most planar, smooth and parallel to horizontal bedding. Some vertical fractures (3" @ 6'2") 3" @ 8') Considerable shale debris along these fractures which are irregular and rough. Last ft has more, same character. Cross beds are lighter gray than shale as before		18 %	10'	10'	Good return on drilling water No methane detected Picked up 7" of previous run but must have pulverized other Added 7' of NX casing T = 39'6" Generator ran out of fuel so we're shut down for ½ hr
								88.5		
90, 95				475'6" elevation	Much improved rock condition with corresponding decrease in cross bed sets. N-vertical fractures. Somewhat worn or weathered zone at 1'4" which could be due to lousy drilling technique		63 %	10'	9.8'	
								98.5'		
100										

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-296

PROJECT: Stage II Drilling Offshore, PNPP W.O. 04-4549-000 SITE AREA Lake Erie

SHEET 5 OF 6

DRILL HOLE NO. 5-10

CONTRACTOR: Warren George COORDINATES 782,613.4N 2,369,045.7E

ELEVATION 574±

DRILLER: Ed Fritsch/Jake Harris

GWL 0 HRS 574±

CLASSIFIED BY: LDS/JGD DATE: 7/4-5/75

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100, 105				465'6" elevation	Dark gray shale with little (20%) light gray siltstone lenses, interlaminated thin and flat wavy lamination, truncated cross lamination, medium hard, unweathered, several bedding fractures, no joints Maximum piece 4"		3 %	10'	9.8'	Seem to be getting most of drill water No gas detected
								108.5'		
110, 115				455'6" elevation	Gray shale with trace 15% interlaminated light gray siltstone lenses, wavy, relatively flat, thin lamination, medium hard, unweathered, several bedding fractures, 15° joint @ 458' el.		73 %	10'	10'	Gas detected Unable to bail hole tried to add more 4" casing only able to knock it a couple inches
								118.5'		
120, 125					Dark gray shale with trace 10-15% light gray siltstones lenses interlaminated thin and wavy, relatively flat lamination, some truncated cross lamination, medium hard, relatively unweathered, bedding fractures, near vertical joints, clay filling Max pc 7"		34 %	10'	10'	

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-297

PROJECT: Stage II Offshore Drilling, PNPP W.O. 04-4549-000 SITE AREA Lake Erie
CONTRACTOR: Warren George
DRILLER: Ed Pritsch/Jake Harris
CLASSIFIED BY: LDS/JD
COORDINATES 782,613.4N 2,369,045.7E
DATE: 7/4-5/75
SHEET 6 OF 6
DRILL HOLE NO. S-10
ELEVATION 574±
GRL 0 HRS 574±
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
						435'6"				[illegible]		
						785'6" elevation	Dark gray shale with 25-30% light siltstone interlaminated, wavy and thin lamination, relatively flat, some cross laminae, medium hard, unweathered, several bedding fractures, no joints. Maximum piece 9½"		20 %	10	9.6'	Shift change
						915'6" elevation	RQD somewhat misleading since core is competent and fractures are smooth, planar, and parallel to horizontal bedding. The silicious silty sandy light gray (N-7 - N-8) cross laminae are abundant (up to 50%) and inter-layered with typical medium gray (N3-N4) thinly bedded shale. When the cross bed set are present in abundance lower RQD's and increased fractures are characteristic owing to the variable physical properties of the two. Although RQD is poor this in part due to the interbedded cross bed sets & shale as previously described. Drill water was run through for a while to wash the well		10 %	10'	10'	Gas tests 1st ½% 2nd (30 seconds later) 0% Could have been some in meter from water test Waited 20 mins before testing from time core barrel liner was taken out. Return on drilling water indicates an imperfect seal. It's either going into or
							/BOTTOM OF BH @ 415'6" TOTAL CORED ROCK 140'			[illegible]	9X	out seal

8 bags of cement used to grout hole

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-298

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing
DRILLER: Ed Sezovek
CLASSIFIED BY: HHZ
COORDINATES N 779830.0 E 2370063.0
DATE: 12-5-75
SHEET 1 OF 1
DRILL HOLE NO. S-1
ELEVATION 620 Appr.
GRL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												
5												
10												Set Monitoring Wellpoint
15												
20												
	1	A	7	10			Gray Silty Clay trace of Shale fragment - slightly mottled with red					
25							T.D. 23.5'					
30							Knocked Down & Replaced in July, 1978					
							New coordinates N779844.2 E 2370119.5					
35												
40												
45												
50												

GAI-227 8/72

2E-299

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. S-4

CONTRACTOR: Herron Testing COORDINATES N 779808.8 E 2370069.4

ELEVATION 620 Appx.

DRILLER: Ed Sezwyck

GWL 0 HRS

CLASSIFIED BY: WHL DATE: 12-8-75

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–20												Set Monitoring Wellpoint
20–23'7"	1	3	4	7			Mottled Gray-Red Silty Clay					
							T.D. 23'7"					

GAI-337 8/72

2E-300

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. S-4A

CONTRACTOR: Herron Testing COORDINATES N 779808.8 E 2370069.4

ELEVATION 620

DRILLER: Ed Sezwyck

GWL 0 HRS

CLASSIFIED BY: WHL DATE: 12-8-75

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–35												Set Monitoring Wellpoint
35–38.5'	1	16	19	41			Hard Gray Clayey Silt with Shale Fragments	CC				
							T.D. 38.5'					

GAI-337 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-301

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 779808.9 E 2370074.2
DRILLER: Ed Sezwyck
CLASSIFIED BY: WHL DATE: 12-12-75

SHEET 1 OF 2
DRILL HOLE NO. S-6B
ELEVATION 620 Appx.
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–50							Glacial Overburden					Set Monitoring Well point

GAI-SEP 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-302

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 779808.9 E 2370074.2
DRILLER: Ed Sezwyck
CLASSIFIED BY: WHL DATE: 12-12-75

SHEET 2 OF 2
DRILL HOLE NO. S-6B
ELEVATION 620
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50–65												
65							T.D. 65' Approximately					

GAI-SEP 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-303

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 779763.9 E 2370085.7
DRILLER: Ed Serwyck
CLASSIFIED BY: WHL DATE: 7-26-75

SHEET 1 OF 1
DRILL HOLE NO. S-5
ELEVATION 620.49
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Desc., Ground Water, Construction Problems, etc.
10												Set Monitoring Well point
25	1	3	4	4			Gray Silty Clay					
							T.D. 24.5					

GAI-227 2/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-304

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 779649.0 E 2370126.1
DRILLER: Ed Serwyck
CLASSIFIED BY: WHL DATE: 7-25-75

SHEET 1 OF 1
DRILL HOLE NO. S-6
ELEVATION 621.93
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Desc., Ground Water, Construction Problems, etc.
15												Set Monitoring Well point
25	1	4	7	12			Gray Silty Clay, trace shale fragments - upper till					
							T.D. 25.5'					

GAI-227 2/72

Revision 12
January, 2003

2E-305

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. S-7

CONTRACTOR: Herron Testing COORDINATES N 779424.9 E 2370206.6 ELEVATION 623 Appx.

DRILLER: Ed Sezwyck GWL 0 HRS

CLASSIFIED BY: WHT DATE: 7-5-75 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–25												Set monitoring well point
25–27.5	1	3	5	7			Gray clayey silt - silty clay trace shale frags - upper till	CL				
							T.D. 27.5					

GAI-227 2/72

2E-306

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. S-7A

CONTRACTOR: Herron Testing COORDINATES N 779426 E 2370201.7 ELEVATION 623 Appx.

DRILLER: Ed Sezwyck GWL 0 HRS

CLASSIFIED BY: WHD DATE: 7-8-75 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–45							- Lower Till -					Set Monitoring Well Point
45–46.5	1	32	72				Gray Silty Clay w/shale frags.	CL				

GAI-227 2/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-307

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
SHEET 1 OF 2
DRILL HOLE NO. S-7B
CONTRACTOR: Herron Testing COORDINATES N 779424.1 E 2370210.5
ELEVATION 623 appx.
DRILLER: Sezwyck
GWL 0 HRS
CLASSIFIED BY: WHL DATE: 7-24-75
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0										
5										
10										
15										
20										
25										
30										
35										
40										
45										
50										

GAI-227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-308

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
SHEET 2 OF 2
DRILL HOLE NO. S-7B
CONTRACTOR: Herron Testing COORDINATES N 779424.1 E 2370210.5
ELEVATION 623 Appx.
DRILLER: Sezwyck
GWL 0 HRS
CLASSIFIED BY: WHL DATE: 7-24-75
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50										
55										
60										
65					Shale					
70					T.D. Approximately 68'					

GAI-227 9/72

2E-309

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant — W.O. 04-4549-000 — SITE AREA N. Perry, Ohio — SHEET 1 OF 1

CONTRACTOR: Herron Testing — COORDINATES N 778975, E 2370372.7 — DRILL HOLE NO. G-8

DRILLER: Ed Sezwyck — ELEVATION 626 Appx.

CLASSIFIED BY: WHL — DATE: 7-8-75 — GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Struc., Ground Water, Construction Problems, etc.
25–30												Set Monitoring Well Point
30–32.5	1	12	20	22			Gray Silty Clay, trace shale frags, some f. sand lenses					
							T.D. 32.5					

GM-237 2/72

2E-310

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant — W.O. 04-4549-000 — SITE AREA N. Perry, Ohio — SHEET 1 OF 1

CONTRACTOR: Herron Testing — COORDINATES N 780548.2, E 2370101.3 — DRILL HOLE NO. P-3

DRILLER: Ed Sezwyck — ELEVATION 622 Appx.

CLASSIFIED BY: WHL — DATE: 8-6-75 — GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Struc., Ground Water, Construction Problems, etc.
15–20												Set Monitoring Well Point
20–22	1	4	4	6			Gray silty clay, plastic	CL				
							T.D. 22'					

GM-237 2/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-311

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 780543.8 E 2370103.7
DRILLER: Ed Sezewck
CLASSIFIED BY: WHL DATE: 8-8-75

SHEET 1 OF 1
DRILL HOLE NO. P3A
ELEVATION 622 Appx.
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–45												Set Monitoring Well Point
45	1	15	25	42			Gray silty clay with shale fragments - lower till -					
							T.D. 46'					

GM-327 6/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-312

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 780552.6 E 2,370,099.6
DRILLER: Sezwyck
CLASSIFIED BY: WHL DATE: 8-12-75

SHEET 1 OF 2
DRILL HOLE NO. P-3B
ELEVATION 622 Appx
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–50							Glacial Overburden					Set Monitoring Well Point

GM-327 6/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-313

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing
DRILLER: Sezwyck
CLASSIFIED BY: WHL
COORDINATES N 780 552.6 E 2370099.6
DATE: 8-12-75
SHEET 2 OF 2
DRILL HOLE NO. E-3R
ELEVATION 622 Appx
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50–67					Shale					
67					T.D. 67' Approximately					

GAI-227 2/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-314

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing
DRILLER: Ed Sezwyck
CLASSIFIED BY: WHL
COORDINATES N 780601.5 E 2370182.2
DATE: 8-2-75
SHEET 1 OF 1
DRILL HOLE NO. E-4
ELEVATION 622 Appx.
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–22.5	1	3, 3, 5			Gray silty clay	CL				Set Monitoring Well Point
22.5					T.D. 22.5'					

GAI-227 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. E-5

CONTRACTOR: Herron Testing COORDINATES N 780661.3 E 2370221.5

ELEVATION 623 Appx.

DRILLER: Ed Sezwyck

GWL 0 HRS

24 HRS

CLASSIFIED BY: WHL DATE: 7-12-75

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0–20												Set Monitoring Well Point
20	1	4	6	9			Gray clayey silt w/sand lenses (varied)	ML				
							T.D. 21.5'					

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. E-6

CONTRACTOR: Herron Testing COORDINATES N 780686.2 E 2370307.8

ELEVATION 615 Appx.

DRILLER: Ed Sezwyck

GWL 0 HRS

24 HRS

CLASSIFIED BY: WHL DATE: 8-2-75

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0–20												Set Monitoring Well Point
20	1	5	6	11			Gray silty sand	SM				
							T.D. 21.5'					

GAI - 227 9/72

2E-317

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant — W.O. 04-4549-000 — SITE AREA N. Perry, Ohio — SHEET 1 OF 1
CONTRACTOR: Herron Testing — COORDINATES N 780769.0 E 2370534.0 — DRILL HOLE NO. E-7
DRILLER: Ed Sezwyck — ELEVATION 620 Appx.
CLASSIFIED BY: WHL — DATE: 7-10-75 — GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
0–20												Set Monitoring Well Point
20–21.5	1	18	14	10			Gray silty sand	SM				
21.5							T.D. 21.5'					

GAI - 227 9/72

2E-318

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant — W.O. 04-4549-000 — SITE AREA N. Perry, Ohio — SHEET 1 OF 1
CONTRACTOR: Herron Testing — COORDINATES N 780764.7 E 2370537.8 — DRILL HOLE NO. E-7A
DRILLER: Ed Sezwyck — ELEVATION 620 Appx.
CLASSIFIED BY: WHL — DATE: 7-11-75 — GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
0–42												Set Monitoring Well Point
42–43.5	1	12	22	34			- Lower Till - Gray silty sand w/shale frags.					
43.5							T.D. 43.5'					

GAI - 227 9/72

2E-319

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing
DRILLER: Ed Sezwyck
CLASSIFIED BY: WHL
COORDINATES N 780444.1 E 2370529.8
DATE: 7-31-75
SHEET 1 OF 2
DRILL HOLE NO. P-7B
ELEVATION 620 Appx.
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	% Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–50					Glacial Overburden					See Monitoring Well Point

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50

GAI-227 8/72

2E-320

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing
DRILLER: Ed Sezwyck
CLASSIFIED BY: WHL
COORDINATES N 780444.1 E 2370529.8
DATE: 7-31-75
SHEET 2 OF 2
DRILL HOLE NO. P-7B
ELEVATION 620 Appx.
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	% Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
60–65					Dark Gray Shale interbedded with light gray thin shale beds & a few ironstone beds 0.1-0.2' pieces, horizontal bed fractures		14	5'	4.75	
65					T.D. 65'					

Depth scale: 50, 55, 60, 65

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 06-4549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. P-8

CONTRACTOR: Herron Testing

COORDINATES N 780932.4 E 2370985.9

ELEVATION 621 Appx.

DRILLER: Ed Sezwyck

GWL 0 HRS

CLASSIFIED BY: WHL

DATE: 7-10-75

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Desc., Ground Water, Construction Problems, etc.
0–20												See Monitoring Well Point
22–23.5	1	5	8	11			Gray Clayey Silt - Silty Clay w/ a trace of shale frags	CL/ML				
							T.D. 23.5'					

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 06-4549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. H-3

CONTRACTOR: Herron Testing

COORDINATES N 781006.6 E 2369702.0

ELEVATION 620 Appx.

DRILLER: Ed Sezwyck

GWL 0 HRS

CLASSIFIED BY: JGD/WHL

DATE: 10-8-76

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Desc., Ground Water, Construction Problems, etc.
0–20												See Monitoring Well Point
22.5–24	1	2	4	4			Light brown, mottled silty clay trace fine sand	CL				
							T.D. 24.0'					

GAI-227 8/72

2E-323

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 06-4549-000 SITE AREA N. Perry, Ohio
SHEET 1 OF 1
DRILL HOLE NO. N-6
CONTRACTOR: Herron Testing
COORDINATES N 781054.2 E 2369647.8
ELEVATION 620 Appx.
DRILLER: Ed Sezmock
GWL 0 HRS
CLASSIFIED BY: JGD/WHL
DATE: 10-6-76
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–21												See Monitoring Well Point
21–24	1	2	5	9			Light brown to gray silty clay lenses of sand & fine gravel	CL				
24							T.D. 24'					

GAI-SRP 8/73

2E-324

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 06-4549-000 SITE AREA N. Perry, Ohio
SHEET 1 OF 2
DRILL HOLE NO. N-6A
CONTRACTOR: Herron Testing
COORDINATES N 781054.5 E 2369651.7
ELEVATION 620 Appx.
DRILLER: Ed Sezwyck
GWL 0 HRS
CLASSIFIED BY: JGD/WHL
DATE: 10-7-76
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–50							Glacial Overburden					See Monitoring Well Point

GAI-SRP 8/73

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-325

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 781054.5 E 2369651.7
DRILLER: Ed Sezwyck
CLASSIFIED BY: JGD/WHL DATE: 10-7-76
SHEET 2 OF 2
DRILL HOLE NO. H-6A
ELEVATION 620 Appx.
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50					Shale fragments, sand, gravel					
					T.D. 52'					
55										
60										

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-326

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 781053.7 E 2369643.2
DRILLER: Ed Sezwyck
CLASSIFIED BY: JGD/WHL DATE: 10-5-76
SHEET 1 OF 2
DRILL HOLE NO. H-6B
ELEVATION 620 Appx.
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0										
5										Set Monitoring Well Point
10					Glacial Overburden					
15										
20										
25										
30										
35										
40										
45										
50										

GAI-227 8/72

2E-327

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron Testing COORDINATES N 781053.7 E 2369643.2

DRILLER: Ed Sezwyck

CLASSIFIED BY: JGD/WHL DATE:

SHEET 2 OF 2.
DRILL HOLE NO. N-4B
ELEVATION 620 Appx.
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50												
55												
60												
65							Dk. Gray Shale, hard-few Fe rich silt beds - 0.1' thick, 2-3" pieces, bedding fractures		0%	5.0'	4.5'	
70												
75												

GAI - 227 8/73

2E-328

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron Testing COORDINATES N 781395.6 E 2369465.4

DRILLER: Ed Sezwyck

CLASSIFIED BY: JGD/WHL DATE: 9-29-76

SHEET 1 OF 1
DRILL HOLE NO. N-8
ELEVATION 620 Appx.
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												
5												
10												Set Monitoring Well Point
15												
20												
	1	3	4	7			Grayish-brown silty clay trace fine sand					
25												
30												

GAI - 227 8/73

2E-329

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
SHEET 1 OF 2
DRILL HOLE NO. N-8A
CONTRACTOR: Herron Testing COORDINATES N 781396.8 E 2369468.8
ELEVATION 620 Appx.
DRILLER: Ed Sezwyck
GWL 0 HRS
CLASSIFIED BY: JGD/WHL DATE: 9/30/76
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–50							Glacial Overburden					Set Monitoring Well Point

GAI - 227 9/72

2E-330

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
SHEET 2 OF 2
DRILL HOLE NO. N-8A
CONTRACTOR: Herron Testing COORDINATES N 781396.8 E 2369468.8
ELEVATION 620 Appx.
DRILLER: Ed Sezwyck
GWL 0 HRS
CLASSIFIED BY: JGD/WHL DATE: 9-30-76
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50–55							Dk. Gray, very stiff silty clay with about 15% large shale gravel	CL				
55	1	20	37	39								
							T.D. 55					

GAI - 227 9/72

2E-331

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 2

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. N-8B

CONTRACTOR: Herron Testing COORDINATES N 781393.5 E 2369461.6

ELEVATION 620 Appx.

DRILLER: Ed Sezwyck

GWL 0 HRS

CLASSIFIED BY: WHL/JGD ✓ DATE: 10-1-76

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												
15							Glacial Overburden					Set Monitoring Well Point
50												

GAI - 227 9/72

2E-332

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 2

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. N-8B

CONTRACTOR: Herron Testing COORDINATES N 781393.5 E 2369461.6

ELEVATION 620 Appx.

DRILLER: Ed Sezwyck

GWL 0 HRS

CLASSIFIED BY: WHL/JGD DATE: 10-1-76

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50												
65							Dark Gray Shale, Hard, interbedded with thin shale beds & a few Fe stone bands, bedding fractures 2-3"		0%	5	3.3	
70							T.D. 69'					
75												

GAI - 227 9/72

2E-333

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
SHEET 1 OF 1
DRILL HOLE NO. W-4
CONTRACTOR: Herron Testing COORDINATES
ELEVATION 620 Appx.
DRILLER: Ed Sezwyck
GWL 0 HRS
CLASSIFIED BY: WHL DATE: July 1975
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
20–23.5	1	3	5	6			Gray silty clay w/f. Sa. lenses varied, red clay streaks	CL				Set Monitoring Well Point
23.5							T.D. 23.5'					

GAI - 227 2/72

2E-334

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio
SHEET 1 OF 1
DRILL HOLE NO. W-5
CONTRACTOR: Herron Testing COORDINATES N 780347.9 E 2369360.4
ELEVATION 620 Appx.
DRILLER: Ed Sezwyck
GWL 0 HRS
CLASSIFIED BY: WHL DATE: 7-2-75
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
20–23.5	1	3	5	7			Gray silty clay w/f. sand lenses varied					Set Monitoring Well Point
23.5							T.D. 23.5'					

GAI - 227 2/72

2E-335

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. H-6

CONTRACTOR: Herron Testing COORDINATES N 780317.6 E 2369267.0

ELEVATION 620 Appx

DRILLER: Ed Sezwyck

GWL 0 HRS

CLASSIFIED BY: WHL DATE: 7-1-75

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–20							Gray-brown silty clay trace f. sand pockets					Set Monitoring Well Point
22	1	2	3	4								
25							T.D. 22'					

GAI-337 8/73

2E-336

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. H-6A

CONTRACTOR: Herron Testing COORDINATES N 780315.9 E 2369267.6

ELEVATION 620 Appx.

DRILLER: Ed Sezwyck

GWL 0 HRS

CLASSIFIED BY: WHL DATE: 7-2-75

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–45							Gray gravelly silty clay - lower till -	GC				Set Monitoring Well Point
45	1	16	24	36								
50							T.D. 45'					

GAI-337 8/7

2E-337

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron Testing COORDINATES N 780161.7 E 2369059.9

DRILLER: Sezwyck

CLASSIFIED BY: WHL DATE: 12-13-75

SHEET 1 OF 1

DRILL HOLE NO. W-7

ELEVATION

GWL 0 HRS

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core / Run	Grain Shape / Rec. / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												
5												See Monitoring Well Point
10												
15												
20							Upper Till					
							Approximately 22'					
25												
30												
35												
40												
45												
50												

GAI-307 9/73

2E-338

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: CEI-Perry Nuclear Power Plant W.O. 04-4549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron Testing COORDINATES N 779822.9 E 2368720.3

DRILLER: Ed Sezwyck

CLASSIFIED BY: WHL/JGD DATE: 10-13-76

SHEET 1 OF 1

DRILL HOLE NO. W-8

ELEVATION 620 Appx.

GWL 0 HRS

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core / Run	Grain Shape / Rec. / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												
5												
10												
15												
20												
	1	3	6	7			Moist, medium dense, gray clayey silt, varied with trace sand lenses	ML				
25							T.D. 24'					

GAI-307 9/73

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-339

SHEET 1 OF 3

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio
DRILL HOLE NO. BS1
CONTRACTOR: Herron Testing COORDINATES N 781,230 E 2,369,120
ELEVATION 611.3
DRILLER: Ed Sezwick
GWL 0 HRS 7'7"
CLASSIFIED BY: Renken DATE: 6/18/73 2:30 pm
24 HRS 6'11"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
						.5	6 inches topsoil					
							Lacustrine sediments, brown silty clay, stiff, moist with gray mottling.	CL				
	1	3	5	7								
5	shelby				20½"							
							Medium brown clayey silt and gray silty clay, stiff, moist, gray mottling					
	2	4	3	4		8.0						
							Upper till, Gray silty clay, with some very fine sand, medium to firm, moist, with trace of frags.	CL				
10	shelby				21"							
	3	1	3	3								
15	shelby				21"							
							Gray silty clay, low plasticity, trace to some fragments, pebble about ¼ in diameter					
	4	3	6	7								
20	shelby				21"							
							Increase in % rock fragments, stiff to hard 15% angular, subangular fragments, moist					
	5	3	7	12								
25												

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-340

SHEET 2 OF 3

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio
DRILL HOLE NO. BS1
CONTRACTOR: Herron Testing COORDINATES
ELEVATION 611.3
DRILLER: Ed Sezwyck
GWL 0 HRS 7'7"
CLASSIFIED BY: Renken DATE: 6/18/73 2:30 pm
24 HRS 6'11"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
	shelby				21"							
	6	3	7	10			Same as above (moist)					
30	shelby				21"							
						32.0	Lower Till					
	7	10	14	18			Same as above, dry, hard					
	shelby				6"							
35							Spoon refusal boulder in way					Used roller bit and H_2O
	8	17	27	30			Dry gray silty clay, large % fragments (30%)					
40												
	9	35	55	73			Dry brittle, hard, gray, silty clay with some fragments, low plasticity					
45												
	10	40	62	78								
50												

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-341

SHEET 3 OF 3
DRILL HOLE NO. BS1
ELEVATION 611.3
GWL 0 HRS 7'7"
24 HRS 6'11"

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES
DRILLER: Ed Sezwyck
CLASSIFIED BY: Renken DATE: 6/18/73 2:30 pm

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
							Hard, brittle, dry, some larger fragments, gray silty clay, low plasticity					
55	11	50	90	150			Gray hard, brittle, silty clay with 25-30% fragments					
60	12	150				60.0	Penetration of fragments shale top of bedrock Shale					GWL after pulling augers 6'11" @ 1:50 pm 7/20/73
							Hole Td at 60' shale					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-342

SHEET 1 OF 3
DRILL HOLE NO. BS2
ELEVATION 618.3
GWL 0 HRS -
HRS 10'9"

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 781,348 E 2,369,070
DRILLER: Ed Sezwyck and L. Humphrey
CLASSIFIED BY: Renken DATE: 7/25/73 3:00 pm

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
						.5	6inches topsoil					
							Lacustrine sediments sandy silt with some clay, very fine sand, light brown, mottled, firm non-plastic, moist	SM				
	1	5	7	10								
5	2	3	5	5			Sandy silt to clayey silt, medium brown very low plasticity, mottled firm					
10	3	3	4	5			Sandy and clayey silt, very low plasticity mottled, moist firm					
	4	3	2	4		12.5	Brown and sandy silt near top of spoon					
							Gray sandy silt on bottom					
15	5	3	5	5			Upper till, firm, no plasticity, trace clay					
							Clayey silt and silty clay, some very fine sand, low plasticity and firm, moist					
	6	2	1	2			Silty clay, low plasticity, gray, firm, moist	CL				
20												
25	7	4	5	6			Silty clay, with trace very fine sand, moist, no fragments, gray firm					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-343

PROJECT: Perry W.O. 064569-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Rexron Testing COORDINATES

DRILLER: Ed Serwyck and L. Bumphey

CLASSIFIED BY: Renken DATE: 7/25/73 3:00 pm

SHEET 2 OF 3

DRILL HOLE NO. BS2

ELEVATION 618.3

GWL 0 HRS -

19 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Core Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
30	8	1	3	5			Same as above					
	shelby				24"							
35	9	3	5	10			Silty clay (gray) with trace rock fragments, very firm, moist, low plasticity	CL				
	shelby				24"							
						38.5	Lower till					
40	10	5	14	19			Hard brittle silty clay (gray) dry, with rock fragments (10%) low plasticity, ½ in diameter maximum fragments in sample					
45	11	13	22	26			Same as above, hard, dry fragments ½ in. maximum diameter 10% - 15% fragments					
50	12	8	18	24			Same as above, some large rock fragments subangular to subrounded hard brittle, largest fragment 1" diameter (15-20%)					

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-344

PROJECT: Perry W.O. 064569-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Rexron Testing COORDINATES

DRILLER: Ed Serwyck and L. Bumphey

CLASSIFIED BY: Renken DATE: 7/25/73 3:00 pm

SHEET 3 OF 3

DRILL HOLE NO. BS2

ELEVATION 618.3

GWL 0 HRS -

19 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Core Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
55	13	49	[illegible]				Sample is dry, unconsolidated, 15% fragments, crumbly chunks, no plasticity, clayey sand					
60	14	29	68	107			Hard, dry gray, brittle, silty clay with trace sand and some fragments (25% - very low plasticity)					
	15	128				61.5						
65							128 blow for 6 in penetration no recovery, shale hole td at 63½'					

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-345

SHEET 1 OF 1

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. GW1

CONTRACTOR: Herron Testing COORDINATES N 781,195 E 2,369,135

ELEVATION 608.4

DRILLER: Ed Serwyck

GWL 0 HRS 18.1'

CLASSIFIED BY: Renken DATE: 7/16/73 3:30 pm

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock (Range Size / Grain Shape / Core Run / Rec. Core)	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
				1.0	Topsoil				This boring was drilled for the purposes of measuring ground-water levels.
					Lacustrine sediments dark brown sandy trace clay, moist low plasticity, clayey silt	CL			
5									
10					Dark brown sandy silt, moist to very moist				
				12.5					
15					Upper till gray, silty clay, trace rock fragments, low plasticity, saturated				
				18.1					
20					Hole td at 18' 1", installed PVB to 18' GWL @ 0 hrs 18' 1" 24 hrs 6' 6" 72 hrs 6' 1" 168 hrs 5' 2½" 234 hrs 5' 1½" 360 hrs 5' 2"				

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-346

SHEET 1 OF 1

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. GW2

CONTRACTOR: Herron Testing COORDINATES N 781,220 E 2,369,125

ELEVATION 610.0

DRILLER: Ed Serwyck

GWL 0 HRS 18' 6"

CLASSIFIED BY: Renken DATE: 7/17/73 10:30 am

24 HRS 7'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock (Range Size / Grain Shape / Core Run / Rec. Core)	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
				1.2	Topsoil				Auger borings, no sampling This boring was drilled for the purposes of measuring ground-water levels.
					Lacustrine sediments dark brown, silty sand, (fine) non plastic to low plasticity also clayey silt	ML CL			
5									
10									
				12.0					
15					Upper till, gray, moist silty clay, trace rock fragments, low plasticity, very moist to saturated				
				18.5					
20					Td @ 18' 6" installed 18' of PVB pipe GWL @ 0 hrs 18' 6" GWL @ 24 hrs 7' GWL @ 48 hrs 6' 8" GWL @ 144 hrs 5' 11" GWL @ 215 hrs 5' 7" GWL @ 331 hrs 5' 7"				

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-347

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 781,255 E 2,369,115
DRILLER: Ed Sezwyck
CLASSIFIED BY: Renken DATE: 6/17/73 11:30 am

SHEET 1 OF 2
DRILL HOLE NO. GW3
ELEVATION 615.3
GWL 0 HRS -
24 HRS 13' 11"

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
				1.0	Topsoil					This boring was drilled for the purposes of measuring ground-water levels.
					Lacustrine sediments medium to light brown, moist to very moist, very fine silty sand, clayey silt					
5										
10										
15				15.0						
					Upper till, gray silty clay, saturated, low plasticity					
20										
25										

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-348

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES
DRILLER: Ed Sezwyck
CLASSIFIED BY: Renken DATE: 6/17/73 11:30 am

SHEET 2 OF 2
DRILL HOLE NO. GW3
ELEVATION 615.3
GWL 0 HRS -
24 HRS 13' 11"

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
					Td @ 25', installed 27' of PVB pipe GWL @ 0 hrs - GWL @ 24 hrs 13' 11" GWL @ 50 hrs 10' 6" GWL @ 147 hrs 6' 7" GWL @ 214 hrs 6' 7" GWL @ 332 hrs 7' Moved hole slightly					imp't to note that no measurable ground-water has seeped into hole 2 hrs after hole was dug. While material is saturated, it apparently evaporates quicker than it seeps in.
30										

GAI - 227 8/72

2E-349

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 2

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. GW4

CONTRACTOR: Herron Testing COORDINATES N 781,280 E 2,369,100

ELEVATION 616.8

DRILLER: Ed Sezwyck

GWL 0 HRS -

CLASSIFIED BY: Renken DATE: 6/17/73 3:30 pm 24 HRS 9'9"

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
				1.0'	Topsoil					This boring was drilled for the purposes of measuring ground-water levels.
					Lacustrine sediments light to medium brown silty fine sand and clayey silt having no to low plasticity	SM CL				
5										
10					Very moist, same as above					
				12.0'						
					Upper till, gray saturated silty clay material, low plasticity	CL				
15										
20										
25										

GAI - 227 8/72

2E-350

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 2

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio

DRILL HOLE NO. GW4

CONTRACTOR: Herron Testing COORDINATES

ELEVATION 616.8

DRILLER: Ed Sezwyck

GWL 0 HRS -

CLASSIFIED BY: Renken DATE: 6/17/73 3:30 pm 24 HRS 9'9"

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
					Td. hole @ 25', 27' of PVB pipe installed GWL 0 hrs - GWL 24 hrs 9' 7" GWL 48 hrs 8' 4" GWL 144 hrs 8' 2" GWL 210 hrs 8' 2½" GWL 334 hrs 8' 1"					While material is saturated GWL at 0 hrs is not present. Water may evaporate more quickly than it seeps into the hole.
30										

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-351

SHEET 1 OF 2

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES N 781,300 E 2,369,090
DRILLER: Ed Serwyck
CLASSIFIED BY: Renken DATE: 6/17/73 1:30 pm

DRILL HOLE NO. GW5
ELEVATION 617.5
GWL 0 HRS -
24 HRS 11'6"

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
				1.0	Topsoil					
					Lacustrine sediments medium brown, silty sand, moist, low plasticity, changing to sandy or clayey silt					Auger borings, no sampling was done
5										This boring was drilled for the purposes of measuring ground-water levels.
10				10.0						
					Upper till, gray, saturated, silty clay, having low plasticity					
15										
20										
25										

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-352

SHEET 2 OF 2

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio
CONTRACTOR: Herron Testing COORDINATES
DRILLER: Ed Serwyck
CLASSIFIED BY: Renken DATE: 6/17/73 1:30 pm

DRILL HOLE NO. GW5
ELEVATION 617.5
GWL 0 HRS -
24 HRS 11'6"

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
30				30.0						
					Hole td @ 30', installed 33' of PVB pipe GWL @ 0 hrs - no water GWL @ 24½ hrs - 11' 6" GWL @ 48 hrs - 9' 1" GWL @ 145½ hrs - 9'1" GWL @ 272 hrs - 8'6½" GWL @ 334 hrs - 8' 5 3/4"					@ 0 hrs material was saturated but only to the extent that no measureable amount of ground-water is seeping into the hole

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-353

SHEET 1 OF 2

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron Testing COORDINATES N 781,325 E 2,369,080

DRILLER: Ed Sezwyck

CLASSIFIED BY: Renken DATE: 7/18/73 9:45 am

DRILL HOLE NO. GW6

ELEVATION 617.9

GWL 0 HRS 28.25'

24 HRS 13' 11"

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
				1.0	Topsoil					This boring was drilled for the purposes of measuring groundwater levels.
					Lacustrine sediment, light brown moist, silty sand, no plasticity, medium to fine grain sand, also clayey silt	SM CL				
5										
10				12.0						
					Upper till gray, saturated, silty clay low plasticity	CL				
15										
20										
25										

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-354

SHEET 2 OF 2

PROJECT: Perry W.O. 044549-000 SITE AREA N. Perry, Ohio

CONTRACTOR: Herron Testing COORDINATES

DRILLER: Ed Sezwyck

CLASSIFIED BY: Renken DATE: 7/18/73 9:45 am

DRILL HOLE NO. GW6

ELEVATION 617.9'

GWL 0 HRS 28.25'

24 HRS 13' 11"

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
30				30.0	Hole td @ 30' installed 33' of PVB pipe GWL @ 0 hrs 28.25' GWL @ 24½ hrs 13' 11" GWL @ 48 hrs 11' 6¼" GWL @ 120 hrs 11' 1" GWL @ 192 hrs 11' 1" GWL @ 304 hrs 11' 1"					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-355

SHEET 1 OF 2

PROJECT: PNPP W.O. 04-4549-000 SITE AREA Intermediate Building DRILL HOLE NO. EX-1

CONTRACTOR: Herron COORDINATES N780690.9 E2369906.8 ELEVATION Datum 564.8 stick up 2.2

DRILLER: Sezwyck GWL 0 HRS See Note

CLASSIFIED BY: WJS & LDS DATE: 9/3/75 24 HRS

Depth Ft.	Profile	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
0–5.7	El. 559.1	Set casing to 1.5' Roller bitted to 5.7'	5.7		
5.7–10.7	El. 550	Light to medium dark good shale thin interbeds of grey fine sandstone to 8.5' Brown oxidized siltstone bands at 7.3, 8.5, 10.0, 11.6, 14.3, 16.8, 20.4+ Thin siltstone grey interbeds	5.0 10.7	4.7	Bedding at 10° LP - .6' SP - .1' Most pcs 0.2 to 0.3'
10.7–15.7			5.0 15.7	4.2	
15.7–20.7			5.0 20.7	3.8	
20.7–25.7	El. 540		5.0 25.7	4.0	
25.7–28.5	El. 530	Brown bands at 26.7, 27.0, 27.8 about ½" thick Thin sand laminae ¼" at 26.8, 27.2 Brown band at 29.5 Sandy laminae at 29.6, 29.9, 30.1 2" vertical joint at 29.2 to 29.4	2.8 28.5	2.4	Bedding about 5°
28.5–30.8			2.3 30.8	2.2	Bedding about 5° to 10°
30.8–33.4			2.6 33.4	2.1	
33.4–35.7			2.3 35.7	1.2	
35.7–38.3			2.6 38.3	2.1	
38.3–40.8	El. 520	Brown band at 40.6 Sandy laminae at 41.6 and 45.0 45° joint at 42.7 Brown band at 48.05 and 50.8	2.5 40.8	2.3	Bedding horiz.
40.8–45.7			4.9 45.7	4.1	Bedding <5°
45.7–51			5.3 51	3.2	

T.D. 51.0'

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-356

SHEET 2 OF 2

PROJECT: PNPP W.O. 04-4549-000 SITE AREA Intermediate Bldg. DRILL HOLE NO. EX-1

CONTRACTOR: Herron COORDINATES N 780690.9 E 2369906.8 ELEVATION 564.8 stick up 2.2

DRILLER: Sezwyck GWL 0 HRS

CLASSIFIED BY: WJS & LDS DATE: 9/3/75 24 HRS See note

DESCRIPTION:

Less than complete core recovery is attributed to short core runs (ie. 5 ft for initial 20 ft and last 10 ft of borehole; 2.5 ft for remainder of borehole) Shorter core runs were required in order to document specific elevations of inclined bedding. Note that borehole locations offset 10-15 ft from test pit 1 in which continuous bedrock was exposed to base; no voids or vertical separation between bedding (horizontal or inclined) occurred. In addition, the borehole did not yield groundwater and upon completion was grouted.

GAI-227 8/72

2E-357

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 2

PROJECT: PNPP W.O. 04-4549-000 SITE AREA Intermediate Bldg
DRILL HOLE NO. EX-2
CONTRACTOR: Herron COORDINATES N 780688.5
E 2369901.2
ELEVATION 564.8
DRILLER: Ed Sezwyck
GWL 0 HRS See Note
CLASSIFIED BY: JGD DATE: 9/5/75 & 9/8/75-9/9/75
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0				El.561.3	Roller Bit			3.5		
5				El.550	Gray shale, unweathered, medium hard. Brown ox. siltstone bands ½" thick at 6.35, 7.45, 9.5, 11.15, 12.3, 14.65			5 8.5	4.55	
10					Light gray siltstone laminae at 5.3-5.9, 12.5-12.8 70° joints at 9.8-11.25, 5-5.2, 11.75-12.25, 14-14.1, 14.5-14.8, 15-15.1, 16.55-17.35			4.9 13.4	4.7	5° dip
15								4.8 18.2	4.8	
20				El.540	Brown ox. siltstone bands ½" thick at 18.4, 20.2, 21.3, 22.5, 24.7, 26, 28.4, 28.9, 30.5 ¼" thick at 23, 23.8, 23.9, 30.65			5.3 23.5	4.85	
25					Light gray sandstone laminae at 28.2, 30.5, 31.1, 31.7			2.3 25.8	2.3	5° dip
								2.5 28.3	2.4	
30				El.530	70° joints at 19.2-19.6, 20.7-21.2, 21.7-21.9, 27.6-27.9, 29.5-30			2.7 31	2.7	10° dip
					Light gray weathered clay-like material 32.3-32.7, 34.6-34.9			2.2 33.2	1.2	
35					Brown ox. siltstone bands ½" thick at 34.05, 44 ¼" thick at 39.2, 39.3, 40.6			2.8 36	2.1	
					Light gray sandstone laminae at 33.2, 34, 36, 37.3, 39.6 (¼ to 1" thick) 42.3			2.5 38.5	2.4	
40								2.4 40.9	2.35	
				El.520	70° joints at 33.3-33.6, 33.9, 38.1-38.5			2.6 43.5	2.55	
45					35° joints at 36.9, 44.5, 45.5			2.4 45.9	2.3	5° dip
50					Brown ox. siltstone bands at 47.9 (3/4") 49.6, 50.2, 50.4 (¼") Sandy laminae at 48, 50.3, 50.8 49.3			4.9 50.8	4.65	

T.D. 50.8

GAI - 227 8/72

2E-358

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 2

PROJECT: PNPP W.O. 04-4549-000 SITE AREA Intermediate Bldg
DRILL HOLE NO. EX-2
CONTRACTOR: Herron COORDINATES N 780688.5
E 2369901.2
ELEVATION 564.8
DRILLER: Sezwyck
GWL 0 HRS
CLASSIFIED BY: JGD DATE: 9/5/75 & 9/8/75-9/9/75
24 HRS See note

Depth Ft.	Sample No.	SPT Blows/6 In. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
					Less than complete core recovery is attributed to short core runs (ie. 5 ft for initial 20 ft and last 10 ft of borehole; 2.5 ft for remainder of borehole). Shorter core runs were required in order to document sepcific elevations of inclined bedding. Note that borehole locations offset 10-15 ft from test pit 1 in which continuous bedrock was exposed to base; no voids or vertical separation between bedding (horizontal or inclined) occurred. In addition, the borehole did not yield groundwater and upon completion was grouted.					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-359

PROJECT: PNPP W.O. 04-4549-000 SITE AREA Intermediate Bldg

CONTRACTOR: Herron

DRILLER: Sezwyck

CLASSIFIED BY: JGD

COORDINATES N 780692.4 E 2369900.5

DATE: 9/10/75-9/11/75

SHEET 1 OF 2

DRILL HOLE NO. EX-3

ELEVATION 564.7

GWL 0 HRS ~~See Note~~

24 HRS

Depth Ft.	Profile	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	Core Run	Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
0	El.560	Roller bit	3.8		
5		Gray shale, relatively unweathered medium hard	4.6	.8	
		Brown ox. siltstone bands at 8.3, 11.1, 12.5, 17.6, 11.8, 34.2, 34.3 (~½" thick), 21.5, 21.9, 22.6, 26.6, 27.2 (¼" thick)	4.2 / 8.8	4.2	15° dip at 8.3
10	El.550		6.2 / 14.6	5.3	10° dip at 11.1; 5° dip at 12.5
15		Light gray sandy laminae at 6.1, 7.8, 8, 20.8, 21.8, 24.6, 27.2, 29.4, 29.6, 30.5, 31.1, 34.2	4.9 / 19.5	4.8	
20		70° joints at 4.2-4.4, 18.8-19.1, 33.1-33.4, 31.9-32.1	20.5	1	
	El.540		53 / 25.8	44	< 5° dip
25		30° joints at 6.2, 7.3, 8.8, 16.5, 17.9-18.1, 22.8-23	2.4 / 28.2	2.4	
30			2.6 / 30.8	2.6	
	El.530		2.7 / 33.5	2.7	
35		Broken zone 33.5-34.3			
		Gray shale, unweathered, medium hard	2.4 / 35.9	2	
		Brown ox. silstone bands ½" thick at 36.2, 40.2, 43,7, 46.1 (latter two are not distinct)	2.5 / 38.4	1.8	
40		½" thick at 47.2, 49.6, 50, 50.1	4.7 / 43.1	4.2	
	El.520	Light gray sandy laminae at 36.5, 41.5, 44.5, 50.7			
45		30° joints at 39.4, 42.3	2.8 / 45.9	2.8	< 5° dip
50			5.1 / 51	4.9	

T.D. 51

GAI - 227 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-360

PROJECT: PNPP W.O. 04-4549-000 SITE AREA Intermediate Bldg

CONTRACTOR: Herron

DRILLER: Sezwyck

CLASSIFIED BY: JGD

COORDINATES N 780692.4 E 2369900.5

DATE: 9/10/75-9/11/75

SHEET 2 OF 2

DRILL HOLE NO. EX-3

ELEVATION 564.7

GWL 0 HRS ~~See Note~~

24 HRS

Description:

Less than complete core recovery is attributed to short core runs (ie. 5 ft for initial 20 ft and last 10 ft of borehole; 2.5 ft for remainder of borehole). Shorter core runs were required in order to document specific elevations of inclined bedding. Note that borehole locations offset 10-15 ft from test pit 1 in which continuous bedrock was exposed to base; no voids or vertical separation between bedding (horizontal or inclined) occurred. In addition, the borehole did not yield groundwater and upon completion was grouted.

GAI - 227 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-361

SHEET 1 OF 2

PROJECT: PNPP W.O. 04-4549-000 SITE AREA Intermediate Bldg

DRILL HOLE NO. EX-4

CONTRACTOR: Herron COORDINATES N 780696 E 2369900.4

ELEVATION

DRILLER: Sezwyck

GWL 0 HRS See note

CLASSIFIED BY: JGD DATE: 9/12/75 & 9/15/75-9/16/75

24 HRS

Depth Ft.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0	El.561.9	Roller Bit	3.5		
5		Gray shale, relatively unweathered medium hard Brown ox. siltstone bands at 6 (½") 7.3 (3/4"), 10.5 (1") and (½") 10.7, 14.8, 16.1, 16.5, 17.4	5 8.5	3.8	
10	El.550	Light gray sandstone laminae at 5.6, 9.6, 15.5 Joints 85° at 4.9-5.3 65° at 9.2-9.4	5 13.5	2.3	5° dip
15			5.1 18.6	4.9	
20	El.540	Brown ox. siltstone bands at (½") 19.1, 19.2, 21.1, 21.2, 23.2, 24.7, 25.5, 26.7 (½") 27.6 26.4, 28.9, 29.5, 29.1 (3/4") 31	5.1 23.7	4.9	10° dip
25		Light gray sandstone laminae at 20.1, 29.1, 30.7	2.2 25.9	2.2	5 to 10° dip
		No joints, surface fractures only	2.5 28.4	2.5	10° dip
30			2.5 30.9	2.5	
	El.530	Brown ox siltstone bands at 34.4, 35.1, 35.2, 36.1, 38.5, 39.2 (3/4")	2.2 33.1	2.2	5-10° dip
35		Light gray sandstone laminae at 31.7, 34.3, 36.3, 39.7	3 36.1	2.65	dip flattens out at 34.7
		Joints 80° to vertical 37.8-38.3	2.5 38.6	2.4	
40		Gray clay seams 36.7, 37, 1" thick	3 41.6	1.1	
45	El.520	Coring still in progress; will terminate at approximately 50'			
50					Dips greater than 10° may be depositional in origin

GAI - 227 2/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-362

SHEET 2 OF 2

PROJECT: PNPP W.O. 04-4549-000 SITE AREA Intermediate Bldg

DRILL HOLE NO. EX-4

CONTRACTOR: Herron COORDINATES N 780696 E 2369900.4

ELEVATION 564.8

DRILLER: Sezwyck

GWL 0 HRS See note

CLASSIFIED BY: JGD DATE: 9/12/75 & 9/15/75-9/16/75

24 HRS

Depth Ft.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
		Less than complete core recovery is attributed to short core runs (ie. 5 ft for initial 20 ft and last 10 ft of borehole; 2.5 ft for remainder of borehole). Shorter core runs were required in order to document specific elevations of inclined bedding. Note that borehole locations off-set 10-15 ft from test pit 1 in which continuous bedrock was exposed to base; no voids or vertical separation between bedding (horizontal or inclined) occurred. In addition, the borehole did not yield groundwater.			

GAI - 227 2/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-363

SHEET 1 OF 3

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing
DRILLER: Joe Minarchick
CLASSIFIED BY: R. T. Wardrop DATE: 8/21/78
COORDINATES Sta. 10+30 N 781950 E 2368660
DRILL HOLE NO. TX-1
ELEVATION 440.2'
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6 / 12 / 18	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					Med. hard, med. gy., silty shale interlam w/little dk. gy. brn. shale lam., little fracts. in various orientations, flat lying.		0%	.75'	.46'	First run taken w/3-3/4" I.D. bit to set top casing. Machine running rough - rpms inconsistent.
1					Same, interlam w/some lt. gy., v. fi. gr., sandy siltstone stringers and lenses, little dk. gy. brn. lam. (1/16"-1/4" thk.), tr. bedding fracts., flat.		0%	1.0'	.67'	No gas. Lt. gy. wash. Machine still rough. Occasional brown influx to wash.
2					Same. Top of gouge zone felt w/probe @ 2.9'.		33%	1.0'	.71'	No gas. Machine stabilizing rpms. Lt. gy. wash. No gas.
3					Gouge Zone felt w/probe. Fault Zone indicated by recovery. Bottom of gouge zone felt @ 3.67'.		0%	1.0'	0'	Cream gy. wash w/lt. gy. platy clay particles. Lost water momentarily. Gas bubbling in hole. (20-40% LEL 1" abv. hole.) (0-3% LEL 1' abv. hole.)
4					Same as above fault zone, more sandy shale than siltstone 2" thk. ss band @ 4.1' - interlam w/ a 1/4" thk., gy. shale lam. dipping @ 25°-3/4" long fracts. in ss band parallel dip of gy. shale lam.		0%	1.0'	.71'	Lt. gy. wash. Water bubbling in hole after run 0% LEL.
5										

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-364

SHEET 2 OF 3

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing
DRILLER: Joe Minarchick
CLASSIFIED BY: R. T. Wardrop DATE: 8/21/78
COORDINATES Sta. 10+30 N 781950 E 2368660
DRILL HOLE NO. TX-1
ELEVATION 440.2'
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6 / 12 / 18	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
5					Med. hard, med. gy., shale, void of sandy stringers and lenses, flat bedded, 2" thk., lt. gy., ss band @ 5.4'.		0%	1.0'	.9'	Lt. gy. wash. Gas bubbling in hole - No methane detected.
6					Bottom of Hole - 5.75'.					8/22/78 - Gas continuous to bubble in TX-1 until the 1.6'-2.6' interval was encountered in TX-2. At this point, TX-1 did not bubble and TX-2 commenced.

GAI-227 8/72

Sheet 3 of 3
Drill Hole No. TX-1

INSPECTOR'S COMMENT:

TX-1 was drilled approximately five feet down dip of where the fault intersects tunnel invert. This location enabled the boring to encounter faulted rock at a shallow depth. Indicators from the drilling process and core inspection were carefully noted for fault identification in other, deeper test holes.

The fault was recognized in the 2.9-3.67' interval for the following reasons. A creamy grey influx with platy clay particles dominated the typically light grey wash in the 2.75-3.75' run. All fractured rock and clay gouge was ground up during drilling. An influx of gas made drill water churn in the 2.75'-3.75' run.

Identification of fault was confirmed through the use of a steel feeler probe with which the faulted interval (fractured rock and clay gouge) was actually detected.

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4569-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES Sta. 10+25 N 781930 E 2368680
DRILLER: Joe Minarchick
CLASSIFIED BY: R. T. Wardrop DATE: 8/22/78
SHEET 1 OF 6
DRILL HOLE NO. TX-2
ELEVATION 440.1'
GW. 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Cons., Geologic Desc., Ground Water, Construction Problems, etc.
0							Med. hard, mod. gy., silty shale, interlam. w/some lt. gy. sandy shale lenses (0-1/4" thk.), tr. dk. gy. brn. lam. (1/8" thk.) - Broken along flat lying bedding fracts. Long piece - .25' flat bedded.		0%	.6	.6	4" hole on first run to set top casing. No gas.
1							Same		0%	1.0	.7	Lt. gy. wash No gas.
2							Same, Hard, tn. brn., cherty, "Fe" band (1-1/8" thk.) @ 1.7'. Hard, lt. gy., fi. gr., ss band (2-1/2" thk.) @ 2.5'. 2 jts. dipping @ 35° @ 2.2' and 2.25'. Core pieces broken every 1/2" - 2-1/2".		0%	1.0	1.0	Gas begins to bubble in TX-2, stops in TX-1. Lt. gy. wash 0% LEL detected.
3							Same, w/tr. sandy lenses & stringers. Soft seam of highly fract. fissile shale (3/4" thk.) @ 3.2' - w/35° dip. Core pieces 1/8 - 3" long		0%	1.0	1.0	Lt. gy. wash Gas bubbling in hole, 0% methane
4							Same, flat lying. Hard, lt. gy., sandy shale band (1" thk.) @ 3.65'. Top of zone probed @ 4.5'		0%	1.0	.8	Lt. gy. wash w/ occasional brn. influx
5							Fault Zone. Top of zone indicated by recovery. See note on Page 6					No gas detected Water bubbling in hole.

GAI-257 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-367

SHEET 2 OF 6

PROJECT: PNPP W.O. 04-4549-310 SITE AREA: Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES: Sta. 10+25, N781930, E 2368680
DRILLER: Joe Minarchick
CLASSIFIED BY: B. T. Wardrop DATE: 8/22/78

DRILL HOLE NO. TX-2
ELEVATION 440.1'
GWL 0 HRS ____
24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
5					Fault Zone		0%	1.0	.1'	Cream gy. wash
					Bottom of 5.5'.					Water bubbling in hole - No gas detected.
6					5.5-6.6' - Same as abv. fault Tn. brn., cherty, "Fe" band (3/4" thk.) @ 5.65'.					
					Flat bedded w/localized variation.		0%	1.0	.77'	Lt. gy. wash
					Core pieces 3/4" to 3-3/4" long					Water bubbling 0% LEL.
7					6.6'-9.6' - Hard, lt. gy., sandy shale and siltstone, interlam w/ some med. hard, med. gy., shale in v. thin lam. (1/16" - 3/4" thk)					
					Med. gy. shale bands @ 7.4' (1" thk.), 7.8' (1-1/2" thk.), 8.5' 2-1/4" thk.), & 9.3' (1-1/4" thk.)		31%	1.5'	1.4'	Lt. gy. wash
8					Concentrations of fi. sand high from 7.0 - 7.35' (x-bedded), 7.95-8.3', and 9.35-9.6'.					
					Core pieces 3/4" to 5-1/2" long					Gas same.
							74%	1.5'	1.4'	Lt. gy. wash
9					9.6'-10.3' - Hard, lt. gy. to gy. shale w/some sandy stringers and lenses up to 1/2" thk.					
					Long piece - 7-1/2" long					Gas detector registers 10% LEL 1' abv. hole.
10										

GAI - 227 8/73

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-368

SHEET 3 OF 6

PROJECT: PNPP W.O. 04-4549-310 SITE AREA: Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES: Sta. 10+25, N 781930, E 2368680
DRILLER: Joe Minarchick
CLASSIFIED BY: B. T. Wardrop DATE: 8/23/78

DRILL HOLE NO. TX-2
ELEVATION 440.1'
GWL 0 HRS ____
24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
10					10.3'-10.8' - Lt. & dk. gy., med. hard, shale interlam in 1/4-1/2" bands.					Water bubbling in hole @ start of day 3-4% LEL detected.
11					10.8'-11.75' - Hard, lt. gy. to gy. shale w/some sandy stringers and lenses up to 1/2" thk. w/ minor x-bedding.		88%	3.0	3.0	Wash varies from lt. gy. to dk. gy. to dk. brn.
					Long piece - 11-1/2"					
					11.75-12.05 - Med. hard, dk. gy. shale, tr., v. thin sand stringers.					
12					12.05-12.35 - Hard, lt. gy. to gy. shale w/some sandy lenses & stringers up to 1/2" thk.					
					12.35-12.5 - Hard, th. gy., sandy shale.					
					12.5-12.85 - Med. hard, dk. gy. shale, thinly lam.					Gas bubbling in hole. 0% LEL detected.
13					12.85 - 13.15 - Med. hard, th. gy. sandy shale.					
					13.15-13.75 - Med. soft, dk. gy. silty shale, w/little sandy shale, little med. gy. shale, lam. 1/2" to 1-1/4" thk.					Dk. and lt. gy. wash.
					13.75-15.8 - Hard, lt. gy., v. sandy shale.		83%	4.4	4.4	
14					Tn. gy., fi. gr., ss bands (1"-2" thk.) occurring @ 13.8', 14.15', 15.1', 15.25', and 15.65' (w/"Fe" band inside, pinching, 0"-1/2" thk)					
15										

GAI - 227 8/73

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-369

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel

SHEET 4 OF 6

DRILL HOLE NO. TX-2

CONTRACTOR: Herron Testing

COORDINATES Sta. 10+25, N 781930, E 2368680

ELEVATION 440.1'

DRILLER: Joe Minarchick

GWL 8 HRS ______

CLASSIFIED BY: R. T. Wardrop DATE: 8/23/78

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
15										Lt. gy. wash
					15.8-16.15 - Med. hard, dk. gy. & med. gy., shale, interlam in 1/4" -1/2" thk. bands.		33%	4.4	4.4	
16					16.15-16.95 - Med. hard, dk. gy. shale in 1" thk. bands interlam. w/lt. gy. sandy shale in 1-1/2" thk. bands @ 16.55 and 16.85. Flat bedded. Long piece - 15"					
17					16.95-17.2 - Med. hard, dk. gy. silty shale.					Gas begins to bubble violently in hole when core barrel is removed - Water surging out of hole up to 1'. 20-40% LEL detected 1' abv hole.
					17.2-17.85 - Hard, tn. gy., v. sandy shale, x-bedded - Sand content & x-bedding increasing w/ depth. Thin clay seams seen as gy. clay remnants in partings @ 17.45, 17.55, and 17.65'.					
18					17.85-18.55 - Dk. gy. shale interlam w/some thin, lt. gy. shale lam.		76%	4.0	3.85	Lt. gy. wash varying to dk. gy. and brown.
19					18.55-19.75 - Med. hard, dk. gy. shale, interlam w/same lt. gy. sandy shale in 1"-2" thick bands. Lt. gy. lam. of sandy shale show elipsoid nodules which appear to be concretions w/concentric growth. Nodules avg. 1/4" length, 1/8" width, w/long axis lying horizontal w/bedding. Nodules occur approx. 1 every 1" @ 18.6'.					
20					19.75-20.7 - Dk. gy., med. hard, shale interlam w/little dk. gy. brn. lam. (1/2" thk.) Flat bedded.					

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-370

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel

SHEET 5 OF 6

DRILL HOLE NO. TX-2

CONTRACTOR: Herron Testing

COORDINATES Sta. 10+25, N 781930, E 2368680

ELEVATION 440.1'

DRILLER: Joe Minarchick

GWL 8 HRS ______

CLASSIFIED BY: R. T. Wardrop DATE: 8/23/78

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
					20.7-21.0 - Med. hard, dk. gy. shale interlam w/lt. gy., v. sandy hard shale in 1-1-1/2" bands.		76%	4.0	3.85	Dk. gy. wash
					Bottom of Hole - 21.0'					Gas bubbling lightly. 8/24/78 - 5-10% LEL 1' abv. hole.

GAI-227 8/72

Sheet 6 of 6
Drill Hole No. TX-2

INSPECTOR'S COMMENT:

TX-2 was also located relatively close to the fault/tunnel invert intersection.

Here a creamy grey wash influx occured in the 4.6 to 5.6' run. One and one-tenth feet of sample was absent from the 4.5' to 5.6' interval. The feeler probe detected broken rock and clay gouge at appropriate depth.

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PHPP W.O. 04-4549-310 SITE AREA Intake Tunnel SHEET 1 OF 5
CONTRACTOR: Herron Testing COORDINATES Sta. 10+05 DRILL HOLE NO. TX-3
DRILLER: Joe Minarchick N 781900 ELEVATION 440.0'
CLASSIFIED BY: R. T. Wardrop DATE: 8/24/78 E 2368700 GRL. 0 HRS. ____ 24 HRS. ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil or Rock: Range Size / Core Run	Soil or Rock: Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					Broken, med. hard, med. gy., silty shale, w/little dk. gy. brn. shale bands (1/8-1/4" thk.) Lt. gy., v. sandy shale band (3/4" thk.) @ 1.1'. Core pieces 1-1/2"-2" long		0%	.75	.75	No gas.
1					Same. Tn. brn., cherty, "Fe" band, pinch., @ 1.7'. Flat bedded. Core pieces 1/4" - 2-1/4" long.		0%	1.5	1.1	Lt. gy. wash w/occasional brown influx. No gas.
2–3					Hard, lt. gy., sandy shale bands (3/4" thk.) @ 2.3', (2-1/2" thk. broken) @ 3.0', and (1/4" thk.) @ 4.6'. Same. Core pieces 1/4" - 2-1/4" long.		0%	1.5	9.5	Wash same. Gas starts bubbling in TX-3 - Continues to bubble in TX-2. Gas bubbling in hole - 0% LEL.
4–5					Same to 4.65'. Flat bedded. 4.65-4.85 - Hard, lt. gy., sandy shale bands, stringers & lenses, w/little med. gy., little, dk. gy. grn. shale. Hard, tn. brn., cherty "Fe" band (1/4" thk.) @4.95'.		0%	2.0	1.6	Lt. gy. wash.

GAI-237 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-373

SHEET 2 OF 5

PROJECT: FNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
DRILL HOLE NO. TX-3
CONTRACTOR: Harron Testing COORDINATES Sta. 10+05
ELEVATION 440.0'
DRILLER: Joe Minarchick N 781900 E 2368700
GWL 0 HRS
CLASSIFIED BY: R. T. Wardrop DATE: 8/24/78
24 HRS

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Core Run	Core Rec.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
5	Concentration of sand high from 5.0-5.25 and 6.1-6.3. Broken in 1/2"-3-1/2" pieces.	0%	2.0	1.6	Gas bubbling 80-100% 1" abv. hole. 5% 1' abv. hole.
6–7	6.85-7.2 - Med. hard, dk. gy. shale interlam w/some lt. gy. sandy, shale in 1/8"-1/4" thk. bands. 7.2-7.5 - Hard, med. gy. & dk. gy. brn., siltstone in 1-3/4" bands. 7.5-8.0 - Lt. gy., sandy shale in thin lam. Flat bedded Long piece - 9"	77%	2.0	2.0	Wash turns lt. gy., to tn. brn., to brn.
8–9	8.0-8.5 - Med. hard, med. gy. & dk. gy. shale and lt. gy. thin lam., sandy shale interlam. 5° jt. @ 8.15' 8.5-9.1 - Same, w/little sandy shale lam. Flat bedded Long piece - 18" 9.1-9.35 - Hard, lt. gy. sandy shale, tr. x-bedding becom. lt. gy. to tn. gy. siltstone. Last piece recovered - 1-1/2" long tn. brn. siltstone interlam w/a 1/4" thk. med. gy. shale band-dipping @ 74°. Fault Zone	70%	2.0	1.6	0% LEL 1' abv. hole. Lost core in hole replaced core retainer recovered core. Driller notes reduced resistance @ 9.4'. Lt. creamy gy. wash w/platy clay particles.
10					

See note on Page 5

GAI-287 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-374

SHEET 3 OF 5

PROJECT: FNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
DRILL HOLE NO. TX-3
CONTRACTOR: Harron Testing COORDINATES Sta. 10+05
ELEVATION 440.0'
DRILLER: Joe Minarchick N 781900 E 2368700
GWL 0 HRS
CLASSIFIED BY: R. T. Wardrop DATE: 8/24/78
24 HRS

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Core Run	Core Rec.	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
10	.6' of hard, lt. gy., iron stained sandy shale interlam w/little med. gy. shale, tr. x-bedding - Upper 3" of core, beveled by overcore.	0%	.75	.7	Lt. gy. wash darkening occasionally.
11	Clay remnants in partings. 1.2' of med. hard, med. gy. broken shale w/some dk. gy. brn. shale lam. (1/2" thk.) dipping @ 10° - remnants of gy. clay (gouge) throughout pieces. Lt. gy. sandy shale band (1" thk.) .6' into section, x-bedded.	0%	1.0	.8	Gas begins to bubble violently in hole - lifts core barrel - 80% LEL detected 1' abv. hole. Worked stopped @ 10.75 when methane readings stay consistently high.
12–13	Pieces - 1-1/2"-1-3/4" long Edges of pieces rounded. End of Fault Zone 11.95' 11.95-13.15 - Med. hard, med. gy. shale, w/some dk. gy. brn. lam (1/4-1/2" thk.). Remnant clay in partings - flat bedded. 13.15-13.4 - Hard, lt. gy. sandy shale interlam w/little med. gy. shale in v. thin lam., x-bedded. Pieces - 1/2-4-1/2" long. 13.4-14.4 - Med. hard, dk. gy. shale interlam w/lt. gy. siltstone in 1"-2" bands.	32.5%	2.0	1.7	8/25/78 - Pulled off TX-3 - began TX-5 due to gas 8/29/78 - 100% LEL 1' abv. hole 8/30/78 - Resumed TX-3 w/ blo-jo apparatus to dissipate gas in flow. Lt. gy. wash turning brown occasionally.
14	14.4-15.1 - Hard, lt. gy. sandy shale, w/little med. gy. shale in 1/4" bands. Sandy shale broken w/clay remnants @ 15.1'.	77%	1.5	1.4	Lt. gy. wash.
15					

GAI-287 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-375

SHEET 4 OF 5

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel

DRILL HOLE NO. TX-3

CONTRACTOR: Herron Testing COORDINATES Sta. 10+05

ELEVATION 440.0'

DRILLER: Joe Minarchick N 781900

E 2368700

GWL 0 HRS

CLASSIFIED BY: R. T. Wardrop DATE: 8/24/78

24 HRS

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
15	15.1-15.9 - Hard, lt. gy. siltstone interlam w/some v. thin dk. gy. shale lam.				Lt. gy. wash.
16	15.9-16.5 - Med. hard, dk. gy. & med. gy., shale in 1" thk. bands, interlam w/tr. lt. gy. siltstone.				Lt. to dk. gy. wash w/influx of brn. occasionally.
	16.5-17.05 - Hard, lt. gy., sandy shale, w/band of lt. gy. siltstone 1-1/2" thk. @ 16.6, tr. dk. gy. brn. shale.				
17	17.05-17.65 - Med. hard, med. gy. shale, w/tr. siltstone and sandy shale.	51%	4.6	4.4	
	17.65-18.75 - Hard, lt. gy. sandy shale, and siltstone in 1/2" - 1" thk. bands - interlam w/little dk. gy. shale in 1/4" - 1" bands.				
18					Wash same.
	18.75-19.6 - Med. hard, dk. gy. shale dky. gy. brn. siltstone band (1/2" thk.) @ 19.25'.				
19	Broken, sandy shale seam w/clay remanants @ 18.75'				Gas Bubbling in hol 0% LEL w/blo-j 0% LEL w/minimal bubbling.
	Bottom piece broken off @ 65° fract.				
	Bottom of Hole - 19.6'.				80-100% - 1' abv. hole @ irregular surge shooting water 1'-2' abv. hole
20					

2E-376

Sheet 5 of 5
Drill Hole No. TX-3

INSPECTOR'S COMMENT:

An influx of very light creamy grey wash with platy clay particles was noted at the end of the 7.75' to 9.75' run. Four-tenths of a foot of core was lost in this run. Further evidence of test hole intersection with fault zone was found in the bottom 1-1/2" piece of core extracted from the barrel. This piece consisted of a 1/4" thick band of medium grey shale, dipping 25° and interlaminated on top and bottom by light grey siltstone.

Very little core loss occurred in the 9.75'-10.5' and 10.5' to 11.5' runs. Pieces of core did, however, show a slight dip to laminae and grey clay (gouge) remnants. Penetration through the clayey gouge zone released a quantity of methane sufficient enough to delay work on hole.

Fifteen percent core loss experienced at the top of the 11.5' to 13.5' run indicated advance through the bottom of faulted strata.

Weston Geophysical confirmed the existence of faulted rock from 9.35' to 11.95' by recognizing a zone of low sonic velocity via sonic logging.

Weston also ran a gamma log in TX-3. That log further supported fault zone location by detecting zones of low radiation between 9.4' and 12.0'.

2E-377

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES STA. 7+44 N 777333 E 2365924
DRILLER: Joe Minarchick
CLASSIFIED BY: R. T. Wardrop DATE: 9/11/78
SHEET 1 OF 20
DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Dem., Ground Water, Construction Problems, etc.
0					0.-2.85- Med. hard, dk.gy. & med. gy., shale interlam. w/some thin lt.gy. sandy shale lam. (1/16-1/8"), tr. siltstone lam.			.5	.5	4" Core for 1st 1/2 foot to set top casing
1							78%	1.5	1.5	Lt. gy. wash
2					Pieces 1/2-7 1/2" long					
3					2.85-4.05 - Hard, lt.gy. sandy lenses and thin gy. shale lam. in (1/2-1"bands), slightly broken		53%	1.5	1.4	Encountered gas @ 3.0' 100% L.E.L. 1' abv. hole
					Pieces 2-5 1/2" long					0% w/blo-jo
					Bedding flat					This condition remains for entire coring of hole w/ notable increases where indicated
4					4.05-4.25 - Hard, lt. gy. siltstone		53%	1.5	1.5	
					4.25-4.7 - Med. hard, dk. gy shale interlam w/thin lt. gy siltstone lam, tr. sandy shale					
5					4.7-6.75 - Hard, lt.gy. sandy shale and dk. gy. brn. shale to siltstone in 1/16-2 1/2" bands Pieces 2-5 1/2" long					Gas bubbling in hole -

GAI-227 8/73

2E-378

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES STA. 7+44 N 777333 E 2365924
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW DATE: 9/12/78
SHEET 2 OF 20
DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Dem., Ground Water, Construction Problems, etc.
5										Foul, LP-gas like order associated w/ methane occurrence
6										Wash, lt. gy. for the most part, except where noted different
					6.75-7.5 Hard, lt.gy., siltstone and sandy shale 1/4"-3/4" bands					
7					7.5-8.85 - Med. hard., med. gy., shale interlam w/lt. gy. siltstone in 1/2-1" bands, little dk. gy. brn. siltstone lam.		100%	5.0	5.0	Brown wash
8					8.85-9.0 - Med. hard, dk. gy. shale interlam w/ little lt. gy. siltstone lam. 1/8" thk.					
					9.0-9.75 - Med. hard, dk. gy. shale interlam. w/some lt. gy. siltstone lam. (1/8")					
9					Hard lt. gy. sandy shale bands (3/4") @ 9.25 and 9.35					
					9.75-10.0 - Med. hard, dk. gy. shale interlam. w/some dk. gy. brn. shale, tr. lt. gy. siltstone lam.					
10					Long piece 4 ft.					

GAI-227 8/73

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel

CONTRACTOR: Herron Testing COORDINATES N 777333 E 2365924

DRILLER: Joe Minarchick

CLASSIFIED BY: KTW DATE: 9/12/78

SHEET 3 OF 20

DRILL HOLE NO. TX-4

ELEVATION 438.7

GW. 0 HRS ______

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
10					10.0-14.4 - All, Med. hard, dk. gy. shale interlam. with thin lt. gy. sandy shale and siltstone					
					Heavy concentrations of sand X-bedded, in bands @ 10.2 (1 1/2"), 10.75 (2 1/2), 11.5 (3), 11.9(1/2), 12.6 (3 1/2), 14.05 (3 1/2")					
11										
12							84%	5.0	5.0	
13										
					Bedding flat					
14					14.4-15.9 Med. hard, dk. gy. shale interlam. w/some lt. gy. (1/2-3/4") sandy shale and siltstone bands					
15					Long piece 21 1/2"					

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel

CONTRACTOR: Herron Testing COORDINATES STA. 7+44 N 777333 E 2365924

DRILLER: Joe Minarchick

CLASSIFIED BY: R. T. Wardrop DATE: 9/12/78

SHEET 4 OF 20

DRILL HOLE NO. TX-4

ELEVATION 43.87'

GW. 0 HRS ______

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
15										
					1" Vertical fract. @ 15.8"					
16					15.9-16.85 - Med. hard, dk. gy. shale and lt. gy. sandy shale in 1/2" bands, tr. siltstone lam.					
					16.85-17.0 - Hard lt. gy. sandy shale, X-bedded		71%			
17					17.0-17.4 - Med. hard, dk. gy. shale, interlam. w/little dk. gy. brn. shale (1/4" thk.)			5.0	4.7	Momentary Brown influx to wash
					17.4-17.6 - Hard, lt. gy. sandy shale, X-bedded					
18					17.6-18.3 - Med. hard, dk. gy. shale interlam. up 1/4-1" thk. sandy shale to siltstone bands					
					18.3-19.1 - Med. hard dk. gy. shale and lt. gy. sandy shale					
19					19.1-19.6 - Med. hard, dk. gy. shale, tr. lt. gy. sandy shale					
					9.6-20.0 - Med. hard, dk. gy. shale and lt. gy. sandy shale					
					Lt. gy., sandy shale band, 2" thk. @ 19.75 (X-bedded)					
20					Long piece 21 1/2"					

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-381

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel

CONTRACTOR: Herron Testing

DRILLER: Joe Minarchick

CLASSIFIED BY: RTW

COORDINATES N 777333 E 2365926

DATE: 9/12/78

SHEET 5 OF 20

DRILL HOLE NO. TX-4

ELEVATION 438.7

GWL 0 HRS

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
20					20.0-20.45 Med. hard, dk. gy. shale, some dk. gy. brn shale, little lt. gy. sandy shale					
					20.45-20.75 - Hard, lt. gy. sandy shale, w/little dk. gy. shale lam.					
21					20.75-21.75 - Med. hard, dk. gy. and dk. gy. brn. shale					
					Lt. gy. sandy shale band @ 21.45 - 1 1/4" thk.					dk. gy. wash
22					21.75-22.15 - Med. hard, dk. gy. shale w/some thin, lt. gy. sandy lam.					
					22.15-22.6 - Med. hard dk. gy. shale w/tr. lt. gy. sandy shale lam.		80%	5.0	4.9	
23					22.6-24.1 - Med. hard, dk. gy. shale, w/tr. siltstone, tr. lt. gy. sandy shale in feeding pattern type clast. @ 23.2'					
					Bedding flat w/minor local variations (depositional)					
24					24.1-26.0 - Med. hard, dk. gy. shale, w/some lt. gy. sandy shale					
					lt. gy. sandy band, 1-1/2" thk., @ 24.5 X-bedded					
25					Long piece 17"					

GAI-237 8/78

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-382

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel

CONTRACTOR: Herron Testing

DRILLER: Joe Minarchick

CLASSIFIED BY: RTW

COORDINATES N 777333 E 2365926

DATE: 9/12/78

SHEET 6 OF 20

DRILL HOLE NO. TX-4

ELEVATION 438.7

GWL 0 HRS

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
25										Lt. gr. wash
26					26.0-26.2 - Hard, lt. gy. sandy shale, X-bedded					
					26.2-26.35 - Med. hard, dk. gy. shale					
					26.35-26.5 - Hard, lt. gy. sandy shale					
					26.5-27.8 - Med. hard, dk. gy. shale w/little lt. gy. sandy shale, little dk. gy brn. shale Lt. gy. sandy band @ 27.1' (1/2")					
27							71%	5.0	5.0	
28					27.8-28.1 - Hard, lt. gy., siltstone, dk. gy. shale, and lt. gr. sandy shale, thinly lam.					
					28.1-29.15 - All, med. hard, dk. gy. shale w/little lt. gy. sandy shale					
29					29.15-29.3 Hard, lt. gy., sandy shale, interlam w/little dk. gy. shale lam.					
					29.3-30.0 - Med. hard, dk. gy. shale w/tr. lt. gy. sandy shale in 1/8" thin lam.					
30										

GAI-237 8/78

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-383

SHEET 7 OF 20

PROJECT: P.B.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
DRILL HOLE NO. TX-4
CONTRACTOR: Herron Testing
COORDINATES N 777333 E 2365924
ELEVATION 438.7
DRILLER: Joe Minarchick
GWL 0 HRS
CLASSIFIED BY: RTW
DATE: 9/12/78
24 HRS

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Run	Core	Remarks
30	30.0-30.8 - Med. hard, dk. gy. shale. lt. gy. sandy shale band @ 30.3 (1" thk.)					
31	30.8-32.3 - Med. hard, med. gy. silty shale, tr. lt. gy. lam. (1/8-1/4" thk.)					
32	32.3-32.85 - Med. hard, dk. gy. shale, tr. lt. gy sandy shale, tr. dk. gy. brn. shale lam.		62%	5.0	4.85	Momentary brown influx to wash
	32.85-33.4 - Med. hard, med. gy. silty shale w/little lt. gy. lam. (1/16-1/4" thk.)					
33	33.4-34.1 - Med. hard., dk. gy. shale					
	Lt. gy. sandy shale band @ 33.75 (1 1/2" thk.)					
34	34.1-35.0 - Med. - dk. gy. shale, tr. dk. gy. brn. shale, tr. lt. gy. sandy shale, thinly lam.					
35	Long piece 17 1/2"					

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-384

SHEET 8 OF 20

PROJECT: P.B.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel STA 7464
DRILL HOLE NO. TX-4
CONTRACTOR: Herron Testing
COORDINATES N 777333 E 2365924
ELEVATION 438.7
DRILLER: Joe Minarchick
GWL 0 HRS
CLASSIFIED BY: R. T. Wardrop
DATE: 9/12/78
24 HRS

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Run	Core	Remarks
35	35.0-35.5 - Med. hard, dk. gy. shale and lt. gy. sandy shale in 1/16-1/4" lam.					
	35.5-35.75 - Med. hard, med. gy. to dk. gy. silty shale					
36	Clay remnants in parting @ 36.0					
37	37.25-38.3 - Med. hard, dk. gy. to med. gy. shale, w/some siltstone in 1" bands @ 37.3, 37.4, 37.6		54%	5.0	4.9	
	2" lt. gy. sandy, X-bedded band @ 38.4'					
38	38.4-38.85 - Med. gy. shale 20° fract. @ 38.6'					
	38.85-40.0 - Hard, lt. gy. sandy shale, X-bedded - minature fracts along X-bed laminae					Gas shot water out of hole at 39.5' Fracts. indicate new influx of gas.
39	lt. gy. siltstone band @ 38.7 (2" thk.)					
	Bedding flat					100% L.E.L. recorded 3-4 ft. abv. hole w/o blo-jo on
40	Long piece 12"					

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-385

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Harron Testing
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW
COORDINATES N 777333 E 2365924
DATE: 9/12/78
SHEET 9 OF 20
DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type • Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
40					40.0-43.0 - Med. hard, med. gy. to dk. gy. silty shale w/little lt. gy. sandy shale thinly lam.					Momentary loss of water @ 40.0'
					Lt. gy. sandy shale bands @ 40.5 (1 1/4") and 41.0 (1 3/4", X-bedded)					
41										
42							74%	5.0	5.0	
43					43.0-43.6 - Hard, lt. gy. siltstone, tr. dk. gy. brn. lam. sandy ooze or feeding pattern @ 43.4"					
					43.6-45.25 - Med. hard, dk. gy. to med. gy. silty shale					
44					Lt. gy. sandy band @ 44.7' (1-1/4")					
45					Long piece -2'					

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-386

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Harron Testing
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW
COORDINATES N 777333 E 2365924
DATE: 9/13/78
SHEET 10 OF 20
DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type • Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
45					45.25-46.0 - Hard lt. gy. sandy shale, X-bedded					
46					46.0-46.9 - Med. hard, med. gy. shale, to siltstone					
47					46.9-47.15 Hard, tn. lt. gy., sandy shale, X-bedded					
					17° fract. @ 46.9					
					47.15-48.3 - Med. hard, dk. gy. to med. gy. shale, w/little lt. gy. sandy lam.		57.5%	5.0	4.85	
48					Clay remnants in parting @ 47.5'					
					48.3-48.8 Med. hard, med. gy. shale					Dk. gy. wash
49					48.8-50.2 - Hard lt. gy. sandy shale to siltstone - X-bedded @ bottom - some dk. gy. shale					
					Bedding flat					
50					Long piece 27"					

GAI-227 8/72

2E-387

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel SHEET 11 OF 20

CONTRACTOR: Herron Testing COORDINATES N 777333 E 2365924 DRILL HOLE NO. TX-6

DRILLER: Joe Minarchick ELEVATION 438.7

CLASSIFIED BY: DTW DATE: 9/12/78 GWL 0 HRS ___ 24 HRS ___

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50					50.2-50.4 - Med. hard dk. gy. shale					
					50.4-50.5 - lt. gy. sandy shale					
					Possible "Fe" band missing from core @ 50.55					
51					50.5-51.05 - Hard, lt. gy. siltstone					
					51.05-51.2 - Med. hard, dk. gy. shale					
					51.2-51.3 - Hard, lt. gy. siltstone					
					51.3-51.75 - Med. hard, med. gy. siltstone, w/some dk. gy. shale, little lt gy. sandy stringers					
52					51.75-52.7 - Hard, lt. gy. sandy shale to siltstone (X-bedded), tr. thin gy. shale lam.		81%	5.0	4.95	
53					52.7-53.7 - Med. hard, med. gy. shale, tr. dk. gy. brn. shale lam., w/little lt. gy siltstone lam.					
					53.7-54.0 - Hard lt. gy. sandy shale, X-bedded					
54					54.0-55.2 - Med. hard, med. gy. and lt. gy. sandy shale, oozed features present @ 55.2'					Increase in constant gas seen as increased pressure in bubbling hole @ 55.0
55					Long piece -19"					

GAI-227 2/72

2E-388

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4540-320 SITE AREA Intake Tunnel SHEET 12 OF 20

CONTRACTOR: Herron Testing COORDINATES STA 7+44 N 777333 E 2365924 DRILL HOLE NO. TX-6

DRILLER: Joe Minarchick ELEVATION 438.7

CLASSIFIED BY: R. T. Wardrop DATE: 9/13/78 GWL 0 HRS ___ 24 HRS ___

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
55					55.25-possilbe "Fe" band					
					55.3-55.4 - Hard, lt. gy. sandy shale					
56					55.4-56.3 - Med. hard, med. gy. and lt. gy. shale, tr. siltstone in 1-2" bands					
					Clay remnants in parting @ 55.7					
					56.3-56.55 - Hard, lt. gy. sandy shale, X-bedded					
57					56.55-57.7 - Med. hard, dk. gy. shale and lt gy. siltstone in 1/4-1" lam.					
					57.7-58.25 - Hard, lt. gy. siltstone, ooze features present, w/little med. gy shale, thinly lam.		72%	5.0	4.95	
58					58.25-58.85 - Med. hard, med. gy. shale w/little lt. gy. depositional features of silty concentric rings-actual size @ 58.55					
59					58.85-60.4 - Med. hard, med. gy. shale interlamd w/lt. gy. siltstone bands @ 59.0 (1 1/2") 59.3 (1"), and 59.75 (2")					
					tr. dk. gy. brn. thin lam.					
60					Long piece 19.5"					

GAI-227 2/72

2E-389

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES N 777333 E 2365924
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW DATE: 9/13/78
SHEET 13 OF 20
DRILL HOLE NO. TX-4
ELEVATION 438.7
GW. 0 HRS
24 HRS

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Run	Core	Remarks
60					
	60.4-60.65 - Hard, lt. gy. siltstone, thinly lam.				
	60.65-61.9 - Med. hard, med. gy. shale, w/little lt. gy. sandy shale, tr. dk. gy. brn. lam.				
61	61.9-62.1 - Hard, lt. gy., sandy shale, X-bedded				
62	62.1-62.95 - Med. hard, dk. gy. shale, tr. dk. gy. brn shale lam. tr. lt. gy. sandy stringers	78%	5.0	4.95	
63	62.95-63.1 - Hard, lt. gy., sandy shale, X-bedded				
	63.1-64.9 - Med. hard, dk. gy. and med. gy., siltstone bands, 2" thk.				
64	64.9-65.2 - Hard, lt. gy. sandy shale				
65	Long piece 17"				

GAI-227 8/72

2E-390

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing COORDINATES N777333 E 2365924
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW DATE: 9/14/78
SHEET 14 OF 20
DRILL HOLE NO. TX-4
ELEVATION 438.7
GW. 0 HRS
24 HRS

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Run	Core	Remarks
65	65.2-66.1 - Med. hard, dk. gy. shale and lt. gy. X-bedded, sandy shale in 1/4"-1" bands				
66	66.1-66.45 - Med. hard, lt. gy. siltstone, thinly lam up little dk. gy. shale				
	66.45-67.35 - Med. hard, med gy. shale, w/little lt. gy. sandy shale, tr. dk. gy. brn. shale, thinly lam.				
67	67.35-67.45 - Lt. gy. sandy, shale, X-bedded	58%	5.0	5.0	
	67.45-67.9 - Med. hard, med. gy. shale, w/little lt. gy. siltstone				
68	67.9-68.05 - Lt. gy. sandy, X-bedded, shale				
	68.05-69.5 - Med. hard, dk. to med by. shale, tr. lt. gy. siltstone lam., tr. dk. gy. brn. shale, tr. lt. gy. sandy shale lam.				Brown influx to wash
					Dk. gy. wash
69	69.8-70.0 - Med. hard, dk. gy. shale				
	Bedding flat				
70	Long piece 16.5"				

GAI-227 8/72

2E-391

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 15 OF 20

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel DRILL HOLE NO. IX-4
CONTRACTOR: Herron Testing COORDINATES N 777333. E 2365924 ELEVATION 438.7
DRILLER: Joe Minarchick GR. 0 HRS
CLASSIFIED BY: RTW DATE: 9/14/78 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
70					70.0-70.35 - Hard, lt. gy., siltstone					
					70.35-72.4 - Med. hard, med. gy. shale, some lt. gy. siltstone lam.					
71					Siltstone band @ 72.0 (1.5") and @ 72.5 (2")					
					72.6-72.85 - Hard, lt. gy. sandy shale to siltstone, X-bedded @ top					
72							85%	5.0	5.0	
					72.85 - 73.1 - Hard, lt. gy. sandy shale, X-bedded					
73					73.1-76.9 - Med. hard, dk. gy. shale, tr. siltstone, w/little sandy bands @ 73.6 (2.5") and 74.5 (1")					
74										
75					Long piece - 18"					

GAI-337 8/73

2E-392

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 16 OF 20

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel DRILL HOLE NO. IX-4
CONTRACTOR: Herron Testing COORDINATES STA 7+44 N 777333 E 2365924 ELEVATION 438.7
DRILLER: Joe Minarchick GR. 0 HRS
CLASSIFIED BY: R. T. Wardrop DATE: 9/14/78 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
75										
76										
77					76.9-77.3 - Hard, lt. gy., sandy shale, tr. X-bedding					
					77.3-77.85 - Med. hard, med. gy. shale, w/some lt. gy. siltstone in 1/4" lam.		84%	5.0	4.9	
					77.85-78.2 - Hard, lt.gy. sandy shale, X-bedded					
78					78.2-78.6 - Med. hard, med. gy. shale w/some lt. gy. siltstone, tr. dk. gy. brn. shale lam.					
					78.6 - 79.4 - Hard, lt. gy. sandy shale, X-bedded					
79					clay remnants in parting @ 79.2'					
					79.4-80.6 - Med. hard, med. to dk. gy. shale, tr. thin siltstone lam.					
					clay remnants in parting @ 80.7					Brown influx to wash
80					Long piece - 15"					

GAI-337 8/73

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-393

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW
COORDINATES N 777333 E 2365924
DATE: 9/15/78
SHEET 17 OF 20
DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
80					80.6-81.2 - Hard, lt. gy. sandy shale and med. gy. shale in 1/2-2" bands					
81					clay remnant in parting @ 81.2					
					81.2 -84.65 - Med. hard, med. gy. to dk. gy. shale of little lt. gy. sandy shale, tr siltstone, tr. dk. gy. brn. shale					
82					lt. gy. sandy shale bands @ 81.95 (1 1/2") @ 83.55 (1 1/2") and 84.0 (2")		85%	5.0	4.8	
83										
84					Bedding flat					
					84.65-85.0 - Hard, lt. gy. sandy shale, X-bedded, and med. gy. shale					
85					Long piece - 11"					

GAI-337 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-394

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
CONTRACTOR: Herron Testing
DRILLER: Joe Minarchick
CLASSIFIED BY: RTW
COORDINATES N 777333 E 2365924
DATE: 9/15/78
SHEET 18 OF 20
DRILL HOLE NO. TX-4
ELEVATION 438.7
GWL 0 HRS
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
85					85.0-86.45 - Med. hard, med. gy. shale and siltstone, tr. lt. gy. siltstone					Lt. gy. wash
					"Fe" band @ 85.35'					9/15/78 Man cage accident @ 12:33 p.m. prevented afternoon coring
86					Top of Fault Zone - 86.45' See note on Page 20					Coring stopped @ 87.0' -Core barrel raised several inches and water left running in hole over night - Coring resumed - 9/18/78
87					15.5" of recovery over 30.5" of run					Driller notes starting @ 87.0 - continuing to 88' - Milky gray wash
					4" lt. gy. sandy shall					
					4" med. gy. shale					
					3 1/2" Broken, lt. gy. siltstone		80%	5.0	3.65	
88					4" lt. gy. sandy shale					
					Clay remnants in partings and around broken prices					
89					w. Bottom of Fault Zone - 89.0'					
					89.0-90.0 - Med. hard, med. gy. shale, some lt. gy. siltstone in 1/4" bands					
					"Fe" band @ 89.15'					Lt. gy. wash
90					Long piece - 14"					

GAI-337 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Intake Tunnel
SHEET 19 OF 20
DRILL HOLE NO. TX-4
CONTRACTOR: Herron Testing COORDINATES N 777333
E 2365924
ELEVATION 438.7
DRILLER: Joe Minarchick
GWL 0 HRS ____
CLASSIFIED BY: RTW DATE: 9/18/78
24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
90					90.0-90.8 - Mod. hard, dk. gy. shale and lt. gy. sandy shale, X-bedded in 1/4-1 1/4" bands					
					90.8-91.35 - Hard, lt. gy. sandy shale, X-bedded, w/little dk. gy. shale in 1/4" bands					
91					91.35-91.65 - Med. hard, dk. gy. shale, w/little lt. gy. silt-stone, thinly lam.					
					91.65-91.85 - Hard, lt. gy. siltstone					
					91.85-92.35 - Med. hard, dk. gy. shale, w/little, thin, lt. gy. siltstone lam.					
					92.35-92.9 - Hard, lt. gy., sandy shale, X-bedded		82%	5.0	4.85	
93					92.9-93.3 - Med. hard, dk. gy. shale					
					93.3-93.75 - Hard, lt. gy. siltstone					Dk. gy. wash
					Bedding flat					
					93.75-94.05 - Med. hard, dk. gy. shale					
94					94.05-94.3 - Hard, lt. gy. silt-stone					
					94.3-94.55 - Med. hard, med. gy. shale					
					94.55-95.0 - Hard, med. gy. and lt. gy. siltstone					
95					Long piece - 22"					

Bottom of hole - 95.0'

GAI-337 6/72

INSPECTOR'S COMMENT:

The fault was logged between depths 86.45' and 89.0' for the following reasons. One and one tenth feet of core was not recovered over two and five tenths feet of advance in a five foot run between 85.0' and 90.0'. Clay remnants adhered to core pieces from the zone in question. A milky grey influx surfaced in the wash while drilling at 88.0'. The 85.0' to 90.0' interval of faulted rock was consistent with down dip feature projections derived from the occurrence of faulted rock in TX-1, TX-2, TX-3, TX-5 and TX-6.

Weston Geophysical Corporation confirmed the fault in TX-4 by demonstrating low sonic velocity and low gamma partical emission as compared to sections of country rock above and below the 86.45' to 89.0' faulted interval.

2E-397

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PBPP W.O. 04-4549-310 SITE AREA Intake Tunnel SHEET 1 OF 7

CONTRACTOR: Herron Testing COORDINATES Sta. 9+65 DRILL HOLE NO. TX-5

DRILLER: Joe Minarchick N 781890 ELEVATION 439.8'

CLASSIFIED BY: R. T. Wardrop DATE: 8/25/78 E 2368730 GWL 0 HRS ______ 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Desc., Ground Water, Construction Problems, etc.
0							Highly broken, med. hard, med. gy. silty shale w/little dk. gy. brn. lam. (1/8" thk.), flat.		0%	.5	.5	4" core taken to set top casing.
							Same, broken in 1/2" - 2-1/2" pieces, tr. sandy stringers.					No gas.
1							Lt. gy. sandy shale band (1") @ .85', flat.		0%	1.5	1.0	Lt. gy. wash.
2							Pieces 1/4-2-1/2" long.					No gas.
							Same.					
							Tn. brn., pinching, cherty, "Fe" band (1/2-1-3/4" thk.) @ 2.65.		0%	1.5	.75	Lt. gy. wash.
3												
							Pieces 1/2-2" long.					No gas.
							Same to 4.4'					
4							Tn. brn., pinching, "Fe" band (0-3/4" thk.) @ 3.85'.					
							4.4-5.05 - Lt. gy., sandy shale, some dk. gy. shale in 1/8-1" bands broken in 3/4" pieces.		39%	4.0	3.85	
5												

GAI - 227 8/78

2E-398

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PBPP W.O. 04-4549-310 SITE AREA Intake Tunnel SHEET 2 OF 7

CONTRACTOR: Herron Testing COORDINATES Sta. 9+65 DRILL HOLE NO. TX-5

DRILLER: Joe Minarchick N 781890 ELEVATION 439.8'

CLASSIFIED BY: R. T. Wardrop DATE: 8/25/78 E 2368730 GWL 0 HRS ______ 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Desc., Ground Water, Construction Problems, etc.
5							5.05-5.25 - Hard, lt. gy., sandy shale.					
							5.32 - 2" band of med. hard, gy. shale.					
							5.35-5.7 - Hard, lt. gy. sandy shale, w/little, thin, dk. gy. shale lam. (1/16" thk.)					
							5.75 - 1-1/4" gy. shale.					
6							5.85 - 1-3/4" hard, lt. gy. siltstone.		39%	4.0	3.85	
							5.9-6.85 - Med. hard, dk. gy. shale and lt. gy. siltstone in 1/4" bands.					
							6.85-7.3 - Med. hard, dk. & med. gy. shale w/little sandy shale lam. (1/8"-1/4" thk.)					Lt. gy. wash.
7							7.3-7.95 - Hard, lt. gy., sandy shale w/little med. gy. shale lam. in 1/4"-1/2" thicknesses.					
							Long piece - 7" long.					No gas.
							Slight local variances to lam - dep. features - generally flat-bedded.					
8							7.95-8.4 - Med. hard, med. gy. & dk. gy. shale in 1/4"-3/4" lam., w/tr. lt. gy., thin sandy stringers.					Lt. gy. & dk. gy. wash.
							8.4-9.6 - Hard, lt. gy., sandy shale in stringers, thin lam., and lenses - several lam. iron stained upon contact w/tunnel atmosphere - these occur @ 8.75, 8.85, and 9.05.		93%	3.5	3.5	
9												
							9.6-12.0 - Med. hard, med. gy. dk. gy., & dk. gy. brn. shale w/bands of hard, lt. gy. sandy shale @ 10.55 (1/4" thk.) 11.15 (3/4" thk) 11.4 (1-3/4" thk.)(x-bedded) & 11.65 (1" thk.).					Lt. gy. and brn. wash.
10												

GAI - 227 8/78

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 7

PROJECT: TMPP W.O. 04-4549-310 SITE AREA Intake Tunnel

DRILL HOLE NO. TX-5

CONTRACTOR: Herron Testing COORDINATES Sta. 9+65

ELEVATION 439.8'

DRILLER: Joe Minarchick N 781890

GW. 0 HRS ______

CLASSIFIED BY: R. T. Wardrop DATE: 8/28/78 E 2368730

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
10										
11					Long piece - 11-1/2"					No gas.
					11.65-11.8 - Med. hard, dk. gy. shale. 11-8-11.95 - Hard, lt. gy., sandy shale (tr. x-bedding).		95%	2.0	1.9	
12					11.95-13.25 - Med. hard, dk. gy. & med. gy., shale and lt. gy., hard sandy shale interlam in 1/8" - 1-1/2" bands.					
13					Long piece - 12-1/2" long					No gas.
					13.25-13.55 - Hard, lt. gy., fi. gr. sandy, shale to siltstone.					
					13.55-15.45 - Med. hard, dk. gy. shale w/little med. gy. lam. (1/8" - 1/4" thk.) Lt. gy. sandy shale bands (1-1/2" thk. avg.) @ 13.9, 14.05, 14.35, and 14.65.		75%	2.0	1.65	Gas bubbling around core-barrel in top casing -. 0% LEL w/blo-jo on.
14					Thin clay seams seen as remnants in bedding fracts. @ 13.85 and 14.0 Bedding flat.					
15										

GAI - 327 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 7

PROJECT: TMPP W.O. 04-4549-310 SITE AREA Intake Tunnel

DRILL HOLE NO. TX-5

CONTRACTOR: Herron Testing COORDINATES Sta. 9+65

ELEVATION 439.8'

DRILLER: Joe Minarchick N 781890

GW. 0 HRS ______

CLASSIFIED BY: R. T. Wardrop DATE: 8/28/78 E 2368730

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
15					15.45-16.45 - Hard, lt. gy., sandy shale (x-bedded).					
16					Flat bedded.		77.5%	2.0	1.85	Lt. to dk. gy. wash.
					16.45-17.25 - Med. hard, dk. gy. shale interlam. w/little, thin, lt. gy. siltstone lam.					Gas bubbling in hole.
17					Long piece - 5-3/4" long					5% LEL w/blo-jo (1' abv. hole)
					17.25-17.45 - Hard, lt. gy. sandy shale to siltstone (x-bedded).					
					17.45-19.0 - Med. hard, dk. gy. & med. gy. shale interlam. w/some dk. gy. brn. siltstone lam. (1/2" thk.) - Remnants of clay seams in partings from 18.5-19.0.		7.5%	2.0	2.0	60-80% LEL w/o blo-jo (1' abv. hole) Lt.-dk. gy. & brn. wash.
18					18.5-19.0 - Vertical fracts from 17.8-18.0.					
					2 jts. - 1-1/2" apart dipping @ 45° intersected by a 80° (near vertical) fract @ 18.3'.					
19					Core pieces - 1/2" - 3-1/2"					Gas same.
					Fault Zone 19.0-19.75 - 3" of highly fract. shale w/clay remnants on most pieces (1) piece overcored.		50%	3.0	2.5	See Note on Page 7
20					19.75-21.45 - Med. hd., dk. gy. & med. gy. shale interlam w/some dk. gy. brn. siltstone lam. (1/2" thk.) Rem. of clay in partings.					

GAI - 327 8/72

2E-401

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel SHEET 5 OF 7

CONTRACTOR: Herron Testing COORDINATES Sta. 9+65 DRILL HOLE NO. TX-5

DRILLER: Joe Minarchick N 781890 ELEVATION 439.8'

CLASSIFIED BY: R. T. Wardrop DATE: 8/29/78 E 2368730 GWL 0 HRS ______ 24 HRS ______

Columns: Depth Ft. | Sample No. | SPT Blows/6 in. (6, 12, 18) | Ft. Rec. | Profile | DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories | U.S.C.S. | R.Q.D. | Soil Or Rock: Range Size / Core Run; Grain Shape / Rec. Core | REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.

Depth Ft.	Description	R.Q.D.	Core Run	Rec. Core	Remarks
20–22	20.45-22.0 - Hard, lt. gy., sandy shale, x-bedded and interlam. w/ med. hard, dk. gy. lam. (3/4" thk) tr. minute fracts. parallel to x-bedding @ 20.65'.	50%	3.0	2.5	Lt. gy. wash w/occasional dk. gy. influx.
22	Long piece outside of fault zone - 7" long.				Gas same.
22–25	22.0-25.1 - Med. hard, dk. gy., lt. gy. & dk. gy. brn. (1-1-1/2" lam.) shale, w/little lt. gy. siltstone bands @ 22.5, 22.9, 23.3 and 24.3 (all 1/4-1/3" thk.) tr. thin iron stained lam. - All flat bedded.	78%	4.5	4.2	Lt. gy., dk. gy. & brn. wash

GAI-237 9/72

2E-402

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel SHEET 6 OF 7

CONTRACTOR: Herron Testing COORDINATES Sta. 9+65 DRILL HOLE NO. TX-5

DRILLER: Joe Minarchick N 781890 ELEVATION 439.8'

CLASSIFIED BY: R. T. Wardrop DATE: 8/29/78 E 2368730 GWL 0 HRS ______ 24 HRS ______

Depth Ft.	Description	R.Q.D.	Core Run	Rec. Core	Remarks
25–26	25.1-26.1 - Hard, lt. gy. sandy shale and dk. gy. - med. gy. shale w/little dk. gy. brn. shale inter-lam in 1/4"-3/4" bands - Concentrations of sand high in 1-1/2" band @ 25.15'. Flat bedded.	78%	4.5	4.2	Lt. gy., dk. gy., and brn. wash.
26	26.1-27.1 - Med. hard, dk. gy. shale interlam w/little sandy lam (x-bedded), @ 26.25 (1/2" thk.) and 26.55 (1-1/2" thk.) Long piece - 23" long				
26.6	Remnant clay in bedding fracts @ 26.5, 26.65, 27.2 and 27.4.				Gas same.
27	27.1-27.3 - Hard, lt. gy., sandy shale (x-bedded).				
27.3–29.25	27.3-29.25 - Med. hard, dk. gy. - med. gy., shale interlam. in 3/4" 1-1/4" bands, little dk. gy. brn. shale lam. in 1/4"-3/8" bands, tr. lt. gy. siltstone. Lt. gy. sandy shale bands, x-bedded @ 28.65 (3-1/4" thk.) and 28.9 (1-3/8" thk.), tr. iron staining in thin lam. Flat bedded.		2.75	2.67	Gas same.
29.25	Bottom of Hole - 29.25'				

GAI-237 9/72

Sheet 7 of 7
Drill Hole No. TX-5

INSPECTOR'S COMMENT:

The fault was logged in TX-5 at the 19.0'-19.75' interval for the following reasons. One half foot of core was not recovered from the 19.0' to 22.0' run. In addition, the upper portion of the run consisted of three inches of highly fractured core and grey clay (gouge) remnants. A one-inch piece was over-cored, probably the result of a shale fragment in clay adjusting to the downward force of the core barrel.

Weston Geophysical Corporation attempted to geophysically log TX-5 but local caving at the fault interval prevented complete lowering of recording probes.

The 19.0'-19.5' interval of faulted rock was consistent with down dip feature projection derived from occurrences in TX-1, TX-2, and TX-3.

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 11
PROJECT: PNPP W.O. 06-4549-310 SITE AREA Intake Tunnel
DRILL HOLE NO. TX-6
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95
N 781840
E 2368790
ELEVATION 439.5'
DRILLER: Joe Minarchick
GW'L 0 HRS
CLASSIFIED BY: R. T. Wardrop DATE: 8/30/78
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Description (Density or Consistency, Color; Rock or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Range Size / Core Run	Grain Shape / Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
0				0-.5 - Med. hard, broken, med. gy. shale w/tr. sandy shale in stringers and lenses		0%	.5	.5	6" core taken in first .5' to set top casing
1				.5-1.5 - Med. hard-hard, dk. gy. shale and lt. gy. siltstone, tr. dk. gy. brn. shale. 1.5-2.0 - Hard, lt. gy. sandy shale Core pieces 1/4" - 9-3/4" long		53%	1.5	1.3	Gas occurrence in first 6". 100% LEL - 1' abv. hole 0% w/blo-jo Lt. gy. wash Gas same
2 3				2.0-3.3 - Med. hard, med. & dk. gy. shale in 1/2"-1" bands, interlam w/little bands of lt. gy. siltstone, 1/4" thk. Flat bedded w/local waviness due to deposition 3.3-3.5 - Hard, med. gy., siltstone interlam w/ a 3/8", th. brn. cherty, "Fe" band		76%	1.5	1.2	Lt. gy. wash Gas same
4 5				3.5-4.2 - Med. hard, med. gy. & dk. gy. shale in 1/2"-1-1/4" thk. bands, tr. lt. gy. siltstone, vertical fract. from 3.5-4.05 4.2-4.65 - Lt. gy. siltstone, interlam w/1-1/4" dk. gy. shale lam. 4.65-5.8 - Hard, lt. gy. sandy shale, tr. x-bedding interlam w/ 1/4" bands of dk. gy. shale		95%	5.0	5.0	Lt. gy. wash w/ infrequent tn. brn. influx

GAI-257 8/72

2E-405

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 11

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel DRILL HOLE NO. TX-6
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95 ELEVATION 439.5'
DRILLER: Joe Minarchick N 781840 GWL 0 HRS ____
CLASSIFIED BY: R. T. Wardrop DATE: 8/30/78 E 2368790 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
5					1-1/2" seam of weath. shale to clay @ 5.1'					
					5.8-7.5 - Med. hard to hard, thinly lam. lt. gy. sandy shale, dk. gy. shale, and dk. gy. brn. siltstone					
6					except for: a 4-1/2" thk. band of dk. gy. shale from 6.7-7.0'					Lt. gy. wash w/occasional brn. influx
7					Flat bedded		95%	5.0	5.0	
					7.5-7.85 - Hard, lt. gy., sandy shale w/little dk. gy. shale lam. (1/4" thk.)					
8					7.85-8.5 - Med. hard, dk. gy. shale and dk. gy. brn. shale inter lam. w/v. thin, lt. gy. siltstone lam. - shale bands (1/2-1-1/2")					Gas 1' abv. hole
					Long piece - 3.1'					
					8.5-9.1 - Hard, lt. gy. sandy shale, interlam w/some dk. gy. shale lam (1/4" thk.) - A type of feeding pattern appears in sandy areas @ 8.65 and 9.1					100% LEL w/o blo-jo; 3-5% w/blo-jo
9					approx. actual size					
					9.1-10.05 - Med. hard, dk. gy. shale, thinly lam. w/dk. gy. brn. shale, and lt. gy. sandy shale.					
10										

GAI - 227 8/72

2E-406

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 11

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel DRILL HOLE NO. TX-6
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95 ELEVATION 439.5'
DRILLER: Joe Minarchick N 781840 GWL 0 HRS ____
CLASSIFIED BY: R. T. Wardrop DATE: 8/30/78 E 2368790 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
10					10.05-10.1-Dk. gy. brn., hard, silty shale					Dk. brn. wash
					10.1-10.3 - Hard, lt. gy. sandy shale, tr. x-bedding					
					10.3-11.25 - Med. hard, dk. & med. gy. shale, thinly lam w/little lt. gy. siltstone					
11					11.25-12.1 - Hard. lt. gy., siltstone (1-1/2 - 2-1/2") interlam by 3/8" dk. gy. shale seams					Lt. gy. wash
					Flat bedded		97%	5.0	5.0	
12					12.1-12.4 - Med. hard, dk. gy. & med. gy., shale in 1/4"-3/4" bands					
					12.4-12.5 - Hard, lt. gy. sandy shale					occasional brn. influx to wash
					12.5-13.1 - Med. hard, dk. gy. shale, interlam w/some dk. gy. brn. shale, little lam of lt. gy. siltstone					
13					13.1-13.4 - Hard, lt. gy. sandy shale interlam w/little (1/4") lam. of dk. gy. shale					
					13.4-13.7 Long piece - 2' Med. hard, dk. gy. shale, tr. lt. gy. sand stringers					Gas same
14					13.7-14.05 - Hard, lt. gy., sandy shale, x-bedded		76%	5.0	5.0	Lt. to dk. gy. wash
					14.05-15.7 - Hard, lt. gy. sandy shale, lt. gy. siltstone, dk. gy. shale, dk. gy. brn. shale, and med. gy. shale - all interlam in 1/16" - 3/4" lam					
15										

GAI - 227 8/72

2E-407

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 11

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel DRILL HOLE NO. TX-6
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95 ELEVATION 439.5'
DRILLER: Joe Minarchick N 781840 GWL 0 HRS
CLASSIFIED BY: R. T. Wardrop DATE: 8/30/78 E 2368790 24 HRS

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Run	Core	Remarks (Chemical Cons., Geologic Desc., Ground Water, Construction Problems, etc.)
15					
16	15.7-16.05 - Hard, lt. gy., sandy shale, interlam w/some v. thin, dk. gy. shale lam. in a wavy depositional pattern - tr. x-bedding 16.05-19.1 - Med. hard, dk. gy. brn. shale, and dk. gy. shale interlam in 1/4-3-1/4" bands w/ little lt. gy. siltstone and sandy shale in 1/16-1/4"				Lt. gy. wash
17	Flat bedded	76%	5.0	5.0	
18	Long piece - 19"				Gas same
19	19.1-19.5 - Hard, lt. gy., sandy shale interlam w/a 1/2" band of dk. gy. shale @ 19.25 - lam. are locally wavy & x-bedded 19.5-20.45 - Med. hard, dk. gy. shale interlam w/some lt. gy. siltstone, sandy shale, and dk. brn. shale in 1/4-1/2" bands	96%	5.0	4.95	Wash same w/ occasional brn. influx
20					

GAI-237 8/72

2E-408

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 5 OF 11

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel DRILL HOLE NO. TX-6
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95 ELEVATION 439.5'
DRILLER: Joe Minarchick N 781840 GWL 0 HRS
CLASSIFIED BY: R. T. Wardrop DATE: 8/30/78 E 2368790 24 HRS

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Run	Core	Remarks (Chemical Cons., Geologic Desc., Ground Water, Construction Problems, etc.)
20	20.45-24.05 - Med. hard, dk. gy. shale (1-1-1/2") interlam w/1/4" dk. gy. brn. shale, nearly void of other lithologies, except: @ 21.05-21.35 w/v. thin lam of sandy shale, 1/2-1-3/4" apart.				
21	21.35 - 1/2" band of lt. gy. sandy shale 22.9 - 1-1/2" band of lt. gy. siltstone				Med. gy. wash
22	23.2 - 3/8" band of lt. gy. siltstone 23.5 - Suspect occurrence of "Fe" band here (pinching) where a high degree of splintering during coring may have left illustrated void.	96%	5.0	4.95	
23	?"Fe" band Long piece - 30-1/2"				Bubbling diminished in hole - 8/31/78 Gas - 0% LEL
24	24.05-24.55 - Hard, lt. gy. sandy shale interlam w/little med. gy. shale in 3/4-2" bands, tr. dk. gy. brn. shale in 1/4" lam 24.55-25.65 - Med. hard, dk. gy. shale interlam w/thin dk. gy. brn. shale (0-3/8" thk.) Lt. gy. sandy shale @ 24.8 (1/2" thk.) and 25.05 (2-1/4" thk.)	85%	5.0	5.0	
25					

GAI-237 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 6 OF 11

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
DRILL HOLE NO. IX-6
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95
ELEVATION 439.5'
DRILLER: Joe Minarchick N 781840 E 2368790
GWL 0 HRS ____ 24 HRS ____
CLASSIFIED BY: R. T. Wardrop DATE: 8/31/78

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Core Run	Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
25					
	25.65-26.55 - Med. hard, dk. gy. shale, interlam w/little dk. gy. brn. lam (1/4" thk.)				
26	26.55-27.1 - Med. hard, dk. th. gy. siltstone interlam w/little dk. gy. brn. lam (1/4" thk.) into 1" bands	85%	5.0	5.0	Lt. gy. to med. gy. wash w/ occasional brn. influx
27	27.1-27.4 - Lt. gy. sandy shale, broken along dep. wavy partings, x-bedded.				
	27.4-28.45 - Med. hard, dk. gy. shale w/tr. thin dk. gy. brn. lam, tr. sandy stringers				
28	Flat bedded				
	28.45-28.6 - Hard, lt. gy. sandy shale Long piece - 16"				Gas bubbling in hole
	28.6-29.9 - Med. hard, dk. gy. shale, interlam w/some (1/8-1/2" thk.) dk. gy. brn. shale lam @ 1-1/2-2" intervals, little lt. gy. sandy shale, thinly lam.	94%	4.5	4.4	10-30% LEL 1' abv. hole w/o blo-jo; 0-5% w/blo-jo; Wash same
30					

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 7 OF 11

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel
DRILL HOLE NO. IX-6
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95
ELEVATION 439.5'
DRILLER: Joe Minarchick N 781840 E 2368790
GWL 0 HRS ____ 24 HRS ____
CLASSIFIED BY: R. T. Wardrop DATE: 8/31/78

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Core Run	Rec. Core	Remarks
30	29.9-30.2 - Hard, lt. gy. siltstone w/little lt. gy. sandy stringers				
	30.2-33.1 - Med. hard, dk. gy & med. gy. shale to siltstone in 1/2 - 2" bands - interlam w/little lt. gy. ss. shale lam., little dk. gy. brn. siltstone (0-3/8" thk)				
31	Lt. gy. sandy shale bands (1/2" thk.) @ 30.65, (1" thk.) @ 31.4, (1/4" thk.) @ 32.35, & (1/4" thk.) @ 32.8				
	Gy. clay remnants in parting @ 31.7, top of sandy band	94%	4.5	4.4	
32					
33	Long piece - 16-3/4"				
	33.1-33.4 - Hard, lt. gy., sandy shale lenses (1/4-1/2") interlam w/some dk. gy. brn. lam. (1/4-1/2")				
	33.4-33.5 - Med. hard to hard dk. gy. brn. siltstone	91%	5.0	4.8	
	33.5-34.2 - Hard, med. gy. siltstone interlam w/dk. gy. brn. lam. (1/4-1/2"), tr. sandy stringers				
34	34.2-34.45 - Med. hard, dk. gy. to med. gy. shale interlam w/some dk. gy. brn. siltstone bands (1/4")				
	34.45-38.5 - Same, w/little lt. gy. siltstone (1/4") @ 1"-2" intervals				
35					

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-411

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel SHEET 8 OF 11
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95 DRILL HOLE NO. TX-6
DRILLER: Joe Minarchick N 781840 ELEVATION 439.5'
CLASSIFIED BY: R. T. Wardrop DATE: 8/31/78 E 2368790 GWL 0 HRS ____
24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
35										
					Gy. clay remanant of thin clay seam in parting @ 35.7					
36					1/4" sandy shale bands @ 36.45, 36.8, and 36.95		91%	5.0	4.8	Lt. gy. wash
37										
38					Long piece - 15"					OK 1.5 1' abv. hole w/blo-jo
					38.5-38.7 - Hard lt. gy. sandy shale					
					38.7-38.85 - Med. hard, dk. gy. shale					Lt. gy. wash
39					Remanant clay in parting @ 38.85					
					38.85-39.0 - Hard, lt. gy. sandy shale					
					39.0-39.6 - Med. hard, dk. gy. shale interlam w/little lt. gy. sandy shale in 1/4-1/2" lam.					
40					39.6-39.75 - Lt. gy. sandy shale to siltstone					

GAI-227 8/73

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-412

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel SHEET 9 OF 11
CONTRACTOR: Herron Testing COORDINATES Sta. 8+95 DRILL HOLE NO. TX-6
DRILLER: Joe Minarchick N 781840 ELEVATION 439.5'
CLASSIFIED BY: R. T. Wardrop DATE: 8/31/78 E 2368790 GWL 0 HRS ____
24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
40					39.75-40.3 - Med. hard, dk. gy. shale interlam w/tr. lt. gy. siltstone lam. (1/16" thk.) @ 1/4-2-1/4" intervals					
					Fault zone indicated by 2.35' of recovery in 3.2' of run + 12° dip in bedding parting w/clay remanant @ 40.3'.					
41					a) 5" of core parted every 1/4"-1-1/2" of dk. gy. shale and lt. gy. sandy shale (x-bedded) gy. clay remanants between all pieces.					
					b) 5-1/4" of competant, med. hard, dk. gy. shale, tr. thin sandy lam.		55%	5.0	4.35	Lt. gy. wash
					c) 3" of dk. gy. shale & lt. gy. (x-bedded) sandy shale in 1/2-1" bands.					
42					d) 1/2" of lt. gy. sandy shale, (x-bedded) vertically fractured.					
					e) 3-1/4" dk. gy. shale.					
					f) 2-1/4" of lt. gy. sandy shale broken in half-upper piece w/ 10° dipping jt.					
					g) 1-3/4" of broken sandy shale frags. and clay.					
43					h) 2" of tn. gy. sandy shale fract. in half @ 80°.					Pieces outside of fault - 4-1/2 - 13" long
					See note page 11					Gas same
					Bottom of fault zone @ 43.5'.					
					43.5-44.7 - Med. hard, dk. gy. & med. gy. shale interlam w/little lt. gy. siltstone (1/16" thk.)		51%	5.0	4.8	
44										
					44.7-44.8 - Hard, lt. gy. sandy shale.					
					44.8-45.2 - Med. hard, dk. gy. & med. gy. shale w/tr. lt. gy. siltstone lenses.					
45										

GAI-227 8/73

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-413

PROJECT: PNPP W.O. 04-4549-310 SITE AREA Intake Tunnel SHEET 10 OF 11
CONTRACTOR: Barron Testing COORDINATES Sta. 8+95 DRILL HOLE NO. TX-6
DRILLER: Joe Minarchick N 781840 ELEVATION 439.5'
CLASSIFIED BY: R. T. Wardrop DATE: 8/31/78 E 2368790 GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
45					45.2-46.2 - Med. hard, dk. gy. shale, and lt. gy. siltstone to sandy shale in 1/8-1/4" lam.					
					46.2-47.45 - Dk. gy. & med. gy. shale, tr. thin siltstone lam.					
46					1/4" th. gy. siltstone band @ 46.5'					Lt. gy. wash
							51%	5.0	4.8	
47										
					47.45-47.7 - Hard, lt. gy. sandy shale to siltstone - broken in 3 1" pieces.					
					47.7-48.0 - Med. hard, dk. gy. shale, flat.					
48					Bottom of Hole - 48.0' Long piece - 5-3/4"					0% w/bio-jo 10-20% LEL 1' abv. hole w/o bio-jo

GAI-227 9/73

2E-414
Sheet 11 of 11
Drill Hole No. TX-6

INSPECTOR'S COMMENT:

The fault was logged in the 40.3' to 43.5' interval for the following reasons. Nine-tenths of a foot of core loss occurred over ten feet of drilling, the sum of two five foot runs which stradled the feature. A slight dip to normally horizontal laminae is noted at 40.3'. Core pieces, recovered from the faulted zone exhibit gray clay remnants, vertical fracturing, and low angle fracturing. The 40.3' to 43.5' interval of faulted rock was consistent with down dip feature projection from fault recognitions in TX-1, TX-2, TX-3, and TX-5.

Weston Geophysical Corporation was able to demonstrate low sonic velocity and low gamma partial emission at the faulted interval.

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluffs SHEET 1 OF 9

CONTRACTOR: Herron Testing COORDINATES N30,490.93 DRILL HOLE NO. TX-7

DRILLER: Joe Minarchick E 9, 095.96 ELEVATION 618.1

CLASSIFIED BY: R. T. Wardrop DATE: 9/21/78 GWL 0 HRS

48-24 HRS 99.7'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Desc., Ground Water, Construction Problems, etc.
0					9/21/78 Advanced to 63' w/hollow stem augers-unable to seal augers on top of bedrock for casing-abandoned hole					
					9/22/78 Advanced to 63' in second hole - roller bit advanced to 105' - Augers unable to seal hole - losing water					
10					9/23/78 - Bentonite slurry added to hole to seal					
					9/24/78 - Bentonite will not seal hole - hole abandoned					
20					9/25/78 - Casing inserted after augering 63' in third hole - casing seals hole properly					
30										
40										
50										

GAI-237 2/78

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluffs SHEET 2 OF 9

CONTRACTOR: Herron Testing COORDINATES N30, 490.93 DRILL HOLE NO. TX-7

DRILLER: Joe Minarchick E 9, 095.96 ELEVATION 618.1

CLASSIFIED BY: R. T. Wardrop DATE: 9/25/78 GWL 0 HRS

48-24 HRS 99.7'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Desc., Ground Water, Construction Problems, etc.
50										
60					Augered to top of bedrock @ 63.0' - Augers removed, casing driven					
63					start of Roller Bit Advance					
70										Mostly lt. gy. wash occasional influxes of dk. gy. and and brn. wash
80										
90										
100										

GAI-237 2/78

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 9

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-7

CONTRACTOR: Herron Testing COORDINATES N50, 490.93 ELEVATION 618.1'

DRILLER: Joe Minarchick E 9, 095.96 GWL 0 HRS

CLASSIFIED BY: R. T. Wardrop DATE: 9/30/78 48 HRS 99.7'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Soil Or Rock (Range Size / Core Run; Grain Shape / Rec. Core)	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
100–150					Entire Section Spudded w/Roller Bit				Mostly lt. gy. wash w/ occasional influxes of dk. gy. and brn. wash

GAI-337 8/73

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 9

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-7

CONTRACTOR: Herron Testing COORDINATES N50, 490.93 ELEVATION 618.1'

DRILLER: Joe Minarchick E 9, 095.96 GWL 0 HRS

CLASSIFIED BY: R. T. Wardrop DATE: 10/3/78 48 HRS 99.7'

Depth 150–200 ft.

Roller bit employed from 63' to 168' below top of ground

HX Coring starts @ 168'

168-171.7 Med. hard, med gy. shale, tr. lt. gy. sandy shale lam. fissile seam @ 170.6'

175.0-178.35 Dk. gy. shale w/ little sandy shale in 1 1/4" bands @ 175.95, 176.55 and 177.45" "Fe" band @ 176.85' feeding patterns in tr. siltstone @ 177.75 and 178.05'

178.35-195.85 Hard, lt. gy. sandy, shale interlam w/some dk. to med. gy. shale in 1 1/2 - 6" bands, tr. lt. gy. siltstone lam. "Fe" bands occurring @ 180.45; 181.5; and 184.6' clay remnants in partings @ 185.0 and 193.10 Feeding patterns in siltstone. @ 195.1'

R.Q.D.	Run	Core
23%	7.0'	7.0'
91%	10.0'	9.8'
80%	10.0	9.83'
28%	10.0'	9.73'

Remarks:

Pieces 4-9.5" long

Lt. gy. wash w/ occasional influx of dk. gy. or brn. wash

Pieces 3.5-12" long

Pieces 2 1/2-7 1/2" long

GAI-337 8/73

2E-419

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff SHEET 5 OF 9

CONTRACTOR: Herron Testing COORDINATES N 50, 490.93 DRILL HOLE NO. TX-7

DRILLER: Joe Minarchick E 9, 095.96 ELEVATION 618.1'

CLASSIFIED BY: R.T. Wardrop DATE: 10/5/78 GRL 0 HRS ______ 48 HRS 99.7'

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Core Run	Rec. Core	Remarks (Chemical Comp., Geologic Desc., Ground Water, Construction Problems, etc.)
200	195.85'-220.15' Med. hard, dk. gy. shale, little lt. gy. sandy shale, little, lt. gy. siltstone, tr. dk. gy. brn. thin lam.	28%	10.0'	9.73'	Pieces 4-6"
205	Ooze type clasts in lam. from 195.85-198.05. Broken medium soft shale from 199.05-199.75. Y" lt. gy. siltstone band @ 199.9'	77.5%	10.0'	10.0'	Long piece 11"
215	Zones of broken shale from 202.05-203.5 and 204.8-205 thin clay seam in parting @ 205'. Broken sandy shale band @ 206.9'. Vertical fracts in core @ 202.1' (2 1/2", long) and 204.3' (1" long)	66.7%	10.0'	10.0'	Black oily film floating in drill water catch barrel. Long piece - 12.5"
225	3.5" lt. gy siltstone band @ 219.25	60.[illegible]%	10.0'	9.88'	Long piece - 17"
235	220.15'-232.7' Med. hard, dk. gy. to med. gy. shale, w/some lt. gy. sandy shale, little lt. gy. siltstone, tr. dk. gy. brn. lam. (2) 2 1/2", X-bedded sandy bands @ 229.75 and 230.3	76.7%	10.0'	9.96'	Long piece - 10"
245–250	232.7'-242.3' Med. hard, dk. gy. to med. gy. shale w/little lt. gy. sandy shale in 2-4" bands, 4-1/2" lt. gy. siltstone band @ 233.5' tr. lt. gy. siltstone, thinly lam.	87.1%	10.0'	9.96'	

GAI-227 8/72

2E-420

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff SHEET 6 OF 9.

CONTRACTOR: Herron Testing COORDINATES N 50, 490.93 DRILL HOLE NO. TX-7

DRILLER: Joe Minarchick E 9, 095.96 ELEVATION 618.1'

CLASSIFIED BY: R. T. Wardrop DATE: 10/7/78 GRL 0 HRS ______ 24 HRS ______

Depth Ft.	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	R.Q.D.	Core Run	Rec. Core	Remarks (Chemical Comp., Geologic Desc., Ground Water, Construction Problems, etc.)
250	247.3'-254.45' - Med. hard, med. gy. to dk. gy. shale w/tr. lt. gy. sandy shale, tr. lt. gy. siltstone, tr. dk. gy. brn. thin lam	87.1%	10.0'	9.96'	Dk. gn. brn. wash. Long piece - 14"
260	254.45'-255.8' - 16" of lt. gy. sandy, X-bedded bands w/some dk. gy. shale, bottom 2" broken along X-beds. 255.8'-258.5' - Dk. gy. shale, tr. thin dk. gy. brn. lam.	[illegible]9.2%	10.0'	10.0'	Momentary loss of water @ 269.0'. Long piece - 17"
270	258.5'-265' - Med. hard, dk. gy. shale and hard, lt. gy. sandy shale to siltstone a) X-bedded sandy band @ 259.0' b) 3 1/2" siltstone bands @ 261.2', 262.35', and 263.15' c) tr. clay remnants in parting @ 260.5'	80.[illegible]%	10.0'	10.0'	Long piece - 18"
280	265-266.15 - Hard, lt. gy. sandy shale and siltstone in 2" bands interlam of little thin dk. gy. shale lam. 266.15-268.35 - Med. hard, dk. gy. shale, w/little lt. gy. sandy shale lam.	[illegible]2.9%	10.0'	10.0'	Long piece - 11"
290	268.35-275.0 - Hard, lt. gy. sandy shale, w/some lt. gy. siltstone, little dk. gy. shale lam. X-bedded in lower 1' foot. 275.0-278.7 - Med. hard, dk. gy. and med. gy. shale w/tr. lt. gy. sandy shale lam. "Pe" band @ 277.7'	50.[illegible]%	10.0'	9.875'	Long piece - 16"
300	278.7'-295.05' - Med. hard, dk. gy. to med. gy. shale and hard, lt. gy. sandy shale, tr. lt. gy. siltstone lam. a) 10" of sandy shale at top of sect. b) X-bedded from 280.7'-281.35' c) clay remnants in parting @ 291.0'				

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-421

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff

CONTRACTOR: Herron Testing COORDINATES N 50,490.93

DRILLER: Joe Minarchick

CLASSIFIED BY: R. T. Wardrop DATE: 10/10/78

SHEET 7 OF 9

DRILL HOLE NO. TX-7

ELEVATION 618.1

GRL 0 HRS

48-XX HRS 99.7'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Core Run	Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
300–305					295.05-296.2'-Med. hard dk. gy. shale w/some 3" thk. lt. gy. siltstone bands - broken band @ 295.5' 296.2'-297.5'-Hard, lt.gy. sandy shale		71.8%	10.0'	10.0'	Long piece-11"
305–315					297.5'-299.05'-Dk.gy and med. gy. shale interlain w/little lt. gy. sandy shale, little lt. gy. siltstone lam. 4 1/2" X-bedded, sandy, band @ 298.5 299.05-303.45' Hard, lt.-gy. siltstone		68.8%	10.0'	9.88'	
315–325					303.45'-318.3'-Dk. gy to med. gy. shale, and lt. gy. sandy shale, little dk. gy. brn. shale lam. tr. lt. gy. siltstone a) X-bedded @ 309.2 and 318.2 b) 2" long overcored piece @ 315.1 c) 13" band of hard, lt.gy.sandy shale and siltstone from 307.95'-309.05'		77.9%	10.0'	9.75'	Long piece-12.3" Small seam of oil encountered in 315-325' run Barrel left in hole over week-end, 0.1 had seeped up to top of hole, along casing by Monday morning.
325–335					318.3'-320.6'-Med.hard,med.gy. shale, some lt.gy. sandy shale, some lt. gy. siltstone 320.6'-329.3'-Hard,lt.gy. sandy shale w/some dk.gy.shale,tr.dk. gy. brn. lam. a) Badly broken zone from 325.0'-325.35'-clay remnants around pieces, no loss of recovery! b) Clay remnants in partings @ 324.3' & 324.7'		58.3%	10.0'	10.0'	Long piece-12.5" Methane bubbling in drill water.
335–345					329.3'-336.3'-Dk. to med. gy. shale, w/little lt. gy. sandy shale, tr. dk. gy. brn. lam., tr. lt. gy. siltstone lam., overcored piece @ 335.1' 336.3'-338.2'-Hard, Dk. gy. brn. siltstone, w/little med. gy. shale, little sandy shale 1" broken seam @ 337.25'		61.3%	10.0'	9.71'	Long piece 14" Oily film floating in drill water catch barrel, Wash-Dk. gn. brn.
345–350							29.2%	10.0'	10.0'	Long piece-11 1/4"

GAI-389 9/78

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-422

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff

CONTRACTOR: Herron Testing COORDINATES N 50, 490.93 E 9, 095.96

DRILLER: Joe Minarchick

CLASSIFIED BY: R. T. Wardrop DATE: 10/12/78

SHEET 8 OF 9

DRILL HOLE NO. TX-7

ELEVATION 618.1

GRL 0 HRS

48 HRS 99.7'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Core Run	Rec. Core	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
350–355					338.2'-363.6' - Med. hard, med. gy. shale w/some dk. gy. brn. siltstone lam. little lt. gy. sandy shale bands, tr. thin lt. gy. siltstone lam.		29.?%	10.0'	10.0'	Long piece - 5-1/2"
355–365					a) High concentration of siltstone lam. from 350.2'-351.4' b) Thin fissil shale seams @ 362.8' and 364.0' c) Clay remnants in partings @ 352.65', 362.8', and 361.6' d) 1/8" seam of pyrite @ 356.5'		?1.7	10.0'	10.0'	Long piece - 10"
365–375					363.6'-371.3' - Med. hard, dk. gy. shale to med. gy. shale, w/ some dk. gy. brn. siltstone lam. 1/8"-1/2" thk. tr. lt. gy. sand shale, tr. thin siltstone lam. a) X-bedded sandy bands @ 363.95 and 366.3' b) Clay rems in partings @ 368.5' c) Seam of thin fissile shale @ 368.4'		36.9%	10.0'	9.17'	Long piece - 6 1/2" 365-375' run cored smoothly, yet @ fast rate Driller has very difficult time pulling barrel after 365'-375' run
375–385					Suspected FAULT ZONE -371.3'-372.4' 10" of core missing (?) 1" core pieces w/clay remnants - pieces do not interlock w/each other or w/core above and below		57.?%	10.0'	9.96'	Bottom 3' of barrel coated w/1/16 thk. layer of lt. gy. clayey film when retrieved
385–395					372.4'-395.0' - Med. hard, dk. gy. shale w/some dk. gy. brn. siltstone lam., some lt. gy. sandy shale bands, tr. thin lt. gy. siltstone lam. a) 4" thk. sandy band @ 380.6' and 6-1/2" @ 386.4' BOTTOM OF HOLE 395' (elev.223.1')		29.?%	10.0'	9.79'	Long piece - 28" Drill water getting plugged up in bottom of hole Pieces 2 1/2"-4" Long piece-10" No detectable methane

(b) clay rems. in partings @ 376.5', 379.0', 382.55', 382.65', 383.6', 391.35'.

(c) Broken seams of rock frags. @ 375.4', 385.05', 392.45' (4"), associated w/clay rems. @ 392.45' and 393.8'

(d) Thin fissile seams @ 386.1'

(e) Possible "Fe" band @ 394.3'

GAI-389 9/78

Sheet 9 of 9
Drill Hole No. TX-7

INSPECTOR'S COMMENT:

A suspected fault was noted in the 371.3' to 372.4' interval for the following reasons. Eight-tenths of a foot of core was lost in the 365.0'-375.0' run. A thin grey clay seam in a bedding parting occurred at 368.5', topped by fissil shale at 368.4'. Two, vertically adjacent, 1" long core pieces were recovered from the suspect zone, speckled by grey clay (gouge remnants). These pieces, though vertically adjacent would not interlock.

In addition, drilling of the 365'-375' run took less time than the average for other ten foot runs. After run completion, the driller had a very difficult time retrieving the core barrel. Barrel would not pull. When the driller was finally able to recover the barrel, a thin grey clay film was seen covering the bottom three foot of steel cylinder. The tool could have been stuck in a gouge zone.

Down dip feature projection derived from TX-1, TX-2, TX-3, TX-5, TX-6, and TX-4 fall slightly lower than the suspected fault interval in TX-7.

Weston Geophysical Corporation recognized no zones of low sonic velocity nor low gamma partical emission at any depth in TX-7.

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: F.N.P.P. W.O. 04-4349-310 SITE AREA North Shoreline Bluff SHEET 1 OF 4
DRILL HOLE NO. TX-7 (cont.)
CONTRACTOR: PA Drilling Co. COORDINATES N 781,963.08 E 2,369,376.54
ELEVATION 618.1
DRILLER: Jim Adams GWL 0 HRS ______
CLASSIFIED BY: R. Hardrop DATE: 6/22/79 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp. Geologic Desc. Ground Water, Construction Problems, etc.
0					Continuation of HX-Hole TX-7 w/HC coring					
										Driller reams HX-Hole TX-7 to Bottom, 393.5', w/HC size roller bit. No indication of new gas influxes, TX-7 has emitted methane since original boring. No significant soft zones (gouge) were noted in the 372' area where a suspected fault was recorded on the original TX-7 log.
390										
395					Top of new HC size coring - 395.5'					
					M. hard, m. gy., flat lying shale w/some dk. gy. brn. shale in very thin laminations	6/22/79	93%	4.5'	4.2'	Lt. gy. wash; long piece = 12"
400										

GAI-237 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 4

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-7(Cont.)
CONTRACTOR: PA Drilling Co. COORDINATES N 781,963.08 E 2,369,376.54 ELEVATION 618.1'
DRILLER: Jim Adams GWL 0 HRS ____
CLASSIFIED BY: R. Wardrop DATE: 6/25/79 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
400					Continuation of NX Hole-TX-7 w/NC coring M. hard, m. gy., flat lying, shale w/some hard, lt. gy., sandy shale to siltstone laminae, some dk. gy. brown shale, all in thin lamination Bands of lt. gy. ≥ 2" thk. @400.25-401.05', 401.25'(2" thk.), 403.25' (2"), m. gy. siltstone @ 406.6' (2")		99%	10.0'	9.9'	Lt. gy. wash No gas Long piece= 14"
410					Bands of dk. gy. brn. shale @ 403.0'(1-1/2"), & 408.55'(2") Load cast horizon at 407.1' Same, w/tr. lt. gy. laminae, Suspected fault Top 412.8' .5' of core missing from 1.1' of core where highly fractured rock occurs, approx. 50% of fractures appear rounded from coring, 50% angular; all pieces spotted w/remenant gy. clay. Bot. 413.9'		90%	10.0'	9.5'	Rig running roughly, rattling rods at top of run No change in drill watercolor-water pressure rises to avg. of 350 psi from avg. of 250 psi @ top of run long piece=12"
					Bands lt. gy. lam. at 415.4'(1/2"), 417.4'(1/2"), 419.55'(1/2") Bands of dk. gy. brn. shale at 410.8'-411.05; 411.5'(2"), 413.9'(3/4") & 419.4'(1-1/2") load cast horizons at 411.95' & 418.6' partings which do not interlock at 417.5' & at 416.3' (w/clay remenants)		97%	10.0'	10.0'	No change in dip of horizontal beds @ suspected fault zone. L.P. = 8"
420					Same, w/some lt. gy. laminae Lt. gy. bands at 422.0'(3-1/2"), 422.35'(2"), 422.6'-423.0'(fi. gr. ss., x-lam.) 423.9(2.5"), 426.65-426.85, 427.15-427.8(x-lam.) Dk. gy. brn. bands at 425.7'(2")		100%	10.0'	10.0'	No gas L.P. = 20"
					seam of broken gs at 428.8'(1") 4" fract. at 85° dip, 428.0' Same v. thinly laminated Same, little lt. gy. lam., little dk. gy. brn. lam. flat lying		98%	10.0'	10.0'	No gas L.P. = 15"

GAI-227 2/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 4

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-7(cont)
CONTRACTOR: PA Drilling Co. COORDINATES N 781,963.08 E 2,369,376.54 ELEVATION ____
DRILLER: Jim Adams GWL 0 HRS ____
CLASSIFIED BY: R. Wardrop DATE: 6/25/79 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
					M. hard, greenish, gy. shale, w/little dk. gy. brn. shale lam., tr. lt. gy., sandy shale to siltstone lam. Lt. gy. band at 457.15-457.7' (x-lam.) Flat and thinly bedded Tr. pyrite in horizontal seams	6/25/79	100	10.0'	10.0'	Lt. greenish gy wash No gas Long piece=10"
					Same, w/some dk. gy. brn. shale lam., little lt. gy. lam., tr. pyrite Lt. gy. bands at 465.3'(3") & 468.2'(1-3/4") siltstone Dk. gy. brn. bands at 462.9'-463.3' & 464.05'-464.4'		100%	10.0'	10.0'	Minimal gas. 0 psi shut in pressure on gauge L.P. = 9"
470					Same, little lt. gy. lam., little dk. gy. brn. lam. Lt. gy. band at 478.4-479.25 (siltstone)		100%	10.0'	10.0'	No gas L.P. = 11"
480					Same, Lt. gy. bands at 484.8'-485.1', & 488.5'(2") both siltstone Load cast horizon at 486.25' Pyrite seam at 481.65' (1/8")		100%	10.0	10.0	Minimal gas 0 psi shut-in pressure L.P. = 9"
					Same Lt. gy. band at 496.85' (x-lam.)		100%	7.6'	7.6'	Minimal gas, 0 psi shut-in pressure on gauge LP=10" Gas bubbles violently outside of outer rods when lifted 8' off bottom
					Bottom of Hole 497.6 6/26/79					

GAI-227 2/72

Sheet 4 of 4
Drill Hole No. TX-7
Continuation of
NX-Hole w/HC coring

INSPECTOR'S COMMENT:

The zone of highly fractured rock from 412.8'-413.9' may represent a splay off the main gouge zone, if not the primary fault itself. Exposed fault zones in the Cooling Water Tunnels display a high degree of variance for clay/shale fragment ratios in gouge. Minimal clay means minimal binding of shale fragments which could have prohibited the HC-double core barrel from actually coring fault gouge. Six-tenths of a foot of highly fractured rock with gray clay remnants was recovered from the one and one-tenth foot interval (412.8-413.9) in question. Fifty percent of the fragments displayed rounding from coring as compared to fifty percent angular fragments, typical of brecciated fault zones. Angularity, however, may be a natural characteristic of fragments generated by the drilling of fractured shale. In addition, drill water pressure increased from an average of 250 psi to 350 psi while drilling the upper portion of the 410-420 foot run. Pressures returned to an average of 250 psi at approximately 415 feet.

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET
04-4594-310

PROJECT: P.N.P.P. W.O. ______ SITE AREA Beach, West of Site
CONTRACTOR: Warren Testing COORDINATES N 777,278.17 E 2365,760.881
DRILLER: Joe Minarchick
CLASSIFIED BY: R. T. Hardron DATE: 11/20/78

SHEET 1 OF 6
DRILL HOLE NO. TX-8
ELEVATION 576.6'
GR. @ HRS ______
TD Hours 10.0'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0										
1					Driller augered through 19.0' of overburden, beach sand, glacial till, and weathered shale					
2										
3										
4										
5										
6										
7										
8										
9										
10				↓						

GAI - 227 8/73

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-429

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Beach, West of Site
CONTRACTOR: Herron Testing
DRILLER: Joe Hinarchick
CLASSIFIED BY: R. T. Hardrop
COORDINATES N779 218.19 E 2365 760.881
DATE: 11/20/78
SHEET 2 OF 9
DRILL HOLE NO. TX-8
ELEVATION 576.6'
GWL 0 HRS
24 HRS 10.0'

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
10										
11										
12										
13										
14					Top of weathered shale 14.5'					Driller notes change in resistance on augers @ 14.5', this continues to 19.0' when augers will no longer advance
15										
16										
17										
18										
19					Augers advanced to 19.0' Casing to 19.5' Top of weathered rock 19.5'					NX coring starts
20										

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-430

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Beach, West of Site
CONTRACTOR: Herron Testing
DRILLER: Joe Hinarchick
CLASSIFIED BY: R. T. Hardrop
COORDINATES N 779 218.19 E 2365 760.881
DATE: 11/20/78
SHEET 3 OF 9
DRILL HOLE NO. TX-8
ELEVATION 576.6'
GWL 0 HRS
24 HRS 10.0'

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
20										
21					19.5 - 29.5' Med. soft to med. hard, med. gy. shale w/little sandy shale in v. thin lam. (1/16" thick) and tr. rn. brn. "Fe" bands @ 25.6' (3/4" thk.), 25.15' (3/4), 23.45' (1"), 21.3' (1/4")					
22										Lt. gy. drill wash
23					clay remnants in partings @ 19.5' (1" of clay @ top of run, seam), 21.85 (1/8" thk, seam), 22.0', 23.1', 23.2' 23.45, 24.85' & 25.65'					
24					Thin seams of fissile shale @ 19.75' & 21.65'		49%	10.0'	9.5'	Dk. gy. brn. to black oily film collecting on surface of drill water catch barrel
25										
26										
27										
28										
29					fract. dipping @ 10° @ 29.5' 29.5'					Core Pieces - 1 1/2-8" long
30										

GAI-227 8/72

2E-431

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Beach, West of Site SHEET 4 OF 9

CONTRACTOR: Herron Testing COORDINATES N 779 218.19 DRILL HOLE NO. XX-8

DRILLER: Joe Minarchick E 2365 760.881 ELEVATION 575.6'

CLASSIFIED BY: R. T. Wardrop DATE: 11/21/78 GWL 0 HRS ____ 24 HRS 10.0'

Depth Ft.	Description	U.S.C.S.	R.Q.D.	Core Run	Rec. Core	Remarks
30–40	29.5' - 37.2' Same, med. gy. to dk. gy. med. hard, tr. "fe" bands @ 30.0', 30.8', 31.6' (1/2"), 32.65' (3/4"), 35.25' (3/4"), 36.4' (1/2"). Clay rems. in partings @ 30.5', 37.25', & 37.6'		91%	10.0'	10.0'	Lt. gy. drill wash w/oily film
	37.2' - 37.6' - some sandy lam, w/tr. small sandy depos. features					
	37.6' - 39.5' - Same as above 37.2'					
	39.5'					long piece-12"

2E-432

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Beach, West of Site SHEET 5 OF 9

CONTRACTOR: Herron Testing COORDINATES N 779 218.19 DRILL HOLE NO. XX-8

DRILLER: Joe Minarchick ELEVATION 576.6'

CLASSIFIED BY: R. T. Wardrop DATE: 11/21/78 GWL 0 HRS ____ 24 HRS 10.0'

Depth Ft.	Description	U.S.C.S.	R.Q.D.	Core Run	Rec. Core	Remarks
40–50	39.5'-44.9' Med. hard, med. gy. shale w/little lt. gy., sandy shale lam (v.thin) tr. "fe" bands @ 40.75' (3/4"), 41.55' (1/2"). Clay rems in partings @ 39.55' & 42.15'.					Lt. gy. wash; Oily film on drill water
	44.9'-45.5' Hard, med. gy. siltstone & sandy shale, thinly lam.		85%	10.0'	9.95'	
	45.5'-49.5' Med. hard, med. gy. shale w/little lt. gy. sandy shale lam, tr. "fe" bands @ 46.2' (1"), 46.7' (3/4"), 48.2' (1/4"), & 48.65' (1"). clay rems @ 48.8' & 49.3' in partings					
	1" band of slightly x-bedded sandy shale @ 48.6'					
	49.5					Long piece 13"

2E-433

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Beach, West of Site

CONTRACTOR: Herron Testing

DRILLER: Joe Minarchick

CLASSIFIED BY: E. T. Wardrop DATE: 11/21/78

COORDINATES N 779 218.19 E 2365 760.881

SHEET 6 OF 8

DRILL HOLE NO. TX-8

ELEVATION 576.6'

GW. 0 HRS

24 HRS 10.0'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50					49.5'-55.1' Same, "fe" bands @ 52.3'(1") & 53.55(1"). clay rems in partings @ 50.75', 52.95'					
54							86%	10.0'	9.95'	
55					55.1'-56.1' Same, w/some sandy shale lam.					
56					56.1'-57.65' Same, w/little sandy shale lam., tr. "fe" bands @ 56.4'(1/2"), & 56.7'(1") clay rems. in parting @ 56.45'					
57					57.65'-59.1' Same, w/some sandy shale lam. in 1/2" bands @57.7', 58.6', & 59.1'					
60										

2E-434

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Beach, West of Site

CONTRACTOR: Herron Testing

DRILLER: Joe Minarchick

CLASSIFIED BY: E. T. Wardrop DATE: 11/22/78

COORDINATES N 779 218.19 E 2365 760.881

SHEET 7 OF 8

DRILL HOLE NO. TX-8

ELEVATION 576.6'

GW. 0 HRS

24 HRS 10.0'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
60					59.1'-69.5' Mod. hard, dk. gy. shale and hard lt. gy. sandy lam. (v. thin) tr. tn. brn. "fe" band @ 68.8'(1" thk.) clay remnants in partings @ 60.75' & 67.35'					Lt. gy. wash, Oily film decreasing
64					Band of dk. gy. shale, nearly absent of sand influx from 65.6'- 64.95'		90%	10.0'	9.35'	
65					Suspected fault - 65.85' 65' of core missing in .85' of rem. 3 (3/4" thk.) pieces of core and 2 frags. w/minimal clay remnants					No notable change in drilling
68										Gas released through hole hen core arrel pulled- ater rose up nd out of oring
69.5										Long piece 12"
70										

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Beach, West of site
CONTRACTOR: Warren Testing COORDINATES N 779 218.19
DRILLER: Joe Minarchick E 2365 760.881
CLASSIFIED BY: R. T. Wardrop DATE: 11/22/78

SHEET 8 OF 9
DRILL HOLE NO. TX-8
ELEVATION 576.6'
GWL 0 HRS
24 HRS 10.0'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
70					69.5'-72.7' Med. hard. to hard, dk. gy. shale and lt. gy. sandy shale (thinly lam.) 1/2" bands of hard lt. gy. sandy shale @ 72.05' & 72.35'; clay rems in partings @ 71.75'.					
71										
72					72.7'-73.5' Same, w/little lt. gy. sandy shale-band of dk. gy. brn. shale from 73.5'-73/7'					
73										Lt. gy. drill wash
74					73.7'-75.5' Med. hard to hard, dk. gy. shale and lt. gy. sandy shale lam. in 1/2" thk. bands @ 73.75'. Clay rems in parting @ 75.5'					
75										
76					75.5'-76.8' Same, w/little lt. gy. siltstone in 1/4"-3/4" bands					
77					76.8'-79.5' Same, no siltstone, bands of hard lt. gy. sandy shale @ 77.0'(1/2" thk.), & 77.2'(1 1/4"). Tr. tn. brn. "Fe" bands @ 78.4'(1") & 78.95'(1").					
78					Clay rems. in partings @ 78.5' & 79.1'					
79										
80					Bottom of Hole 79.5'					

INSPECTOR'S COMMENT:

A fault was suspected in the 65.85' to 66.75' interval at TX-8 for the following reasons. Sixty-five hundreths of a foot were lost over eighty-five hundreths foot of advance in the 59.5'-69.5' run. Traces of clay remnants were found adhering to fragmented core pieces in the above mentioned interval. Gas pushed water up and out of TX-8 when the barrel was retrieved at the end of the 59.5'-69.5' run.

Weston Geophysical Corporation did not confirm fault occurrence by either sonic velocity or gamma logging.

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-437

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Shoreline West of Site
SHEET 1 OF 9
DRILL HOLE NO. TX-9
CONTRACTOR: Herron Testing COORDINATES N779,333.051 E2,365,924.335
ELEVATION 576.5'
DRILLER: Joe Minarchick
GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 12/4/78
24 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Grain Shape; Core Run / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
1					Driller augers 20 feet and sets casing.				
3					Beach sand and gray lacustrine.				
7					Top of till - 7.5' Gray, clayey glacial till.				Driller notes change in resistance to augering.

GAI-237 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-438

PROJECT: P.N.P.P W.O. 04-4549-310 SITE AREA Shoreline West of Site
SHEET 2 OF 9
DRILL HOLE NO. TX-9
CONTRACTOR: Herron Testing COORDINATES N779, 333.051 E2, 365,924.335
ELEVATION 576.5'
DRILLER: Joe Minarchick
GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 12/4/78
48 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Grain Shape; Core Run / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
11					Gray, clayey glacial till.				
12					Top of weathered rock (12.5')(?)				Driller notes change in resistance to augers.
13					Gray weathered shale.				
19									Driller sets casing @ 20.0'.

GAI-237 4/72

2E-439

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Shoreline West of Site

CONTRACTOR: Herron Testing COORDINATES N779,333.051 E2,363,924.335

DRILLER: Joe Minarchick

CLASSIFIED BY: R. Wardrop DATE: 12/5/78

SHEET 3 OF 9
DRILL HOLE NO. TX-9
ELEVATION 576.5'
GW. 0 HRS
48 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
20					20.0-22.2 Soft to med. soft, gray weathered shale w/little gray clay in 2" seam @ top of run, tr. tn. brn., cherty "Fe" band @ 20.7'. (Weathered zone)					
21										
22					22.2-41.25 Bottom of Weathered Zone Med. hard, med. gy. shale w/little lt. gy. sandy shale in thin lam. tr. tn. brn. "cherty, "Fe" bands @ 23.1'(1" thk.), 24.7'(1"), 27.45'(1"), 28.45'(1-1/2"), 29.25 (1/2").					Lt. gy. wash w/oily film floating in drill water catch barrel.
23										
24					Clay remenants in parting @ 28.85 and 29.55'.		54%	10.0'	9.8'	
25					Sandy feeding pattern @ 29.55'.					
26										
27										
28										
29										
30										Long piece 8.5"

GAI-337 6/72

2E-440

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Shoreline West of Site

CONTRACTOR: Herron Testing COORDINATES N779,333.051 E2,363,924.335

DRILLER: Joe Minarchick

CLASSIFIED BY: R. Wardrop DATE: 12/5/78

SHEET 4 OF 9
DRILL HOLE NO. TX-9
ELEVATION 576.5'
GW. 0 HRS
48 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
30					Med. hard, med. gy. to dk. gy. shale w/little lt. gy. sandy shale in thin laminae, tr. tn. brn. cherty "Fe" bands @ 32.2' (1/4" thk.), 33.3'(1/4"), 33.7 (1/2"), 35.15(1"), 35.5'(1/4"), 38.05'(1/4"), 39.35'(1"), 39.9 (1-1/2").					
31										
32					Clay remenants in partings @ 30.5', 30.8', 33.05'.					
33					1/4" thick clay seam under "Fe" band @ 39.4'.					
34					2 fracts intersecting in core @ 32.8', one dipping 10°, one approximately 75°.		52%	10.0	9.95	Lt. gy. wash w/oily film.
35										
36										
37										
38										
39										Core pieces 2"-6" long. Long piece - 8"
40										

GAI-337 6/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-441

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Shoreline West of Site
SHEET 5 OF 9
DRILL HOLE NO. TX-9
CONTRACTOR: Herron Testing COORDINATES N779,333.051 E2,365,924.335
ELEVATION 576.5'
DRILLER: Joe Minarchick
GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 12/5/78
48 HRS 8.1'

Columns: Depth Ft. (40–50) | Sample No. | SPT Blows/6 in. (6, 12, 18) | Ft. Rec. | Profile | Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories) | U.S.C.S. | R.Q.D. | Soil Or Rock (Range Size / Grain Shape; Core Run / Rec. Core) | Remarks (Chemical Conc., Geologic Data, Ground Water, Construction Problems, etc.)

41.25-42.05
Med. hard, med. gy. shale w/some lt. gy. sandy shale laminae
2" dk. gy. brn. siltstone band @ 41.95'.

42.05-42.8
Same, w/little lt. gy. sandy shale lam.

42.8-43.6
Same, and thin lt. gy. sandy shale lam., hard.

43.6-44.2
Same, med. gy. to dk. gy. shale w/little lt. gy. sandy lam.
Tn. brn. "Fe" band @ 44.0' (1" thk.)

44.2-46.5 (R.Q.D. 100%; Core Run 10.0; Rec. Core 9.9')

46.5-46.9
Med. hard, dk. gy. shale, tr. sandy thin laminae.

46.9-48.5
Hard, med. gy. to dk. gy. shale and sandy shale.
4" sandy band from 46.9-47.25 x-bedded.
1" band @ 48.25' x-bedded.
Clay remenants in partings @ 47.25' and 48.3'.

48.5-54.75
Same, w/little sandy shale lam.
1-1/4" thk. "Fe" band @ 49.95'.

Remarks:
- Lt. gy. wash w/oily film in catch barrel (at ~43')
- Long piece 13.5". (at ~49')

GAI-337 8/78

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-442

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Shoreline West of Site
SHEET 6 OF 9
DRILL HOLE NO. TX-9
CONTRACTOR: Herron Testing COORDINATES N779,333.051 E2,365,924.335
ELEVATION 576.5'
DRILLER: Joe Minarchick
GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 12/5/78
48 HRS 8.1'

Columns: Depth Ft. (50–60) | Sample No. | SPT Blows/6 in. (6, 12, 18) | Ft. Rec. | Profile | Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories) | U.S.C.S. | R.Q.D. | Soil Or Rock (Range Size / Grain Shape; Core Run / Rec. Core) | Remarks (Chemical Conc., Geologic Data, Ground Water, Construction Problems, etc.)

"Fe" band @ 53.6' (1/2" thk.)
clay rem in partings @ 53.5'.

54.75-56.7
Med. hard, dk. gy. shale w/some lt. gy., thin, sandy shale lam., tr. lt. gy. siltstone lam.
(R.Q.D. 77; Core Run 10.0; Rec. Core 10.0)

Slight dip to bedding starting @ 58.7'.

56.7-62.15
Same, and lt. gy. sandy lam.
feeding pattern @ 61.75'.

1/2" band of lt. gy. siltstone @ 61.45'.

Remarks:
- Lt. gy. wash w/oily film in drill water catch barrel. (at ~53')
- Pieces 3-7" long. (at ~59')

GAI-337 8/78

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-443

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Shoreline West of Site

SHEET 7 OF 9

CONTRACTOR: Herron Testing

COORDINATES N779,333.051 E2,365,924.335

DRILL HOLE NO. TX-9

ELEVATION 576.5'

DRILLER: Joe Minarchick

GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 12/5/78

48 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
60										
61										
62					62.15-63.8 Same, w/some thin lt. gy. sandy shale lam. Feeding pattern @ 62.65'. Sandy bands @ 62.9' (1-1/4") x-bedded, and 63.2' (3/4") x-bedded. Clay rems in partings @ 62.3', 62.85' and 64.2' seams of clayey fissile shale @ 62.4' (1/8"). 12° fract. @ 62.35'.					
63										
64										
65							84%	10.0	10.0	
65.8					65.8-72.2 Same, and lt. gy. sandy shale laminae, hard. "Fe" band @ 65.9'(1/2") Bands of sandy shale @ 68.75(1/2") 69.1'(1/4"), 69.45'(1"). Clay rems in partings @ 66.8', 67.3', 67.5', and 69.2'.					
66										
67										
68										
69										Core pieces 3-7".
70										

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-444

PROJECT: P.N.P.P W.O. 04-4549-310 SITE AREA Shoreline West of Site

SHEET 8 OF 9

CONTRACTOR: Herron Testing

COORDINATES N779,333.051 E2,365,924.335

DRILL HOLE NO. TX-9

ELEVATION 576.5'

DRILLER: Joe Minarchick

GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 12/5/78

48 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
70					"Fe" band @ 70.4' (1-1/2" thk.) Clay rems in partins @ 70.2', 70.4', 70.5' and 71.35'.					
71										
72					72.2-82.3 Same, w/little sandy shale lam. tr. tn. brn. cherty "Fe" bands @ 73.2'(1") 75.3'(1"), 75.85' (1/2") and 77.25 (3/4"). Clay rems in partings @ 73.2', 73.7', 74.15', 74.6', 75.2', 75.6', 76.2', 76.6', 76.8', 77.9' 79.1', and 79.7'.					
73										
74							65%	10.0'	10.0'	
75										
76										
77										
78										
79										Core pieces 3-8" Long piece 8"
80										

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Shoreline West of Site

SHEET 9 OF 9

DRILL HOLE NO. TX-9

CONTRACTOR: Herron Testing COORDINATES N779,333.051 E2,365,924.335

ELEVATION 576.5'

DRILLER: Joe Minarchick

GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 12/5/78

48 HRS 8.1'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp. Geologic Data, Ground Water, Construction Problems, etc.
80					Hard lt. gy. brn. siltstone band @ 81.0 (1-1/2").					
81					"Fe" bands @ 80.3'(1-1/4") and 80.45' (1/4") sandy shale band @ 81.3 (1/2").					
82					82.3-83.65 Same, w/some lt. gy. sandy shale lam.					
83					"Fe" within (1-1/2") sandy band @ 82.4" and 83.25'. Sandy bands @ 82.55'(1/4" thk.) 82.7'(1-3/4"), 82.9'(1/2"), 83.45 (3/4") slightly x-bedded feeding patterns @ 83.65'.					
84					Clay rem in parting @ 83.5'.		5K	10.0'	10.0'	
85					83.65-90.0 Same, w/little sandy shale thin lam. "Fe" bands @ 84.65(1/2"), and 85.1'(1/2") sandy band @ 86.45-					
86					86.7'(3" thk.), w/x-bedding to feeding patterns, broken), 86.95' (1/2"), 87.4'(1) x-bedded, and 88.05(1-1/2") x-bedded.					
87					Clay rems in partings @ 83.75', 84.1', 854.4', 86.6', 87.35' 89.25', and 89.75'.					
88					Clay seams @ 87.45' (1/4") and 88.55' (1/4").					
89										Core pieces 3"-6.5".
90					Bottom of Hole - 90'					

GAI-327 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Boat Slip, Perry Park

SHEET 1 OF 9

DRILL HOLE NO. TX-10

CONTRACTOR: Herron Testing COORDINATES N 778, 675.86 E 2, 365, 078.76

ELEVATION 593.6

DRILLER: John Clark

GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 11/27/78

48 HRS 6.15'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp. Geologic Data, Ground Water, Construction Problems, etc.
0										
1					Driller augered to 31.0' (lacustrine and glacial till)					New driller, other TX series holes drilled by Joe Minarchick
2										
3										
4										
5										
6										
7										
8										
9										
10										

GAI-327 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-447

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Boat Slip, Perry Park
CONTRACTOR: Herron Testing COORDINATES N 778, 675.86 / E 2, 365, 078.76
DRILLER: John Clark
CLASSIFIED BY: R. Wardrop DATE: 11/27/78
SHEET 2 OF 9
DRILL HOLE NO. TX-10
ELEVATION 593.4
GWL 0 HRS
48 HRS 6.15'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Desc., Ground Water, Construction Problems, etc.
10–20				↓	Continued augering in glacial till					

GAI-227 8/78

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-448

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Boat Slip, Perry Park
CONTRACTOR: Herron Testing COORDINATES N 778, 675.86 / E 2, 365,078.76
DRILLER: John Clark
CLASSIFIED BY: R. Wardrop DATE: 11/27/78
SHEET 3 OF 9
DRILL HOLE NO. TX-10
ELEVATION 593.4'
GWL 0 HRS
48 HRS 6.15'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Desc., Ground Water, Construction Problems, etc.
20–30				↓	Continued augering in glacial till					
28										Driller did not recognize top of weathered rock due to change in resistance on augers

GAI-227 8/78

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 9

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Boat Slip, Perry Park DRILL HOLE NO. TX-10

CONTRACTOR: Herron Testing COORDINATES N 778, 675.86 ELEVATION 593.4'

E 2, 365,078.76

DRILLER: John Clark GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 11/27/78 48 HRS 6.15'

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
30–31										Driller augered to 31.0' casing to 31.0'-Gy. shale frags in bottom augers
31–33.9					31.0-32.0-Hard, lt. gy., sandy shale and dk. gy. brn. shale 32.0-33.9-Med. Hard, dk. gy. weath. shale to gy. clay (med. soft) rock sections of core fractured, vertically — — — — — — Bottom of weathered rock @ 33.9'		47%	3.2'	3.15'	Oily film floating in drill water catch barrel
33.9–40					33.9-51.2 Med. hard, med. to dk. gy. shale, hard tn. brn. "Fe" bands @ 35.15 (0-1/2" thk.) 36.6' (1/2"), 38.35' (1"), 38.95' (1"), 40.5' (3/4"), 41.8' (1/4"), 45.45' (1"), Gy. clay remenants in partings @ 37.0', 37.45; 38.9; 39.45; 41.3; 42.6; 47.65; 48.0' Lt gy. sandy ooze or feeding patterns @ 47.1' - bands of sandy shale @ 47.5' (1/2" thk.) 48.9' (3/4"), and 50.7' (1/4").		33%	10.0'	9.95'	Pieces - 1/2"-6-1/2" Lt. gy. wash

GAI-337 6/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 5 OF 9

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Boat Slip, Perry Park DRILL HOLE NO. TX-10

CONTRACTOR: Herron Testing COORDINATES N 778, 675.86 ELEVATION 593.4'

DRILLER: John Clark E 2, 365, 078.76 GWL 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 11/27/78 48 HRS 6.15'

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
40–44					Same to 51.2' "Fe" bands @ 40.5' (3/4"), 41.8' (1/4"), and 45.45' (1") Clay rems. in partings @ 41.3', 42.6', 47.65', and 48.0' Lt. gy. sandy feeding pattern or ooze @ 47.1' Lt. gy. sandy shale bands @ 47.5' (1/2") and 48.9' (1/2") Flat bedded		33%	10.0'	9.95'	
44–50							60%	10.0'	9.95'	Pieces 2"-6" Lt. gy. wash

GAI-337 6/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-451

PROJECT: P.N.P.P. W.O. 04-4569-310 SITE AREA Boat Slip, Perry Park

SHEET 6 OF 9

CONTRACTOR: Herron Testing COORDINATES N 778, 675.86 / E 2, 365,078.76

DRILL HOLE NO. TX-10

DRILLER: John Clark

ELEVATION 593.4'

CLASSIFIED BY: R. Wardrop DATE: 11/29/78

GWL 0 HRS

48 HRS 6.15'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Core Run	Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50										
51					51.2-51.9 Med. hard, dk. gy. shale w/some lt. gy., thin, sandy shale lam. Sandy feeding pattern or core @ 51.9' (1/2" thick) clay rems. in parting @ 51.8'		60%	10.0'	9.95'	Lt. gy. wash
52					51.9-52.9' Same, w/littile sandy shale lam. "Fe" band @ 52.55 (1") clay rem in parting @ 52.1, and 52.65'					
53					52.9'-53.75' Same w/some sandy shale lam. "Fe" band @ 53.4' (1") clay rem in parting @ 53.15'					
54					53.75'-54.2' Same w/little sandy shale lam. tn. brn. "Fe" band @ 54.15 (1/2" thk.)					Pieces 3"-7"
55					54.2'-54.8' Med. hard to hard, dk. gy. shale and lt. gy. sandy shale lam. *Thin fissile seam @ 54.5'					
56					54.8'-56.2' Same w/little sandy shale lam. med. hard "Fe" band @ 55.65' (1/2")		66%	10.0'	9.3'	Driller makes several machine adjustments during run - this is untypical of previous TX runs
57					56.2-56.7' Same w/some sandy shale lam. "Fe" band @ 56.5' (3/4")					
58					56.7'-59.0' Same w/little sandy shale lam. "Fe" bands @ 57.1' (1") and 57.85' (1/2") *Fissile shale seams @ 58.2'					
59					*Fissile seams end in partings which do not interlock with bottom shale - fissile seams may have been larger and ground up in drilling, accounting for recovery loss					
60										

GAI-327 2-72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-452

PROJECT: P.N.P.P. W.O. 04-4569-310 SITE AREA Boat Slip, Perry Park

SHEET 7 OF 9

CONTRACTOR: Herron Testing COORDINATES N 778, 675.86 / E 2, 365,078.76

DRILL HOLE NO. TX-10

DRILLER: John Clark

ELEVATION 593.4

CLASSIFIED BY: R. Wardrop DATE: 11/29/78

GWL 0 HRS

24 HRS 6.15'

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Core Run	Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
60					59.0-59.4' Med. hard med. gy. to dk. gy. shale, w/some thin lt. gy. sandy lam.					
61					59.4'-62.3' Same, w/little sandy shale lam. 1/2" "Fe" band @ 59.75					Oily film on wash, stops
62					62.3'-63-05' Same, w/some sandy shale lam.					1/2" overcored piece @ 60.5'
63					63.05-63-5 Same w/little sandy shale lam. 1/2" "Fe" band @ 63.45' clay rems on partings @ 63.5'		66%	10.0'	9.3'	
64				?	Possible fault from 63.5'-64.9' a) 1/2" core piece w/clay rems. all around, overturned b) 5-1/4" core w/pinching "Fe" band, shale lam. dipping w/pinch bottom grooved, w/clay rems. c) 2-1/4" core beveled at top w/clay rems.					Core Pieces 2"-6" long No gas when barrel pulled @ end of run
66					All core pieces seem to interlock in 64.2'-74.2' run, except where clay rems are found on smooth horizontal partings. If these represent only very thin clay seams, then bulk of recovery loss would be at top of run - supporting fault occurence.					
67					64.9'-68.3' Med. hard, med. gy. to dk. gy. shale w/little, thin sandy lam. "Fe" band @ 65.4' (1/4" thk)		66%	10.0'	9.3'	
68					68.3'-68.9' Same, w/some sandy shale lam.					
69					68.9'-71.9' Same, w/little sandy shale lam. "Fe" bands @ 69.4' (1" thk.) 71.3' (1") and 71.85' (1/4") clay rems in partings @ 71.15 and 71.45 sandy bands @ 71.15 (1/4") and 71.45 (1") Flat bedded					
70										

GAI-327 2-72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-433

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA Boat Slip, Perry Park
SHEET 8 OF 9
DRILL HOLE NO. TX-10
CONTRACTOR: Herron Testing
COORDINATES N 778, 675.86
E 2, 365,078.76
ELEVATION 593.4'
DRILLER: John Clark
GWL 0 HRS
CLASSIFIED BY: R. Wardrop DATE: 11/29/78
48 HRS 6.15'

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type • Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Cons., Geologic Desc., Ground Water, Construction Problems, etc.
70							71.9-72.35' Hard, dk. gy. shale, lt. gy. siltstone, and sandy shale lam.					
71							Sandy band @ 71.95' (1/2" thick)					
							72.35'-73.85' Med. hard, dk. gy. shale, w/ some lt. gy. sandy shale lam		56%	10.0'	9.3'	Lt. gy. wash
72							Sandy band (1-1/4" thk) @ 73.4' feeding patterns of sand through shale from 73.65'-73.75'					
73							73.85'-74.2' Same, w/little sandy shale lam. (All pieces interlock, hole measured at 74.2', recovery loss must be at top of run.)					No gas when barrel pulled from hole
74							Bottom of Hole - 74.2 feet					Pieces 3-7 3/4" long

GAI-237 8/72

Sheet 9 of 9
Drill Hole No. TX-10

2E-434

INSPECTOR'S COMMENT:

A fault was suspected in the 63.5' to 64.9' interval of TX-10 for the following reasons. Clay remnants were found in a bedding parting at 63.5'. Overturned core pieces with clay remnants occurred at the top of the suspect interval. One and four-tenths feet of core was lost in the two ten foot runs stradling the interval (See note on sheet 7 of 9).

Weston Geophysical did not recognize a zone of low velocity or low gamma partical emission in the sonic and gamma logs of TX-10.

2E-455

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 16

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot
DRILL HOLE NO. TX-11
CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12
ELEVATION 624.04'
DRILLER: Jim Adams
GWL 0 HRS
CLASSIFIED BY: LDS DATE: Logged 5/8/79
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					Hole Started 4/19/79					
10–50					OVERBURDEN					Augered to bedrock

GAI-337 9/72

2E-456

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 16

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot
DRILL HOLE NO. TX-11
CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E 2,369,806.12
ELEVATION 624.04'
DRILLER: Jim Adams
GWL 0 HRS
CLASSIFIED BY: LDS DATE: Logged 5/8/79
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50										
					Boulder Horizon in Lower Till					Grinding on augers at 550' boulder zone in till
60					Top of weathered bedrock	4/19/79				Driller notes increased resistance on augers at 630', top of weathered rock.
67										
68–70					Top of unweathered rock, 68.0' Shale scratch but Slt. is hard Med. gray fissile shale & minor lt. gr. slt. Fe stones (1/2"-3/4") at 68.75, 70.2, 70.67, 71.9, 73.25, 75.0, 76.4, 76.5					Originally roller bit, advanced was concieved to a depth of 180', driller opted to core from 68-180'. This interval logged two weeks after drilling.
					Core parts parallel to bedding (spacing 1/4 to several ins.) slight to moderate weathering 2 in. vertical fracture at 70' & 71.9'; irregular fracture at 73.2-73.3' (could be due to coring.) Horizontal bedding		0	10'	10'	Longest = 3½"
80					As above but shales are slightly darker from 80-84'. Slt are rippled at 79.5 and interlaminated with shale. Partings parallel to bedding as before.		20%	10'	9.9'	Longest 6"
90					Fe stone bands less distinct, Occasionally as thin as ½" but overall more freq. occur at 77.4, 77.5, 78.3, 82.2, 86.9, 86.6. Some shale bed surfaces show scour at top where overlain by slt.		32%	10'	9.75'	Longest 12"
100					(continued)					

GAI-337 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-457

SHEET 2 OF 16

PROJECT: ______ W.O. ______ SITE AREA ______
CONTRACTOR: ______ COORDINATES ______
DRILLER: ______
CLASSIFIED BY: ______ DATE: ______
DRILL HOLE NO. ______
ELEVATION ______
GWL 0 HRS ______
24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
90					As before but med. dark shale dominate; partings parallel to bedding less frequent. Fe stone (1") at 89.75 in contact with underlying x-bedded gr. slt. Interlaminated sh. & slt. bed sets about 1" thick occur occasionally Fe. stone at 94.8, 95.5, & 96.		37%	10'	9.75'	Longest = 12"
100					Bottom of Sheet 2					

GAI-237 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-458

SHEET 3 OF 16

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot
CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12
DRILLER: Jim Adams
CLASSIFIED BY: R. Wardrop Logged DATE: 5/8/79
DRILL HOLE NO. YX-11
ELEVATION 624.04
GWL 0 HRS ______
24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100					As before with slight increase in amount of thin lt. gr. slt. laminae Dk. gr. concretionary nodule at 98' with abundant finely disseminated pyrite Fe stone beds (1/2-1") at 102.6, 103.2, 105.7; other fine pyrite observed occasionally. Shales return to med. gr. and exhibit greater tendency to part parallel to bedding; lt. gr. slt. interbedded laminae		25%	10'	9.8'	
110					to 10%; Zones of load casts at 107.6', 107.3 & 116. Fine pyrite laminate at 112, Fe stone bed at 111, 113.5, 112.8 2" slt. bed on scour base of shale at 116.		16%	10'	9.8'	Longest = 11"
120					Possible clay remenants at 109.5' & 110' As before - fine pyrite disseminated at 121.3'. Darker shale at 122.3 to 122.6'.		16%	10'	9.9'	Longest = 6"
130					Generally slt. laminae becoming thicker, more frequent and exhibiting rippling at upper surface. Fe stone beds at 121.2, 121.3, 122.6, 125.3, 125.7, 126.6. Lithology as before but rock parts parallel to bedding with greater frequency. Some breakage probably due to coring and some may be natural.		3%	10'	9.8'	Longest = 4"
140					Fe stone beds up to 1" at 134.1, 135.3 and 1/4-1/2" at 128.1, 128.7, 134.3; Sh. laminae sets in last ft. reveal scour base load casts, & rippling. Some sets up to 2". Initial 2 ft. as before; At appx. 139 slt. laminae increase significantly. Large Fe stone		45%	10'	9.9'	Longest = 8"
150					(continued)					

GAI-237 8/72

(continued)

2E-459

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 16

PROJECT: ______ W.O. ______ SITE AREA ______ DRILL HOLE NO. ______

CONTRACTOR: ______ COORDINATES ______ ELEVATION ______

DRILLER: ______ GWL 0 HRS ______

CLASSIFIED BY: ______ DATE: ______ 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
140					slt. in fine-grained lt. gr. sand at 139.8 with considerable current rippling showing flame structure. Fe stone (2) at 139.5' slt. decrease at 140' to base of 145' where return to more typical 10% slt sequences.		65%	10'	9.9'	Longest = 8"
								3.0'	3.0'	
150					Vertical fractures at 140-140.5 due to coring.					

Bottom of Sheet 3

GAI-337 2/78

2E-460

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 16

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NR Parking Lot DRILL HOLE NO. 2X-11

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12 ELEVATION 626.06

DRILLER: Jim Adams GWL 0 HRS ______

CLASSIFIED BY: LDS - 150 to 180' RTH 180' - 200' DATE: 5/8/79 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
150					As before Med. hard med. gray sh. and 10-20% lt. gr. slt. Fe. stone beds at 161.75 X-beds at 153 & 154.3, load casts at 154.5 and less well developed at 153.3 Horizontal bedding			10.0'	9.92'	Longest = 9"
160					No change Slt. beds up to 2" with x-beds & or rippling at 157.7, 157.9 Fe. stone bed at 161.3. Very dark gr.-bl. laminae between 162.8 & 165 occur with irregular frequency			10.0'		
170					No change in lithology, load casts at 165.7, 166.45, SH interbeds less than 10%, breakage at 167.9' due to coring. SH darkens at 169' although still interlayered with lt. gr. slt. and previous med. gr. shale. Parts parallel to bedding. Rippling at 174.5' Increased frequency of lt. gr. slt. Sets occurs at 176.5. 2½" of x-bedded slt. at 178.6. Fe stone bed and slt bed in contact at 177.5'	4/20/79		10.0'		
180					Med. hard, med. gy. shale, and hard lt. gy. sandy shale (v.fi. grained) to siltstone, bands (0-2" thk.), thicker bands at 181.6'(2.5") (with cn. fi. gr. influx) 184.3'(4") siltstone, 186.5 to 187.25', and 188.45' to 189.0', all x-bedded. Load cast horizons at 188.2' & 188.5', little dk. gy. brn. shale, one band 5-1/2" thick at 186.5' on 1/4 pinching "Fe" band at 180.0'		74%	10.0'	9.92'	Lt. gy. wash; Long piece 14½"
190					Same sandy shale to siltstone laminae 0-1-1/2" thk., tr. dk. gy. brn. shale lam.		25%	10.0'	10.0'	
200										

GAI-337 2/78

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-461

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot SHEET 5 OF 16
CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 DRILL HOLE NO. TX-11
DRILLER: Jim Adams E 2,369,806.12 ELEVATION 624.04
CLASSIFIED BY: R. Wardrop DATE: 4/21/79 GRL. 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
200					Same, Hard; lt. gy. bands at 203.4(2") 205.0 (2-3/4"), & 205.7(2"), all X-bedded. Horizontal bedding, thinly laminated		63%	10.0'	10.0'	Lt. gy. wash
210					Same, some hard, lt.gy. sandy shale to siltstone laminae(0-2" thk.), little dk. gy. brn. oil shale lam; w/one band from 214-215.3' Thin clay seams at 212.9' & 213.4' one X-bedded siltstone band at 219.8'(3") Fracture dipping 80° at 215.9' lined with clay remenants, no displacement		92%	10.0'	10.0'	
220					Same, and hard, lt. gy. laminae, tr. dk. gy. brn laminae Hard, lt. gy. sandy bands at 221.7' (3"), 222.3'(3"), 126.5' (2½"), 127.0'(2½") 127.5'(5"), 128.6'(6"), & 129.3'(4), all x-bedded	4/21/79	58%	10.0'	10.0'	Lt. gy. wash
230					Same Hard, lt.gy., sandy shale to silt-stone bands at 231.2(2"), 231.7 (4"), 233.2 to 234.5. & 238.0 to 238.6, all x-bedded, Load cast horizons at 235.0', 235.2' & 239.5' Bedding parting at 238.0'		92%	10.0'	10.0'	
240–250					Same Hard, lt. gy. bands at 241.9(2½") & 247.4', (2½ siltstone), x-bedded Bedding partings at 241.65' & 249.2'		80%	10.0'	10.0'	

GAI-227 8/78

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-462

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot SHEET 6 OF 16
CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 DRILL HOLE NO. TX-11
DRILLER: Jim Adams E2,369,806.12 ELEVATION 624.04'
CLASSIFIED BY: R. Wardrop DATE: 4/22/79 GRL. 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
250					Med. Hard, med. gy., shale interlaminated with some, thin, hard, lt-gy., sandy shale to siltstone bands (0-2½"), tr. dk. gy. brn shale lam. one 2½" lt. gy. band at 255.0' Bedding partings at 252.3', 255.5', 255.7', 257.4', 258.9', & 259.9'		91%	10.0'	9.88'	Lt. gy. wash
260					Same, and lt. gy. sandy shale to siltstone laminae bands at 260.9' (2½") and 261.5 to 262.3, x-bedded load casts at 268.5' & 268.75' Bedding parting at 266.75'		76%	10.0'	9.92'	
270					Same, Lt. gy. bands at 274.5(2½"), 274.9(2½"), 276.0 to 276.5, & 279.4-280.0' all x-bedded Bedding parting at 270.6'		74%	10.0'	9.83'	Long piece 10"
280					Same, Hard, lt. gy. bands from 280-280.55', 280.8-281.2', 281.6'-282.5', & 286.2'-286.75' Horizontal Bedding parting at 286.75'		90%	10.0'	10.0'	Long piece 10"
290–300					Same, interlaminated with some, hard, lt. gy., sandy shale to siltstone laminae 0-2" thick. Bands of greater thickness at 292.3-292.65, 292.9-293.1, 298.0-298.3', all x-bedded.		92%	10.0'	10.0'	Long piece 29"

GAI-227 8/78

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-463

SHEET 7 OF 16

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot DRILL HOLE NO. TX-11

CONTRACTOR: Pa. Drilling Co. COORDINATES N781,586.77 E2,369,806.12 ELEVATION 624.04

DRILLER: Jim Adams GWL 0 HRS ____ 24 HRS ____

CLASSIFIED BY: R. Wardrop DATE: 4/23/79

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Core Run (Range Size)	Rec. Core (Grain Shape)	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
300					Med. hard m. grey, shale, and hard lt. gy., siltstone to sandy shale laminae 0-2" thk. Bands of greater thickness at 300.1 to 302.6 (x-bedded) 303.45(2.5"), 304.0(3.5"), 304.8(3") & 309.0(4"), trace of dk gy. brn. shale laminae. Load cast horizon at 305.2'		96%	10.0'	10.0'	
310					Same, lt. gy. siltstone bands >2" thk. at 318.3 to 318.9, 317.3 (3.5"), 316.5-316.9, 312.75-313.15, 313.45-313.75, 314.0-314.35, & 314.5-314.85, all x-laminated. ¼" thk. clay seam at 318.3'		98%	10.0'	10.0'	long piece 41½" Gas shoots water out of hole when barrel pulled
320					Same lt. gy. bands >?" at 326.9' (3") & 328.75-329.65, both x-laminated. Bedding parting at 327.85' Horizontal Bedding		72%	10.0'	9.88'	long piece-25" gas indicated as above
330					Same, lt. gy. bands >2" thk. at 333.65 to 334.0', little dk. gy. brn shale Laminae, concentrated from 338.5-340.0. Bedding parting at 337.5		79%	10.0'	9.83'	long piece-14" gas bubbling in hole when barrel pulled
340					Med hard. m. grey, shale interlam w/little lt. gy. sandy shale to siltstone lam., little dk. gy. brn. (oil shale) lam. concentrated between 340.6' to 341.9', one 1½" band at 344.25 1/4" thk. fissile shale seam at 346.75.		95%	10.0'	10.0'	long piece-27½" gas in hole
350										

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-464

SHEET 8 OF 16

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot DRILL HOLE NO. TX-11

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12 ELEVATION 624.04

DRILLER: Jim Adams GWL 0 HRS ____ 24 HRS ____

CLASSIFIED BY: R. Wardrop DATE: 4/23/79

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	Description (Density (or Consistency), Color, Rock Or Soil Type - Accessories)	U.S.C.S.	R.Q.D.	Core Run (Range Size)	Rec. Core (Grain Shape)	Remarks (Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.)
350					Med. hard, med. gy., shale, w/ some dk. gy. brn. shale lam. every 1-6", little hard lt. gy. siltstone to sandy shale lam., Pyrite traces at 353.8', 354.9', 355.55, & 356.4' Seams of soft fissile shale at 350.15, 350.3 (broken, ½" thk.) 351.2, 354.95(½"), & 357.7(1")		94%	10.0'	10.0'	Gas bubbling in hole
360					Same, lt. gy. siltstone bands at 362.8(2-1/4") 364.1(3"), fi. sandy bands at 366.5'(3"), 367.1' (1.5") both x-bedded, concentration of dk. gy. brn. (oil sh.), lam. at 365.5-366.1'	4/23/79	93%	10.0'	9.96'	Long piece-29.5" Gas bubbling in hole
370					Med. hard, med. gy. shale interlam w/1/4" to 1-1/2" dk. gy. brn. lam. with little lt. gy. sandy shale lam. one 3" band at 378.4' x-bedded. Fissile seam at 378.25'(1/4") Broken rx in seam at 376.0'		96%	10.0'	10.0'	Long piece-26" strong odor to gas from hole at start of day
380					Same, with some lt. gy. sandy shale to siltstone bands at 383(4.5"), 386.7-386.5 bec. med. lt. gy., 385.7'-386.0', little thin lam, of dk. gy. brn. shale, concentrated from 382.3 to 382.8.		93%	10.0'	9.67'	Long piece-23"
390					Same, with tr. lt. gy. lam.		31B	5.0'	5.0'	Long piece-16"
					Same, some dk. gy. brn lam (0-2-1/4")		95%	10.0'	10.0'	Long piece-20" Gas pushes water out of hole. 5' high
400										

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-465

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot SHEET 1 OF 16

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 DRILL HOLE NO. TX-11

DRILLER: Jim Adams E2,369,806.12 ELEVATION 624.04

CLASSIFIED BY: R. Wardrop DATE: 4/24/78 GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
400					Hard, lt. gy. sandy shale to siltstone at 400.3-401.0(x-laminated) & 403.2 to 403.3' Fissile seams at 400.3'(1/4") & 404.4'(1/2"), Load cast horizon at 402.7'		96%	10.0'	10.0'	Lt. gy. wash with dk. brn. influxes
410					Med. hard, med. gy. shale interlam. with little dk. gy. brn. shale lam. (0-2-1/4"), tr. lt. gy. lam.		93%	5.0'	5.0'	Long piece-30". Minimal Gas
					Same, and dk. gy. brn (oil shale) lam. (0-1-1/2")		96%	5.0'	5.0'	L.P. - 25". Minimal Gas
					Same, some dk. gy. brn. lam. (0-1") Bedding parting at 416.7'		93%	5.0'	5.0'	LP-23"
420					Med. hard., med. gy., shale, and hard lt. gy. fi. gr. sandy shale to siltstone with little dk. gy. brn. lam. (0-1/2"), lt. gy. bands at 420.5-420.85, 421.4-422.7, & 423.5-423.8 bec. lt. gy. brn.		92%	5.0'	5.0'	LP-22"
430					Same, concentration of lt. gy. lam. from 425.3-427.75 (siltstone bec. x-laminated, sandy sh.)	4/24/79	99%	5.0'	4.96'	LP-21". LP-17"
					Med. gy. shale with little lt. gy. lam. tr. dk. gy. brn. lam. (0-1/2")		90%	5.0'	5.0' LP-21"	Gas blowing out of hole at start of day
440					..me, tr. lt. gy. lam. Thin seam .f broken shale at 435.35'		96%	5.0'	4.96' LP-16"	Gas expands like gun shot when helper breaks drive on casing, 40 sec. later water column fountains 30' into air - high gas
					Same, flat lying. v. thinly lam., bands of cone-in-cone limestone bordering 1" siltstone from 440.6'-441.0'. Upper band (1/2"), lower band (3/4"). Fract. dipping 60° at 444.5'.		84%	5.0'	4.92' LP-12"	
450					Same		73%	5.0'	4.94' LP-15"	Minimal Gas. LP-15"

GAI - 227 6/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-466

PROJECT: PNPP W.O. 04-4549-310 SITE AREA NE Parking Lot SHEET 10 OF 16

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 DRILL HOLE NO. TX-11

DRILLER: Jim Adams E2,369,806.12 ELEVATION 624.04

CLASSIFIED BY: R. Wardrop DATE: 4/25/79 GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
450					Med. hard, m. grey, shale interlam. with little hard, lt. gy. siltstone, little dk. br. shale Fissile shale seam. 1/4" thick at 451.5' - Load cast horizons at 451.35', & 454.2'		92%	5.0'	5.0'	Minimum gas bubbling wash in hole-lt. gr. wash w/occasional brn. influxes - long piece-18"
460					Same, with some hard lt. gy., siltstone lam., brn. shale lam. 0-1" thick. Sandy shale band at 458.0'-458.6' (x-bedded), siltstone band at 458.85'-459.15'		83%	5.0'	5.0'	Same wash & gas long piece-17"
					Same with little lt. gy. lam. & some gy. brn. oily shale lam. 0-3" thick, heavily concentrated in the 463.75-465.0' interval.		85%	5.0'	5.0'	Same. Long piece-14"
470					Same, lt. gy. siltstone band from 465.3-465.7' & at 466.55'(2-1/2")		83%	5.0'	4.94'	Same. Long piece-18"
					Same, rock shattered from 473.7-474.3'. Thin clay seams and fissile shale at 470.75, 472.85, 474.5(3/4"). Very thin clay seam at 471.6'.	4/25/79 Sample disturbed		5.0'	5.0'	Gas blows column from top of hole followed by barrel lifted from approx. 300', 20' out the [illegible] above hole. Sample in barrel lands on platform greatly disturbing sample. [illegible] gas left to blow-off over night.
480					Same shale is med. to lt. gy. with trace gy. brn. lam., lt. gy. siltstone band at 479.4-479.85' Fissile shale at 476.2'(v. thin)		95%	5.0'	4.96'	Long piece-13". Min. gas
					Same, tr. lt. gy. siltstone lam. w/ one band at 480.55, tr. of iron staining in thin seam (?) at 483.4'-Load cast horizon at 481.3'		100%	5.0'	5.0' Long piece 30"	
490					Same, little lt. gy. siltstone lam., little dk. brn. shale lam. Lt. gy., x-laminated sandy shale band at 485.8'-486.05' Fractured rx. with clay (pulverized from hammering) at 486.05'(1/4") 487.8(1/4"); & 488.4(1/2")	Sample disturbed		5.0'	4.75'	Barrel pulled to 300' below surface when gas [illegible] slowly to top of hole. Have drove block of drill steps and hold barrel under pressure. Gas left to blow-off over [illegible]. Upon returning barrel is being repeatedly [illegible] against block under slightly less pressure.
							91%	5.0'	5.0' Long piece 19"	
500					Same, tr. siltstone lam., tr. brn. shale-siltstone band from 494.6'-494.9'		97%	10.0'	9.92' Long piece 20"	Driller is pulling barrel slowly, [illegible] gas on [illegible]

(continued)

GAI - 227 6/72

(continued)
2E-467

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 10 OF 16

PROJECT: ____ W.O. ____ SITE AREA ____ DRILL HOLE NO. ____
CONTRACTOR: ____ COORDINATES ____ ELEVATION ____
DRILLER: ____ GRL 0 HRS ____
CLASSIFIED BY: ____ DATE: ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
499–500					Same with some lt. gy. siltstone to sandy shale lam., band from 499.8 500.4' (x-laminated)		97%	10.0'	9.92'	
					Bottom of Sheet 10					

GAI-227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-468

SHEET 11 OF 16

PROJECT: PNPP W.O. 04-4569-310 SITE AREA NE Parking Lot DRILL HOLE NO. XX-11
CONTRACTOR: Pa. Drilling Co. COORDINATES N 781 586.77 E2,369,806.12 ELEVATION 624.06
DRILLER: Jim Adams GRL 0 HRS ____
CLASSIFIED BY: R. Wardrop DATE: 4/26/79 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
500					Med. hard, m. gy. shale, with some hard lt. gy. sandy shale to siltstone lam., some brn. (oil shale) lam.		97%	10.0' [illegible] to 505' run	9.92'	Min. gas-no problems. Lt. gy. wash w/ brn. influxes. Long piece-20"
					Lt. gy. bands at 501.55-501.8' and 503.8'-504.2' (x-laminated). Tan, sandy (fi. grained) influx at 504.5'(1/4"). Med. hard brn. shale concentrated from 506.7-508.7', with some gy. shale lam., little lt. gy. lam. with band at 505.2'(2-1/2"). (x-laminated)	4/26/79	[illegible]	5.0'	5.0'	High gas pressure [illegible] Barrel left in hole overnight - sample pushed up to top of 10' barrel
510					Same, brn. lam. 0"-3" thick concentrated between 515.6' and 518.5' with some gy. shale, little lt. gy. siltstone in bands at 513.3' (3"), 514.25'(2"), and from 514.7'-515.0'. Vertical fract. at 510.77'-511.05'	4/27/79	98%	10.0'	9.88'	Brown wash w/ lt. gy. influxes. Oily film in drill water. Long piece-18"
					Fissile shale seam with clay at 518.75(1/4") Very thinly bedded		92%	2.5'	2.5' [illegible]	Barrel blocks up, [illegible] @ 521.5' barrel pulled.
520					Same with little gy. shale lam. Vertical fract from 520.0' - 520.3'. Lt. gy. band from 520.55-521.05.		96%	7.5'	7.5'	Greenish brown wash. Minimal gas. Long piece-15"
530					Same tr. lt. gy. lam., brn. shale in 0-6" thick bands. Rock broken with some overcoring between 523.5' and 523.85'. Same gy. shale, thinly laminated, one 3-1/2" thick band at 532.5'. Lt. gy. siltstone band at 3-3/4" thick at 538.7'. Horizontal Bedding		97%	10.0'	10.0'	No indication of gas
540–550					Same, and med. hard gy. shale lam. Lt. gy. lam. at 549.55' (1-1/4" thick)		100%	10.0'	10.0'	Long piece-28". No indication of gas. Long piece-21"

GAI-227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-469

SHEET 12 OF 16

PROJECT: PNPP   W.O. 04-4549-310   SITE AREA NE Parking Lot   DRILL HOLE NO. TX-11

CONTRACTOR: Pa. Drilling Co.   COORDINATES N 781,586.77 E2,369,806.12   ELEVATION 624.04

DRILLER: Jim Adams   GWL 0 HRS ______

CLASSIFIED BY: R. Wardrop   DATE: 4/28/79   24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
550							Med. Hard, med. gy. shale and brn. oil shale 0-6" thick bands, larger brn. shale bands at 551.7-552-25, 558.5-558.9, & 559.5-560.0' Some laminae seem to have slight dip, probably local depositional feature		100%	10.0'	10.0'	Lt. gy. and dk. brn. wash. No gas. Long piece-15"
560							Med. hard, brn. shale and med. gy. shale laminae. Brn. shale band at 560.0-561.9' Pryrite deposited along laminae at 566.65, 568.5, & 569.15' Vertical fract. 2" long at 566.9'		43%	10.0'	10.0'	No gas. Long piece-65"
570							Med. hard, med. gy. shale and brn. shale 0-5" thick, band at 574.1-574.8, trace v. thin lt. gy. siltstone lam. Very slight dip to laminae between 577.7 and 578.1' Pyrite in circular bleb at 574.0' (1/4" diameter)	4/28/79	98%	10.0'	9.92'	Brown and grey wash, smooth coring. No gas. Long piece-21"
580							Same, with only traces of brn. shale laminae, tr. very thin lt. gy. siltstone lam. med. hard Partially developed, tr. brn. siderite bands at 582.35' (1"), 583.4' (1"), 586.6' (1"), 587.4 (3/4") & 588.25 (1")		100%	10.0'	9.92'	Long piece-60"
590							Same with little brn. shale, little lt. gy. siltstone becoming brown shale at 594.95' with traces of v. thin lt. gy. siltstone and gy. shale laminae, pyrite in lam. 594.95 Between 592.35 and 594.95, every 1"-2". Other trace deposits in seams at 598.45 and 598.7' (1/8" thick a piece)		100%	10.0'	10.0'	Long piece-76-½"
600												

GAI-223 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-470

SHEET 13 OF 16

PROJECT: PNPP   W.O. 04-4549-310   SITE AREA NE Parking Lot   DRILL HOLE NO. TX-11

CONTRACTOR: Pa. Drilling Co.   COORDINATES N 781,586.77 E 2,369,806.12   ELEVATION 624.04

DRILLER: Jim Adams   GWL 0 HRS ______

CLASSIFIED BY: R. Wardrop   DATE: 4/29/79   24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
600							Hard, brown, shale (oil shale) to siltstone w/trace lt. gy. siltstone in 3/4" laminae @ 608.75, tr. thin gy. shale lam. Traces of pyritic, micro-crystalline mineralization @ 603.4', 605.85', & 607.85'		100%	10.0'	10.0'	Dk. brown wash. Long piece 56½"
610							Same, traces of pyrite at 613.15, 615.05, 616.45, 610.6, 611.5		100%	10.0'	10.0'	Core catcher fails-sample left in hole-retrieved in one attempt-no overcoring. All one piece-120"
620							Same to 623.9' Trace pyrite to 623.9' becoming med. hard, gray shale with little dk. brn. oil shale, trace thin, lt. gy. siltstone lam. Thinly laminated, tight, flatlying	4/29/79	95%	10.0'	10.0'	Long piece-48"
630							Beds of med. hard., grn. gy. shale and dk. brown shale to siltstone in the following sequence: 630-633.8 lt. greenish gy. shale, some brn shale, with 0-6" thicknesses: 633.8-634.65-brn. shale, 634.65-634.9-lt. grn. gy. shale, 634.9-637.5-brn. shale, hard, 637.5-640.0-lt. grn. gy. shale w/ some brn. shale. Slightly broken in partings at 638' & 638.8' Trace micro-crystalline pyrite at 637.77 & 636.6'		96%	10.0'	10.0'	Long piece-55"
640							640.0-650.0-brn. oil shale to siltstone, hard, trace, v. thin gy. shale lam., trace pyrite at 645.6', 649.1', & 649.5'		100%	10.0'	10.0'	All one piece-120"
650												

GAI-223 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-471

PROJECT: PNPP W.O. 06-4569-310 SITE AREA NE Parking Lot

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12

DRILLER: Jim Adams

CLASSIFIED BY: R. Hardrop DATE: 4/30/79

SHEET 16 OF 16

DRILL HOLE NO. TX-11

ELEVATION 674.06

GWL 0 HRS

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
650					Hard, brn. shale to siltstone with traces of thin gy. shale lam., traces of lt. gy. siltstone lam. at 653.95-654.25, 654.55-654.9, 657.0-657.15, & 657.75(3/8") traces of micro-crystalline pyrite at 653.6, 651.85, & 655.5 Same to 661.4', becoming, greenish gy. shale-siltstone, and brn. shale hard, in the following sequence		100%	10.0'	10.0'	Lt. gy. and brown wash; long piece-63"
660					661.4-661.7 - M. grey, siltstone 661.7-662.35-br. shale 662.35-662.6-lt. gy. siltstone becoming shale 662.6-663.3-br. shale; 663.3-665.3-lt. gray siltstone; 665.3-666.2 - br. shale 666.2-666.9 - lt. gr. gy. siltstone; 666.9-668.6-br. shale 668.6-669.5 - lt. gy. gr. siltstone; 669.5-670-interlaminated w/ lam. of above lithologies		100%	10.0'	9.92'	long piece-17"
670					Hard, brn. shale-siltstone to 670.4', then med. hard. to hard. lt. gr. gy. shale (670.4-679.55) with some bands of br. shale at 672.6-673.1, 675.7-675.35 & 677.35 (1-1/2") 679.55-680 brn. shale-siltstone with (1") lt. gr. gy. band at 679.15'	4/30/79	92%	10.0'	10.0' P.25	Gas splashes drill water out of hole during run. Driller vents pressure out water gauge to safety gas release hose. Gauge reads 400 psi w/valve 1/2 open Pressure decreases to 300 psi in 20 minutes. Hole left to bleed-off overnight.
680					Hard gr. gy. shale and brn. shale siltstone to 684.0-becoming hard, brn. shale with trace of lt. gr. gy. shale at 684.7(2") & 688.7-689.3		96%	10.0'	10.0'	Long piece-113"
690					Hard lt. gy. gr. shale and br. shale to siltstone interbedded in the following sequence. 690.0-690.8-br. siltstone; 690.8-691.2-lt. gr. gy. shale-siltstone; 691.2-691.55 br. shale siltstone; 691.55-692.65 lt. gr. gy. shale siltstone		96%	10.0'	10.0'	Long piece 45"
700										

(continued)

GAI-287 8/72

(continued)

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-472

PROJECT: W.O. SITE AREA

CONTRACTOR: COORDINATES

DRILLER:

CLASSIFIED BY: DATE:

SHEET 14 OF 16

DRILL HOLE NO.

ELEVATION

GWL 0 HRS

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
690					Brn. Shale to Siltstone: 692.55-694.9 " "; 695.5-696.3 " "; 698.6-699.2 " ". Lt. grn. gy shale to siltstone: 694.9-695.5 " "; 696.3-698.6 " "; 699.2-700.1 " "					long piece-45"
700					Bottom of Sheet 14					

GAI-287 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: PNPP W.O. 06-4549-310 SITE AREA NE Parking Lot

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,586.77 E2,369,806.12

DRILLER: Jim Adams

CLASSIFIED BY: R. Wardrop DATE: 5/1/79

SHEET 15 OF 16

DRILL HOLE NO. TX-11

ELEVATION 624.06'

GWL 0 HRS ______

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
700–710					Lt. greenish gy. shale-siltstone and br. shale laminae in the following sequence: **Br. Shale** / **Lt. Gr. Gy.Shale** — / 700.1-704.55 704.55-704.95 / 704.95-707.5 707.5-709.4 / 709.4-710.0 w. some lt. gr. gy. lam. (0- 2")		96%	10.0'	10.0'	Brown and lt. gy. wash. Minimal gas
710–720					SAME 714.55-715.1 / 710.0-714.55' — / 715.1-715.5' 715.5'-720.0' / Very thin pyritic seams in brn. shales gr. lt. gr. gy. lam. (1") at 717.1 Bands of tan brown calcareous siltstone at 710.85(1") & 713.25(1")		100%	10.0'	10.0'	Long piece-20" Minimal gas
720–730					All brn. shale-siltstone, hard, traces of micro-crystalline pyrite at 723.05', 720.2', 728.75 in. Thin seams at 726.05' & 728.7' massive Horizontally bedded		100%	10.0'	10.0'	Long piece-55" Minimal gas All one piece-120"
730					Bottom of Hole - 730.0' 5/1/79					

GAI - 227 2/73

INSPECTOR'S COMMENT:

Little evidence suggests that 730' deep TX-12 advanced through any zones of faulted rock. The "Remarks" column of sheet 10 of 16 describes two (2) situations during drilling where core samples were disturbed due to problems arising from influxes of natural gas. Although distrubed sections of core lie in close proximity to a straight line fault dip projection derived from TX borings encountering faulted rock at shallower depths, the very character of distrubed seams (i.e. lack of stiff, relatively dry clay) precludes a fault gouge zone interpretation. Disturbed seams had a freshly made appearance.

2E-475

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P W.O. 04-4549-310 SITE AREA North ShorelineBluff SHEET 1 OF 11

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,318.50 DRILL HOLE NO. TX-12

DRILLER: Jim Adams E 2,369,051.21 ELEVATION 618.4'

CLASSIFIED BY: R. Wardrop DATE: 6/1/79 GWL 0 HRS ______ 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	Advance Date	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0										Driller drilling through over-burden w/bentonite slurry. Angle set @ 33° from vertical
10					Lacustrine & Glacial Tills					
20						6/1/79				Coupling threads stripping when new rods added. Driller obtains tapered, threaded male ends over weekend
30										
40										
50										

GAI-227 8/72

2E-476

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North ShorelineBluff SHEET 2 OF 11

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,318.50 DRILL HOLE NO. TX-12

DRILLER: Jim Adams E 2,369,051.21 ELEVATION 618.4'

CLASSIFIED BY: R. Wardrop DATE: 6/4/79 GWL 0 HRS ______ 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50–70					Glacial Till boulder 68.0' zone 70.0'	6/4/79 6/6/79				Hole drilled @ angle 30° to vertical Tapered male ends also strip driller couples male ends w/ torch. Driller injures leg when trying to break rods, when rig accidentally kicks into gear no work Tuesday 6/5/79 Sandy wash @ 68.0', hard drilling. Grey shale chips @ 70.0' in wash
70–80					Top of weathered shale @ 70.0' m. soft, m. grey, weathered shale, w/little lt. gy. siltstone laminae, some (1/2-3") clay seams in fissile shale Dk. brn. "Fe" stone band @ 76.0' Bottom of weathered zone - 80'			10.0'	6.2'	Casing set @ 68.0' Hole left overnight to check caving - No caving 6/7/79-Casing remains @ 68.0' long piece 8"
80–90					Same, m. hard, unweathered, w/ trace thin fissile seams and clay @ 87.8' (1/4), 88.4' (1/4) & 89.3'(3/4") "Fe" bands @ 85.6' (1/2), 86.85' (1/2), 87.25' (1) & 89.25' (1/2) Load casts horizon @ 88.5'	6/7/79		10.0	9.6' 10.	Grey wash 5' Casing added after drilling-casing now @ 72.0' long piece 21.5"
90–100					Same. Bedding Partings @ 92.15', 97.8', & 98.65' "Fe" bands @ 90.3'(1"thick) 91.75' (1"), 94.25'(1/2"), 95.6'(1/2") 96.25'(1/2"), 97.1'(1/2"), 98.7' (1"). Flat lying beds			10.0'	9.9'	long piece 16"

GAI-227 8/72

Revision 12
January, 2003

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 11

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North ShorelineBluff DRILL HOLE NO. TX-12

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,318.50 ELEVATION 618.4'

DRILLER: Jim Adams E 2,369,051.21 GW. 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 6/8/79 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
100					M. hard, m. gy., shale w/some lt. gy. siltstone to v.fi. grain sandy shale laminae, very thin. Trace tn. brn. "Fe" bands @ 104.4'(1/2"), 104.8'(3/4"), 106.0'(1"), 107.0'(1/2"), 107.8'(1/4"), 108.7'(1/4") 109.0'(1/2") Partings @ 101.0' & 103.2', clay seam @ 105.5'(1/2")		84%	10.0'	10.0'	Lt. gy. wash long piece 15"
110					Gy. shale w/tr. fi. gr. sandy shale to siltstone, one band @ 116.8'(2") "Fe" bands @ 111.2'(1/2"), 111.35'(1/4"), 113.4'(1/2"), 113.9'(1/4"), 117.5'(1/4"), 117.7'(1/4") & 118.2'(1/4") Partings @ 115.4' and w/tr. clay @ 119.4'		96%	10.0'	10.0'	L. P. = 14"
120					Same, load cast horizon @ 125.7' "Fe" bands @ 120.1'(1/2"), 121.2'(1/4"), 121.5'(1"), 123.3'(1"), 124.7'(2"), 126.5'(2"), 127.6'(1/2") 128.4'(1"), & 129.9'(1-1/2") Little dk. gy. brn. shale lam. Same, w/little lt. gy. laminae, tr. "Fe" bands @ 131.8'(1"), 136.2'(2"), 137.7'(1"), & 140.0'(2"), tr. dk gy. brn. lam.	6/8/79	98%	10.0'	10.0'	L. P. = 22"
130					Partings @ 132.6', 133.4', 134.2', and 134.8' Flat lying beds Same, w/some lt. gy. lam., load cast horizon @ 147.0' Trace tn. brn "Fe" bands @ 143.6'(1/2"), 144.'(1"), 145.1'(1/2"), 148.0'(1-1/2"), 148.9'(1"), 149.5'(3/4")		93%	10.0'	9.9'	L.P. = 13"
140					Partings @ 144.6', 149.2', & a fissile shale seam w/tr clay @ 149.97', v. thin.		85%	10.0'	10.0'	Assuming horizontal laminae, angle hole is maintaining 30° from vertical Lt. gy. wash. L.P. = 15"
150										

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 11

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North ShorelineBluff DRILL HOLE NO. TX-12

CONTRACTOR: Pa. Drilling Co. COORDINATES N 781,318.50 ELEVATION 618.4'

DRILLER: Jim Adams E 2,369,051.21 GW. 0 HRS

CLASSIFIED BY: R. Wardrop DATE: 6/11/79 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Pt. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
					M. Hard, M gy. shale, and hard, lt. gy. sandy shale to siltstone laminae, one band @ 157.2' (1 1/2") Load cast horizons @ 150.0', 150.4', 151.8', 156.7', & 157.7' Tr. Tn. brn. "Fe" bands @ 150.5'(1/4") 155.3' (1/2") 157.1' (1") 157.6'(1/4")		91%	10.0'	9.7'	Lt. gy. wash Core rotated in barrel, pulverizing shale @ 154.0', broken rock dry Long piece=20"
					Thin fissile shale seams w/tr. clay @ 156.7', 157.8', & 158.7' Same, some lt. gy. bands @ 165.2'(2"), & 169.25' (2.5") Tr. Tn. brn. "fe" bands @ 160.2'(1/2") 161.7' (1/4") & 169.9'(1/4") Tr. dk. gy. brn. shale from 166.0'-167.6'		95%	10.0'	10.0'	L.P. = 25-1/2"
					Partings @ 163.' & 165.2', fissile shale seam @ 169.9' Same, and lt. gy. band from 173.75' to 174.25', load cast horizon @ 172.1'. Tr. Tn brn. "Fe" bands @ 171.75'(1/2"), 176.3' (1/4"), 178.0' (1"), 178.7' (1/2"), & 179.5' (1/2")		95%	10.0'	10.0'	L.P. = 15"
					Partings @ 172.1', 172.4', 173.2', 179.0', & 179.7' Same, w/some lt. gy. laminae, load cast horizon @ 184.6', 186.2', 188.75' Tr. tn brn. "fe" bands @ 184.85' 1/4") 185.5'(1/2"), 186.5'(1"), 187.6'(1/2"), 188.5'(1") & 190.0'(1")	6/11/79	97%	10.0'	10.0'	Torque on rods begin to rattle drill rig - stopped when next 20' rod section added. L.P. = 15"
					Parting @ 186.0' Flat lying beds. Same, white gy. sandy shale band @ 198.5'(2" thk.) No "Fe" bands Dk. gy. brn. shale lam. occur in 20% of core starting @ 191.8' (2" thk) other lam. thin Parting @ 197.2'		98%	10.0'	10.0'	L.P. = 20"

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-479

SHEET 5 OF 11

PROJECT: P.N.P.P.   S.O. 04-4549-310   SITE AREA North Shoreline Bluff   DRILL HOLE NO. TX-12

CONTRACTOR: PA Drilling Co.   COORDINATES N 781,318.50 E 2,369,051.21   ELEVATION 618.4'

DRILLER: Jim Adams   GWL 0 HRS ______

CLASSIFIED BY: R. Wardrop   DATE: 6/12/79   24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
200–210				M. hard, m. gy. shale, w/some hard lt. gy. sandy shale to siltstone lam., bands at 202.35'(2")(fi. gr. sandstone), 207.15'(1.5"), & from 208.3'-208.7', load cast horizon at 205.1', 207.6', 208.7', & 208.9'. Tr. "fe" bands at 205.5'(2"), 207.0'(1"), 208.05'(1"). Partings at 204.8' & 209.8'		98%	10.0'	10.0'	Lt. gy. wash Long piece=33.5"
210–220				Same, and lt. gy. lam. bands at 211.3'(2"), 213.2'-214.6'(v. thin lam.), & 215.3'-216.5', dk. gy. brn. sh. from 212.1'-212.7' (v. thinly lam.). Fissile seams at base of lt. gy. bands at 211.2', 212.1', & 214.7'		96%	10.0'	10.0'	L.P. = 40"
220–230				Same w/some lt. gy. lam., bands at 221.6'(1-1/2"), 227.2'(2"), 228.5(3"), 228.8'(2") & 229.4'(2"). Load cast horizons at 271.1', 224.8', 225.25', 225.7', 226.3'. Tr. dr. gr. brn. lam. (0-1/4" thk). Broken sandstone band at 228.5' (2"), w/tr gy. clay.		97%	10.0'	10.0'	L.P. = 30"
230–240				Same, and lt. gy. lam., bands at 233.35'(1.5"), & 234.5-235.0' (x-bedded) Partings at 236.1'. % of shale increases at 236.4', w/little lt. gy. bands, tr. dk. gy. brn. lam.		98%	10.0'	9.9'	L.P. = 42"
240–250				Same, w/ tr. v. thin lt. gy. lam. band of dk. gy. brn. shale at 245.3'(2"), Partings at 245.7', & 249.7'. 80° fract. striking perp to drill hole azmith from 248.0'-248.6'. Flat lying bedding	6/12/79	95%	10.0'	9.9'	L.P. = 18"

GAI - 227 8'72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-480

SHEET 6 OF 11

PROJECT: P.N.P.P.   S.O. 04-4549-310   SITE AREA North Shoreline Bluff   DRILL HOLE NO. TX-12

CONTRACTOR: PA Drilling Co.   COORDINATES N 781,318.50 E 2,369,051.21   ELEVATION 618.4'

DRILLER: Jim Adams   GWL 0 HRS ______

CLASSIFIED BY: R. Wardrop   DATE: 6/13/79   24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
250–260				M. hard, m. gy. shale and hard, lt. gy. siltstone to sandy shale laminae, lt. gy. bands at 251.7'(1.5") & v. thin lam. concentrated from 256.3'-258.0', tr. dk. gy. brn. sh. Partings w/tr. clay at 252.5 & 253.3. Broken rock from rotation in barrel from 259.6'-260.0'		93%	10.0'	10.0'	Lt. gy. wash No gas Long piece=24"
260–270				Same, lt. gy. bands at 260.2'(2"), 260.5'(2"), 261.5'-262.7'(x-bedded) 264.9'(4.5"), 265.8'(4"), 266.5'-267.9'(x-lam.), & 269.9'(2"). Partings at 264.5' & 267.35'		94%	10.0'	9.9'	Hole is maintaining 30° dip according to dip of beds in core, assuming horizontal bedding L.P. = 29"
270–280				Same, lt. gy. bands at 271.1'-271.45', 271.65'-272.7, 274.4(2"), 276.7(3.5"), 279.2(2"). Partings at 272.1; 272.6'. Fissile shale seam w/tr. clay at 276.0(1/4"), & 277.5'(1/8")		95%	10.0'	9.9'	L.P. = 24"
280–290				Same, lt. gy. bands at 281.0'-282.0' (x-lam.) 284.7'(1.5") (x-lam.), & 288.4'(1.5")(x-lam.) Partings at 283.8' & 285.2'. Broken rock at 287.0'(3"), 287.9'(2.5"), & 289.0'(2")		90%	10.0'	10.0'	Tape split at bottom of barrel causing broken seams in last 3' of core. L.P. = 60"
290–300				Jt. at 285.5'-285.75', strike approx. perp. to bore azmith, dip 65° N. Same, w/some hard. lt. gy. sandy sh. to siltstone bands, 2" at 290.1(2")(x-lam.), 295.0-295.3' (x-lam.), & 295.0'(3")(x-lam.). Partings at 295.85' & 299.2'		98%	10.0'	10.0'	Minimal gas when barrel pulled, 0 psi shut-in pressure L.P. = 30"

GAI - 227 8'72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-481

PROJECT: P.N.P.P.   W.O. 04-4549-310   SITE AREA North Shoreline Bluff   SHEET 7 OF 11   DRILL HOLE NO. 618.4'

CONTRACTOR: PA Drilling Co.   COORDINATES N 781,318.50 E 2,369,051.21   ELEVATION

DRILLER: Jim Adams   GW. 0 HRS -

CLASSIFIED BY: R. Wardrop   DATE: 6/13/79   24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
					M. hard, m. grey shale and hard lt. gy. sandy shale to siltstone laminae, bands at 300.1'(2"), 300.9'(2"), 301.9'(3.5")(x-lam.), becoming mostly lt. gy. bands w/some gy. shale at 305.3', tr. dk. gy. brn. shale Load cast horizon at 304.6' Weathered shale in parting at 306.85'(1/2")		97%	10.0'	10.0'	Lt. gy. wash No gas Long piece=34"
					M. hard, m. gy. shale w/little lt. gy. lam., becoming mostly lt. gy. lam. w/little gy. shale at 316.2', trace dk. gy. brn. shale, lt. gy. bands at 311.3-311.85'(x-lam), 310.4',(2.5') 316.2,-317.0'(x-lam., silt.) 317.35'-318.1', 318.4'-319.7' Parting at 319.7'		99%	10.0'	10.0'	Assuming horizontal bedding, hole is maintaining a 30° dip angle from vertical L.P. = 30°
					M. hard, m. gy., shale w/some hard lt. gy. lam., bands at 322.8'(1/4"), 323.0'-323.55'(x-lam) 323.8'-324.2', 328.35'(2.5")(x-lam) 329.5'-330.0' (siltstone) Load cast horizon at 325.6', Tr. dk. gy. brn. lam. Fissile shale seams at 322.65' & 329.5' Partings at 321.0'		98%	10.0'	10.0'	Gas pushed small stream of water out of rod Pressure gauge leaked at welds on collar, driller repairs for subsequent readings L.P. = 34°
					Same, w/little lt. gy. lam. bands at 330.1(2"), 330.6(2.5"), 331.55-332.3, (thinly lam. w/sh.) 332.9(2.5"), 333.8(2"), 335.7' (2.5"), 336.8'(2.5"), 337.4(3"), tr. dk. gy. brn. sh., becoming 100% lt. gy. siltstone at 338.2' Parting at 339.35'		99%	10.0'	9.9'	No gas L.P. = 53°
					Thin pyrite seam at 336.0' hard lt. gy. siltstone to 340.7'; becoming, m. hard, m. gy. shale w/some lt. gy. lam., bands at 341.05'-341.5', 341.9'(3.5"), 344.35'(4"), & 348.9'-349.3', tr. dk. gy. brn. shale laminae Flat lying bedding		99%	10.0'	10.0'	No gas L.P. = 24"

GAI-227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-482

PROJECT: P.N.P.P.   W.O. 04-4549-310   SITE AREA North Shoreline Bluff   SHEET 8 OF 11   DRILL HOLE NO. TX-12

CONTRACTOR: PA Drilling Co.   COORDINATES N 781,318.50 E 2,369,051.21   ELEVATION 618.4'

DRILLER: Jim Adams   GW. 0 HRS

CLASSIFIED BY: R. Wardrop   DATE: 6/14/79   24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
					M. hard, m. gy. shale w/some hard, lt. gy. siltstone to sandy shale lam. w/bands . 2" at 351.4'(2"), 353.15'-353.85-354.25' 354.8'-355.1', 355.3'-355.6', 356.65' (2"), 357.3'-358.1', 358.35-358.65', tr. dk. gy. brn. shale in 0-1/4" laminae. Thin bleb of coal at 350.15' (1/8" thick) Parting at 358.75'		99%	10.0'	10.0'	Lt. gy. wash No gas Long piece=30"
					Same and lt. gy. lam. bands at 361.3'-361.55'(x-lam.), 363.7'(3"), 364.15'(2-1/4"), 364.6'(2"), 366.25'(2"), 366.7'-367.0', 369.4(2-1/2")(x-lam.), tr. dk. gy. brn. sh. lam., all very thinly laminated. Load cast horizon at 369.7' Partings at 364.25' & 368.9'		100%	10.0'	10.0'	No gas Assuming horizontal bedding hole is maintaining 30° dip angle from vertical L.P. = 24"
				FAULT	Same lt. gy. bands at 370.25-370.7, 371.2-371.7, 373.7-373.9 (thinly interlam. w/gy. shale) 374.2-374.3, 374.5-374.7, 375.2-375.5, 375.7-376.0 Parting at 372.0'	6/14/79	60%	10.0'	9.7'	30° dip angle Fault Zone displays several varied dips to bedding planes.
					Fault Zone top 376' 376.0-376.5-Highly fract. rock 375.5-376.8-Lt. gy. Siltstone 377.5-377.7-fault gouge 378.2-378.4-fault gouge Btm. 380.3' 378.7(1/8")-fissile sh. w/clay 379.0-379.25-fault gouge 379.25-379.50-Lt. gy. siltstone Bottom 380.3'		95%	10.0'	10.0'	Assuming horizontal bedding rods have assumed @20° dip angle from vertical after advancing through fault zone. L.P. = 15"
					Same as above fault w/some lt. gy. bands, @380.3-380.4, 380.5-380.6, 381.45-381.55, 381.7-381.9, 382.7-382.8, 383.6-384.05 (thinly lam. w/gy. shale) 385.7-386.0 (thinly lam. w/gy. sh.) Dk. gy. brn. bands @382.5-382.7, 385.0-385.4, & 385.5-385.7		100%	10.0'	9.9'	L.P. = 24"

GAI-227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-483

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff SHEET 8 (Continued) OF 11
DRILL HOLE NO. TX-12
CONTRACTOR: PA Drilling Co. COORDINATES N 781,964.39 E 2,369,414.82 ELEVATION 618.4'
DRILLER: Jim Adams GWL 0 HRS ______
CLASSIFIED BY: R. Wardrop DATE: 6/13/79 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
390					Same, w/little dk. gy. br shale lam. (0-1/2" thk.) Lt. gy. bands @ 391.9'(2") & 399.6' - 399.9' Dk. gy. brn. band @ 398.8'(2") Load cast horizon @ 393.2' Parting @ 399.8'		100%	10.0'	9.9'	
400										

2E-484

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

SHEET 9 OF 11
PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-12
CONTRACTOR: PA Drilling Co. COORDINATES N 781,318.50 E 2,369,051.21 ELEVATION 618.4'
DRILLER: Jim Adams GWL 0 HRS ______
CLASSIFIED BY: R. Wardrop DATE: 6/15/79 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
400					M. hard, m. gy., shale w/little dk. gy. brn. shale, tr. lt. gy. lam. Shale turns greenish gy. at 408.9'		100%	10.0'	10.0'	Lt. gr. gy. wash Minimal, gas no shut-in pressure Long piece=24"
410					Same, w/little lt. gy. siltstone to sandy shale lam. some dk. gy. brn. shale lam. Lt. gy. bands at 414.0(2.5") & 414.45'(2") Dk. gy. brn. shale band at 412.8'(4-1/2") Parting at 416.75'	6/15/79	98%	10.0'	9.9'	Minimal gas, 5 psi shut-in pressure. Hole maintains 20° angle from vertical L.P.=13"
420					Same, w/some dk gy. brn. lam., tr. lt. gy. lam. Lt. gy. bands at 422.1'(1.5") Dk. gy. brn. bands at 421.2'(2"), & 421.7'(2") down to 422.3', after that core is overcored, turned, and ground to 430.0'		23%	10.0'	8.5'	Minimal gas no shut-in pressure Inner barrel does not lock in place, & is pushed up during coring-no sample, sample has to be over-cored, 1.5' rec. lost during overcoring
430					Same, w/little lt. gy. lam, bands, at 431.85'(2", x-lam.) 434.25' to 434.8'(m. gy. siltstone) 435.15-435.6'(wh. tn. siltstone), 435.6'-435.9'(lt. gy. siltstone)		98%	10.0'	10.0'	Minimal gas, 0 psi shut-in pressure L.P. = 20"
440					Same w/some dk. gy. brn. sh. bec. mostly dk. gy. brn. shale by end of run, and m. gy. shale. Lt. gy. bands at 443.7'(2") Dk. gy. brn. bands at 440.2'-440.5', 445.8'(2"), 448.3'(2"), 449.8'(2-1/2") Broken seam at 440.7'(1/2", fi. gr. sandstone) Partings at 441.3' & 443.8'	6/18/79	99%	10.0'	10.0'	Minimal gas, 0 psi shut-in pressure Hole maintaining 20° angle L.P. = 19"
450										

GAI-227 2/78

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 10 OF 11

PROJECT: P.N.P.P. W.O. 04-4549-310 SITE AREA North Shoreline Bluff DRILL HOLE NO. TX-12

CONTRACTOR: PA Drilling Co. COORDINATES N 781,318.50 E2,369,051.21 ELEVATION 618.4'

DRILLER: Jim Adams GWL 0 HRS ______

CLASSIFIED BY: R. Wardrop DATE: 6/19/79 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
450							Hard, lt. gy., sandy shale to siltstone, tr. gy. shale to 451.05; becoming: M. hard, m. gr. gy. shale, and hard, dk. gy. brn. shale lam., w/little lt. gy. laminae, lt. gy. bands ≥2" at 453.3-453.6'; 454.3'(1.5"), 459.1' (2.5")		100	10.0'	10.0'	Lt. gr. gy. wash Minimal gas. 7 psi shut-in pressure 25° dip to hole
460							1/2" of broken core at 459.6' Same, w/little dk. gy. brn. lam. Lt. gy. bands at 463.95-464.3' & 468.4'(1-1/2", x-lam.) Parting at 468.7'		100	10.0'	10.0'	long piece = 12" 8 psi shut-in on methane gas 25° dip to hole
470							Same, w/some lt. gy. laminae, bands at 472.65'(2.5", x-lam.), 473.65-473.85, 474.1(2.5", x-lam.) 474.45-474.75, & 479.3-479.7' (x-lam.) Dk. gy. brn. shale bands at 470.65(2"), & 477.7'(2-1/4")	6/19/79	99%	10.0'	9.9'	L.P. = 15" 27° dip to hole 5 psi shut-in pressure L.P. = 18"
480							Bottom of Hole - 480.0' Completed 6/19/79					

GAI-227 8/72

INSPECTOR'S COMMENT:

Fault zone identification was readily accomplished in TX-12. HC-size, double barrel, wire-line coring recovered three distinct clayey gouge zones in highly fractured rock between 376.0 and 380.4'. Also present in the zone were several distinct laminae orientations, indicative of plastic deformations to normally flat lying beds, prior to the brittle failure of actual faulting.

2E-487

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio

CONTRACTOR: Herron

DRILLER: L. Humphrey

CLASSIFIED BY: R.V.

COORDINATES N 780,226.5 E 2,369,796.1

DATE: 7-7 thru 7-8-77

SHEET 1 OF 1

DRILL HOLE NO. WP-1

ELEVATION 622.8

GWL 0 HRS

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	Qu	Coarse Granular Soils: Range Size / Grain Shape; Core / Rec.; Run / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0									Heavy water Piezom. Drilled down to 50.0' Bailed out drilling water, added 5' clean water before installing piezometer @ 49.0'
10									
20									
30									
40									
50					End of Boring @ 50.0'				

GAI - 227 12/65

2E-488

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

PROJECT: Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio

CONTRACTOR: Herron

DRILLER: L. Humphrey

CLASSIFIED BY: R.V.

COORDINATES N 781,631.1 E 2,370,360.3

DATE: 7-6 thru 7-7

SHEET 1 OF 1

DRILL HOLE NO. WP-2

ELEVATION 621.2

GWL 0 HRS 8

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	Qu	Coarse Granular Soils: Range Size / Grain Shape; Core / Rec.; Run / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0									Casa Grande Piezometer-installed @ 48.5'
10									
20									
30									
40									
50					End of Boring @ 49.5'				

GAI - 227 12/65

2E-489

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. WP3-A

CONTRACTOR: Herron

COORDINATES N 781,253.1 E 2,369,577

ELEVATION 618.8

DRILLER: L. Humphry

GWL 0 HRS.

CLASSIFIED BY: R.V.

DATE: 6/22-6/26/72

24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color, Soil Type - Accessories	U.S.C.S.	W%	Coarse Granular Soils: Range Size / Grain Shape; Core Run / Rec. / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0									Terra Tec Piezom. installed @ 34.0'
35.0					End of Boring @ 35.0'				

GAI-427 12/68

2E-490

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. WP3-B

CONTRACTOR: Herron

COORDINATES N 781,269.1 E 2,369,577

ELEVATION 619.2

DRILLER: L. Humphrey

GWL 0 HRS.

CLASSIFIED BY: R.V.

DATE: 6/29-7/1/72

24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color, Soil Type - Accessories	U.S.C.S.	W%	Coarse Granular Soils: Range Size / Grain Shape; Core Run / Rec. / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0									Terra Tec Piezom. installed @ 47.5'
48.5					End of Boring @ 48.5'				

GAI-427 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-491

PROJECT: CEI Perry Nuclear Power Plant W.O. 4549-00 SITE AREA: Perry, Ohio
CONTRACTOR: Hexton
DRILLER: L. Humphrey
CLASSIFIED BY: R.V.
COORDINATES: N 781,275.1 E 2,369,577
DATE: 6/27-6/28/72
SHEET 1 OF 1
DRILL HOLE NO. WP3-C
ELEVATION 619.4
GRL 0 HRS.
24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	%	Coarse Granular Soils: Range Size / Core	Grain Shape / Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
												Terra-Tec Piezom. installed @ 64.5'
							End of Boring @ 65.5'					

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-492

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA: N. Perry, Ohio
CONTRACTOR: Hexton
DRILLER: John
CLASSIFIED BY: D.B.S.
COORDINATES: N 780,889.9 E 2,370,197
DATE: 6-8-72
SHEET 1 OF 3
DRILL HOLE NO. WP-4A
ELEVATION 619.7
GRL 0 HRS.
24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	%	Coarse Granular Soils: Range Size / Core	Grain Shape / Rec.	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
												Terra-Tec Piez. installed @ 64.0'
	1	2	3	5			Grey silty clay & interbedded v.f. sand, trace of red clay & RF (1/16"), moist, soft-firm, stratified					
	2	3	4				Same, moist - wet					

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-493

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Horxon
DRILLER: John
CLASSIFIED BY: D.B.S.
DATE: 6-8-72
SHEET 2 OF 3
DRILL HOLE NO. UP-4A
ELEVATION
GWL 0 HRS.
24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	Gp	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
				5								
	3	3	4	6			Same. HF max. ¼"	CL				
							UPPER TILL					
	4	7	11	20			Gray silty clay, 5-10% HF, mostly coarse sand, hard-stiff, moist	CL				
							? ? LOWER TILL					
	5	15	29	40			Gray silty clay, 10-15% HF, hard, damp	CL				
							Boulder Zone					

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-494

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio
CONTRACTOR: Horxon
DRILLER: John
CLASSIFIED BY: D.B.S.
DATE: 6-8-72
SHEET 3 OF 3
DRILL HOLE NO. UP-4A
ELEVATION
GWL 0 HRS.
24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	% Rec.	RQD	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
							Soft weathered shale & clay			58	54	
							TOTAL DEPTH 65.0					

GAI-227 12/68

2E-495

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. HP-4B

CONTRACTOR: Herron

COORDINATES N 78[illegible]
E 2,370,194.8

ELEVATION 620.0

DRILLER: Larry

GWL 0 HRS ____

24 HRS ____

CLASSIFIED BY: D.B.S.

DATE: 6-12-72

Depth Ft.	Sample No.	SPT Blows 6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	GP	Coarse Granular Soils: Range Size / Core Run	Coarse Granular Soils: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0										Start 8 a.m. 12 June - 8½ hrs. Finish 9 a.m. 13 June - 2 hrs. Total Time - 10½ hrs.
10										Terra Tec Piezom. installed @ 48.0'
20										
30										
40										
49.0					End of Boring @ 49.0'			49.0'		
50										

GAI-327 10/68

2E-496

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA N. Perry, Ohio

SHEET 1 OF 1

DRILL HOLE NO. HP-4C

CONTRACTOR: Herron

COORDINATES N 780,879.9
E 2,370,192.7

ELEVATION 620.4

DRILLER: Larry

GWL 0 HRS ____

24 HRS ____

CLASSIFIED BY: D.B.S.

DATE: 6-13-72

Depth Ft.	Sample No.	SPT Blows 6 in. (6 / 12 / 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	GP	Coarse Granular Soils: Range Size / Core Run	Coarse Granular Soils: Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0										Start 9 a.m. 13 June - 4:30 = 7 Piezometer installation Finish 7-8 a.m. 14 June ½ hrs. Total
10										Terra Tec Piezom. installed @ 31.5'
20										
30										
32.5					End of Boring @ 32.5'			32.5'		
40										

GAI-327 10/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-497

CEI - Perry Nuclear

PROJECT: Power Plant W.O. 4549-00 SITE AREA Perry, Ohio

CONTRACTOR: Herron COORDINATES N 780,469.6 E 2,370,672.4

DRILLER: L. Humphrey

CLASSIFIED BY: D.B.S. DATE: 6-16-72

SHEET 1 OF 1

DRILL HOLE NO. WP5-A

ELEVATION 623.3

GWL 0 HRS.

24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	qu	Coarse Granular Soils: Range Size / Grain Shape; Core: Run / Rec. / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0									Start 8:00 a.m. 14 June Tarra Tec Piezometer installed @ 63.0'
64.0					End of Boring @ 64.0'			64.0'	

GAI-227 12/68

GILBERT ASSOCIATES, INC.
SOIL CLASSIFICATION SHEET

2E-498

CEI - Perry Nuclear

PROJECT: Power Plant W.O. 4549-00 SITE AREA Perry, Ohio

CONTRACTOR: Herron COORDINATES N 780,470.1 E 2,370,666.9

DRILLER: L. Humphry

CLASSIFIED BY: R.P.V. DATE: 6-16-72

SHEET 1 OF 1

DRILL HOLE NO. WP5-B

ELEVATION 623.3

GWL 0 HRS.

24 HRS.

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	In. Rec.	Profile	SOIL DESCRIPTION Density (or Consistency), Color Soil Type - Accessories	U.S.C.S.	qu	Coarse Granular Soils: Range Size / Grain Shape; Core: Run / Rec. / Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0									Tarra Tec Piezometer installed @ 50.0'
51.0					End of Boring			51.0'	

GAI-227 12/68

GILBERT ASSOCIATES, INC. 2E-499
SOIL CLASSIFICATION SHEET

PROJECT: CEI - Perry Nuclear Power Plant W.O. 4549-00 SITE AREA Perry, Ohio SHEET 1 OF 1
CONTRACTOR: Herron COORDINATES N 780,470.3 E 2,370,661.5 DRILL HOLE NO. NP5-C
DRILLER: L. Humphry ELEVATION 623.2
CLASSIFIED BY: R.P.V. DATE: 6-20-72 GWL 0 HRS ____ 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	In. Rec.	Profile	Soil Description: Density (or Consistency), Color, Soil Type - Accessories	U.S.C.S.	Qu	Coarse Granular Soils: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0										Terra Tec Piezom. installed @ 32.0'
10										
20										
30										
					End of boring @ 33.0'			330		

GAI-227 12/68

GILBERT ASSOCIATES, INC. 2E-500
SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: Perry Nuclear Power W.O. 04-4549 SITE AREA North Perry, Ohio SHEET 1 OF 2
CONTRACTOR: Herron COORDINATES N49350 E9150 DRILL HOLE NO. PT-1
DRILLER: Sezwyck ELEVATION 620.40
CLASSIFIED BY: Woodward/Clyde DATE: 2/3/75 GWL 0 HRS ____ 24 HRS 4'2"

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	Description: Density (or Consistency), Color, Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	Remarks: Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					LACUSTRINE Firm brown and gray mottled silty clay, trace firm sand	CL				
	1	7								
5					LACUSTRINE Soft to firm gray varved clayey silt, silty clay and fine silty sand	ML CL SM				
	2	4								
10		SHELBY								
15	3	10								
		SHELBY			UPPER TILL Stiff gray silty clay, little to some coarse to fine sand size rock fragments	CL				
	4	13								
20		SHELBY								
25	5	14								
	6	19								
30										
		SHELBY								
35	7	18								
40	8	50			LOWER TILL Hard gray silty clay/clayey silt, some coarse to fine sand size and fine gravel size rock fragments	CL ML				
	9	43								
45	10	46								
50										

GAI-227 8/72

2E-501

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 2

PROJECT: Perry Nuclear Power W.O. 04-4549 SITE AREA North Perry, Ohio DRILL HOLE NO. PT-1

CONTRACTOR: Herron COORDINATES N49350 E9150 ELEVATION 620.40

DRILLER: Sezwyck GWL 0 HRS

CLASSIFIED BY: Woodward/Clyde DATE: 2/3/75 24 HRS 4'2"

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50					Deeply weathered gray shale					
	"	50/1/2"			CHAGRIN SHALE					
55					Gray shale with irregular laminations of siltstone and sandy siltstone. All fractures parallel to flat bedding. Slightly weathered to 56 feet.		0	4	3.3	
60							15	10	9.1	
65							0	2	2	
70					T.D. 68					
75										

GAI-227 9/72

2E-502

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 2

PROJECT: Perry Nuclear Power W.O. 04-4549 SITE AREA North Perry, Ohio DRILL HOLE NO. PT-1A

CONTRACTOR: Herron COORDINATES N49338 E9150 ELEVATION 620.4

DRILLER: Sezwyck GWL 0 HRS

CLASSIFIED BY: Woodward/Clyde DATE: 2/18/75 24 HRS 4'2"

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0										
5					Wash Boring to 39.5 ft. without sampling.					
10										
15										
20										
25										
30										
35										
40		SHELBY		39.5	LOWER TILL Hard gray silty clay/clayey silt, some coarse to fine sand size rock fragments	CL ML				
45										
50		SHELBY								

GAI-227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-503

SHEET 2 OF 2

PROJECT: Perry Nuclear Power G.O. 04-4549 SITE AREA North Perry, Ohio

DRILL HOLE NO. PT-1A

CONTRACTOR: Herron COORDINATES N49338 E9150

ELEVATION 620.4

DRILLER: Sezwyck

GWL 0 HRS

CLASSIFIED BY: Woodward/Clyde DATE: 2/18/75

24 HRS 4'2"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
	1	37	21	1.5"								
							T.D. 51.5					

GAI-227 9/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-504

SHEET 1 OF 2

PROJECT: Perry Nuclear Power G.O. 04-4549 SITE AREA North Perry, Ohio

DRILL HOLE NO. PT-2

CONTRACTOR: Herron COORDINATES N49350 E9800

ELEVATION 622.06

DRILLER: Sezwyck

GWL 0 HRS

CLASSIFIED BY: Woodward/Clyde DATE: 2/16/75

24 HRS 6'5"

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0	1			14			LACUSTRINE					
							Firm orange-brown and gray mottled silty clay, clayey silt and silty fine sand	CL ML SM				
5	2			8								
	3			7		6.5						
							LACUSTRINE					
							Firm to stiff gray varved clayey silt, sandy silt and silty fine sand	ML SM				
10	SHELBY											
	4			13								
15	5			19								
	SHELBY											
20	6			25								
	7			17								
25	SHELBY					25.5						
							UPPER TILL					
	8			5			Soft to firm gray silty clay, trace to little coarse to fine sand size and fine gravel size rock fragments					
30	9			6								
	SHELBY											
35	10			16		35.2						
							LOWER TILL					
	11			53			Hard gray silty clay/clayey silt, some coarse to fine sand size and fine gravel size rock fragments					
40	12			67								
	13			67								
45	14			77								
50												

GAI-227 9/72

2E-505

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: Perry Nuclear Power J.O. 04-4549 SITE AREA: North Perry, Ohio
CONTRACTOR: Herron COORDINATES: N49350 E9800
DRILLER: Sezwyck
CLASSIFIED BY: Woodward/Clyde DATE: 2/16/75

SHEET 2 OF 2
DRILL HOLE NO. PT-2, 2A
ELEVATION 622.06
GWL 0 HRS
24 HRS 6'5"

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50	15	63								
55					Note: offset boring PT-2A located 5 feet north of PT-2. Obtained undisturbed sample from 7.0-9.0 feet.					
60										
65										

GAI - 227 2/72

2E-506

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: Perry Nuclear Power J.O. 04-4549 SITE AREA: North Perry, Ohio
CONTRACTOR: Herron COORDINATES: N49920 E9500
DRILLER: Sezwyck
CLASSIFIED BY: Woodward/Clyde DATE: 2/6/75

SHEET 1 OF 2
DRILL HOLE NO. PT-3
ELEVATION 607.43
GWL 0 HRS
24 HRS 2'6"

Depth Ft.	Sample No.	SPT Blows/6 in. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					LACUSTRINE					
	1	6			Firm orange-brown and gray mottled fine sandy silty clay and silty fine sand	CL SM				
5	2	14								
		SHELBY			Firm gray varved fine sandy silt and silty find sand	ML SM				
10	3	27								
	4	14		14.5						
15		SHELBY			UPPER TILL					
	5	14			Firm gray silty clay, little coarse to fine sand size rock fragments	CL				
20	6	7								
				24.5						
25	7	49			LOWER TILL					
	8	43			Hard gray silty clay/clayey silt, some coarse to fine sand size and fine gravel size rock fragments					
30										
	9	74								
35										
	10	190/6.5"			Rock fragments becoming more abundant with depth					
40										
	11	181/9"		43.2	CHAGRIN SHALE					
45	12	139/6"		46.2	Soft gray weathered shale					
					Gray thinly interbedded shale and light gray siltstone					
50										

GAI - 227 2/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-507

SHEET 2 OF 2

PROJECT: Perry Nuclear Power P.O. 04-4549 SITE AREA North Perry, Ohio
CONTRACTOR: Herron COORDINATES N49920 E9500
DRILLER: Serwyck
CLASSIFIED BY: Woodward/Clyde DATE: 2/6/75

DRILL HOLE NO. PT-3
ELEVATION 607.43
GWL 0 HRS
24 HRS 2'6"

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50					Shale same as above		0	6	4.5	
55							16	5	4.6	
60							43	6	5.7	
65							17	4.33	4.0	
70					T.D. 67.33'					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-508

SHEET 1 OF 2

PROJECT: Perry Nuclear Power P.O. 04-4549 SITE AREA North Perry, Ohio
CONTRACTOR: Herron COORDINATES N48556 E9468
DRILLER: Serwyck
CLASSIFIED BY: Woodward/Clyde DATE: 2/24/75

DRILL HOLE NO. PT-4
ELEVATION 623.24
GWL 0 HRS 3.0
24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0					No sampling from 0-9 ft.					
10	1	10			LACUSTRINE Firm gray varved clayey silt, silty fine sand and fine sandy silt	ML SM				
15	2	8								
		SHELBY								
20	3	22								
	4	21								
25		SHELBY		25						
					UPPER TILL Stiff gray silty clay, trace to little medium to fine sand size rock fragments	CL				
30	5	20								
		SHELBY								
35				35						
	6	32			LOWER TILL Hard gray silty clay/clayey silt, some coarse to fine gravel and sand size rock fragments	CL ML				
40										
		SHELBY								
45										
50		SHELBY								

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-509

SHEET 2 OF 2

PROJECT: Perry Nuclear Power W.O. 04-4549 SITE AREA North Perry, Ohio DRILL HOLE NO. PT-4

CONTRACTOR: Herron COORDINATES N48556 E9468 ELEVATION 623.24

DRILLER: Sezwyck GWL 0 HRS 3.0

CLASSIFIED BY: Woodward/Clyde DATE: 2/24/75 24 HRS

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
50							See Above					
55							T.D. 53					
60												

GAI - 227 3/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-510

SHEET 1 OF 1

PROJECT: Perry Nuclear Power W.O. 04-4549 SITE AREA North Perry, Ohio DRILL HOLE NO. DW-1

CONTRACTOR: Herron COORDINATES N48595.02 E9249.75 ELEVATION 621.24

DRILLER: Sezwyck GWL 0 HRS

CLASSIFIED BY: Woodward/Clyde DATE: 1/28 to 2/2/75 24 HRS 19.34

Depth Ft.	Sample No.	SPT Blows/6 in. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0												
10												
20												
30												
40												
50												
60												Set Pump 62.11 ft. from ground surface
70							T.D. 71.4 ft.					
80												
90												
100												

GAI - 227 3/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-511

SHEET 1 OF 1

PROJECT: Perry Nuclear Power W.O. 04-4549 SITE AREA North Perry, Ohio DRILL HOLE NO. SW-1
CONTRACTOR: Herron COORDINATES N48581.05 E9251.67 ELEVATION 621.80
DRILLER: Sezwyck GWL 0 HRS
CLASSIFIED BY: Woodward/Clyde DATE: 1/75 24 HRS 2.9

Depth Ft.	Sample No.	SPT Blows/6 In. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–22					LACUSTRINE					
					T.D. 22 feet.					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.
SOIL AND ROCK CLASSIFICATION SHEET

2E-512

SHEET 1 OF 1

PROJECT: Perry Nuclear Power W.O. 04-4549 SITE AREA North Perry, Ohio DRILL HOLE NO. OB-1
CONTRACTOR: Herron COORDINATES N48536.32 E9257.83 ELEVATION 622.41
DRILLER: Sezwyck GWL 0 HRS
CLASSIFIED BY: Woodward/Clyde DATE: 1/75 24 HRS 2.84

Depth Ft.	Sample No.	SPT Blows/6 In. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–22.36					LACUSTRINE					Installed observation well
					T.D. 22.36 ft.					

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-513

SHEET 1 OF 1

PROJECT: Perry Nuclear Power W.O. 04-4549 SITE AREA North Perry, Ohio

DRILL HOLE NO. OB-2

CONTRACTOR: Herron COORDINATES N48477.24 E9268.01

ELEVATION 623.36

DRILLER: Sezwyck

GWL 0 HRS

CLASSIFIED BY: Woodward/Clyde DATE: 1/75

24 HRS 3.17

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock (Range Size / Core Run; Grain Shape / Rec. Core)	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0									
10					LACUSTRINE				
20									Installed observation well
					T.D. 22.67 ft.				
30									

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-514

SHEET 1 OF 1

PROJECT: Perry Nuclear Power W.O. 04-4549 SITE AREA North Perry, Ohio

DRILL HOLE NO. OB-3

CONTRACTOR: Herron COORDINATES N48358.70 E9286.66

ELEVATION 623.72

DRILLER: Sezwyck

GWL 0 HRS

CLASSIFIED BY: Woodward/Clyde DATE: 1/75

24 HRS 2.6

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock (Range Size / Core Run; Grain Shape / Rec. Core)	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0									
10					LACUSTRINE				
20									Installed observation well
					T.D. 22.25 ft.				
30									

GAI - 227 8/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

2E-515

PROJECT: Perry Nuclear Power W.O. 04-4549 SITE AREA North Perry, Ohio

CONTRACTOR: Herron COORDINATES N48071.79 E9331.21

DRILLER: Sezwyck

CLASSIFIED BY: Woodward/Clyde DATE: 1/75

SHEET 1 OF 1

DRILL HOLE NO. OB-4

ELEVATION 626.02

GWL 0 HRS

24 HRS 2.43

Depth Ft.	Sample No.	SPT Blows/6 in. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp., Geologic Data, Ground Water, Construction Problems, etc.
0–22.45					LACUSTRINE					Installed observation well
22.45					T.D. 22.45 ft.					

GAI-227 9/72