Geotechnical Report
for the Exelon Generation Company, LLC
Early Site Permit

Site Safety Analysis Report
Appendix A

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Acronyms and Abbreviations

Many of the acronyms and abbreviations listed below are specific to geotechnical terminology in this report and thus may differ from those presented in Appendix A of the Administrative Information for the Exelon Generation Company, LLC, Early Site Permit.

σ_o'	mean confining pressure
γ	shearing strain amplitude
ASTM	American Society for Testing and Materials
bgs	below ground surface
C_c	compression index
C_r	recompression index
CCRR	corrected cyclic resistance ratio
CEUS	central and eastern United States
CFR	Code of Federal Regulations
CIU	isotropically consolidated-undrained
COL	combined operating license
CPS	Clinton Power Station
CPT	cone penetrometer testing
CRR	cyclic resistance ratio
CSR	cyclic stress ratio
D	damping ratio
EGC	Exelon Generation Company
ER	environmental report
ERTS	Earth Resources Technology Satellite
ESP	Early Site Permit
fps	feet per second
FOS	factor of safety
ft	foot/feet

g	acceleration of gravity
G	shear modulus
G/G_{max}	shear modulus ratio
GPS	global positioning system
GRL	GRL Engineers
in.	inch/inches
ISGS	Illinois State Geological Survey
ksf	kips per square foot
LL	liquid limit
LLC	Limited Liability Company
M	earthquake magnitude
MSF	magnitude scaling factor
mi	mile/miles
msl	mean sea level
NMFZ	New Madrid Fault Zone
OBE	Operating Basis Earthquake
P200	percentage of soil finer than the No. 200 sieve
P_c'	preconsolidation
pcf	pounds per cubic feet
pci	pounds per cubic inch
pga	peak ground acceleration
PI	plasticity index
PL	plastic limit
psf	pounds per square foot
psi	pounds per square inch
PVC	polyvinyl chloride
Q	unconfined compression
RQD	rock quality designation
SPT	standard penetration test
SSAR	site safety analysis report

SSE	safe shutdown earthquake
TSC	Testing Service Corporation
tsf	tons per square foot
UHS	ultimate heat sink
USAR	updated safety analysis report
USCS	United Soil Classification System
USGS	Unites States Geological Survey
USNRC	United States Nuclear Regulatory Commission
UU	unconsolidated-undrained
Vs	shear wave velocity
Vp	compression wave velocity
WGS	World Geodetic System
WUS	western United States

CHAPTER 1

Introduction

This Geotechnical Report was prepared as part of the Application for the Exelon Generation Company (EGC), Limited Liability Company (LLC), Early Site Permit (ESP). The EGC ESP Site is located adjacent to the operating Clinton Power Station (CPS) Site, in the center of the State of Illinois, approximately 10 miles (mi) east of the City of Clinton, Illinois. The work carried out for the EGC ESP application included geotechnical field explorations, laboratory testing, and engineering evaluations. This Geotechnical Report documents the methods, results, and interpretations of this work. Information contained in this Geotechnical Report is used as: (1) a basis for preparing sections in both the Site Safety Analysis Report (SSAR) and in the Environmental Report (ER) for the Application for the EGC ESP and (2) input to seismic hazards work completed for the EGC ESP Site. The seismic hazards work is summarized in Section 2.5 of the SSAR and discussed in detail within Appendix B of this SSAR.

1.1 Purpose, Approach, and Scope

The EGC ESP requires that geotechnical conditions at the EGC ESP Site be described and evaluated relative to requirements within the regulatory framework for an ESP. The purpose, approach, and scope of work that were performed to address these ESP requirements are summarized below.

1.1.1 Purpose

The primary purpose of the geotechnical work described in this Geotechnical Report is to demonstrate that geologic and geotechnical conditions at the EGC ESP Site are suitable for the future development of a reactor plant design. The following two conditions are required to demonstrate EGC ESP Site suitability:

- There are no geologic hazards that could affect the construction and operation of the facility. These geologic hazards could include potentially unstable slopes, active faults, or underground cavities.
- Relevant geotechnical site characteristics have been appropriately quantified. These site characteristics include static and dynamic soil properties, and specifically include liquefaction potential, bearing capacity, and shear wave velocity. Geotechnical site characteristics have been evaluated by the recent EGC ESP Site investigation, and by demonstration of consistency of the geotechnical soil properties at the EGC ESP Site with those at the CPS Site, as presented in Section 2.5 of the CPS USAR (CPS, 2002). Figure 1-1 shows the locations of the EGC ESP and CPS Sites.

The purpose of the geotechnical work described in this Geotechnical Report was not, however, to provide sufficient information to finalize the design and construction requirements for future development at the EGC ESP Site. Additional vendor-specific investigation activities may be required once a reactor plant design is selected.

1.1.2 Approach

The approach taken during the planning and performance of geotechnical work for the EGC ESP Site relies heavily on the extensive geotechnical database developed for the CPS Site. This existing database is found in the CPS USAR (CPS, 2002).

Significant numbers of field explorations, laboratory tests, and geotechnical studies were performed in the mid-1970s for design and construction of the CPS Facility, as reported in the CPS USAR. The EGC ESP Site is approximately 700 feet (ft) southwest of the CPS Site. Section 2.5 of the CPS USAR indicates that the geologic conditions are consistent within this distance. On this basis, the extensive geotechnical database for the CPS Site is considered applicable to the EGC ESP Site. A geotechnical program was developed to collect sufficient information at the EGC ESP Site to assess the similarity of conditions between the CPS and EGC ESP Sites. Field explorations and laboratory testing programs that would allow direct comparisons of data collected at the EGC ESP Site with the CPS Site database were developed and performed.

The approach to this geotechnical engineering work was also developed to address advances in soil testing that have occurred since the original geotechnical work was completed for the CPS Site. One of the primary areas of development over the past 30 years has been the characterization of the dynamic properties of soils. New methods of in situ dynamic property measurement and laboratory cyclic (dynamic) testing became available in the 1980s and 1990s. These new methods allow more accurate determination of shear wave velocity in situ and better determination of the variation of shear modulus and material damping properties of soil with shearing strain amplitude. Both developments enable higher quality site response modeling to be carried out during seismic ground response evaluations (that is, determination of time histories and response spectra at the ground surface).

1.1.3 Scope

The scope of the geotechnical work completed for the EGC ESP includes the following activities:

- Review of geologic and geotechnical information summarized in Section 2.5 of the CPS USAR, as well as more current site-related literature available since the preparation of the CPS USAR;
- Field explorations consisting of soil drilling, rock coring, sampling of soil and rock, cone penetrometer testing (CPT) soundings, and shear wave velocity measurements using CPT and in-hole geophysical logging methods;
- Laboratory tests to evaluate physical soil properties, static properties, and dynamic properties of representative soils from the site; and
- Engineering studies to evaluate the liquefaction potential of cohesionless soil layers located below the groundwater table and to assess typical foundation design conditions such as bearing capacity, settlement characteristics, and lateral earth pressures.

When the scope of work was developed for the EGC ESP Site, the geotechnical requirements for an ESP versus the requirements for the combined operating license (COL) stage were

evaluated. A basic difference in concept between an ESP and the COL stage was identified, which affected the scope of geotechnical work developed for the EGC ESP Site. In contrast to the COL stage, an ESP involves an evaluation of the site characteristics relative to the requirements of a number of different potential reactor plant designs. These reactor plant designs differ in terms of size, loads, and geometry. As an example of these differences, the base of the power block could range from 30 ft bgs to over 100 ft bgs, depending on the particular vendor. Since the reactor plant design will not be selected until the future, specific geotechnical criteria required for the design of the specific reactor plant design structure are unknown at the time of this report (2003). Once the reactor plant design is selected, then additional geotechnical studies, including field explorations and laboratory testing, may be required to provide unit-specific design information.

This difference between an ESP and the COL stage led to the development of a scope of work which focused on confirming that geotechnical site characteristics at the EGC ESP Site are consistent with those previously determined for the CPS Site. The scope of the explorations, laboratory testing, and engineering evaluations was less for this confirmation work than would be expected for a green-field development. More attention was given to confirmation that the same soil layering with the same soil properties exists at the EGC ESP Site as exists at the CPS Site. Information normally needed for final design of foundations was deferred until the COL stage, when a specific reactor plant design with known dimensions and weights will be selected. Whether additional explorations and laboratory testing will be required for the COL stage depends on the foundation design requirements for the selected system. This decision will consider the importance of soil-property variation to system performance and the apparent margin in performance for the selected system in light of the potential soil-property variation.

1.2 Investigation Planning and Regulatory Guidance

The EGC ESP Site geotechnical investigation was planned and performed in accordance with guidance in the following two documents:

- Regulatory Guide 1.132: *Site Investigations for Foundations of Nuclear Power Plants* (USNRC, 1979).
- Regulatory Guide 1.138: *Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants* (USNRC, 1978).

These regulatory guides were developed for use in the planning of subsurface investigations for design and licensing of nuclear power plants. The EGC ESP Site investigation is not intended to provide all information sufficient for facility design, but rather to confirm that the site is suitable for future development. Therefore, not all of the guidance provided in these regulatory guides is applicable to the EGC ESP Site. Relevant guidance from these documents, such as subsurface investigation methods, sample collection and preservation procedures, and laboratory procedures, has been followed. Since the reactor plant design has not been selected or configured, other guidance in these documents is not applicable for the EGC ESP, such as the spacing and depth of penetration of geotechnical boreholes beneath Class I Structures. This information will be developed and provided as part of the COL stage.

The following draft regulatory guides were also reviewed during planning of the EGC ESP Site geotechnical investigation:

- Draft Regulatory Guide 1101: *Site Investigations for Foundations of Nuclear Power Plants* (proposed Revision 2 of Regulatory Guide 1.132)(USNRC, 2001a).
- Draft Regulatory Guide 1105: *Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites* (USNRC, 2001b).
- Draft Regulatory Guide 1109): *Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants* (proposed Revision 1 of Regulatory Guide 1.138) (USNRC, 2001c).

As with the regulatory guides, not all of the guidance in the draft guides is applicable to the EGC ESP Site geotechnical investigation. Relevant guidance from the draft guides was considered while planning the EGC ESP Site geotechnical investigation, but guidance in the regulatory guides was given primary consideration where guidance differed between the regulatory guides and the draft guides.

Geotechnical Report for the EGC Early Site Permit

Figure 1-1
EGC ESP And CPS Site Locations Map

Legend

Approximate CPS Site Footprint
EGC ESP Site Footprint

N

Feet
0 300 600 1,200

CHAPTER 2

Existing Information

This chapter provides a summary of information that can be found in the CPS USAR for the CPS Site. The CPS USAR includes information on the regional and site geology, results of field explorations, results of laboratory tests on soil samples from the CPS Site, observations associated with the excavation and backfill work done during construction of the CPS facility, and information on the response of soil and rock to static and dynamic loading. The EGC ESP Site is approximately 700 ft from the CPS Site and the geologic conditions are similar at both sites; therefore, the geologic and geotechnical data for the CPS Site is relevant to conditions at the EGC ESP Site.

2.1 Site Surficial Conditions

Ground surface topography in the vicinity of the CPS Site is relatively flat, ranging from approximately 730 to 740 ft above mean sea level (msl). The CPS Site is occupied by the operating facility and support structures, as well as numerous gravel and paved roadways and parking structures. Clinton Lake is located adjacent to the CPS Site to the northwest.

2.2 Regional and Site Geology

The regional and site geology for the CPS Site is fully described in Sections 2.5.1, 2.5.2, and 2.5.3 of the CPS USAR. The summary of information presented in this section of the Geotechnical Report supports interpretations of the geologic conditions at the EGC ESP Site discussed in Chapter 5.

2.2.1 Regional Physiography

The region of the United States in which the CPS Site is located is part of the Till Plains Section of the Central Lowland Physiographic Province (see the CPS USAR, Section 2.5.1.1.1). Terrain in central Illinois and adjacent Indiana is typical of the province, and it consists of undulating, low-relief topography formed by a glacial drift cover that ranges in thickness from a few tens of feet to several hundreds of feet. Much of the Till Plains Section is characterized by landforms of low, commonly arcuate ridges, called moraines, interspersed with relatively flat intermorainal areas. Postglacial stream development has dissected the drift mantle and, in some areas along the main valleys, preglacial bedrock has been exposed by erosion. However, there are no bedrock exposures near the site area.

2.2.2 Regional Stratigraphy

As discussed in Section 2.5.1.1.2 of the CPS USAR, the regional surface geology is dominated by relatively thin deposits of Quaternary glacial drift. During the Quaternary, widespread glacial deposition occurred in the regional area as a result of continental glaciation. The resulting Quaternary deposits are classified as part of the Pleistocene Series.

The deposits consist predominantly of glacial or glacially-derived sediments of glacial till, outwash, loess (a wind-blown silt), and glaciolacustrine deposits, as well as alluvium.

There were four major periods of glaciation during the Pleistocene time in the regional area that resulted in the surface geology. From youngest to oldest, these periods are known as the Wisconsinan, Illinoian, Kansan, and Nebraskan Stages. Wisconsinan deposits are found near ground surface throughout the region. Illinoian age deposits are present beyond the limit of Wisconsinan glaciation in northern and central Illinois. Illinoian age deposits are also found beneath the Wisconsinan drift cover. Kansan and Nebraskan age glacial deposits are present at the surface and in the subsurface in areas of Iowa, Missouri, and parts of western and east-central Illinois.

Most of the regional Quaternary glacial materials are underlain by thick sequences of gently dipping (25 ft per mi) Paleozoic sedimentary rock, although Mesozoic and Cenozoic age deposits lie above Paleozoic rock in a few areas in the Mississippi Embayment, western Illinois, eastern Missouri, and southern Indiana. The bedrock surface throughout much of Illinois is of the Paleozoic age, Pennsylvanian system, and ranges from hundreds to thousands of feet in thickness. The Paleozoic sedimentary rock sequence is punctuated by several non-conformities of regional importance, reflecting widespread advances and withdrawals of the Paleozoic seas across the interior of North America.

Older Paleozoic bedrock of Mississippian, Devonian, Silurian, Ordovician, and Cambrian Systems underlay Pennsylvanian bedrock. These underlying Paleozoic systems range from hundreds to thousands of feet in thickness, and consist primarily of shales, limestones, and sandstones. The thickness of bedrock sequences is dependant on original deposition and subsequent erosion, and Paleozoic bedrock is significantly thicker at the center of structural basins such as the Illinois Basin. Beneath the Paleozoic is a basement complex of Precambrian igneous and metamorphic rock. Basement Precambrian igneous rock ranges from 2,000 to 13,000 ft bgs.

2.2.3 Regional Structural Geology

The North Central United States is one of the more stable areas of the United States (see the CPS USAR, Section 2.5.2.1.1). The dominant structures of the regional area and vicinity are the Illinois Basin and its bounding structures. The Illinois Basin is an oval-shaped basin in southeastern Illinois with the axis of the basin is approximately 350 mi long, and the minor axis is approximately 250 mi long. The deepest part of the basin in southeastern Illinois has sediments that are 12,000 to 14,000 ft thick. This basin is surrounded by and contains structural arches, embayments, fault zones, and anticlines. Locally, folds and faults are superimposed across the region. Predominant among these is the LaSalle Anticline, located approximately 40 mi of the CPS Site (see Figure 2-1).

The Illinois Basin and other regional structural features typically formed during intermittent slow subsidence and gentle uplift through the Paleozoic. The erosion of most of the upper portion of the Paleozoic and overlying geologic record does not allow precise dating of the end of formation of some of the regional structural features. However, there is no evidence that faulting, folding, or other structural sediments continued during the Pleistocene.

2.2.4 Site Physiography

The site lies within the Bloomington Ridged Plain physiographic subsection of the Till Plains Section, as summarized in the CPS USAR, Section 2.5.1.2.1 (and shown in Figure 2-2). The CPS Site is located in an area of uplands, consisting of Wisconsinan-age ground moraine that have been dissected by the Salt Creek and the North Fork of the Salt Creek. The uplands consist of gently rolling ground moraine, located just east of the Shelbyville end moraine, with local relief of about 10 ft, except near the drainage ways. Average elevation of the uplands is approximately 740 ft above msl.

Two perennial streams, Salt Creek and North Fork of the Salt Creek, are present near the CPS Site. The two streams join in the southern portion of the Site area. The two streams flow generally to the southwest with gradients of 2 to 3 ft per mi in the site area. They have eroded through the upland deposits of the Wisconsinan-age Wedron Formation and Robein Silt, the Illinoian-age weathered Glasford Formation, and into the upper part of the Illinoian-age unaltered Glasford Formation. The elevation of the floodplains of the two streams in the area is at approximately 660 ft above msl. Maximum relief in the area is on the order of 80 ft.

2.2.5 Site Geology

Near the CPS Site, approximately 170 to 360 ft of Quaternary deposits overlie an irregular Pennsylvanian bedrock surface that is largely erosional in origin and characterized by valleys (such as the Mahomet Bedrock Valley) and uplands that developed before glacial time (see the CPS USAR, Section 2.5.1.2.2). The CPS Site is located a few miles inside the extent of Wisconsinan glaciation (see Figure 2-2). Surficial deposits in the upland areas consist of a veneer of Richland Loess over glacial till of the Wedron Formation, both of the Woodfordian substage of the late Wisconsinan Stage. Other stratigraphic units in the upland area, with increasing depth, consist of the organic Robien silt (of the Farmdalian substage of the Wisconsinan Stage), an Interglacial zone consisting of weathered Glasford Formation glacial till deposited during the Illinoian Stage (also referred to as the Sangamonian Interglacial Zone on CPS Site borehole logs), and unweathered Glasford Formation till. Beneath the Glasford Formation lie Yarmouthian Stage lacustrine deposits and pre-Illinoian Stage glacial tills (see Figure 2-3).

In areas of low bedrock elevation in the vicinity, sandy glacial outwash of the Kansan Stage (likely the Mahomet Sand Member of the Banner Formation) are present above bedrock. However, because of a local bedrock high, the Mahomet sands are not present at the CPS Site. Rather, fine-grained alluvial soils associated with pre-Illinoian glaciations are typically present in immediate contact with bedrock in the area.

Bedrock in the vicinity of the CPS Site is of the Pennsylvanian system, and belongs to the Bond and Modesto Formations of the McCleansboro Group (see Figure 2-4). These formations generally consist of alternating bands of limestone, shale, siltstone, sandstone, and some coal seams. The base of the Bond Formation is marked by the Shoal Creek Limestone Member, which corresponds to the top of the Modesto Formation at an approximate elevation of 495 ft above msl at the CPS Site. The No. 8 Coal Member within the Modesto Formation was encountered as a 1-ft thick layer at borehole P-38 during the original CPS Site investigation (at an elevation of 431 ft above msl).

2.2.6 Site Structural Geology

The CPS Site is located in a tectonically stable area of North America. Although the CPS Site is within several miles of structural features, there is no evidence for surface faulting at the CPS Site or the area surrounding the CPS Site within a 25-mi radius. No faulting has been recognized in association with the foregoing structural features either from aerial photographs, Earth Resources Technology Satellite (ERTS) imagery, geophysical studies, borehole control, or excavation mapping. The glacial materials are devoid of lineaments or off-sets suggestive of faulting.

Borehole data show no tectonic folding or faulting in the Pleistocene deposits exposed in the excavations at the CPS Site, including the Robein Silt. Even if the bedrock unit elevation differences could be attributed to structural deformation, the relatively flat-lying and un-deformed Pleistocene drift overlying bedrock demonstrates that the stresses which would have been responsible for the deformation have been inactive since at least pre-Pleistocene time. The bedrock surface is an erosional surface, and in the CPS Site area there is no general relationship between Paleozoic structures and bedrock topography. Structure cannot, therefore, be inferred from bedrock topography. Further, faults which have been mapped in Illinois have shown no sign of movement during Quaternary time (see the CPS USAR, Section 2.5.1.2.3).

2.3 Geotechnical Explorations

Geotechnical investigations were performed to support design and construction of the CPS Facility. These investigations included traditional geotechnical drilling and sampling investigations, as well as seismic surveys (both downhole and surface methods). The scope of these investigations is presented in Section 2.5 of the CPS USAR.

2.3.1 Drilling and Sampling

A total of 76 geotechnical soil boreholes were advanced to various depths within the vicinity of the plant site bounded by Clinton Lake. These include 55 power block (P-series) boreholes, ten of which extended to bedrock. These explorations were advanced in an approximately 0.5 mi square area encompassing the existing CPS Facility and the peninsula of land currently surrounded by Clinton Lake. A few of these P-series boreholes were advanced at locations that are now flooded after the construction of the dam across Salt Creek. An additional 21 boreholes (AH-series) were advanced in the area southwest of the P-series boreholes. In addition to these samples, in the vicinity of the plant site, other boreholes were advanced within the ultimate heat sink (UHS), dam site, dam borrow area, and at several observation well locations. Generally, rotary wash or continuous-flight auger drilling methods were used for these boreholes. Figure 2-5 shows the locations of boreholes advanced near the CPS Site, as reported in the CPS USAR. Figure 2-6 shows the general southwest to northeast stratigraphic cross-section through the CPS Site as reported in the CPS USAR.

Geotechnical samples were collected from each of the CPS Site boreholes at various depths. Disturbed samples were collected during the investigation via standard penetration tests (SPTs), and undisturbed samples were collected with a Pitcher-tube sampler, a double-tube core sampler, a Shelby tube sampler, an Osterberg sampler, and a proprietary Dames and

Moore sampler. Rock coring was conducted in the upper Pennsylvanian bedrock at 12 P-series borehole locations. NX double-tube core barrel samplers were used to collect 2-inch (in.) diameter rock cores at these locations.

2.3.2 Seismic Surveys

Seismic surveys were conducted at the plant site and are described in Section 2.5.4.4 of the CPS USAR. Five different types of surveys were conducted. A seismic wave refraction survey evaluated overburden and bedrock compressional wave velocity. An uphole survey further evaluated overburden compressional wave velocities. A downhole survey evaluated shear wave velocities of overburden and bedrock. A surface wave survey and an ambient noise survey were also conducted.

Interpreted subsurface compressional wave velocity profiles from the seismic wave refraction survey are included in Figures 2.5-359 through 2.5-365 of the CPS USAR. Uphole survey results from the three test locations are included in Figures 2.5-366 through 2.5-368. One of these surveys was performed at plant site borehole P-14. Downhole surveys were performed at the same three locations for the uphole surveys (including at P-14). Results of the downhole surveys are included in Figures 2.5-369 through 2.5-371.

2.4 Laboratory Testing

A comprehensive set of geotechnical tests was performed on samples from numerous site boreholes during the work prior to construction, as well as on samples collected as part of the construction quality control program during the CPS Facility construction. These include strength tests, dynamic tests, and other physical tests as described in Section 2.5.4.2 of the CPS USAR. Specific tests performed on these samples are summarized below.

2.4.1 Strength Tests

Static strength tests were performed on numerous representative soil samples and are reported in Section 2.5.4.2.1 of the CPS USAR. Tests included unconfined compression, unconsolidated-undrained (UU) triaxial shear, consolidated-undrained triaxial shear (some with pore pressure measurement), and direct shear. Results of these tests are reported in Tables 2.5-6 through 2.5-17 of the CPS USAR, and are also summarized on the CPS USAR borehole logs. Strength tests were performed on samples from each stratigraphic unit encountered in the P-series boreholes. Unconfined compression tests were also performed on representative rock core samples.

2.4.2 Dynamic Tests

Dynamic tests were performed on various soil and rock samples from the plant site, dam site, and the UHS area and are described in Section 2.5.4.2.2 of the CPS USAR. Tests included dynamic triaxial shear tests, resonant column tests, and shockscope tests. The cyclic triaxial shear tests provided data on the strain-dependent shear modulus and soil damping values of the samples. Resonant column tests provided data on the shear modulus of the samples. Shockscope tests provided data on the compressional wave velocity of the samples.

Cyclic triaxial tests were performed on P-series borehole sample from each of the major soil stratigraphic units encountered at the site. Resonant column and shockscope tests were generally performed only on stratigraphic units left in place after construction (Illinoian and pre-Illinoian Stage deposits, plus Pennsylvanian bedrock), as well as on remolded samples used for structural fill. Results of the cyclic and dynamic tests are included in Tables 2.5-18 through 2.5-30 of the CPS USAR.

2.4.3 Other Physical Tests

Various other tests were performed on site samples, as reported in Section 2.5.4.2.3 of the CPS USAR. Tests included Atterberg limits, one-dimensional consolidation, in situ moisture, in situ dry density, and permeability, each of which was performed on samples from each major stratigraphic unit encountered in the P-series boreholes. Relative density tests were performed on Mahomet Bedrock Valley granular deposits (not encountered in the P-series boreholes), and chemical tests were performed on groundwater samples and on No. 8 and No. 7 coal samples.

Numerous other physical tests were performed on fill and foundation soils as part of the quality control program during CPS Facility construction, as reported in Section 2.5.4.2.6 of the CPS USAR. These tests included liquefaction (on granular fill), Atterberg limits, compaction and relative density, in situ moisture and dry density, and particle size analyses.

2.5 Clinton Power Station Facility Foundation Excavation and Backfill

A summary of the excavation, subgrade treatment, and backfill activities performed during construction of the CPS Facility main power station is included in Section 2.5.4.5.1 of the CPS USAR. These activities are briefly summarized below to provide context for the foundation performance analyses conducted for the CPS Facility which are described in Section 2.6 of this report.

2.5.1 Excavation

The excavation for the main power station was performed with heavy earth moving scrapers. The excavation extended to an elevation of between 680 to 683 ft above msl, to locate the subgrade for foundations in the Illinoian till of the unweathered Glasford Formation. The depth of excavation was up to 56 ft, and the horizontal extent of the base of the excavation extended a minimum of 20 ft outside the structure extents. Cut slopes were no steeper than 1:1 (horizontal to vertical).

2.5.2 Dewatering

Dewatering was accomplished by a network of perforated pipes and ditches set along the perimeter of the base of the excavation. Groundwater seepage into the excavation during construction was minimal due to the tight nature of the clayey till soils. Some water was contributed by isolated sand lenses within the till.

2.5.3 Excavation Base Treatment

A comprehensive construction quality control program was implemented to verify a suitable subgrade for foundation construction. The subgrade consisted predominantly of unweathered till, with some local pockets of sand. Native soils in the subgrade that did not meet the construction specifications of 130 pounds per cubic foot (pcf) (for cohesive soils) or relative density of 85 percent (for granular soils) were improved by compaction. Soils that could not be improved were locally excavated and replaced with a cement/fly ash mixture, which was field tested to meet a deflection specification. Figure 2.5-375 of the CPS USAR shows the locations where the subgrade was excavated and replaced.

2.5.4 Structural Fill and Backfill

Compacted granular fill was used to fill the excavation from the subgrade to the foundation elevation. The granular fill was taken from a borrow location approximately 2.25 mi south of the main power station. The borrow was a clean sandy Salt Creek alluvial material. The borrow material was placed in horizontal lifts, and compacted with a smooth-wheel vibratory roller. Relative density and dry density were measured frequently for each 1-ft vertical fill interval as part of the construction quality control program. Of the 4,798 density tests performed, only 175 resulted in relative densities below the specification of 85 percent. Analysis of the distribution of these results indicated that they were well dispersed, and would not adversely affect the foundation performance.

Upon completion of structural fill placement, the monolithic basemat foundation for the main power block was constructed, and building construction commenced. The Salt Creek borrow material was also used as backfill around the structures, and was placed and compacted under the same performance specifications as the subgrade materials. A compacted cohesive material was used as backfill at elevations greater than 720 ft above msl.

2.6 Response of Soil and Rock to Static and Dynamic Loading

The responses of soil and rock to static and dynamic loading for the CPS Facility are presented in Section 2.6.5 of the CPS USAR, and are summarized below. These evaluations considered the liquefaction potential of granular fill and the static stability conditions for each structure. The liquefaction potential of native materials left in place after excavation, and of the backfill material itself, was evaluated and is described in Section 2.5.4.8 of the CPS USAR. Evaluation of static stability included calculation of bearing capacity, settlement, and lateral earth pressures for each structure, as presented in Section 2.5.4.10 of the CPS USAR. Table 2.5-63 of the CPS USAR summarizes critical foundation loading information for the main power plant including the foundation elevation, gross static foundation pressure, and net static foundation pressure for each of the structures. This information was used for the evaluation of static stability. A summary of parameters utilized for soil-rock-structure interaction analyses is presented in Table 2.5-48 of the CPS USAR. Results of the soil-structure interaction analyses are summarized in Section 3.7 of the CPS USAR. Section 6 of this Geotechnical Report compares the soil responses to static and dynamic loading for the CPS Site, as summarized below, with expected responses at the EGC ESP Site.

2.6.1 Liquefaction Potential

The potential for liquefaction of subsurface sand deposits near the main power station (both granular structural fill and subsurface sand lenses left below the excavation) was evaluated and is summarized in Section 2.5.4.8 of the CPS USAR. Liquefaction potential in the structural fill was evaluated based on the cyclic triaxial compression test results for compacted fill samples, specifically on the resulting cyclic vertical stress to confining stress ratio that results in liquefaction after 10 cycles. The factor of safety (FOS) was calculated as the ratio of the cyclic shearing stress at liquefaction (producing liquefaction at 10 cycles) to the average cyclic shearing stress induced by the earthquake. The minimum calculated FOS against liquefaction was reported to be approximately 2 for the structural fill. Analysis of liquefaction in granular pipe bedding and in sand fill under other structures also determined that liquefaction was not a concern.

Liquefaction analysis for natural sand deposits left below the excavation is summarized in Attachment B2.5 of the CPS USAR. For this analysis, the primary considerations were the relative density of the deposits (as correlated from corrected SPT blowcounts), soil gradation, and overburden pressure. Based on the conditions of the various sand lenses encountered during the subsurface investigation below the main power plant, liquefaction was not considered to be of concern in any of these sand deposits.

2.6.2 Bearing Capacity

Bearing capacity evaluations are discussed in Section 2.5.4.10.2 of the CPS USAR. Conventional analyses assuming local shear failure were used to calculate ultimate bearing capacities for the foundation soils. The results of the analyses are summarized in Table 2.5-63 of the CPS USAR.

The lowest calculated ultimate bearing capacity for the structures was approximately 25.5 tons per square foot (tsf) (for the Service Building, a non-Category I structure founded within the Wisconsinan till). Ultimate bearing capacity for foundations of safety-related structures constructed on the unweathered Illinoian till and engineered granular fill ranged from approximately 40 to 61 tsf. The minimum FOS against bearing capacity failure was 18.8.

2.6.3 Settlement

Settlement of the plant power block structures was evaluated for the foundation loads and elevations summarized in Table 2.5-63 and Section 2.5.4.10.3 of the CPS USAR. The first step involved assessing the rate of rebound and settlement during excavation, fill placement, and construction of the foundation mat. This allowed estimation of the zero-settlement origin for evaluating plant settlement, defined at the completion of the mat foundation and beginning of structure construction.

Settlement of the power block structures with time was modeled with the computer code SETTLE. Consolidation properties for the subgrade soils were taken from representative P-series consolidation test results and are reported in Table 2.5-62 of the CPS USAR. Independent settlement analyses were conducted for the mat, one assuming a completely rigid mat, and another assuming a flexible mat. The actual settlement of the mat was

considered to be a combination of these two modeled conditions. The calculated final settlement of the mat is shown in Figure 2.5-433 of the CPS USAR.

Actual settlement profiles with time were compared to the predicted settlement at four monitoring locations at the main power station. Results are shown in Figures 2.5-434 to 2.5-437 of the CPS USAR. These results show that the actual power block settlement was approximately half of the predicted settlement at most locations, indicating that conventional consolidation analyses using the consolidation test results provided a conservative estimate of settlement.

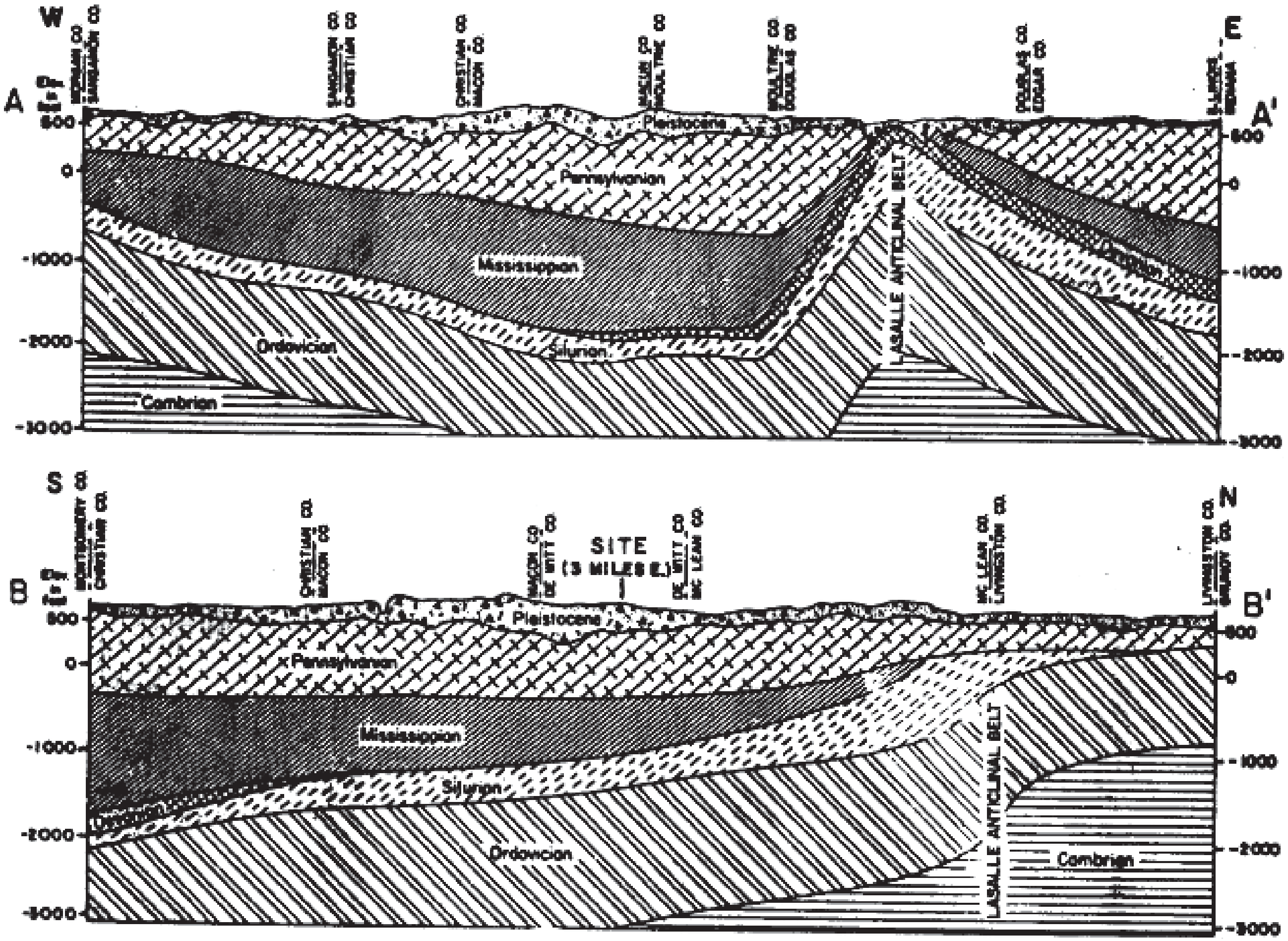
2.6.4 Lateral Earth Pressures

Subsurface walls of structures were designed to withstand lateral soil and groundwater pressures under both static and dynamic loading conditions. The method used to evaluate lateral pressures is described in Section 2.5.4.10.4 of the CPS USAR. At-rest horizontal earth pressure coefficients were approximated based on backfill placement condition and approximate friction angles of the backfill. Dynamic horizontal earth pressures were calculated by applying a horizontal earthquake acceleration to the soil pressure behind the wall. Lateral earth pressure calculations are shown in Figure 2.5-492 of the CPS USAR.

Geotechnical Report for the EGC Early Site Permit

Figure 2-1

Regional Geologic Cross Sections



Notes:
1. Reprinted from: CPS, 2002

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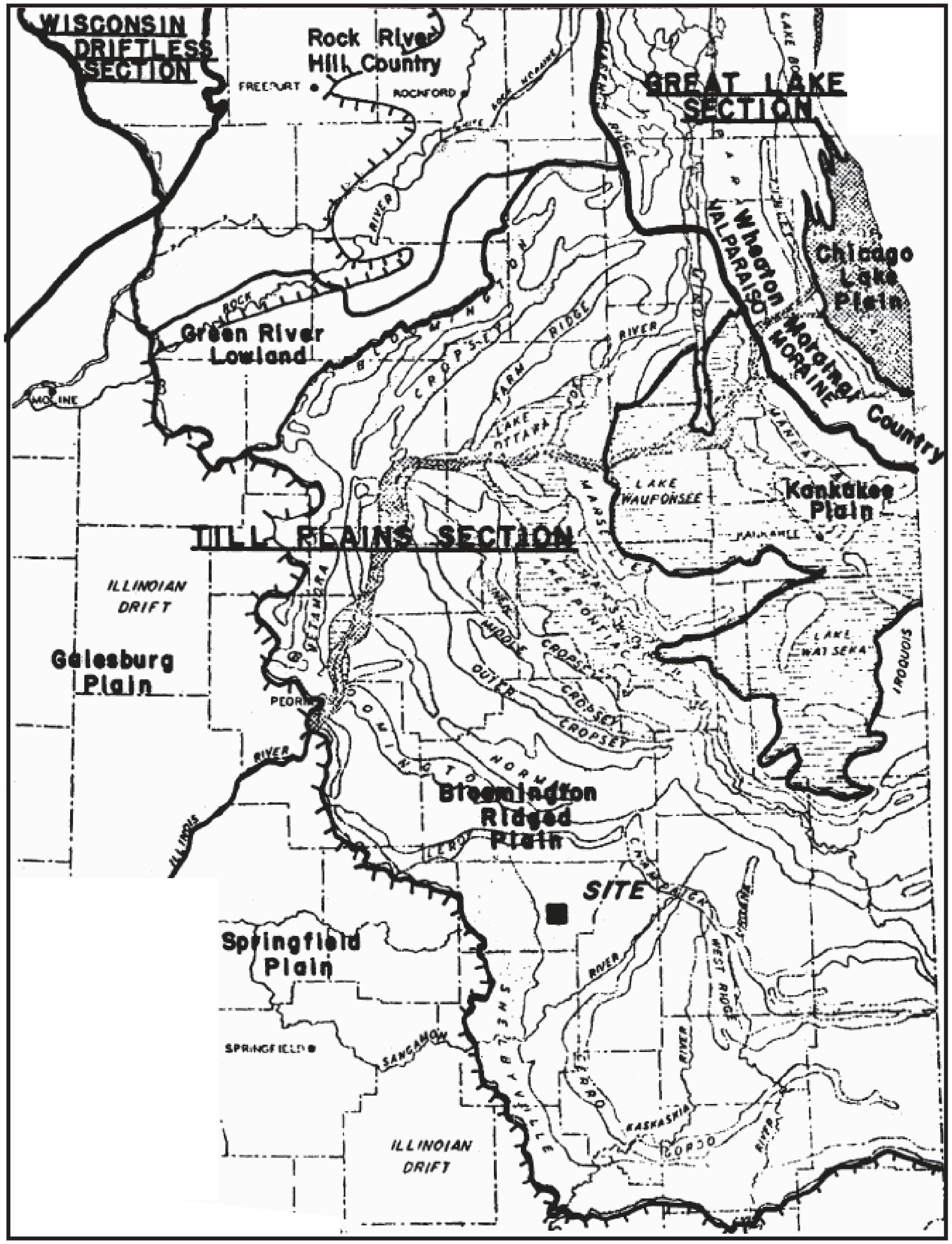
Figure 2-2
Regional Glacial Map and Physiographic Divisions



Legend

- Moraines
- Kankakee Torrent Area
- Lake Chicago and Outlet
- Limit of Wisconsinan Glaciation in Illinois

Notes:

1. These physiographic sections and subsections are part of the central lowland physiographic province.
2. The areas shown in white are primarily glacial drift and ground moraine except for the Wisconsin driftless section and parts of the Green River lowland.
3. Reprinted from: CPS, 2002

N

0 10 20 mi

Scale in miles

TIME STRATIGRAPHY				STRATIGRAPHIC UNITS: FSAR	STRATIGRAPHIC UNITS: PSAR	STRATIGRAPHIC UNITS: BORING LOGS
Quaternary System	Pleistocene Series	Holocene Stage		Cahokia Alluvium; Peyton Colluvium	Salt Creek Alluvium or Flood Plain Alluvium and Recent Channel Deposits	Salt Creek Alluvium
Quaternary System	Pleistocene Series	Wisconsinan Stage	Valderan Substage	Richland Loess	Loess	Loess
Quaternary System	Pleistocene Series	Wisconsinan Stage	Twocreekan Substage	Richland Loess	Loess	Loess
Quaternary System	Pleistocene Series	Wisconsinan Stage	Woodfordian Substage	Wedron Formation; Henry Formation	Wisconsinan Till or Wisconsinan Glacial Till	Wisconsinan Glacial Till
Quaternary System	Pleistocene Series	Wisconsinan Stage	Farmdalian Substage	Robein Silt	Interglacial Zone or Sangamon Interglacial Zone or Sangamon Soil Interval	Interglacial Zone
Quaternary System	Pleistocene Series	Wisconsinan Stage	Altonian Substage		Interglacial Zone or Sangamon Interglacial Zone or Sangamon Soil Interval	Interglacial Zone
Quaternary System	Pleistocene Series	Sangamonian Stage		weathered Glasford Formation	Interglacial Zone or Sangamon Interglacial Zone or Sangamon Soil Interval	Interglacial Zone
Quaternary System	Pleistocene Series	Illinoian Stage		weathered Glasford Formation / unaltered Glasford Formation	Illinoian Till or Illinoian Glacial Till	Illinoian Glacial Till
Quaternary System	Pleistocene Series	Yarmouthian Stage		Banner Formation	Lacustrine Deposit	Lacustrine Deposit
Quaternary System	Pleistocene Series	Kansan Stage		Banner Formation	Pre-Illinoian Glacial Till or Kansan Till; Pre-Illinoian Alluvial and Lacustrine Deposit or Kansan Alluvial or Lacustrine Soils; Bedrock Valley Outwash Deposit or Mahomet Valley Deposit	Pre-Illinoian Glacial Till; Pre-Illinoian Lacustrine Deposit; Mahomet Bedrock Valley Deposit
Unconformity						
Pennsylvanian System				Bedrock	Bedrock	Bedrock

Geotechnical Report for the EGC Early Site Permit

Figure 2-3

Comparison of Terminology Used During Previous Site Investigations

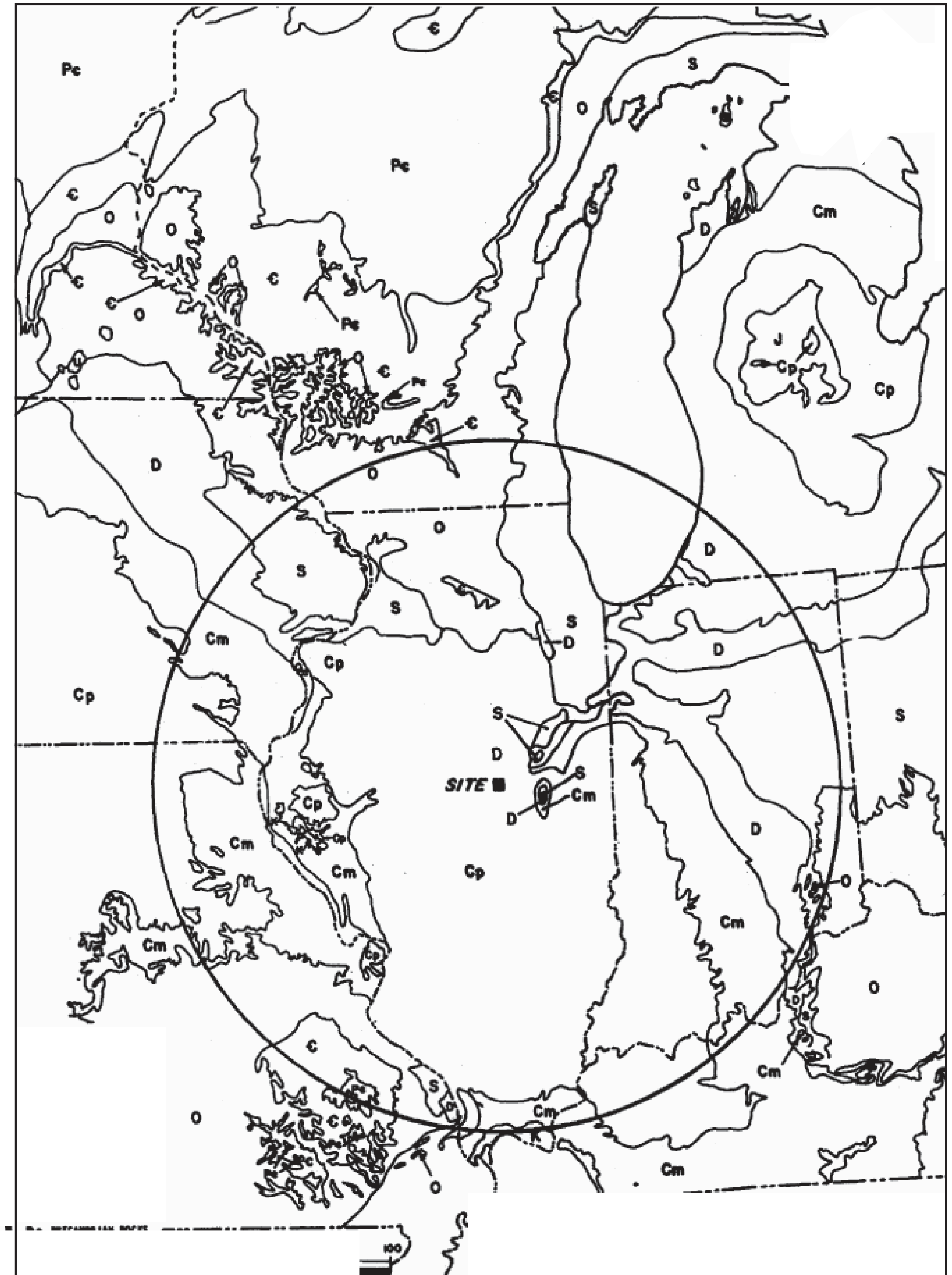
Legend

Notes:

1. Excavations for the Clinton Power Station did not extend below the unaltered Glasford formation.
2. Borings for the Clinton Power Station did not extend into rocks older than those of the Pennsylvanian system.
3. Illinoian-age till of the Glasford formation was subjected to a significant period of weathering during the Sangamonian stage and Altonian substage.
4. Deposits of Cahokia alluvium and Henry Formation were not differentiated.
5. The Holocene stage is represented by a significant period of weathering and development of agricultural soil profiles (modern soil).
6. Vertical scale does not represent either relative thickness of stratigraphic units or relative duration of time interval.
7. PSAR = Preliminary Safety Analysis Report
8. FSAR = Final Safety Analysis Report
9. USAR uses terminology listed in both the FSAR and PSAR columns.
10. Reprinted from: CPS, 2002

Geotechnical Report for the EGC Early Site Permit

Figure 2-4
Regional Bedrock Geology Map

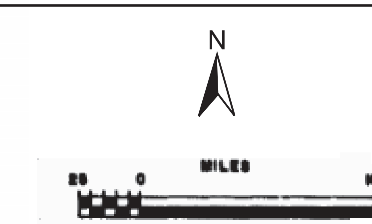


Legend

T	Tertiary Rocks
K	Cretaceous Rocks
J	Jurassic Rocks
Cp	Pennsylvanian Rocks
Cm	Mississippian Rocks
D	Devonian Rocks
S	Silurian Rocks
O	Ordovician Rocks
C	Cambrian Rocks
Pc	Precambrian Rocks

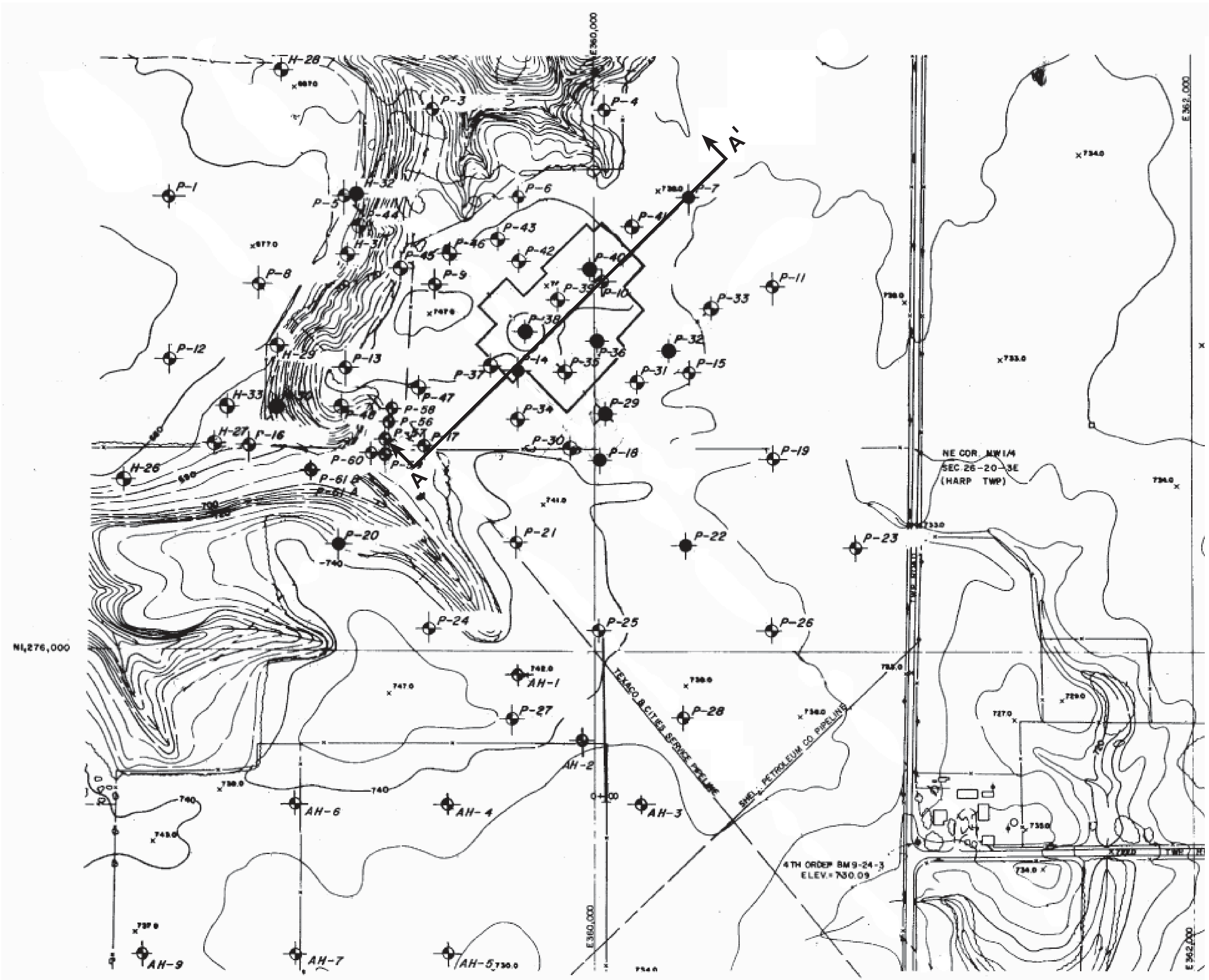
Notes:

1. Reprinted from: CPS, 2002



Geotechnical Report for the EGC Early Site Permit

Figure 2-5
Original CPS Site Investigation Locations



Legend

- 740 — Topographic Contours
- P-1 — Borehole Location
- Location of Borehole that Extended to Bedrock
- A — A' Section A-A' (See Figure 2-6)

Notes:
1. Modified from: CPS, 2002

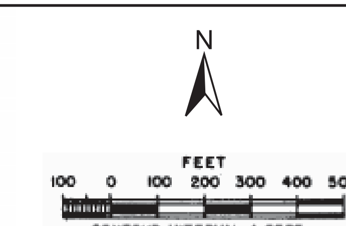
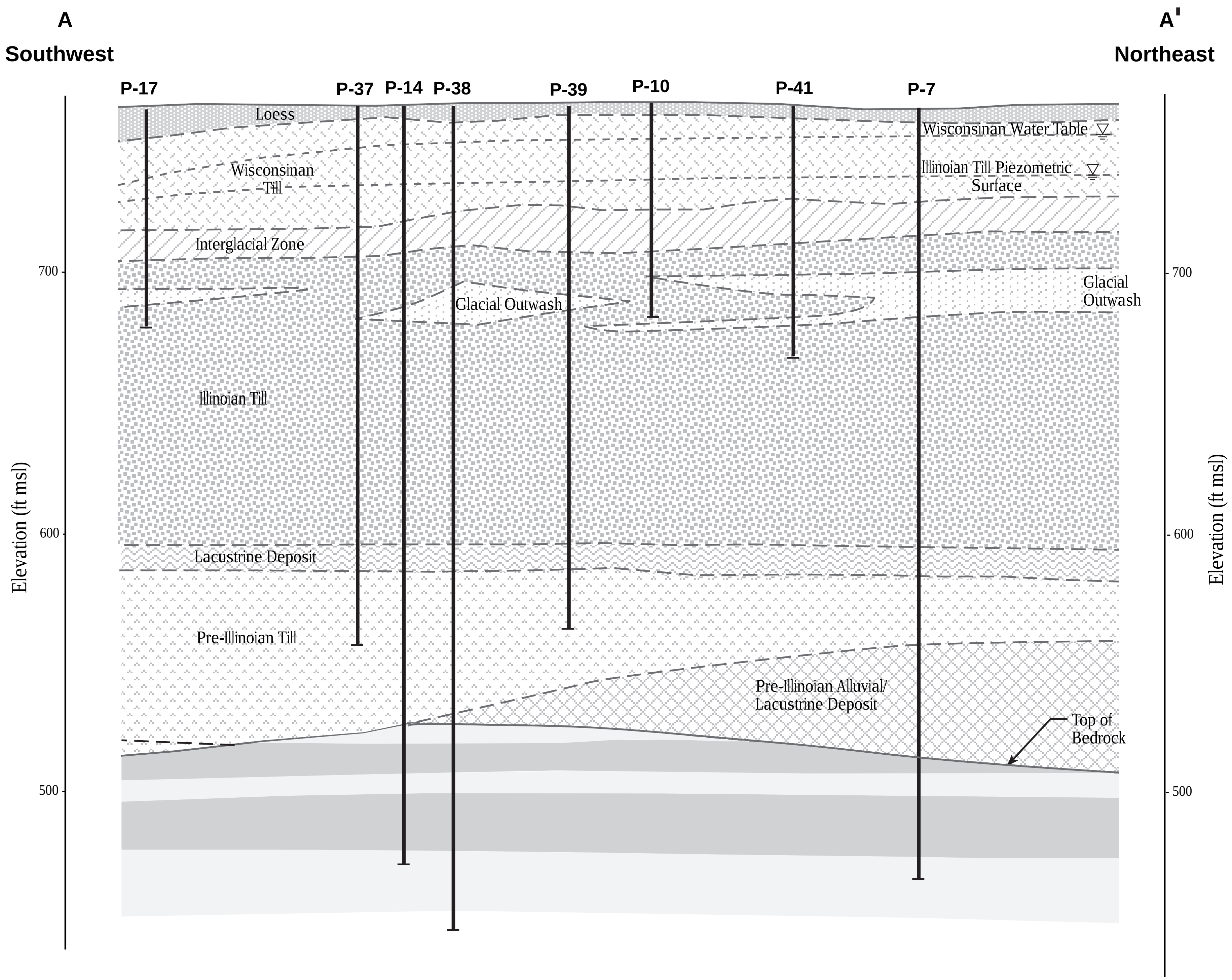
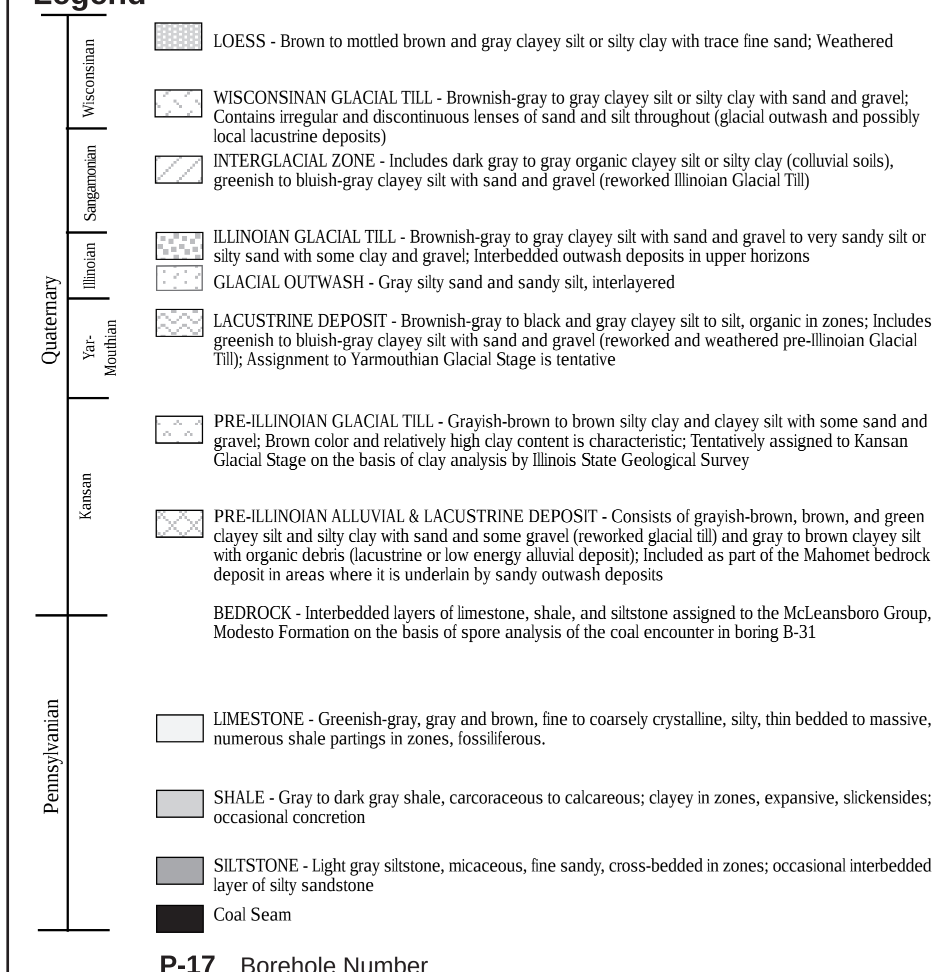


Figure 2-6
Southwest-Northeast Cross Section (A-A') Through CPS Site



Legend



Notes:
1. Elevations refer to the USGS Datum
2. Recreated from: CPS, 2002
3. See Figure 2-5 for cross section location

Approximate Horizontal Scale

CHAPTER 3

Field Explorations and Observations

A field exploration program was conducted in July and August of 2002 within the footprint of the EGC ESP Site. The purpose of this program was to obtain information that could be compared to existing data for the CPS Facility and would supplement existing information from the CPS Site, where new or improved methods of data collection or testing were warranted. The fieldwork consisted of soil drilling and sampling, rock coring, CPTs, and a suspension logging test. The following sections summarize the locations and depths of testing, the methods used during testing, and the results of the testing.

3.1 Soil and Rock Drilling and Sampling

Four boreholes were advanced by Testing Service Corporation (TSC) of Carol Stream, Illinois during the weeks of July 22, July 29, and August 5, 2002. Two of the boreholes (boreholes B-1 and B-4) were advanced to a depth of 100 ft bgs, and the other two (boreholes B-2 and B-3) were advanced to depths of 292 and 284 ft bgs, respectively. Rock coring was then conducted at boreholes B-2 and B-3. The locations of these explorations are shown in Figure 3-1.

3.1.1 Locations of Boreholes

The borehole locations shown in Figure 3-1 were selected to provide information about the spatial variability of the soils and the depth to bedrock. Previous explorations had been made within the footprint of the EGC ESP Site during field explorations conducted in the mid-1970s for the CPS Site. Results of the CPS Site explorations showed very consistent conditions within the area planned for the EGC ESP Facility. Results of the review of regional and site geology provided in the CPS USAR and in more recent literature, also indicated that very uniform conditions would occur within the limited distance being considered for the EGC ESP Site.

In view of this consistency in existing geotechnical data and geology, the scope of the drilling and sampling program consisted of two boreholes drilled to 100 ft bgs on the perimeter of the footprint and two deep boreholes drilled into rock at the center of the footprint. These explorations were supplemented by the results of four CPTs pushed to refusal at locations between the borehole locations. If any significant soil property variations (for example, different soil types or different blowcounts from the SPT) had been revealed during the drilling and sampling program, additional explorations would have been added to resolve the observed differences.

The number of boreholes drilled and sampled during the exploration for the EGC ESP Site is less than the recommendations given in Appendix C of Regulatory Guide 1.132 (USNRC, 1979). The rationale for the reduced number of explorations was as follows:

- Over 10 explorations had been previously drilled, sampled, and tested within the general EGC ESP Site footprint area during the investigation work for the CPS Site. A

careful review of this existing information determined that the methods used for drilling and sampling, soil classification, and laboratory testing of soils from these explorations was of sufficient quality to allow re-use of the data for the EGC ESP Site work.

- The work being carried out for the EGC ESP was being done before the reactor plant design had been selected. Therefore, some of the spacing and depth requirements given in Appendix C of Regulatory Guide 1.132 could not be established. Once a reactor plant design is selected, then the requirements in Appendix C of Regulatory Guide 1.132 will be reviewed again during the COL stage, along with the design requirements of the reactor plant design, to determine whether additional drilling and sampling is needed.

As will be shown in Chapter 5 of this Geotechnical Report, a comparison of the field and laboratory data from the EGC ESP Site to similar data from the CPS Site confirmed that the geology and geotechnical conditions in the EGC ESP and CPS Site areas is, for practical purposes, the same. This similarity provides confidence in using the database from the CPS Site work to supplement the information collected during the EGC ESP Site work.

3.1.2 Soil Drilling and Sampling

Boreholes were advanced using mud-rotary drilling methods. The TSC used a truck-mounted Gus Pech 7500 drill rig with NW rods and a J taper thread. In one of the 100-ft deep boreholes (borehole B-1), a biodegradable drilling mud (BioBore) was used to maintain the open borehole. A piezometer was installed in this borehole, as described in Section 3.2 of this report. In the other 100-ft deep borehole (borehole B-4), and in the two deeper boreholes (boreholes B-2 and B-3), bentonite drilling mud (Quik-Gel) was used. Each borehole was reamed to a diameter of 6 in. during drilling to allow Pitcher-tube sample collection and also to allow installation of piezometers and the suspension logging equipment.

3.1.2.1 Sampling Intervals, Methods, and Logging

Soil sampling was conducted throughout each borehole, as follows:

- At depths shallower than 100 ft bgs, 2-in. nominal diameter by 1.5-ft long split-spoon samples were collected at 5-ft intervals using SPT methods (ASTM D 1586-99*, Standard Test Method for Penetration Resistance and Split Barrel Sampling of Soils*). A manually operated SPT safety hammer with a rope cathead was used to drive the sampler. Undisturbed soil samples were collected between the split-spoon samples from fine-grained soils at each major change in stratigraphy or soil consistency following methods given in ASTM D 1587-00*, Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes.* In general, a Pitcher-tube sampler was used to collect undisturbed samples wherever SPT blowcount exceeded 30 blows per ft, and Shelby-tubes were used elsewhere.
- At depths between 100 and 150 ft bgs (at boreholes B-2 and B-3), the split-spoon sampling interval was increased to 10 ft. Undisturbed soil samples were also collected from fine-grained soils at each major change in stratigraphy or soil consistency.

- At depths greater than 150 ft bgs, the split-spoon sampling interval was increased to 15 ft. Undisturbed soil samples were also collected from fine-grained soils at each major change in stratigraphy or soil consistency.
- At boreholes B-2 and B-3, soil sampling was continued to the top of bedrock. Once the presumed top of bedrock was encountered, a split-spoon sample was attempted to verify the presence of rock. Once the presence of rock was confirmed, rock coring was initiated, as described in Section 3.1.2.

A geotechnical engineer logged each soil sample for visual soil classification, SPT blowcount, moisture content, sample recovery, and other observations on a standard geotechnical borehole log. Samples were described in accordance with recommendations given in ASTM D 2487-00, *Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)* and ASTM D 2488-00, *Standard Practice for Description and Identification of Soils (Visual – Manual Procedure)*. Soil borehole logs for boreholes B-1 through B-4 are included in Attachment A-1. These logs have been edited to incorporate results of laboratory tests.

3.1.2.2 Standard Penetration Tests Hammer Calibration

The efficiency of the SPT hammer used at the site was tested in borehole B-2 on August 2, 2002 by GRL Engineers of Arlington Heights, Illinois. GRL used a pile driving analyzer to measure hammer energy transfer efficiency at eight depth intervals between 40 and 80 ft bgs. Each of the three TSC employees who operated the hammer during the investigation (that is, the driller and two drillers helpers) operated the hammer during the testing.

Results of the SPT hammer calibration test program indicate that hammer efficiency ranged from 39 to 60 percent, with an average of 52 percent during the tests and a standard deviation of approximately 8. Details from the hammer calibration test program including equipment used and methods of data analysis are presented in Attachment A-3.

3.1.2.3 Sample Handling, Preservation, and Transport

Soil samples were handled, preserved, and transported in accordance with procedures outlined in ASTM D 4220-95, *Standard Practices for Preserving and Transporting Soil Samples*. The following methodology was used during the investigation:

- Soil samples were collected for classification and processing. Split-spoon samples were then photographed, placed into labeled glass sample jars, and sealed with a hand-tightened cover.
- For Shelby-tube and Pitcher-tube samples, excess fall-in material in the top of the tube was removed and discarded. The soil in the top and bottom of the tube was visually classified, and the unconfined compression and undrained shear strengths of the soil in the bottom of the tube were estimated using both a pocket penetrometer and a torvane device. The tube was then cleaned, labeled with identifying information, sealed with wax at the top and bottom of the soil sample, packed with moistened newspaper to fill any voids in the tube, capped, and taped to seal both ends of the tube. Shelby-tube and Pitcher-tube samples were maintained in a vertical orientation after collection.

- Soil samples were stored in a temperature-controlled room at the CPS Facility until the end of each work week. TSC transported Shelby-tube and Pitcher-tube samples to the TSC soil testing laboratory in Carol Stream, Illinois once each week during the field investigation. These samples were protected from disturbance during transport by maintaining the samples in a vertical orientation and by using cushioning material (plastic padding) below and around each tube to protect it from vibrations. The SPT sample jars were stored and retained by the CH2M HILL representative.

3.1.2.4 Borehole Completion

Drilling fluid and soil cuttings were generally discharged to the ground surface near each borehole at the approval of the CPS and EGC ESP field representatives. One of the deep boreholes (borehole B-2) was kept open with drilling mud upon completion of the drilling and sampling for subsequent access by the suspension logging subcontractor. Immediately prior to the start of the suspension logging work, the TSC circulated the drilling mud in the borehole.

Upon completion of sampling and testing, each borehole was completely abandoned with cement-bentonite slurry to the ground surface, except for at borehole B-1, which was completed with a piezometer installation. The slurry was pumped into place through a tremie pipe.

3.1.3 Rock Coring and Sampling

Rock coring was advanced at boreholes B-2 and B-3, to 30 and 20 ft beyond the drilling depths of 292 and 286 ft, respectively. Coring was conducted using a 3-in. outer diameter diamond-tip double tube core barrel, with water used as the cutting fluid. Continuous rock-core samples were collected for classification. Methods of rock coring followed recommendations given in ASTM D 2113-99, *Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigations*. At borehole B-2, the rock core hole was reamed to a 6-in. diameter upon completion of coring in order to facilitate the suspension logging test at that location.

Each rock core segment was collected and placed into a protective wooden core box with a locking lid. A rock core log was completed with information about each core including rock type, descriptions of fractures and inclusions, recovery, and rock quality designation (RQD).

Procedures for preserving and transporting rock core samples conformed with the "routine care" requirements of ASTM D 5079-02, *Standard Practices for Preserving and Transporting Rock Core Samples.* Each rock core was photographed, and each box was sealed with tape and labeled upon completion of coring. Rock cores were transported to the CH2M HILL office in Chicago, Illinois for storage.

Rock core logs for boreholes B-2 and B-3 are included in Attachment A-1. Interpretation of the soil and rock stratigraphy and lithology is presented in Chapter 5.

3.2 Piezometer Installation

Three groundwater piezometers (B-1-Piezo, B-2-Piezo, and B-3-Piezo) were installed at the site near boreholes B-1, B-2, and B-3, respectively, by the TSC during the week of August 22, 2002. The locations of the boreholes are shown in Figure 3-1.

Two of these (B-2-Piezo and B-3-Piezo) were installed to intersect the shallowest encountered groundwater surface with well screens set from 8 to 28 ft bgs and from 16 to 26 ft bgs, respectively. These were set within new hollow-stem augered boreholes advanced within 15 ft of borehole B-2 and B-3. Drilling mud was not used in either of these two piezometer borings. The third piezometer (B-1-Piezo) was set to monitor the piezometric head within the upper Illinoian glacial till with the screen set at 80 to 90 ft bgs. This piezometer was installed within borehole B-1. Prior to installation of B-1-Piezo, the borehole B-1 was partially abandoned with bentonite chips from the base of the borehole to the base of the piezometer (that is, from 90 to 100 ft bgs). Borehole B-1 was advanced with a biodegradable drilling mud (Biobore), so that the mud would not permanently influence the hydraulic conductivity of the soils adjacent to the piezometer screen.

Each piezometer was constructed of a 2-in. diameter schedule 40 polyvinyl chloride (PVC) pipe with screens constructed with 0.010-in. factory milled slots. A 10-ft length screen was used in B-1-Piezo and B-3-Piezo, and a 20-ft length screen was used in B-2-Piezo. The longer screen was installed in B-2-Piezo to ensure that the screen intersected the piezometric surface in the shallowest water bearing unit. Each piezometer was completed with filter sand pack, annular bentonite seal, and a stickup locking steel protective cover with a formed, square concrete pad. Three steel, concrete-filled bumper posts were installed around each piezometer.

Following construction, each piezometer was developed by purging one piezometer volume of water with a disposable bailer. This purge volume included the approximate pore volume of the sand filter pack. The piezometers were installed only to monitor the static piezometric head at each screen location. The corresponding development method was intended to remove excess fines from the piezometer screens and filter packs, such that static water levels could be monitored. The development method was not intended to maximize specific capacity of the piezometers, nor reduce water turbidity within the piezometers. Therefore, the development method was considered appropriate for the intended piezometer use.

Upon development, the location and elevation of each piezometer were surveyed by Homer Chastain and Associates of Decatur, Illinois. Static water levels were monitored at each piezometer at the end of the field investigation (on August 9, 2002) and again on August 28, 2002 and on February 3, 2003. Groundwater elevations recorded at the three piezometers are included in Table 3-1. Completion diagrams for the three piezometers are included in Attachment A-2.

3.3 Cone Penetrometer Testing

Cone penetrometer testing (CPT) soundings were advanced on August 23 and 24, 2002 at four locations by Stratigraphics of Glen Ellyn, Illinois. The locations of the CPT soundings are shown in Figure 3-1.

Each sounding was advanced with a 25-t self-contained CPT truck to equipment refusal, as determined by Stratigraphics. The total depths of the soundings at CPT-1, CPT-2, CPT-3, and CPT-4 were 78.1, 55.7, 54.0, and 76.9 ft, respectively. At each CPT location, end bearing, sleeve friction, and pore water pressure were measured continuously with depth.

Two of these soundings (CPT-2 and CPT-4) also included seismic shear wave velocity measurements. One of the seismic tests (CPT-2) was located approximately 15 ft from borehole B-2, and the other test was performed at CPT-4. The seismic test consisted of shear wave generation at the ground surface using a sledge-hammer to strike a board placed on the ground (to create horizontal shear at the ground surface) and detection of the shear wave arrival with a velocity sensitive geophone located at the tip of the CPT rod assembly. Measurements of shear wave propagation times were made at 3-ft depth intervals from the ground surface until the cone assembly could no longer be pushed into the ground. Shear wave velocities were interpreted based on the travel time and travel distance.

Upon completion of each sounding, the CPT hole was abandoned with bentonite slurry. The bentonite slurry was used to avoid leaving a hole in the ground that could serve as a conduit for surface or groundwater.

A copy of the CPT investigation report prepared by Stratigraphics is provided in Attachment A-4. This report includes a description of the procedures followed during the CPT soundings, as well as tables and plots of the data recorded at each location. The tabulated data summarize cone end resistance, side resistance, friction ratio, and pore water pressure as a function of depth. Then the tabulated data present interpretations of soil type, undrained shear strength, and equivalent SPT blowcount for each depth. The CPT interpretations are based on published empirical relationships. Comparison of the CPT results with the results from other EGC ESP and CPS Site investigations is discussed in Chapter 5.

3.4 Suspension Logging Test

Shear and compressional wave velocity measurements were conducted in borehole B-2 on August 8, 2002 by GeoVision of Corona, California. GeoVision used an OYO P-S suspension logging device to conduct the test.

The test was performed by lowering the OYO P-S logging probe into the open borehole filled with bentonite drilling fluid, and repeating velocity measurements at depth increments of approximately 1.5 ft. Each measurement recorded the average shear wave and compressional wave velocity of the subsurface material between two receivers located near the top of the probe. The quality of the test results was influenced by the integrity of the borehole sidewalls and by the consistency of the drilling mud. Therefore, in order to optimize the quality of the recordings, the test was performed on the same day as the

completion of the rock coring at borehole B-2, and the bentonite drilling fluid was mixed immediately prior to the start of the test.

During the test, measurements were recorded from depths of approximately 2 ft bgs to 15 ft below the top of the bedrock surface (to a depth of 307 ft bgs). Upon completion of the test, borehole B-2 was abandoned with cement bentonite slurry by the drilling subcontractor.

A copy of the suspension logging test report prepared by GeoVision is included in Attachment A-5. This report discusses the procedures and equipment used during the test, describes the analysis of the recorded data, and presents results in the form of shear and compressional wave velocities as a function of depth. Discussion of the compression and shear wave velocity test results, including comparison with other EGC ESP investigation results and the CPS USAR results, is included in Chapter 5.

3.5 Survey of Investigation Locations

Homer Chastain and Associates of Decatur, Illinois performed a survey of boreholes, piezometers, and CPT sounding locations during the week of August 5, 2002. Horizontal locations were surveyed in both plant coordinates and in WGS '84 coordinates, using differential GPS surveying methods. Elevations were surveyed using differential leveling at an accuracy of less than 0.1 ft.

At each piezometer location, elevations were surveyed at the top of the concrete pad, top of the PVC casing, and at the top of the protective casing. At each borehole and CPT sounding location, top of ground surface elevations were surveyed. Surveyed coordinates and elevations for each location are provided in Table 3-2.

CHAPTER 3

Tables

TABLE 3-1
Piezometer Construction Information and Groundwater Piezometric Surface Elevations

Piezometer	Plant North (ft)	Plant East (ft)	Screen Depth Interval (ft bgs)	Stratigraphic Unit of Screen Interval	Ground Surface Elevation (ft above msl)	Measuring Point Elevation (ft above msl)	Piezometric Surface Elevation (ft above msl)		
							09-Aug-02	28-Aug-02	03-Feb-03
B-1-Piezo	-970.6	589.4	80 to 90	Illinoian Till	738.5	740.92	710.88	711.08	710.91
B-2-Piezo	-675.4	823.1	8 to 28	Wisconsinan Till	737.1	739.55	729.68	733.46	732.08
B-3-Piezo	-629.9	1474.1	16 to 26	Wisconsinan Till	734.0	736.37	719.34	728.53	728.96

TABLE 3-2
Surveyed Investigation Point Coordinates and Elevations

Location	Longitude [a]				Latitude				Plant Coordinates (ft) [b]		Elevations (ft above msl) [c]				As-Left Conditions	
	d	m	s		d	m	s		North	East	Ground	Conc.	Top PVC	Top Casing	Subsurface	Surface
B-1 PIEZO [d]	88	50	15.44721	W	40	10	08.79666	N	-970.67	589.37	---	738.59	740.92	741.15	See Piezometer Log [e]	See Piezometer Log
B-2	88	50	10.58890	W	40	10	09.41613	N	-661.42	813.00	737.8	---	---	---	Borehole Diameter = 6 in. Bentonite Grout (3 – 285 ft bgs) Bentonite Chips (0 – 3 ft bgs)	Bentonite chips at surface
B-2 PIEZO	88	50	10.62305	W	40	10	09.24800	N	-675.35	823.07	---	737.17	739.55	739.63	See Piezometer Log	See Piezometer Log
B-3	88	50	04.38445	W	40	10	04.98811	N	-641.25	1469.36	734.2	---	---	---	Borehole Diameter = 6 in. Bentonite Grout (3 – 285 ft bgs) Bentonite Chips (0 – 3 ft bgs)	Bentonite chips at surface
B-3 PIEZO	88	50	04.23809	W	40	10	05.03454	N	-629.93	1474.13	---	734.06	736.37	736.60	See Piezometer Log	See Piezometer Log
B-4	88	50	05.56461	W	40	10	01.15656	N	-980.70	1676.55	735.36	---	---	---	Borehole Diameter = 6 in. Bentonite Grout (3 – 100 ft bgs) Bentonite Chips (0 – 3 ft bgs)	Bentonite chips at surface
CPT-1	88	50	12.36301	W	40	10	11.45042	N	-612.02	570.75	737.9	---	---	---	Hole Diameter = 2 in. Bentonite Grout (3 – 78 ft bgs) Bentonite Chips (0 – 3 ft bgs)	Bentonite chips at surface
CPT-2	88	50	10.49240	W	40	10	09.34617	N	-661.18	823.29	737.5	---	---	---	Hole Diameter = 2 in. Bentonite Grout (3 – 56 ft bgs)	Bentonite chips at surface

TABLE 3-2
Surveyed Investigation Point Coordinates and Elevations

	Longitude [a]				Latitude				Plant Coordinates (ft) [b]		Elevations (ft above msl) [c]				As-Left Conditions	
Location	d	m	s		d	m	s		North	East	Ground	Conc.	Top PVC	Top Casing	Subsurface	Surface
															Bentonite Chips (0 – 3' bgs)	
CPT-3	88	50	11.72763	W	40	10	05.97505	N	-970.58	994.73	734.3	---	---	---	Hole Diameter = 2 inches Bentonite Grout (3 – 54 ft bgs) Bentonite Chips (0 – 3 ft bgs)	Bentonite chips at surface
CPT-4	88	50	08.51243	W	40	10	03.37064	N	-982.37	1356.87	735.1	---	---	---	Hole Diameter = 2 inches Bentonite Grout (3 – 77 ft bgs) Bentonite Chips (0 – 3 ft bgs)	Bentonite chips at surface

Notes:

[a.] Longitude and Latitude are reported in World Geodetic System (WGS) '84 Coordinates

[b.] Plant coordinate system is rotated approximately 45 degrees clockwise from true north. Origin based on the center of the CPS reactor at coordinates 350 North, 245 East. Control points were identified by CPS personnel.

[c.] Elevations are reported in feet above mean sea level (msl), surveyed from control points noted in existing CPS records.

[d.] "B1 Piezo" was installed in borehole B1. Piezometers "B2 Piezo" and "B3 Piezo" were installed in dedicated borings, offset from boreholes B2 and B3.

[e.] Piezometer Logs are provided for each of the piezometers in Attachment A-1. These logs list details of materials and dimensions for the construction of each piezometer.

Geotechnical Report for the EGC Early Site Permit

Figure 3-1
EGC ESP Geotechnical Investigation Locations

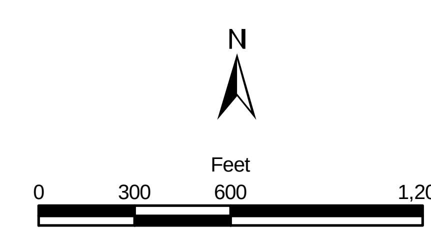
Legend

- Approximate CPS Site Footprint
- EGC ESP Site Footprint
- Approximate Outline of Existing Roads, Buildings & Structures
- Cross Sections (See Figures 2-6, 5-1 & 5-2)

EGC ESP Site Borings & Soundings

- 100 ft Deep Boring
- > 250 ft Deep Boring
- CPT Sounding
- Surface Water

Notes:
1) Piezo-1, Piezo-2 & Piezo-3 are located within 15 feet of Borings B-1, B-2 & B-3 respectively.
2) See Figure 2-5 for Locations of CPS Site Borings



CHAPTER 4

Laboratory Testing Methods and Results

Approximately 110 split-spoon samples and 45 Shelby-tube and Pitcher-tube samples were collected from the four soil boreholes during the field investigation for the EGC ESP Site. Physical property and engineering property tests were performed on selected samples from the EGC ESP Site to provide soil classification and static soil property information. A series of dynamic tests were also conducted on samples in order to determine dynamic soil property data. The soil tests were selected to fulfill the following objectives:

- Provide soil classification, engineering property, and dynamic property information for each major stratigraphic unit encountered within the EGC ESP Site;
- Facilitate evaluation of soil variability within the EGC ESP Site; and
- Allow for comparison of the new EGC ESP Site soil test results with previous soil test results reported in the CPS USAR for the CPS Site.

TSC of Carol Stream, Illinois performed various geotechnical tests on 22 of the collected samples. The University of Texas at Austin performed resonant column/cyclic torsion tests on an additional six samples.

4.1 Classification and Static Engineering Properties Testing

Classification and static engineering property tests were performed by the TSC laboratory. The TSC laboratory is certified by the ASTM as meeting certification requirements described in ASTM D 3740-01, *Standard Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction.*

The following types and numbers of tests were conducted by TSC on soil samples recovered from the EGC ESP Site:

- ASTM D 1587-00, *Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes*: Total of 17 tests
- ASTM D 2216-98, *Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass*: Total of 21 tests
- ASTM D 2166-00, *Standard Test Method for Unconfined Compressive Strength of Cohesive Soil*: Total of 13 tests
- ASTM D 2974-00, *Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils*: Total of 4 tests
- ASTM D 1140-00, *Standard Test Methods for Amount of Material in Soils Finer than the No. 200 (75μ) Sieve*: Total of 17 tests
- ASTM D 422-63, *Standard Test Method for Particle-Size Analysis of Soils*: Total of 17 tests

- ASTM D 2435-96, *Standard Test Method for One Dimensional Consolidation Properties of Soils*: Total of 3 tests
- ASTM D 2850-95, *Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils*: Total of 2 tests
- ASTM D 4767-02, *Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils*: Total of 1 test

Results of the tests performed by TSC, along with descriptions of each of the 45 Shelby-tube and Pitcher-tube samples collected during the field investigation, are summarized in Table 4-1. Geotechnical laboratory test data from TSC are included in Attachment A-6.

TSC performed most of these tests during the weeks of September 9 and 16, 2002. Additional tests were performed in November and December of 2002 upon return of a partial sample tube originally sent to the University of Texas at Austin for resonant column/cyclic torsional shear testing.

4.2 Dynamic Testing

Representative portions of six Pitcher-tube samples were tested by Professor Kenneth H. Stokoe of the University of Texas at Austin to determine the dynamic properties of the soil samples. The samples tested by University of Texas were selected from the six primary soil layers that have been identified at the EGC ESP Site. Tests were carried out between September and December of 2002.

The dynamic property tests were conducted using resonant column/cyclic torsional shear testing methods. Each sample was tested at a range of mean confining pressures (σ_o') and for different levels of shearing strain amplitude (γ). The confining pressures were determined based on the average unit weight of the soil and the location of the water table. Typically, tests were conducted at five levels of mean effective in situ stress: $0.25\sigma_o'$, $0.5\sigma_o'$, $1\sigma_o'$, $2\sigma_o'$, and $4\sigma_o'$. Shearing strain amplitudes ranged from very low values (that is, less than 10^{-4} percent) to approximately 0.1 to 0.5 percent. The maximum applied shearing strain varied according to the torque capacity of the test equipment and the stiffness of the soil. The stiffness of the soil was determined primarily by the mean effective confining pressure during the test, but was also influenced by the void ratio, the plasticity, and the degree of overconsolidation.

The product of the University of Texas testing program was a series of data tables and plots showing the variation of shear modulus and material damping ratio with duration of confinement, confining stress, and shearing strain amplitude. The modulus data were also interpreted to give the shear modulus ratio (G/G_{max}) as a function of shearing strain amplitude. The recorded variations in shear modulus ratio and material damping ratio for soil from the EGC ESP Site were used for comparisons to published modulus ratio and damping ratio plots, as well as for developing the soil model used during site-response studies, as summarized in Section 2.5 of the SSAR and discussed in detail in Appendix B to the SSAR.

Results of the testing conducted by University of Texas are presented in Attachment A-7.

CHAPTER 4

Tables

TABLE 4-1
Summary of Shelby Tube and Pitcher Samples and Corresponding Geotechnical Test Results

											Classification														Consolidation				Triaxial Compression (CIU[a])		Triaxial Compression (UU[b])
Boring ID	Sample ID	Top Depth (ft bgs[c])	Bottom Depth (ft bgs)	Surface Elevation (ft above msl[d])	Sample Elevation (ft above msl)	Sample Recovery (ft)	Field Soil Description	Pocket Pen (tsf[e])	Pocket Torvane (tsf)	Stratigraphic Unit	LL[f]	PL[g]	PI[h]	P4[i] (%)	P10[i] (%)	P40[i] (%)	P200[i] (%)	Silt (%)	Clay (%)	Dry Density (pcf[j])	Moisture Content (%)	Qu[k] (tsf)	Carbon (%)	USCS[l] Class	Cc[m]	Cr[n]	Pc'[o] (tsf)	Void Ratio	Phi[p] (deg.)	C[q] (tsf)	Su[r] (tsf)
B-1	2-ST	5	7	738.6	731.6	2	Sandy CLAY (CL), moist. Yellowish Brown. Some small gravel.	2.5	6	Loess	22	14	8	96	91	79	56	31	25	111.4	14.7	1.05	1.9	CL[s]							
B-4	2-ST	5	7	735.4	728.4	2	Silty CLAY (CL), moist. Black. Slightly organic.	2	8	Loess																					
B-3	2-ST	5	7	734.2	727.2	2	Lean CLAY (CL), moist. Olive brown. Some fine sand.	2	5	Loess	72	14	28	100	100	98	96	63	33	104.1	19.9	2.08		CL							
B-1	4-ST	10	12	738.6	726.6	1.4	Sandy CLAY (CL), moist. Brown. Some small gravel.	>4	8	Loess																					
B-4	4-ST	10	12	735.4	723.4	1.3	Lean CLAY (CL), moist. Black with grey and yellowish brown mottles. Trace fine sand.	0.75	3	Loess																					
B-1	6-PIT	15.5	18.5	738.6	720.1	2.2	Lean CLAY (CL) slightly moist. Dark Grey. Some small gravel.	NA[s]	NA	Wisconsinan Till	23	13	10	96	94	85	62	33	29	117.7	15	1.78	2.4	CL							
B-4	6-ST	15	17	735.4	718.4	0.4	Lean CLAY (CL), moist. Brown. Some small gravel.	1.5	3	Wisconsinan Till																					
B-3	6-ST	15	17	734.2	717.2	1.5	Lean CLAY (CL), moist. Dark grey. Some small gravel & sand.	>4	7	Wisconsinan Till																					
B-4	10-PIT	25.5	28.5	735.4	706.9	2.2	Lean CLAY (CL), moist. Grey. Trace fine sand.	3.75	6.5	Wisconsinan Till																					
B-2	7-ST	31.5	33.5	737.8	704.3	1.7	Lean CLAY (CL), slightly moist. Dark Grey. Some sand and small gravel.	2	8	Wisconsinan Till																					
B-3	10-ST	30	32	734.2	702.2	1.7	Lean CLAY (CL), moist. Dark grey. Some sand and small gravel.	1.25	5	Wisconsinan Till	23	13	10	100	99	90	67	40	27	115.7	15.9	1.26		CL							
B-1	11-PIT	35.5	38.5	738.6	700.1	1.8	Well graded SAND (SW), moist. Dark grey. With some silt and small gravel. Rounded.	0.25	1	Wisconsinan Till																					
B-4	13-ST	35	37	735.4	698.4	0.9	Lean CLAY (CL), moist. Grey. Some gravel to 1" dia.	1	4	Wisconsinan Till																					

TABLE 4-1
Summary of Shelby Tube and Pitcher Samples and Corresponding Geotechnical Test Results

											Classification														Consolidation				Triaxial Compression (CIU[a])		Triaxial Compression (UU[b])
Boring ID	Sample ID	Top Depth (ft bgs[c])	Bottom Depth (ft bgs)	Surface Elevation (ft above msl[d])	Sample Elevation (ft above msl)	Sample Recovery (ft)	Field Soil Description	Pocket Pen (tsf[e])	Pocket Torvane (tsf)	Stratigraphic Unit	LL[f]	PL[g]	PI[h]	P4[i] (%)	P10[i] (%)	P40[i] (%)	P200[i] (%)	Silt (%)	Clay (%)	Dry Density (pcf[j])	Moisture Content (%)	Qu[k] (tsf)	Carbon (%)	USCS[l] Class	Cc[m]	Cr[n]	Pc'[o] (tsf)	Void Ratio	Phi[p] (deg.)	C[q] (tsf)	Su[r] (tsf)
B-1	13-ST	40	42	738.6	696.6	1.3	Lean CLAY (CL), slightly moist. Dark Grey. Some small gravel	NA	NA	Interglacial Zone	25	13	12	96	93	82	59	36	23			4.54	3.1	CL							
B-4	15-ST	40	42	735.4	693.4	0.4	SILT (ML), slightly moist. Very dark brown. Organic, slightly fibrous.	1	3.5	Interglacial Zone	62	51	11							65.1	58.8		13.4	OH							
B-3	13-ST	40	42	734.2	692.2	2	Lean CLAY (CL), moist. Dark Grey. Some sand.	1.2	4.5	Interglacial Zone																					
B-3	15-ST	45	47	734.2	687.2	2	Silty SAND (SM), moist. Grey. Very fine.	1.25	4	Interglacial Zone																					
B-1	17-ST	50	52	738.6	686.6	2	Lean CLAY (CL), moist. Dark Grey. With some small gravel.	1.5	5	Interglacial Zone	33	13	20	94	92	70	55	30	25	107.8	18.9	0.58		CL							
B-4	19-ST	50	52	735.4	683.4	2	Clayey SAND (SC), moist. Grey. Well graded, angular.	NA (sand)	NA (sand)	Interglacial Zone	NP[t]	NP	NP	89	77	57	13	9	4		15.4			SP							
B-1	19-ST	55	57	738.6	681.6	0.9	SILT (ML), moist. Dark greenish grey.	>4	8	Interglacial Zone																					
B-3	18-PIT	55.5	58.5	734.2	675.7	2.3	Sandy SILT (ML), moist. Grey. Some gravel.	>4	NA	Illinoian Till	NP	NP	NP	99	98	89	62	53	9	NP	14.9			ML							
B-1	21-PIT	60.5	63.5	738.6	675.1	1.4	Sandy SILT (ML), slightly moist. Grey.	>4	>10	Illinoian Till																					
B-4	22-PIT	60.5	63.5	735.4	671.9	1.9	Sandy SILT (ML), moist. Grey. Some small gravel (up to 1/2" dia). Slightly plastic.	>4	7	Illinoian Till	19	13	6	98	98	90	78	48	30	NP	12.9	1.68		CL-ML							
B-3	20-PIT	60.5	63.5	734.2	670.7	1.5	Sandy SILT (ML), slightly moist. Grey. Some sand and small gravel (to 3/4", rounded).	>4	5.5	Illinoian Till																					
B-3	23-PIT	70.5	73.5	734.2	660.7	2.4	Sandy SILT (ML), moist. Greenish Grey. Some sand and small gravel.	>4	6.5	Illinoian Till																					
B-1	25-PIT	75.5	78.5	738.6	660.1	1.7	SILT (ML), moist. Dark grey. Some small gravel & sand.	2.75	6	Illinoian Till																					
B-4	28-PIT	80.5	83.5	735.4	651.9	2	Sandy SILT (ML), moist. Dark grey. Some gravel. Slightly plastic.	>4	>10	Illinoian Till																					
B-3	26-PIT	80.5	83.5	734.2	650.7	2.1	Sandy SILT (ML), slightly moist. Dark grey. Some sand & small gravel.	>4	>10	Illinoian Till	17	10	7	95	93	78	48	27	21	134.2	8.5	7.82		SC							
B-1	28-PIT	85.5	88.5	738.6	650.1	1	Sandy SILT (ML), slightly moist. Grey. Some large cobbles.	>4	>10	Illinoian Till																					

TABLE 4-1
Summary of Shelby Tube and Pitcher Samples and Corresponding Geotechnical Test Results

											Classification														Consolidation				Triaxial Compression (CIU[a])		Triaxial Compression (UU[b])
Boring ID	Sample ID	Top Depth (ft bgs[c])	Bottom Depth (ft bgs)	Surface Elevation (ft above msl[d])	Sample Elevation (ft above msl)	Sample Recovery (ft)	Field Soil Description	Pocket Pen (tsf[e])	Pocket Torvane (tsf)	Stratigraphic Unit	LL[f]	PL[g]	PI[h]	P4[i] (%)	P10[i] (%)	P40[i] (%)	P200[i] (%)	Silt (%)	Clay (%)	Dry Density (pcf[j])	Moisture Content (%)	Qu[k] (tsf)	Carbon (%)	USCS[l] Class	Cc[m]	Cr[n]	Pc'[o] (tsf)	Void Ratio	Phi[p] (deg.)	C[q] (tsf)	Su[r] (tsf)
B-1	30-PIT	90.5	93.5	738.6	645.1	2.6	Sandy SILT (ML), slightly moist. Grey. Some large cobbles.	>4	>10	Illinoian Till	20	9	11							140.5	5.4				0.079	0.0055	5	0.1991			2.376
B-2	20-PIT	90.5	93.5	737.8	644.3	2.7	Sandy SILT (ML), slightly moist. Grey. Some sand & small gravel	>4	>10	Illinoian Till	19	8	11	94	89	76	49	30	19	140.2	7.4	14.4		SC							
B-4	32-PIT	95.5	98.5	735.4	636.9	1.7	Sandy SILT (ML), moist. Dark grey. Some gravel, coble to 1 1/2" dia.	>4	>10	Illinoian Till	17	8	9	97	95	80	50	30	20	140.4	7.4			CL							
B-3	30-PIT	95.5	98.5	734.2	635.7	2.8	Sandy SILT (ML), moist. Dark grey. Some sand & small gravel.	>4	>10	Illinoian Till																					
B-3	33-PIT	115.5	118.5	734.2	615.7	2.7	Sandy SILT (ML), moist. Dark grey. Some sand & small gravel.	>4	>10	Illinoian Till																					
B-3	36-PIT	135.5	138.5	734.2	595.7	2.7	Sandy SILT (ML), moist. Dark grey. Some sand & small gravel.	>4	>10	Illinoian Till	18	9	9	99	97	86	58	35	23	135.2	8.7	6.45		CL							
B-2	27-PIT	145.5	148.5	737.8	589.3	2.1	Sandy SILT (ML), slightly moist. Dark grey. Some sand & small gravel.	>4	>10	Illinoian Till	19	9	10							136.5	7.6				0.089	0.0075	7	0.234			8.64
B-3	39-PIT	155.5	158.5	734.2	575.7	2.7	Sandy SILT (ML), moist. Dark grey. Some sand & small gravel.	>4	>10	Illinoian Till																					
B-3	42-PIT	170	173	734.2	561.2	2.7	Sandy SILT (M), moist (may be lean clay). Olive & Grey mottling. Some sand and small gravel.	>4	>10	Lacrustine	28	11	17							117.9	12.7				---	0.009	---	0.429	32.6	0	
B-2	32-PIT	190.5	193.5	737.8	544.3	2.3	SILT (ML), slightly moist. Dark greyish brown. Some sand & small gravel.	>4	>10	Pre-Illinoian Till	17	8	9	97	94	78	47	25	22	134.4	8.6	4.85		SC							
B-3	47-PIT	205.5	208.5	734.2	525.7	2.8	SILT (ML), dry to slightly moist. Dark grey. Trace fine sand, no gravel.	3.5	6	Pre-Illinoian Till																					
B-2	35-PIT	210	213	737.8	524.8	2.3	Lean CLAY (CL), moist. Dark greyish brown. With trace small gravel & sand.	>4	>10	Pre-Illinoian Till	37	15	22							120.1	14.9	5.72		CL							
B-3	50-PIT	225.5	228.5	734.2	505.7	1.7	Lean CLAY (CL), moist. Olive grey. Trace sand & small gravel.	>4	>10	Pre-Illinoian Till	32	18	14	96	95	86	65	29	35	110.6	17.6	4.55		CL							
B-2	38-PIT	240	243	737.8	494.8	1.9	Sandy SILT (ML), slightly moist. Dark greyish brown.	>4	>10	Pre-Illinoian Till																					
B-3	53-PIT	245.5	248.5	734.2	485.7	2.8	Lean CLAY (CL), moist. Dark greyish brown. Trace sand & small gravel.	>4	>10	Pre-Illinoian Till																					

TABLE 4-1
Summary of Shelby Tube and Pitcher Samples and Corresponding Geotechnical Test Results

											Classification														Consolidation				Triaxial Compression (CIU[a])		Triaxial Compression (UU[b])
Boring ID	Sample ID	Top Depth (ft bgs[c])	Bottom Depth (ft bgs)	Surface Elevation (ft above msl[d])	Sample Elevation (ft above msl)	Sample Recovery (ft)	Field Soil Description	Pocket Pen (tsf[e])	Pocket Torvane (tsf)	Stratigraphic Unit	LL[f]	PL[g]	PI[h]	P4[i] (%)	P10[i] (%)	P40[i] (%)	P200[i] (%)	Silt (%)	Clay (%)	Dry Density (pcf[j])	Moisture Content (%)	Qu[k] (tsf)	Carbon (%)	USCS[l] Class	Cc[m]	Cr[n]	Pc'[o] (tsf)	Void Ratio	Phi[p] (deg.)	C[q] (tsf)	Su[r] (tsf)
B-2	40-PIT	265.5	268.5	737.8	469.3	2.7	Sandy SILT (ML), moist. Dark greenish grey.	3.5	3.5	Pre-Illinoian Till	NP	NP	NP	100	100	83	67	52	14		22.9			ML							
B-2	42-SS	280	280.5	737.8	457.3	0.5	Lean CLAY (CL), slightly most. Greenish Grey, mottled.	NA	NA	Pre-Illinoian Alluvial/Lacustrine	48	17	29	100	100	98	96	24	72					CL							

Notes:

a. consolidated isotropically undrained
b. unconsolidated undrained
c. below ground surface
d. mean sea level
e. tons per square foot
f. liquid limit
g. plastic limit
h. plasticity index
i. soil fraction (%) passing the No. 4, 10, 40, and 200 standard sieves, respectively
j. pounds per cubic foot
k. unconfined compression strength
l. Unified Soil Classification System
m. compression ratio
n. recompression ratio
o. preconsolidation pressure
p. friction angle
q. cohesion intercept
r. undrained shear strength
s. not applicable
t. not performed

CHAPTER 5

Geologic and Geotechnical Conditions at the EGC ESP Site

Results of literature reviews, the field exploration program, and the laboratory testing program were used to evaluate regional and site geology and the geotechnical conditions at the EGC ESP Site. This evaluation was performed as part of the assessment of site suitability. The assessment of the geology and geotechnical conditions was used for the following purposes:

- The geologic information was used to update the understanding of geologic hazards that could exist in proximity to the site, relative to the conclusions that were made during the original CPS Site investigation in the mid-1970s. The discovery of new geologic hazards would require an assessment of their risk relative to construction and operations.
- The geotechnical information was used to draw comparisons between soil conditions at the EGC ESP Site relative to those occurring at the CPS Site. A goal of the EGC ESP program was to show that the engineering characteristics are very similar between the two sites, thereby justifying the use of the existing geotechnical database to supplement the understanding of the geotechnical conditions at the EGC ESP Site.
- New geotechnical information was also used to update the shear wave velocity, shear modulus, and material damping ratio information for the EGC ESP Site. This new information was required to account for advances in the areas of field geophysical testing and cyclic laboratory testing that have occurred since dynamic property investigations were done during the mid-70s for the CPS Site.

As noted previously, this Geotechnical Report does not provide any discussions or updates to the seismic hazard occurring at the site. The seismic hazard for the EGC ESP Site is summarized in Section 2.5 and discussed in detail in Appendix B of the SSAR.

In general, the following discussions will indicate that the regional and site geology and the geotechnical conditions for the EGC ESP Site are consistent with information in the CPS USAR. No new geologic hazards were identified during the study of regional and site geology. Results of the geotechnical evaluation indicate that contacts between stratigraphic units are flat to gently sloping across the two sites, as shown in Figures 5-1 and 5-2. Soil classification properties for each stratigraphic unit are consistent between the EGC ESP and CPS Sites, as are static and dynamic soil engineering properties.

5.1 Regional and Site Geology

The regional and site-specific geology sections of the CPS USAR were reviewed relative to publicly available regional and site-specific geologic information that has become available since the site evaluations were first conducted for the CPS Site. This literature review

included a search of information at the Illinois State Geological Survey (ISGS) to identify new, published research that is applicable to the CPS and EGC ESP Sites. This new information, combined with previously available information published in the CPS USAR and geologic information from the EGC ESP Site, indicate that geologic conditions at the EGC ESP and CPS Sites are consistent.

5.1.1 Regional Geology

Since the publication of the CPS Site geologic information in the mid-1970s, the ISGS has completed significant studies on the regional Mahomet Bedrock Valley and the Quaternary System glacial sediments that fill this valley. Results of these studies indicate that the most prominent Quaternary System feature in the east-central region of Illinois is the Mahomet Bedrock Valley, which is a channel cut into the Pennsylvanian bedrock and is now filled with glacial materials. Lowland valley sediments are more coarse-grained and are important aquifers in the region, while glacial material deposited on the upland side of the bedrock valley are finer-grained. This deep channel was filled with the widespread Mahomet Sand Member, which is as much as 200-ft thick and is interbedded or overlaid by tills of the Banner Formation.

Kempton et al. (1991) notes that the Mahomet Bedrock Valley runs from the northwest edge to the southeast corner of DeWitt County, with smaller channels running away or interconnecting the valley (see Figures 2-1 and 5-3). The EGC ESP and CPS Sites lie on the eastern edge of the Mahomet Bedrock Valley on the edge of the upland. Studies conducted by Kempton and Herzog (1996) in this area indicate that the Mahomet sand and related sediments are not present and that glacial materials are dominated by fine-grained silts and clays (see Figure 5-4).

This new regional geologic information does not result in changes to the overall significance of the regional geologic information discussed in the CPS USAR and presents no hazard from the standpoint of construction or operation of a new facility at the EGC ESP Site.

5.1.2 Site Geology

The surface topography at the EGC ESP Site is similar to conditions around the CPS Site. The closest distance to Clinton Lake is approximately 800 ft northwest of the EGC ESP Site. Generally, the ground surface at the site is covered by grasses and small bushes, and is transected by a grid of gravel access roads and associated drainage ditches. Localized clusters of small trees are present in some areas. The site is currently clear of facilities, except for a fenced-in storage yard and a buried power line. Some remnants of surface grading, filling, and building demolition operations from construction of the CPS Facilities are present at the EGC ESP Site.

Results from classification and testing of soil samples obtained from the four soil boreholes advanced in 2002 within the EGC ESP Site confirm that the general stratigraphic sequence at the CPS Site described in Section 2.2 of this Geotechnical Report (shown on Figure 2-6) is consistent with conditions at the EGC ESP Site. At these boreholes, the unconsolidated deposits consist of the Richland Loess, the Wedron Formation (Wisconsinan glacial till and outwash), the Interglacial Zone (Glasford Formation soils weathered during the Sangamonian Stage), the Glasford Formation (Illinoian glacial till and outwash),

Yarmouthian Stage lacustrine deposits (including pre-Illinoian till weathered during the Yarmouthian Stage), pre-Illinoian Stage glacial till and outwash, and pre-Illinoian alluvial or lacustrine deposits. Figures 5-1 and 5-2 show geologic cross sections cut northwest to southeast and southwest to northeast across the EGC ESP Site, respectively. These sections show original boreholes advanced for the CPS Site, as well as the boreholes from the geotechnical investigation for the EGC ESP Site. These sections illustrate that subsurface conditions at the EGC ESP Site are the same as those at the CPS Site shown on Figure 2-6.

As shown on Figures 5-1 and 5-2, fine sand deposits noted in CPS Site boreholes near the top of the Wedron Formation apparently continue to the south of the CPS Site. The top of the Illinoian till (Glasford Formation) drops toward the south, to an average elevation of 678 ft in the four new boreholes. Lacustrine deposits were encountered below the Glasford Formation at elevations consistent with the CPS Site boreholes (566 ft and 574 ft). Pre-Illinoian alluvial deposits, consisting of interbedded silts, clays, sands, and gravels, were encountered above the top of bedrock.

The additional boreholes indicate that the eroded bedrock surface drops slightly from north to south near the EGC ESP Site, as shown on Figure 5-5. This trend can also be seen on the EGC ESP Site cross sections shown in Figures 5-1 and 5-2. The top of bedrock was encountered at elevations of 445.5 ft and 450.2 ft above msl in boreholes B-2 and B-3. This is approximately 36 to 46 ft lower than bedrock elevations at nearby CPS Site boreholes to the northwest and northeast (P-20 and P-22, with bedrock elevations of 485.8 and 492.0 ft above msl, respectively). Based on the bedrock elevations, EGC ESP Site boreholes B-2 and B-3 appear to be located at the edge of the Mahomet Bedrock Valley present south of the CPS Site (see Figures 5-3 and 5-4).

Groundwater elevations at the EGC ESP Site are consistent with the CPS Site. A detailed discussion of hydrogeologic conditions at the EGC ESP Site is presented in Section 2.4.13.2 of the SSAR. Generally, groundwater exists in a perched water table condition a few feet below ground surface in the shallow Wisconsinan till soils, as indicated by EGC ESP piezometers B-2-Piezo and B-3-Piezo. A downward gradient is observed at the EGC ESP Site. The piezometric head at B-1-Piezo, completed in the Illinoian Till (Glasford Formation), was approximately 20 ft lower than in the shallow Wisconsinan Till (see Table 3-1). Observations at these EGC ESP Site piezometers are consistent with results from the original CPS Site piezometers.

5.1.3 Other Geologic Considerations

A number of other geologic features are discussed in the CPS USAR. The geologic review conducted for the EGC ESP Site found these still to be valid and applicable. Since the initial publication of the CPS Site geologic information, the ISGS has completed additional studies and data summaries for the State of Illinois and DeWitt County that relate to geologic considerations at the EGC ESP Site. Results of these studies are summarized below.

5.1.3.1 Karst Terrain

Karst terrain includes topographic depressions (sinkholes), caves, large springs, fluted rocks, blind valleys, and swallow holes that develop in areas of high rock solubility and well developed porosity and permeability. These features can affect the foundation support for buildings and other structures. Karst terrain can occur in areas where bedrock lithology is

dominated by carbonate rocks such as limestone or dolomite and where drift thickness is less than 50 ft.

The ISGS has identified some areas in Illinois that are susceptible to karst development. However, according to the ISGS assessment, DeWitt County is not susceptible to karstification (Weibel and Panno, 1997; Panno et al., 1997).

5.1.3.2 Mine Subsidence

Mine subsidence is the sinking of the ground surface after the collapse of an underground mine, and this ground movement can damage overlying structures. Mine-related subsidence has occurred in Illinois, and the ISGS has identified areas where subsidence is likely due to known occurrences or possibly due to the proximity to known subsurface mines.

The EGC ESP Site assessment found no historic mines in DeWitt County (Bauer et al., 1993); therefore, there is no mine subsidence risk at the EGC ESP Site based on known data (Treworgy et al., 1989).

5.1.3.3 Natural Gas Production and Oil Fields

Natural gas production from glacial drift has been documented in Illinois, and some of these gas producing wells have been used as fuel sources starting as early as 1900. This gas is derived from organic matter in deep valleys filled with glacial material. Fine-grained materials in glacial materials, such as end moraines, control the accumulation of gases.

Five gas producing wells have been documented in the western part of DeWitt County (Meents, 1960). No wells have been identified in the literature for the EGC ESP Site or CPS Site, indicating that the occurrence of gas producing strata is not of concern.

The locations of the two oil well fields identified in the CPS USAR were verified by the ISGS (Huff, 1994). The Parnell well field has 38 oil wells with pay zones in Silurian- and Mississippian-age formations, and the Wapella East oil field has 36 wells with a pay zone in Silurian limestone (Berggren and Hunt, 1979). Available data indicate that the nearest oil producing wells are located more than 4 mi northeast of the CPS. The locations of these wells are such that they do not pose a hazard to the EGC ESP Site.

5.1.3.4 Groundwater Springs

A groundwater spring occurs at the Weldon Springs State Recreation Area, which is approximately 5 mi west-southwest of the CPS and EGC ESP Sites. This spring originates in the near-surface Wisconsinan silty sands and gravels and discharges to a small lake in the recreation area. Based on tritium studies, the spring water is 20 to 30 years old, which documents the time required for infiltration, migration through the sands and gravels, and then discharge at the spring. Groundwater and surface water in this area discharges toward Salt Creek (Panno and Hackley, 2001; Berggren and Hunt, 1979).

The Weldon Springs State Recreation Area will not be impacted by groundwater extraction activities at the EGC ESP Site because the springs are hydraulically separated from the EGC ESP Site by Clinton Lake and Salt Creek. Similarly, the presence of the spring does not pose a hazard to the EGC ESP Site.

5.1.3.5 Landslides

The ISGS has identified and classified known landslides in Illinois. These data, and a base map from the United States Geological Survey (USGS), were used to form a general landslide potential map for Illinois. There are no landslides documented for DeWitt County, and the landslide potential on the ISGS map is low (Killey et al., 1985).

The only slopes near the EGC ESP Site are those associated with Clinton Lake. These slopes are located approximately 800 ft northwest of the EGC ESP Site. They have been very stable for the past 30 years, and therefore, landsliding does not pose a hazard. Additionally, the distance between the slopes and the EGC ESP Site is such that, if landsliding were to occur, it would not extend to the EGC ESP Site.

During final design of the selected reactor plant design, additional slope stability studies could be required in the area of the outfall pipe, if a new outfall is constructed. These studies will be necessary to confirm that there is no potential for landslides (or slope instability) in the vicinity of the outfall pipe. The landslide evaluations are not performed at the ESP stage, when the need for an outfall is unknown. If landslide issues are identified during the COL stage, there are a number of measures that could be taken to mitigate the problem, such as relocation of the outfall, reducing the ground slope, or improving the ground through use of stone columns or a similar ground improvement method. Thus, slope stability is not a concern for the EGC ESP Site.

5.1.3.6 Overall Geologic Suitability

A geologic planning document for nearby Macon and Sangamon counties, which are immediately south and southwest of DeWitt County, concludes that surficial materials present few serious problems to construction. In addition, the most common problem is poor drainage on relatively flat, dense glacial deposits. Due to the similarity and proximity of these counties, and the fact that DeWitt and Macon counties both lie in the Bloomington Ridged Plain physiographic province, these general conclusions apply also to DeWitt County (Bergstrom et al., 1976).

5.2 Geotechnical Conditions

Each of the major stratigraphic units encountered during the EGC ESP Site geotechnical investigation was also encountered in the original CPS Site investigations. Results of soil classification, static strength and compressibility, and dynamic response tests conducted on soils from each of these units are also generally consistent between the EGC ESP and CPS Sites. The similarity in stratigraphy and soil properties supports the conclusion that the geotechnical conditions relative to foundation behavior at the EGC ESP Site are the same as those reported for the CPS Site in the CPS USAR.

5.2.1 Soil Profile

Table 5-1 summarizes the field observations for each of the major stratigraphic units encountered in boreholes B-1 through B-4. Soil types encountered are very similar among the four boreholes, and contact elevations varied within a vertical range of no more than 20 ft for each stratigraphic unit across the EGC ESP Site footprint. Profiles of the stratigraphic units encountered at the CPS and the EGC ESP Sites are shown graphically on

Figures 2-6, 5-1 and 5-2. These figures show that the contact depths for stratigraphic units across the Sites are also consistent.

Figure 5-6 shows the variation of corrected SPT blowcount ($N'_{[60]}$) with depth for each of the four boreholes, corrected for overburden and hammer efficiency. While conditions among the four boreholes are generally consistent, some variations are noted in these data. In the Wisconsinan till, $N'_{(60)}$ values of greater than 75 were encountered from 15 to 20 ft bgs at B-2, higher than in the other boreholes. In the upper Illinoian till, SPT blowcounts of greater than 50 were encountered at boreholes B-2 and B-3 within the upper 5 ft of the unit, whereas at boreholes B-1 and B-4 these conditions were not encountered until 20 ft within the unit.

The range and average of $N'_{(60)}$ results for each stratigraphic unit from the geotechnical investigation for the EGC ESP Site are listed in Table 5-1. The average $N'_{(60)}$ values are within 20 percent of results from the original CPS Site investigation for all but one stratigraphic unit. The exception is for the Lacustrine deposits, for which the EGC ESP Site $N'_{(60)}$ results were approximately 60 percent higher than the CPS Site results. This may be because soils encountered at boreholes B-2 and B-3 were actually pre-Illinoian tills weathered during the Yarmouthian Stage, which are grouped within in the "Lacustrine deposits" stratigraphic unit. Soils formed by actual lake deposition were likely encountered in some of the original CPS Site borings, which would typically exhibit lower stiffness, and therefore lower $N'_{(60)}$.

Some of the difference between the $N'_{(60)}$ values recorded during the EGC ESP explorations and the CPS Site explorations can possibly be explained on the basis of the SPT hammer energy transfer efficiency. During the EGC ESP Site investigation, the energy of the hammer was analyzed as discussed in Section 3.1.2.2. No information was available regarding the energy delivered by the hammer in the exploration program for the CPS Site. It was assumed that the methods used in the mid-70s, when the CPS Site explorations were conducted, would deliver an energy of 60 percent, similar to the average energy usually attributed to hammers being used in the 1970s. However, variations in the energy would not be unexpected.

5.2.2 Soil Classifications and Rock Characteristics

Soil classification data from the EGC ESP Site geotechnical investigation for each stratigraphic unit are summarized in Table 4-1. Classification data consist of Atterberg limits and grain size distribution data. In situ dry density, moisture content, and limited carbon content data are also summarized in this table. Similar information is also presented in the CPS USAR including Atterberg limits, moisture content, and dry density. Comparison of geotechnical investigation data from the EGC ESP and CPS Sites for each stratigraphic unit are presented in the following sections. Of the data in the CPS USAR, results from the CPS Site boreholes (P-series boreholes) are considered the most directly comparable to conditions at the EGC ESP Site. Therefore, data from the P-series boreholes are used for quantitative comparison with the EGC ESP Site data.

5.2.2.1 Richland Loess

Weathered loess was encountered near the ground surface at most of the P-series boreholes. This material, typically between 5- and 10-ft thick, is described as clayey silt or silty clay, ranging in color from black to mottled gray and brown, and soft to very stiff in consistency.

In most locations, this material overlies the Wisconsinan glacial till (Wedron Formation). Classification tests were performed on this material from several of the P-series boreholes. In the P-series data, the deeper samples are less plastic than the upper samples. It is possible that the upper samples contain higher organic content topsoil and subsoil horizons, and may not represent the weathered loess. This is also indicated by lower dry density in the upper samples than in the lower.

During the EGC ESP Site investigation, the weathered loess material was encountered within the top 10 ft of each of the four boreholes. Samples from the EGC ESP Site investigation were collected from the same depth interval (5 to 7 ft bgs), but represent different soil types.

Figures 5-7 and 5-8 compare the classification results (Atterberg limits, moisture content, and dry density) from the EGC ESP Site samples with results from the P-series boreholes. While the EGC ESP Site samples did vary in plasticity and density, the results are within the range of P-series borehole data.

5.2.2.2 Wisconsinan Till (Wedron Formation)

The Wisconsinan till unit generally consists of brown to gray lean clay and silt. Sand and gravel are typically found within this unit in trace to moderate quantities, and discrete silty sand and gravel outwash zones are present at several of the CPS Site P-series boreholes and at two of the four EGC ESP Site boreholes. The Wisconsinan till was encountered within each of the EGC ESP Site boreholes and at each of the P-series boreholes advanced in the upland area around and south of the existing CPS Site. Classification tests were performed on Wisconsinan soil samples collected from the EGC ESP Site and P-series boreholes. Figures 5-9 and 5-10 compare the results from these investigations.

Results from the CPS Site P-series samples indicate that plasticity of the Wisconsinan till is relatively consistent with depth: plastic limits (PLs) were within a range of 10 percentage points, and liquid limits (LL) were within a range of 11 percentage points. Water contents are near or less than the PL for the samples, indicating that the till is overconsolidated. Dry densities of the samples are also consistent, ranging between 116 and 128 pcf in each sample. Classification tests were performed on two samples from the EGC ESP Site. In these samples, plasticity, moisture content, and dry density are consistent with the P-series results.

5.2.2.3 Interglacial Zone (Weathered Glasford Formation)

The Interglacial zone generally consists of lean clay interbedded with silty sands and sandy silts, which were weathered from parent Glasford Formation tills during the Sangamonian Stage. The clay intervals generally have trace to no gravel. Soil color is typically dark gray to greenish gray. The top of the Interglacial zone is prominently marked by a brown organic peat or paleosol layer, which is nearly horizontal across the site at an elevation of approximately 695 to 700 ft above msl. Classification tests were performed on the Interglacial zone soil samples collected from the EGC ESP Site and CPS Site P-series boreholes. Figures 5-11 and 5-12 compare the results from these investigations.

Results from the nine CPS Site P-series soil samples from the Interglacial zone indicate that soil plasticity, density, and water content are highly variable. This is consistent with the

various interlayered soil types encountered within this stratigraphic unit. Results from the EGC ESP Site samples from the same unit are consistent with this wide range of classification parameter results. For one sample (B-4, 15-ST), LL (62) and PL (51) are outside the range of values reported for the P-series boreholes. This sample was collected from the organic layer that marks the top of the Interglacial. Water content is elevated (59 percent) and dry density is low (65 pcf) in this sample, also indicative of the organic nature of the soil. Samples are not classified from the organic material in the P-series boreholes, but the interval is noted on the P-series borehole logs. Other sample results from the EGC ESP Site boreholes are within the range of values from the P-series samples.

5.2.2.4 Illinoian Till (Unweathered Glasford Formation)

The Illinoian till is a relatively uniform soil unit, which classifies on the borderline between lean clay, silt, and silty sand. Small gravel is included throughout the material. The unit is gray to dark gray, slightly moist, and typically hard to very hard. The Illinoian till is encountered in each of the EGC ESP Site and CPS Site P-series boreholes, and numerous classification tests were performed on samples from each of these investigations. Figures 5-13 and 5-14 compare the classification test results from these investigations.

Results from 13 CPS Site soil samples from the Illinoian till indicate that soil plasticity, water content, and density are very consistent with depth. The PL varies within a narrow range (that is, 5 percent water content), as does the LL (7 percentage points, except for the very bottom of the interval). At each location, water content is below the PL, which indicates that the unit is overconsolidated. The samples also have very high dry density (that is, between 135 and 141 pcf). This material was generally assigned the common classification of "clayey silt" in the CPS USAR, although the Unified Soil Classification System (USCS) classification is likely borderline lean clay or silt.

Classification tests were performed on five Illinoian till samples from the EGC ESP Site investigation. Results from this investigation are consistent with the CPS Site results. Atterberg limits and dry density for each sample are within the range of results from the P-series samples. Water content is less than the PL for each sample. The P200 fraction of the material is slightly less than 50 percent in several of the samples, but typically less than 60 percent (except for the upper portion of the unit). Likewise, the plasticity characteristics of the fine fraction are typically near the borderline between classification as a silt or a clay. As a result of these borderline conditions, the till may vary in USCS classification between silt, lean clay, or silty sand with relatively small changes in gradation and plasticity. Any of these classifications could correlate with the common classification of "clayey silt" assigned to soils in the CPS Site P-series borehole logs.

5.2.2.5 Lacustrine Deposits

Lacustrine deposits of the Yarmouthian Stage near the CPS Site consist of clayey silt to silt with some intervals of organic soil. Weathered pre-Illinoian till (that is, silty clays and clayey silts with gravel), typically greenish gray with some sand and gravel, is also included in this unit. In the CPS Site P-series boreholes, the greenish gray weathered till unit is encountered at most locations, at a nearly constant elevation of approximately 570 ft above msl. This interval is typically approximately 10-ft thick, and grades to the dark gray pre-Illinoian till deposits below. Organic soil is generally not encountered within the lacustrine

deposits in the CPS Site P-Series boreholes. The greenish gray weathered till unit is encountered at both of the deep EGC ESP Site boreholes (boreholes B-2 and B-3), at the same elevation and thickness as reported in the CPS USAR.

Due to the small thickness of and significant depth to the lacustrine unit, two samples were tested for classification parameters from the CPS Site P-series boreholes, and one sample was tested from borehole B-2 during the EGC ESP Site investigation. Data from the P-series boreholes indicate that the soil is a borderline (CL-ML) material, with LLs of 17 and 20, and plasticity index (PI) of 7 for both samples. Dry density is 126 pcf for the two samples tested, and moisture content is near the PL. The lacustrine sample collected from the EGC ESP Site borehole B-2 is more plastic than the P-series samples (LL of 28, PI of 17), and slightly less dense (dry density of 118 pcf).

5.2.2.6 Pre-Illinoian Till and Alluvial/Lacustrine Deposits

The pre-Illinoian till is encountered below the Yarmouthian Stage lacustrine deposits at each of the CPS Site P-series boreholes. The material consists of lean clay and silt with some sand and gravel, and is generally considered to be from the Kansan substage glaciation. This material is of higher plasticity and lower sand and gravel content than the Illinoian till. Frequent interbedded layers of sorted fine sands and silts are common within the till. Definition of the contact between the base of the till and the top of earlier alluvial or lacustrine deposits is often obscured by the presence of this sorted layering within the till. Similar characteristics are observed in the two EGC ESP Site boreholes that were advanced to the pre-Illinoian till (boreholes B-2 and B-3).

Classification tests were performed on various samples from the EGC ESP Site boreholes. Comparisons of these test results with the results from the CPS Site P-series samples are shown in Figures 5-15 and 5-16. The PLs of the P-series samples range from 16 to 18, while the LL results are significantly more variable (ranging from 25 to 43). Water content is near or below the PL in each of the P-series samples, and the dry density is 116 pcf for each of these samples. In general, these results indicate that the pre-Illinoian till is more plastic and less dense than the Illinoian or Wisconsinan till.

The classification tests performed on two EGC ESP Site samples from the pre-Illinoian till are somewhat consistent with the CPS Site P-series results, with a few variations. The uppermost sample of the pre-Illinoian till (B-2, 32-PIT), collected directly below the lacustrine deposits, is more consistent with the Illinoian till results than with the P-series pre-Illinoian results (that is, with lower Atterberg limits of plastic limit (PL) of 8, LL of 17, and higher dry density of 134 pcf). The other results are within the relatively variable range of plasticity results for the P-series pre-Illinoian till samples. The variability of these results reflects the abundance of interbedding and sorting of materials within this unit.

As mentioned previously, the contact between the base of the pre-Illinoian till and deeper alluvial or lacustrine deposits is difficult to identify due to the variable nature of materials included within the till. However, low-energy deposits of well-sorted fine sands, as well as clean silts and clays (with trace to no small gravel), are noted within the top 20 to 30 ft above bedrock in boreholes B-2 and B-3 from the EGC ESP Site. This may indicate either alluvial or lacustrine deposition. Test results for one sample (B-2, 42-SS) indicate that the material is a lean clay, with P200 of 96 percent, and a PI of 29, which may be consistent with a

lacustrine deposition. The presence of pre-Illinoian alluvial or lacustrine material above bedrock in the vicinity of B-2 and B-3 is consistent with the trend indicated by the CPS Site P-Series boreholes, as shown in Figures 2-6, 5-1, and 5-2.

Summary figures comparing moisture content, dry density, and Atterberg limits test results from the EGC ESP Site with the results from the CPS Site P-series samples are shown in Figures 5-17 and 5-18, for all stratigraphic units.

5.2.2.7 Rock Characteristics

Bedrock was encountered at boreholes B-2 and B-3, at elevations of 445.5 and 450.2 ft above msl, respectively. Rock coring was advanced at these locations to additional depths of 30 and 20 ft below the bottom of each soil borehole, at 292 and 286.2 ft bgs, respectively. Note that at borehole B-2, the bottom of the soil borehole was terminated at the top of bedrock, whereas at borehole B-3 the soil borehole advanced through the upper 2.2 ft of weathered bedrock prior to the start of rock coring (from 284 to 286.2 ft bgs).

At borehole B-2, the bedrock core consisted of 24 ft of unweathered to slightly weathered shale over 1- to 2-ft thick intervals of interbedded shale and limestone, coal, and underclay (weathered shale). The coal seam is likely No. 8 coal of the Modesto Formation. The contact elevation of this coal seam at borehole B-2 is approximately 10 ft deeper than reported at P-38, which is located approximately 1,000 ft north of borehole B-2. This indicates that this coal seam drops slightly to the south, which is consistent with the regional stratigraphy summarized in Section 2.2.2.

At borehole B-3, the entire 20-ft bedrock core consisted of slightly weathered shale with abundant thin fine sand to silt partings, with a 1-ft layer of sandstone at the top of the core.

The rock cores at boreholes B-2 and B-3 were collected to confirm the presence of bedrock and to identify the rock type, and were not intended to provide samples for strength or other analytical testing. Therefore, no laboratory testing was performed on the rock core samples. Based on the confirmatory rock cores at boreholes B-2 and B-3, Pennsylvanian bedrock conditions are similar at the EGC ESP and CPS Sites. The bedrock surface indicated by boreholes B-2, B-3, and the CPS Site boreholes is shown on Figure 5-5.

5.2.3 Compressibility and Strength Characteristics

One-dimensional consolidation tests and triaxial shear strength tests were performed on selected samples from the Illinoian till and underlying lacustrine deposits during the EGC ESP Site investigation. Triaxial testing consisted of two UU tests and one isotropically consolidated-undrained (CIU) test. The CIU test included pore water pressure measurements during shear of the sample. The sample depths for testing were selected to provide information on the strength and compressibility characteristics of soils that may be left in place during future construction, and where CPS Site data are available for direct comparison with the results.

5.2.3.1 Consolidation Test Results

Consolidation test results from the EGC ESP Site are presented in Table 4-1. Two of the tested samples are from the Illinoian till, at depths of 90 and 145 ft bgs (elevations of 645 and 589 ft above msl, respectively). The third tested sample is from the lacustrine deposits, at a

depth of 170 ft bgs (elevation of 561 ft above msl). Each sample was loaded past its expected preconsolidation pressure, unloaded, and reloaded to the same pressure. Consolidation laboratory test results are included in Attachment A-6.

The interpreted test results for the two Illinoian till samples (90 and 145 ft bgs, respectively) are as follows:

- Compression index (C_c): 0.08 and 0.09;
- Recompression index (C_r): 0.006 and 0.008;
- Preconsolidation pressure (P_c'): 5 and 7 tsf; and
- Initial void ratio: 0.20 and 0.23.

Results from the lacustrine sample are C_c = 0.1, C_r = 0.009, and initial void ratio of 0.43. The preconsolidation pressure for this sample could not be reliably determined from the test results.

These consolidation test results from the EGC ESP Site are generally consistent with the test results from the original CPS Site reported in Section 2.5.4.2.3.2 and Table 2.5-62 of the CPS USAR. Consolidation tests were performed on 16 CPS Site P-series borehole soil samples collected from the Illinoian till. In these samples, C_c ranges from 0.05 to 0.18, with an average of 0.1, which is consistent with test results from the EGC ESP Site. C_r ranges from 0.007 to 0.017 in the P-series data, with an average of 0.012. The EGC ESP Site data are near the lower end of this range. Initial void ratios range from 0.15 to 0.47 in the P-series data, with an average of 0.20. The EGC ESP Site results are consistent with these data.

The interpreted P_c' for the Illinoian till samples from the EGC ESP Site are slightly lower than reported for the CPS Site P-series samples. In the P-series samples, P_c' ranges from 8 to 12.5 tsf, with an average of 9.9 tsf. The results from the EGC ESP Site (5 and 7 tsf) are outside the lower bound of this range. However, the general shapes of the new consolidation curves, plotted as void ratio versus the logarithm of applied load (log p), are consistent with several of the P-series curves, and the variation in P_c' may be a result of variations on interpretation of the curves. For interpretation of P_c' with the EGC ESP Site test curves, Schmertmann's procedure for overconsolidated soils was applied (Schmertmann, 1955). The CPS USAR does not report how P_c' was interpreted from the P-series test curves.

Values of C_c and C_r for the lacustrine sample from the EGC ESP Site are consistent with results from the two P-series lacustrine samples. Initial void ratio of the EGC ESP sample is higher than the P-series results (0.43 versus the average P-series sample result of 0.275), as is the LL (29 versus 20 percent). Preconsolidation pressure could not be reliably interpreted from the consolidation curve for the EGC ESP lacustrine sample.

It is concluded from these comparisons that the compressibility of soils at the EGC ESP and CPS Sites are essentially the same. Soils at both sites exhibit high preconsolidation pressures, as would be expected for a site that has been consolidated during past glaciations. The compression indices are relatively low, indicative of the silty characteristics of the soil. The ratio of initial compression indices to recompression indices is approximately 10, which is typical of these soil types, further confirming the similarity in

soil conditions at the two sites. If foundation net bearing pressures at the EGC ESP Site are less than 5 tsf, the variation in P_c' between the EGC ESP and CPS Sites will have no effect on foundation settlements between the sites. If net bearing pressures are greater than 5 tsf, the potential for marginally higher settlements at the EGC ESP Site compared to the CPS Site should be considered. However, consolidation settlements would be incorporated in the design during the COL stage, and do not alter the suitability of the EGC ESP Site for construction of a reactor plant design.

5.2.3.2 Shear Strength Results

Three types of shear strength tests were conducted for the EGC ESP Site investigation:

- Unconfined compression (Q) tests were conducted on 13 samples representative of each of the six stratigraphic units;
- UU tests were conducted on two Illinoian till samples, collected from depths of 90 and 145 ft bgs (elevations of 645 and 589 ft above msl, respectively); and
- A CIU test with pore water pressure measurements was conducted on a sample from the lacustrine deposits, at a depth of 170 ft bgs (elevation of 561 ft above msl).

The 13 Q tests are used as an index of unconfined compression strength for comparison with strengths estimated from pocket penetrometer and torvane shear tests. These test results indicate that the soil is generally stiff to hard, consistent with their overconsolidated state. The Q test results for unconfined compression strength range from less than 1 tsf to over 10 tsf. Numerous Q tests were performed on soil samples collected during the original investigation at the CPS Site, as described in Section 2.5.4.2.1.1 of the CPS USAR. These tests were not tabulated in the CPS USAR, but were listed on the individual boring logs. Comparisons of the EGC ESP Site Q test results to results on the CPS Site boring logs indicate that the unconfined compression strengths of soil are similar between the EGC ESP and CPS Sites.

The two UU tests were conducted on samples at their in situ moisture content (that is, they were not saturated prior to the test). Confining pressures of 3 and 5 tsf were applied to these samples, respectively, to approximate the existing overburden. This same UU test method was used on 36 Illinoian till samples collected from the CPS Site P-series borings, as reported in Section 2.5.4.2.1.1 of the CPS USAR. These test results were not tabulated in the CPS USAR, but were rather listed on the individual borehole logs. Shear strength results from the UU tests on Illinoian till samples from the EGC ESP Site are 2.3 and 8.6 tsf, respectively. These results are consistent with the CPS Site UU test results, which ranged from 0.5 to 18 tsf with an average of 7.5 tsf.

For the CIU test on the lacustrine sample (B3-42PIT) from the EGC ESP Site, a confining pressure of 5 tsf was applied to the saturated specimens, and the sample was allowed to consolidate prior to application of the deviator stress. One CIU test was performed on a lacustrine deposit sample at borehole P-38, as reported in Section 2.5.4.2.1.1 and Table 2.5-11 of the CPS USAR. The CPS Site sample was saturated and consolidated at 5 tsf prior to application of the deviator stress.

The CIU test on the lacustrine sample from the EGC ESP Site indicates an effective stress friction angle of 32.6 degrees, for an assumed effective stress cohesion (intercept) of zero.

The lacustrine sample collected from boring P-38 at the CPS Site was also tested at only one confining pressure (5 tsf). This test resulted in an effective stress friction angle of 34 degrees, for an assumed cohesion of zero.

5.2.4 Dynamic Properties of Soil

Dynamic characteristics of subsurface soils at the EGC ESP Site were estimated from both field geophysical and laboratory tests. The dynamic property information is required for site-specific seismic response modeling being conducted as part of the seismic hazard work. The dynamic properties in the field were obtained at very low shearing strain amplitudes by measuring shear and compressional wave velocities in the soil using seismic CPT tests at two locations (CPT-2 and CPT-4) and with a suspension logging test at borehole B-2. The shear wave velocity values were compared to shear wave velocities obtained at the CPS Site. Shear moduli and material damping ratios were also determined for the EGC ESP Site for representative soil samples using resonant column/cyclic torsional shear testing methods. The shear modulus and material damping ratio tests were conducted to determine the variation of soil modulus and damping with shearing strain levels. Similar information from the CPS Site was not evaluated due to limitations in the testing capabilities available at the time that the work for the CPS Site was conducted.

5.2.4.1 Compressional and Shear Wave Velocities

Subsurface soils were evaluated for compressional and shear wave velocity during the geotechnical investigation for the EGC ESP Site. A suspension logging test was conducted within borehole B-2. This test method provides a nearly continuous profile of both compressional and shear wave velocity from ground surface to 15 ft below the top of the bedrock (307 ft bgs). Two shear wave velocity tests were also performed at two CPT locations, CPT-2 and CPT-4, which provided shear wave velocity profiles from the ground surface to CPT refusal (54 and 76 ft bgs, respectively).

5.2.4.1.1 Compressional Wave Velocity

The compressional wave velocity results from both the EGC ESP and CPS Site geophysical programs are summarized in Table 5-2. Figure 5-19 also shows the compressional velocity profile based on receiver-to-receiver suspension logging test measurements at borehole B-2, along with the stratigraphic column and in-situ properties of samples collected from borehole B-2. These data indicate that compressional wave velocity varies by stratigraphic unit, and varies with soil consistency (stiffness or density), SPT blowcount, and in-situ density. Figure 5-19 also shows that the compressional wave velocity rapidly increases to over 4,800 feet per second (fps) below the water table depth at borehole B-2, which is indicative of saturated conditions.

As shown in Figure 5-19, compressional wave velocity increases with depth in the Wisconsinan till, increasing to a maximum value of 6,030 fps at the base of the unit. Compressional wave velocity in the interglacial and Illinoian till is higher than in the Wisconsinan, with localized peaks in the velocity coinciding with observed high SPT blowcounts at depths of 55 ft (in the Interglacial) and 100 ft (in the Illinoian till). Below this peak velocity in the Illinoian, the velocity decreases somewhat to a relatively consistent value averaging 7,550 fps in the Illinoian. The velocity in the underlying lacustrine is markedly lower, increasing again in the underlying pre-Illinoian till. The average velocity

in the pre-Illinoian till is 6,925 fps, but is slightly higher than this in the upper portion of the pre-Illinoian till (up to 8,230 fps) decreasing somewhat with depth (to a low value of 5,270 fps). The velocity decreases yet again in the underlying sorted pre-Illinoian alluvial or lacustrine deposits, which coincides with the relatively low blowcounts and dry density of these materials. Compressional wave velocity increases at the top of the upper weathered bedrock to an average of 8,096 fps.

Compressional wave velocity results from the suspension logging test are generally consistent with the uphole compressional velocity survey conducted at P-14 for the CPS Site. Results from the test at P-14 along with the suspension logging test results for borehole B-2 are summarized in Table 5-2. For the CPS USAR, the P-14 results were interpreted over large ranges in depth to minimize the effects of data scatter. These results indicate a compressional wave velocity of approximately 4,800 fps in the Wisconsinan till, and of approximately 7,400 fps in the Illinoian till and underlying unconsolidated deposits. Compressional wave velocity of the upper bedrock is reported as approximately 12,000 fps. These results are generally consistent with the average suspension logging results from borehole B-2 for each stratigraphic unit. However, the suspension logging data at borehole B-2 provide better resolution of variations over short depth intervals than did the uphole compressional survey data. Results at P-14 do not identify the relatively short intervals of higher or lower velocity which are recorded by the suspension logging results.

5.2.4.1.2 Shear Wave Velocity

Shear wave velocity results based on receiver-to-receiver measurements from the suspension logging test at borehole B-2 are generally consistent with trends in the compressional wave velocity profile. The major exception is that the effect of the groundwater depth is minimal, as is normally the case for shear wave measurements.

As shown in Figure 5-19 and summarized in Table 5-2, shear wave velocity results for the Wisconsinan till and Interglacial zone are available from the suspension logging test and from the seismic CPT soundings. In general, results between the two test methods are consistent. Suspension logging results indicate that the shear wave velocity ranges from 820 to 1,340 fps in the Wisconsinan till, with an average velocity 975 fps. Results in the Interglacial increase to a high of 1,970 fps, with an average value of approximately 1,343 fps. Results from CPT-2 (located approximately 15 ft from borehole B-2) are generally within the ranges of results from the suspension logging test at borehole B-2. The shear wave velocity within the Wisconsinan till is slightly higher at CPT-2 than at CPT-4 (average of 1,034 fps at CPT-2 versus 838 fps at CPT-4). Cone end bearing resistance and friction ratio results indicate that the Wisconsinan till encountered at CPT-2 could be slightly more granular than at CPT-4, which may correspond to the difference in shear wave velocity between these locations.

The typical shear wave velocities obtained during the original CPS Site investigation are listed for each of the stratigraphic units in Figure 2.5-369 of the CPS USAR. These values are very consistent with the suspension logging test and seismic CPT test shear wave velocity results from the EGC ESP Site investigation. The primary difference is the higher resolution of changes in shear wave velocity with depth in the suspension logging test results from borehole B-2. This better resolution allows evaluation of relatively small variations in shear wave velocity within the stratigraphic units.

Based on the above information, the minimum site characteristic soil shear wave velocity is greater than 1,000 fps at all depths below 50 ft bgs. The minimum characteristic shear wave velocity in rock is greater than 3,000 fps.

5.2.4.2 Modulus and Damping Properties

Modulus and damping ratio results were obtained for five of the six soil units. These results are plotted in Figures 5-20 and 5-21 to show the variation of shear modulus ratio (G/G_{max}) versus shearing strain amplitude (γ) and material damping ratio (D) as a function of shearing strain amplitude (γ). Figure 5-22 presents the variation of the maximum low-amplitude shear modulus (G_{max}) with increasing confining pressure for each of the six samples.

Table 5-3 provides a comparison of the shear wave velocity measured from the six resonant column tests on EGC ESP Site samples with shear wave velocities measured for the same depths during the suspension logging test. As shown, shear wave velocity results for the first four laboratory samples (from depths of 33, 41.5, 115, and 171 ft bgs) are very consistent with the suspension logging test results. The ratio of laboratory-to-field measured shear wave velocity is between 86 and 95 percent for each of these samples. For the deepest two samples (from depths of 208 and 242 ft bgs), this ratio decreases to 68 and 76 percent, respectively.

The difference between shear wave velocities given in Table 5-3 is attributed primarily to sample disturbance associated with the laboratory testing process. This disturbance results from the unavoidable stress relief that occurs when the soil sample is removed from the ground and from handling effects as the sample is extruded from its tube and placed in the testing device. This disturbance usually results in lower values of shear wave velocity than those measured in the field. Laboratory-to-field velocities ratios in the 80 to 90 percent range indicate minimum disturbance during the soil sampling process. The lower ratios for the deeper two samples suggest more disturbance occurred – which is consistent with the greater amount of stress relief that has occurred for these samples.

There are two other potential sources of the difference between laboratory and field values of shear wave velocity shown in Table 5-3. The first is the effective confining pressure used during the conduct of the laboratory tests. The mean confining pressure was based on a groundwater table located 30 ft bgs and on a coefficient of earth pressure at rest (k_o) of 1.0, which is typical for overconsolidated silty clay. The second source is the limited duration of the laboratory test. Various researchers (for example,Anderson and Stokoe, 1977) have shown that the shear wave velocity measured in the laboratory increases with time – particularly for fine-grained soil. By extrapolating these time effects, the differences between the laboratory and field velocities (or shear moduli) decrease. These other potential sources of the velocity difference are, however, thought to be secondary to the normal and unavoidable effects of sampling.

The potential effects of sample disturbance on the variation in shear modulus and material damping ratio with shearing strain were also evaluated. This evaluation was made by comparing the laboratory modulus and damping results to published curves for modulus ratio and damping ratio. The primary comparison was made to curves developed by the Electric Power Research Institute (EPRI) in the early 1990s (EPRI, 1993). Figures 5-23 and

5-24 shows the comparison between the shear modulus ratio and material damping ratio curves from the EGC ESP Site samples and similar curves developed by the EPRI. These comparisons indicate that the laboratory results from tests on samples from the EGC ESP Site gave modulus ratio and damping ratio results that are very consistent with the published EPRI curves. The shapes of the modulus and damping ratio curves shown in Figures 5-20 and 5-21 are also consistent with the range of results predicted using the Vucetic and Dobry (1991) and the Sun et al. (1988) relationships.

The comparisons shown in Figures 5-20 and 5-21 were used to discredit results from the set of tests on the sample from 208 ft bgs. It is apparent from the modulus and damping comparisons for this sample that the results were too far from normal behavior to be useable. The cause of this anomaly was discussed with Professor Stokoe. The apparent cause of the inaccurate test results was vertical fissures that developed in the soil sample when it was extruded from the sampling tube. The fissures were likely the result of the combination of large stress relief and the specific plasticity of the test sample. This issue was not observed for the deeper sample; however, the characteristics of this sample also were different.

Additional disturbance checks were made on the shear modulus ratio and material ratio curves by adjusting the shape of the curves by a reference-strain adjustment method. This adjustment has been suggested as a method of accounting for the difference in laboratory and field shear wave velocity noted in Table 5-3. The adjustment effectively shifts the shearing strain, which result in the modulus and damping ratio curves shifting slightly to the right in Figures 5-20 and 5-21. This adjustment is relatively small when the velocity ratio in Table 5-3 is above 85 percent, and increases as the velocity ratio decreases. It was concluded from these checks that the variation in the modulus and damping ratios would be small and well within the normal amount of uncertainty assigned to results of laboratory testing programs.

In view of the good comparisons between the measured modulus and damping data for the samples from the EGC ESP Site and the published EPRI values of modulus ratio and damping ratio, it was concluded that the conditions at the EGC ESP Site could be adequately represented by the EPRI soil model when developing a site response model, as discussed in both Section 2.5 and Appendix B of the SSAR. Variations noted between the published EPRI curves and those obtained by laboratory testing reflect the normal variation that can be expected when testing soil samples. These variations are accounted for during ground response modeling by introducing a variation between the upper and lower bound modulus and damping ratio curves.

It is important to note that no attempt has been made to make a comparison of the modulus and damping results for the EGC ESP Site to the modulus and damping ratio data reported in the CPS USAR. At the time that tests were conducted for the CPS Site, most high-strain amplitude cyclic testing was conducted with cyclic triaxial testing methods. This method of modulus and material damping determination typically could not reach the low shearing strains levels that can be reached by the resonant column/cyclic torsional shear equipment used in this EGC ESP Site testing program. The consequence of this limitation, as well as some boundary effects with the cyclic triaxial equipment, is that the shapes of the modulus and damping curves at lower shearing strain levels are usually very inaccurate relative to results from newer equipment. These inaccuracies result in an inaccurate shape in the

modulus ratio (G/G_{max}) curve and unreasonably high material damping (D). Given these inaccuracies, the dynamic results from the CPS Site were disregarded.

CHAPTER 5
Tables

TABLE 5-1
Field Recorded Characteristics of Major Stratigraphic Units

Stratigraphic Unit	Depth Range (ft bgs)	Elevation Range (ft above msl)	General Soil Types Encountered	Corrected SPT Blowcount, $N'_{(60)}$, Range and (Mean)	Range of Pocket Penetrometer (tsf)
Richland Loess	0 to 12	725 to 739	Lean clay of moderate plasticity. Some fine sand inclusions.	12 to 25 (16)	0.75 to 4
Wisconsinan Till	9 to 42	695 to 727	Lean clay of low to moderate plasticity. Some sand and gravel inclusions. Some silty sand outwash intervals.	8 to 93 (31)	0.25 to 4
Interglacial Zone (Weathered Illinoian Till)	39 to 59	675 to 699	Peat or paleosol zone at top. Lean clays and silts. Some sand and small gravel.	9 to 99 (28)	1 to 4
Illinoian Till	59 to 169	565 to 681	Borderline lean clay to sandy silt, may be silty sand in zones. Some small gravel throughout.	17 to 100 (66)	> 4
Lacustrine Deposits	163 to 190	545 to 576	Lean clay, olive grey throughout with some mottling. Some sand and small gravel.	17 to 82 (44)	> 4
Pre-Illinoian Till	189 to 269	469 to 548	Till consisting of lean clay and silt with some sand & gravel, over alluvial or lacustrine deposits of silt and sand.	21 to 70 (39)	> 4
Pre-Illinoian Alluvial/ Lacustrian	249 to 292	446 to 485	Includes layers of lean clays and silts with distinct bedding, as well as intervals of clean silt, uniform sand, and gravel.	11 to 40 (18)	> 4

TABLE 5-2
Summary of Shear and Compression Wave Velocity Test Data

		EGC ESP Site Results								CPS Site Results	
		Suspension Logging Test at B-2 Receiver to Receiver Measurements				Seismic Cone Test at CPT-2		Seismic Cone Test at CPT-4		Uphole Survey at P-14	
		Compression Wave Velocity (fps)		Shear Wave Velocity (fps)		Shear Wave Velocity (fps)		Shear Wave Velocity (fps)		Compression Wave Velocity (fps)	
Depth Interval at B-2 (ft bgs)	**Stratigraphic Unit**	**Range**	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**	**Typical**
0 to 42	Loess & Wisconsinan Till	1680 to 6030	4788	820 to 1340	975	703 to1354	1034	641 to 1077	838	NA	4800
42 to 59	Interglacial Zone (Weathered Illinoian Till)	5720 to 7500	6465	860 to 1970	1343	1022 to 1231	1132	1006 to 1602	1256	NA	4800
59 to 162	Illinoian Till	5720 to 8880	7552	1100 to 3250	2188	NA	NA	NA	NA	NA	7400
162 to 190	Lacustrine	6080 to 8040	6971	1390 to 2670	1829	NA	NA	NA	NA	NA	7400
190 to 269	Pre-Illinoian Till	5270 to 8230	6925	1560 to 2800	2068	NA	NA	NA	NA	NA	7400
269 to 292	Pre-Illinoian Alluvial / Lacustrine	5270 to 7940	6579	1190 to 3310	2045	NA	NA	NA	NA	NA	7400
292 to 307	Weathered Bedrock	7850 to 8440	8096	3250 to 3880	3420	NA	NA	NA	NA	NA	12000

TABLE 5-3
Comparison of Laboratory Shear Wave Velocity to In Situ Velocity

Sample Number	Depth (ft)	Geologic Unit	Mean Confining Pressure (psi)	PI [a]	$V_{s\ lab}$ [b] (fps)	D_{min} [c] (%)	V_{sfield} [d] (fps)	V_{slab}/V_{sfield} (%)
UTA-34-A	33	Wisconsin Till	27	10	811	4.6	880	92
UTA-34-B	41.5	Interglacial Zone	31	12	797	2.9	840	95
UTA-34-D	115	Illinoian Till	60	10	2064	3.2	2390	86
UTA-34-C	171	Lacustrine	90	17	1386	2.5	1470	94
UTA-34-E	208	Pre-Illinoian Till	100	22	1261	1.2	1860	68
UTA-34-F	242	Pre-Illinoian Till	120	15	1315	0.6	1720	76

Notes:

[a.] plasticitty index estimated from closest laboratory test result

[b.] shear wave velocity from laboratory test

[c.] minimum damping ratio from laboratory tests

[d.] shear wave velocity based on receiver-to-receiver suspension logging result at closest depth to lab test

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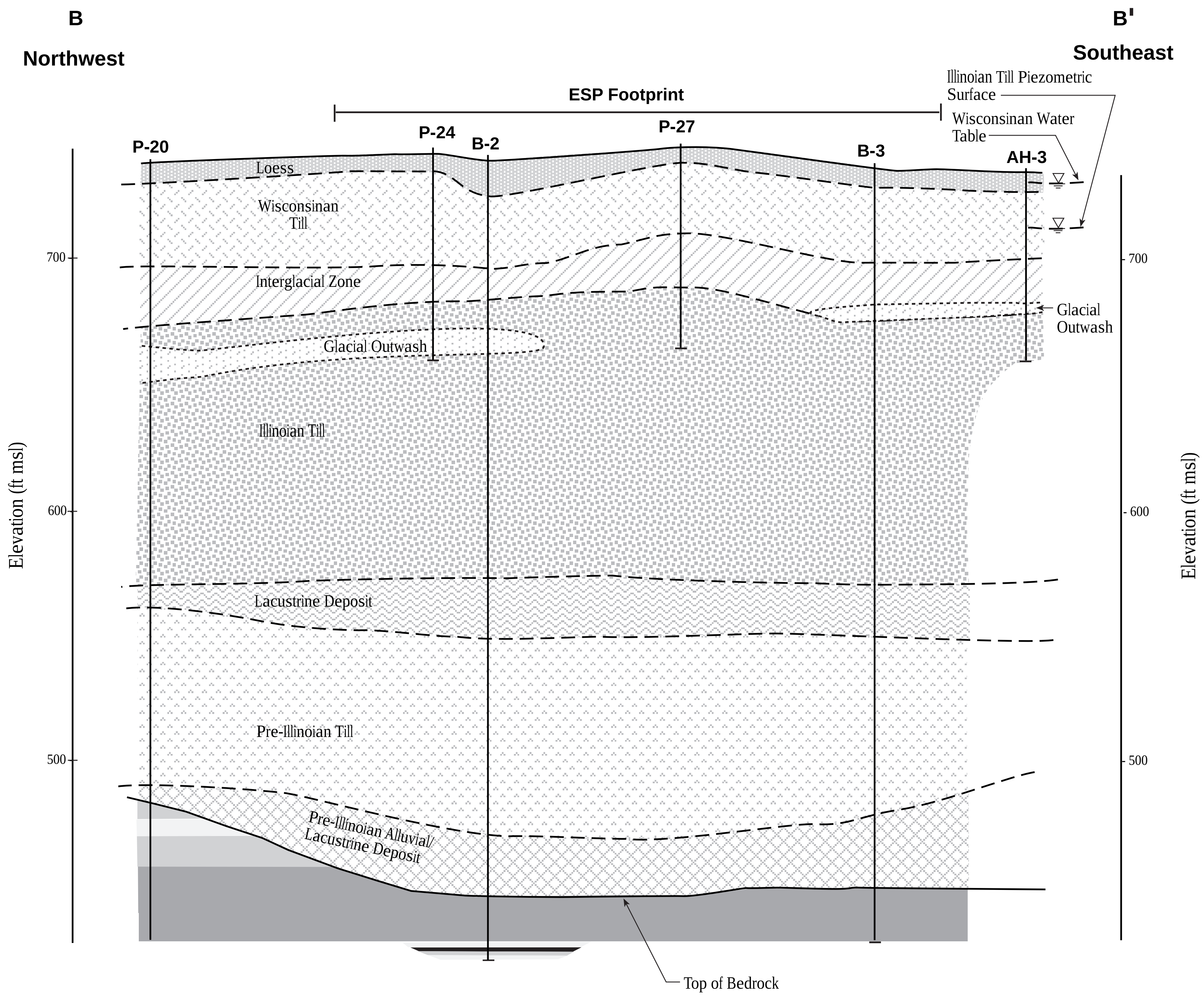
Figure 5-1
Northwest-Southeast Cross Section (B-B') Through EGC ESP Site



Legend

Quaternary

- Wisconsinan
  - LOESS - Brown to mottled brown and gray clayey silt or silty clay with trace fine sand; Weathered
  - WISCONSINAN GLACIAL TILL - Brownish-gray to gray clayey silt or silty clay with sand and gravel; Contains irregular and discontinuous lenses of sand and silt throughout (glacial outwash and possibly local lacustrine deposits)
- Sangamonian
  - INTERGLACIAL ZONE - Includes dark gray to gray organic clayey silt or silty clay (colluvial soils), greenish to bluish-gray clayey silt with sand and gravel (reworked Illinoian Glacial Till)
- Illinoian
  - ILLINOIAN GLACIAL TILL - Brownish-gray to gray clayey silt with sand and gravel to very sandy silt or silty sand with some clay and gravel; Interbedded outwash deposits in upper horizons
  - GLACIAL OUTWASH - Gray silty sand and sandy silt, interlayered
- Yar-Mouthian
  - LACUSTRINE DEPOSIT - Brownish-gray to black and gray clayey silt to silt, organic in zones; Includes greenish to bluish-gray clayey silt with sand and gravel (reworked and weathered pre-Illinoian Glacial Till); Assignment to Yarmouthian Glacial Stage is tentative
- Kansan
  - PRE-ILLINOIAN GLACIAL TILL - Grayish-brown to brown silty clay and clayey silt with some sand and gravel; Brown color and relatively high clay content is characteristic; Tentatively assigned to Kansan Glacial Stage on the basis of clay analysis by Illinois State Geological Survey
  - PRE-ILLINOIAN ALLUVIAL & LACUSTRINE DEPOSIT - Consists of grayish-brown, brown, and green clayey silt and silty clay with sand and some gravel (reworked glacial till) and gray to brown clayey silt with organic debris (lacustrine or low energy alluvial deposit); Included as part of the Mahomet bedrock deposit in areas where it is underlain by sandy outwash deposits

Pennsylvanian

- BEDROCK - Interbedded layers of limestone, shale, and siltstone assigned to the McLeansboro Group, Modesto Formation on the basis of spore analysis of the coal encounter in boring B-31
- LIMESTONE - Greenish-gray, gray and brown, fine to coarsely crystalline, silty, thin bedded to massive, numerous shale partings in zones, fossiliferous.
- SHALE - Gray to dark gray shale, carcoraceous to calcareous; clayey in zones, expansive, slickensides; occasional concretion
- SILTSTONE - Light gray siltstone, micaceous, fine sandy, cross-bedded in zones; occasional interbedded layer of silty sandstone
- Coal Seam

B-2 Borehole Number

Notes:
1. Elevations refer to the USGS Datum
2. See Figure 3-1 for cross section location

0 200 ft

Approximate Horizontal Scale

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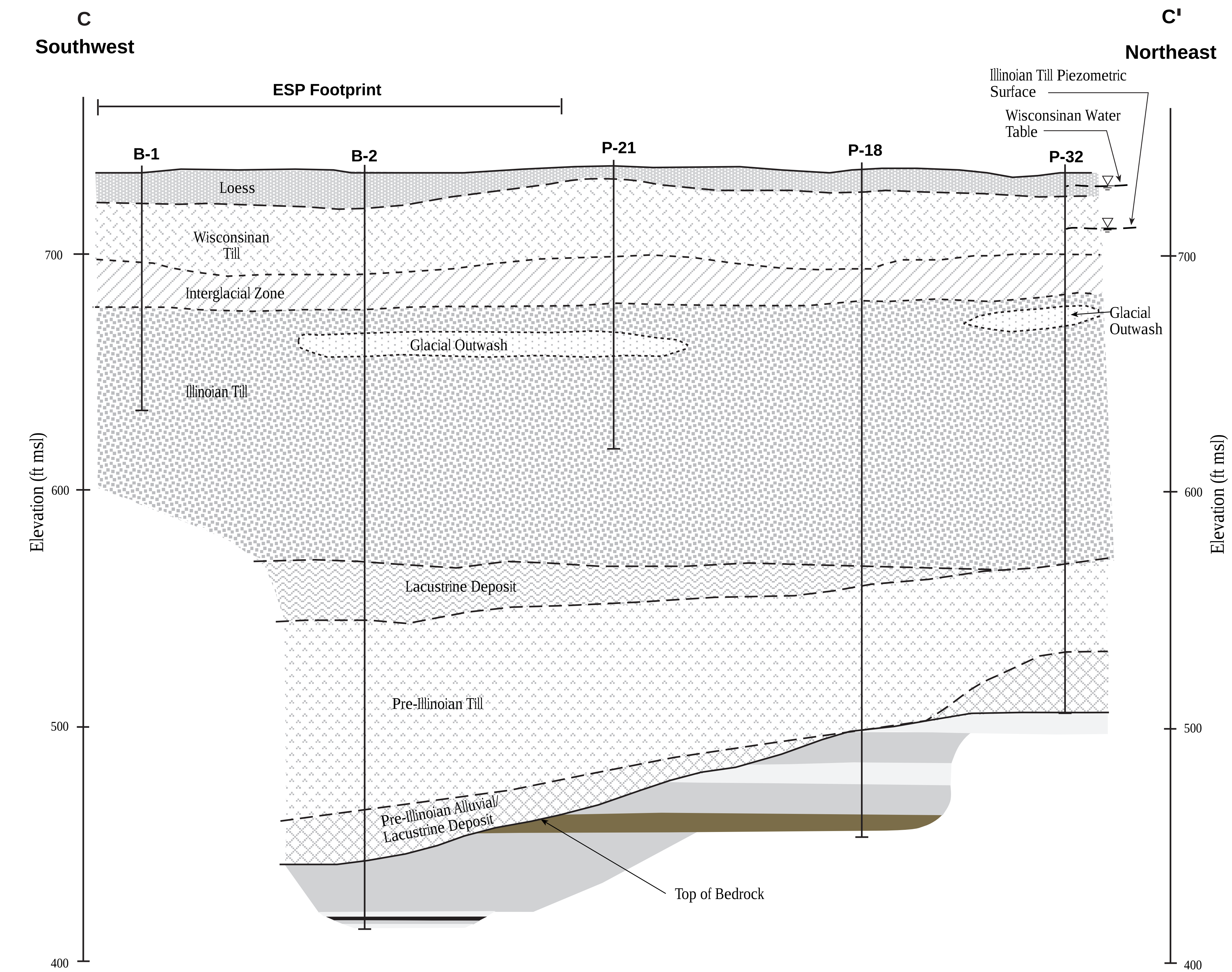
Figure 5-2
Southwest-Northeast Cross Section (C-C') Through EGC ESP Site



Legend

Quaternary — Wisconsinan:

- LOESS - Brown to mottled brown and gray clayey silt or silty clay with trace fine sand; Weathered
- WISCONSINAN GLACIAL TILL - Brownish-gray to gray clayey silt or silty clay with sand and gravel; Contains irregular and discontinuous lenses of sand and silt throughout (glacial outwash and possibly local lacustrine deposits)

Quaternary — Sangamonian:

- INTERGLACIAL ZONE - Includes dark gray to gray organic clayey silt or silty clay (colluvial soils), greenish to bluish-gray clayey silt with sand and gravel (reworked Illinoian Glacial Till)

Quaternary — Illinoian:

- ILLINOIAN GLACIAL TILL - Brownish-gray to gray clayey silt with sand and gravel to very sandy silt or silty sand with some clay and gravel; Interbedded outwash deposits in upper horizons
- GLACIAL OUTWASH - Gray silty sand and sandy silt, interlayered

Quaternary — Yar-Mouthian:

- LACUSTRINE DEPOSIT - Brownish-gray to black and gray clayey silt to silt, organic in zones; Includes greenish to bluish-gray clayey silt with sand and gravel (reworked and weathered pre-Illinoian Glacial Till); Assignment to Yarmouthian Glacial Stage is tentative

Quaternary — Kansan:

- PRE-ILLINOIAN GLACIAL TILL - Grayish-brown to brown silty clay and clayey silt with some sand and gravel; Brown color and relatively high clay content is characteristic; Tentatively assigned to Kansan Glacial Stage on the basis of clay analysis by Illinois State Geological Survey
- PRE-ILLINOIAN ALLUVIAL & LACUSTRINE DEPOSIT - Consists of grayish-brown, brown, and green clayey silt and silty clay with sand and some gravel (reworked glacial till) and gray to brown clayey silt with organic debris (lacustrine or low energy alluvial deposit); Included as part of the Mahomet bedrock deposit in areas where it is underlain by sandy outwash deposits

Pennsylvanian:

- BEDROCK - Interbedded layers of limestone, shale, and siltstone assigned to the McLeansboro Group, Modesto Formation on the basis of spore analysis of the coal encounter in boring B-31
- LIMESTONE - Greenish-gray, gray and brown, fine to coarsely crystalline, silty, thin bedded to massive, numerous shale partings in zones, fossiliferous.
- SHALE - Gray to dark gray shale, carcoraceous to calcareous; clayey in zones, expansive, slickensides; occasional concretion
- SILTSTONE - Light gray siltstone, micaceous, fine sandy, cross-bedded in zones; occasional interbedded layer of silty sandstone
- Coal Seam

B-2 Borehole Number

Notes:
1. Elevations refer to the USGS Datum
2. See Figure 3-1 for cross section location

0 200 ft

Approximate Horizontal Scale

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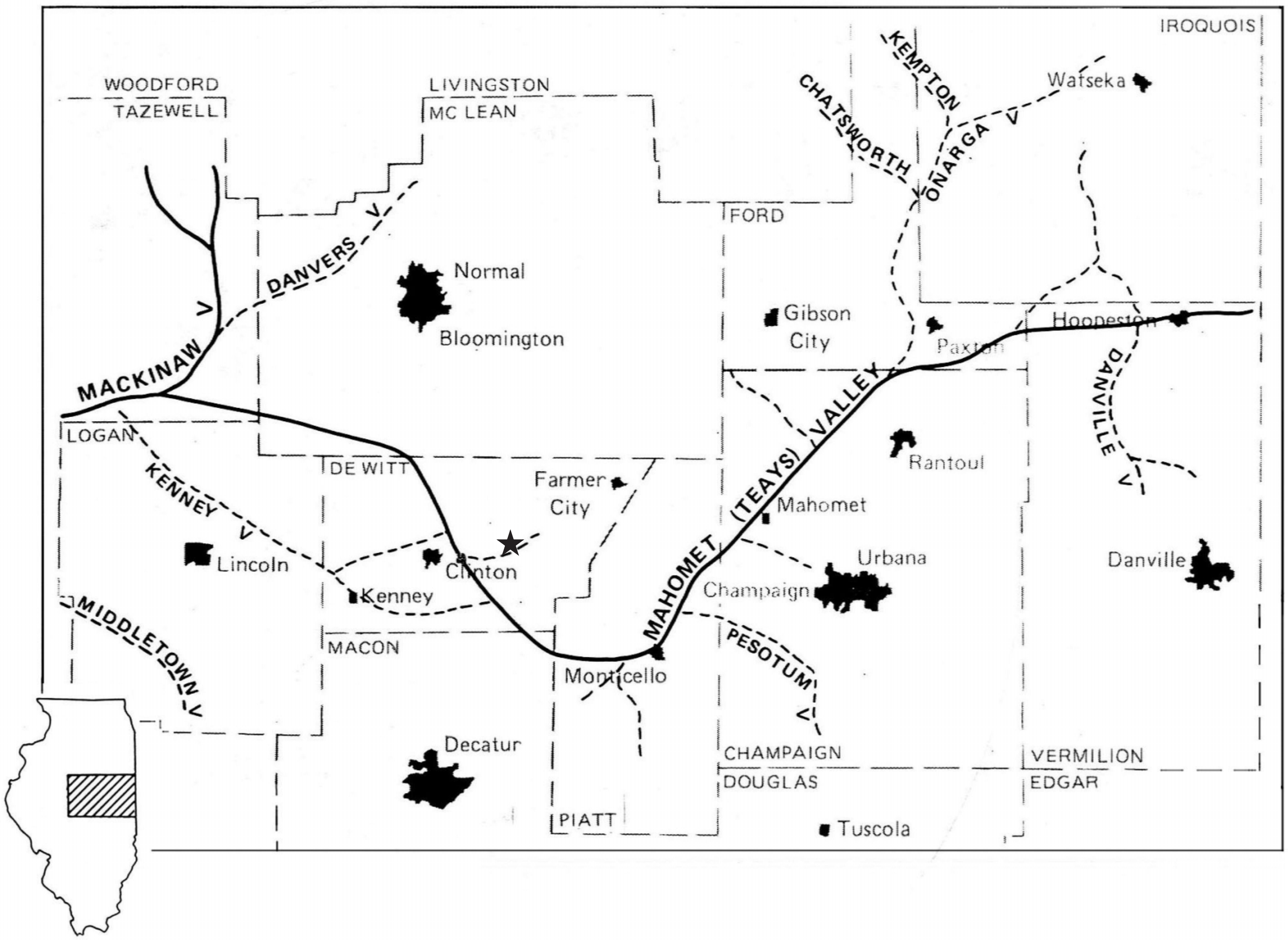
Figure 5-3
Axes of Major Bedrock Valleys in Central Illinois



Legend

- ★ Site Location
- — — County Boundaries
- ▬ Approximate Axis of the Bedrock Valley Main Channels
- - - - Other Principal Valleys

Note:
1. Reprinted from: Kempton et al., 1991

N

Not to Scale

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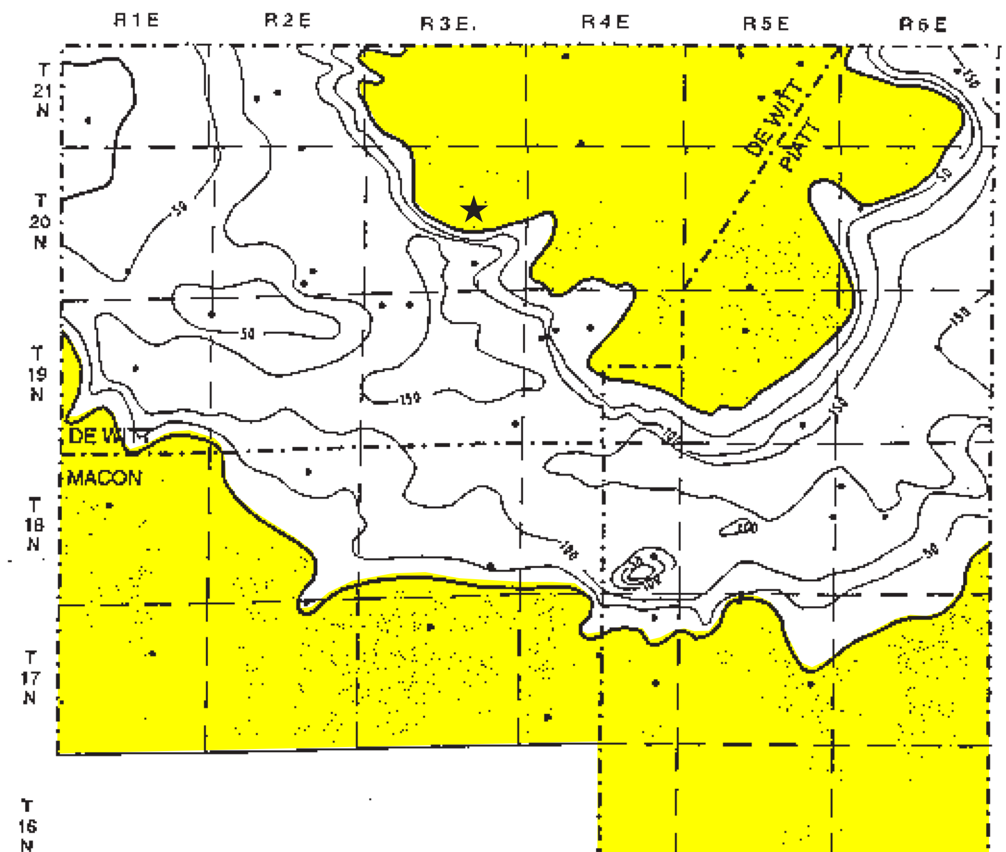
Figure 5-4
Thickness of the Mahomet Sand



Legend

- Absent
- Township lines
- County lines
- Edge of Mahomet Valley
- Thickness Contour interval 50 ft
- Well or borehole location
- ★ Site location

Note:
1. Reprinted from: Kempton and Herzog, 1996

N
Not to Scale

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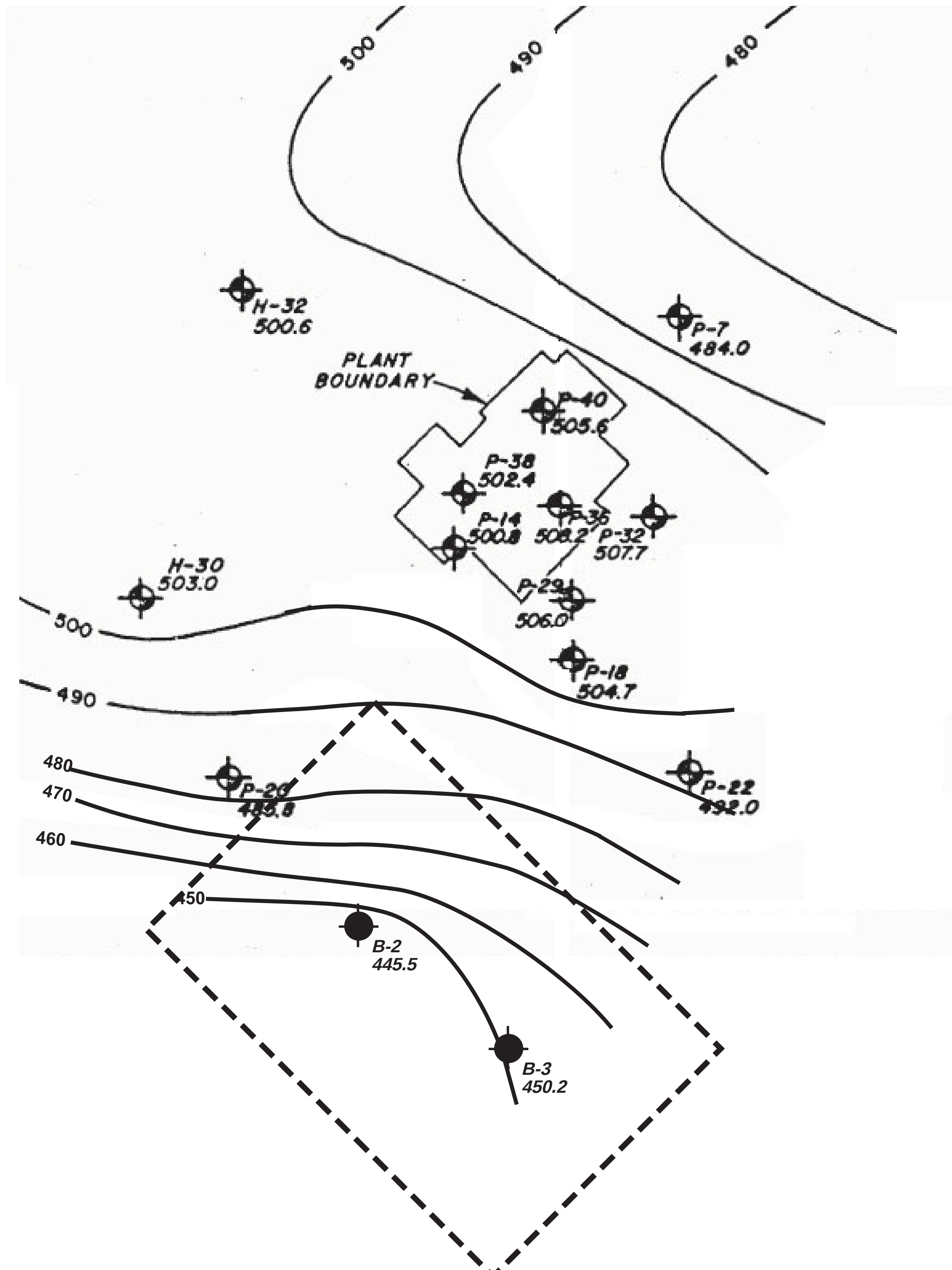
Figure 5-5
Bedrock Surface Contours



Legend

- CPS Site Borehole Location Advanced to Bedrock as Reported in the CPS USAR, (CPS, 2002)
- EGS ESP Site Borehole Advanced to Bedrock
- 498.0 Elevation of Top of Bedrock
- —470— Contour on Top of Bedrock Surface (Contour Interval 10 Feet)
- Approximate EGC ESP Site Boundary

Notes:

1. Modified from: CPS, 2002

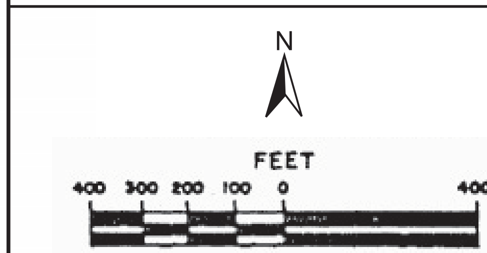


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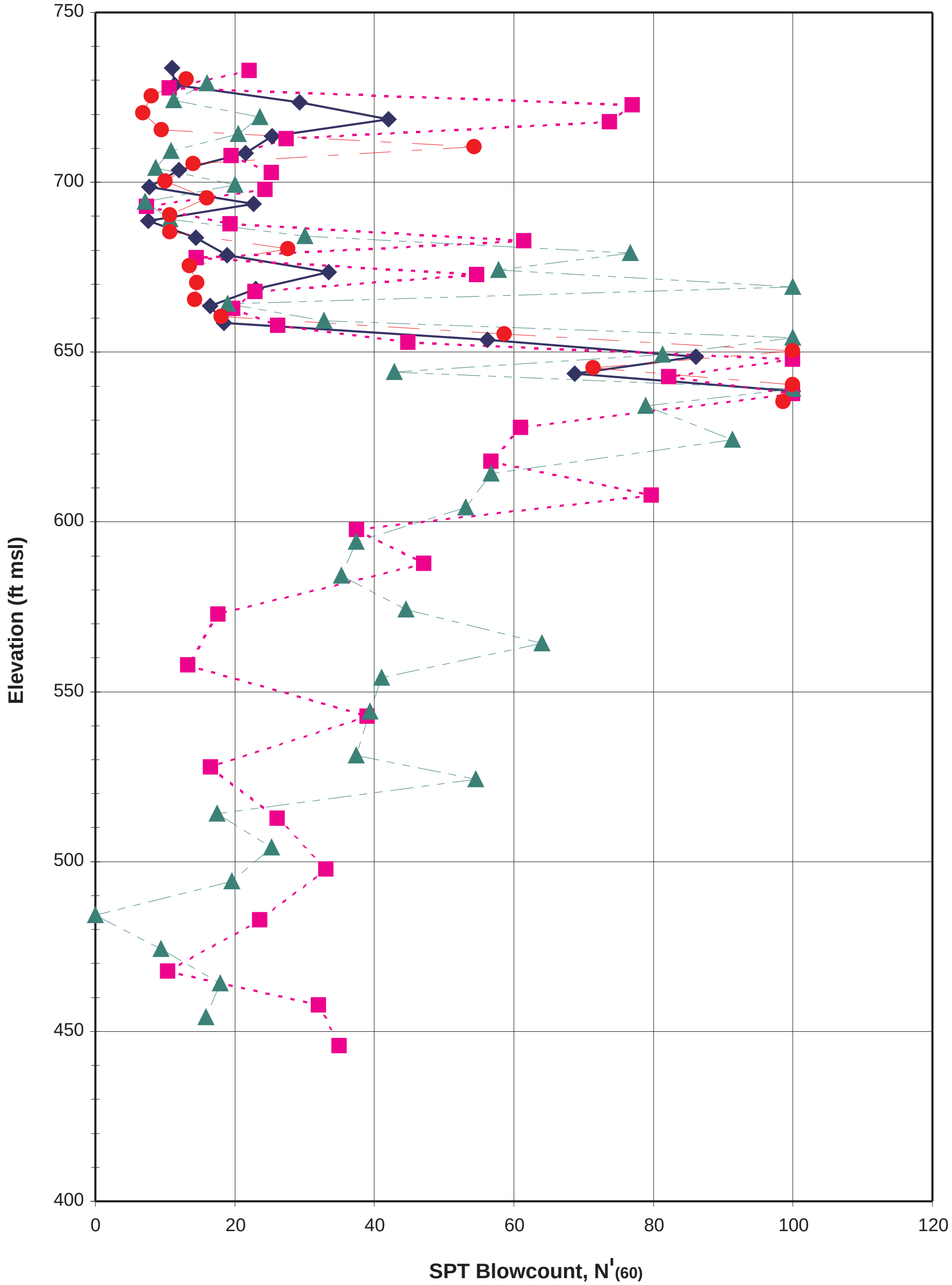
Figure 5-6

Variation of SPT Blowcount $N'_{(60)}$ with Elevation - EGC ESP Site



Legend

- Borehole B-1
- Borehole B-2
- Borehole B-3
- Borehole B-4

Note:

1. $N'_{(60)}$ values >100 are shown as 100 on this figure.
2. $N_{(60)}$ determined as SPT blowcount normalized for overburden and hammer efficiency.

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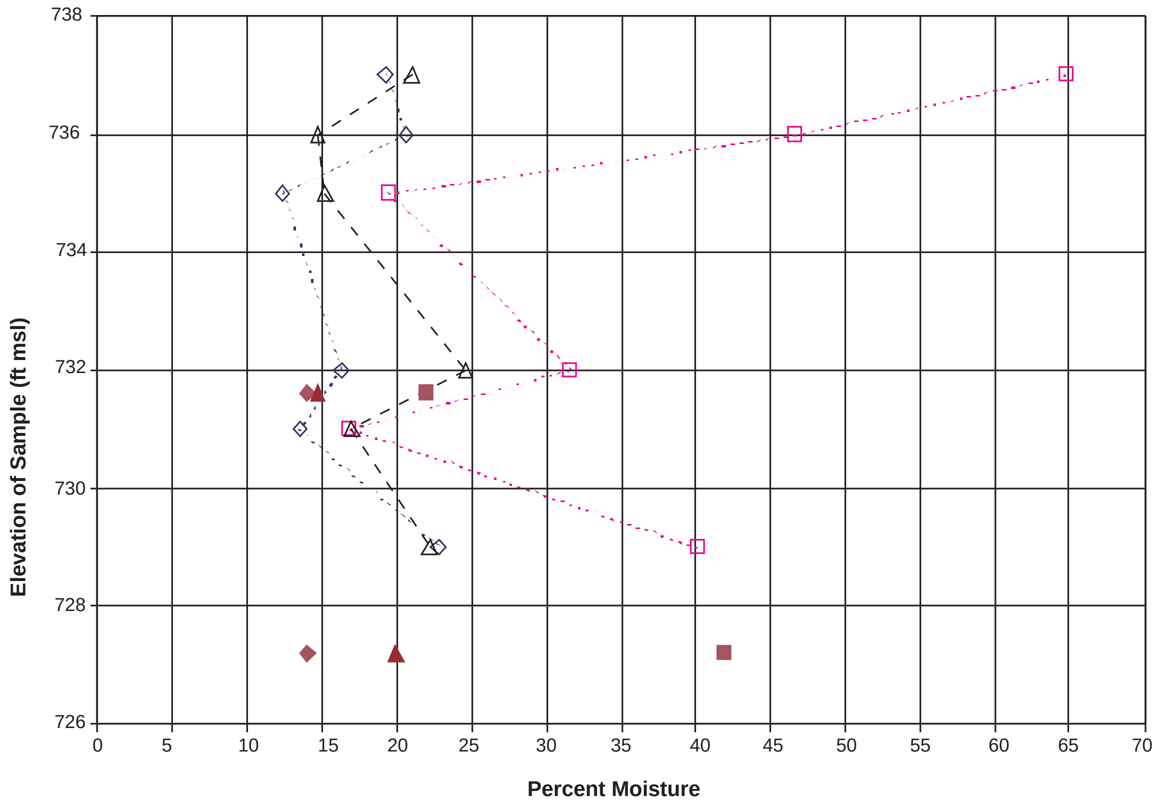
Figure 5-7

Richland Loess -Atterberg Limits (PL and LL) and Moisture Content



Legend

CPS Site (P-Series Boreholes)

- PL
- LL
- Moisture Content

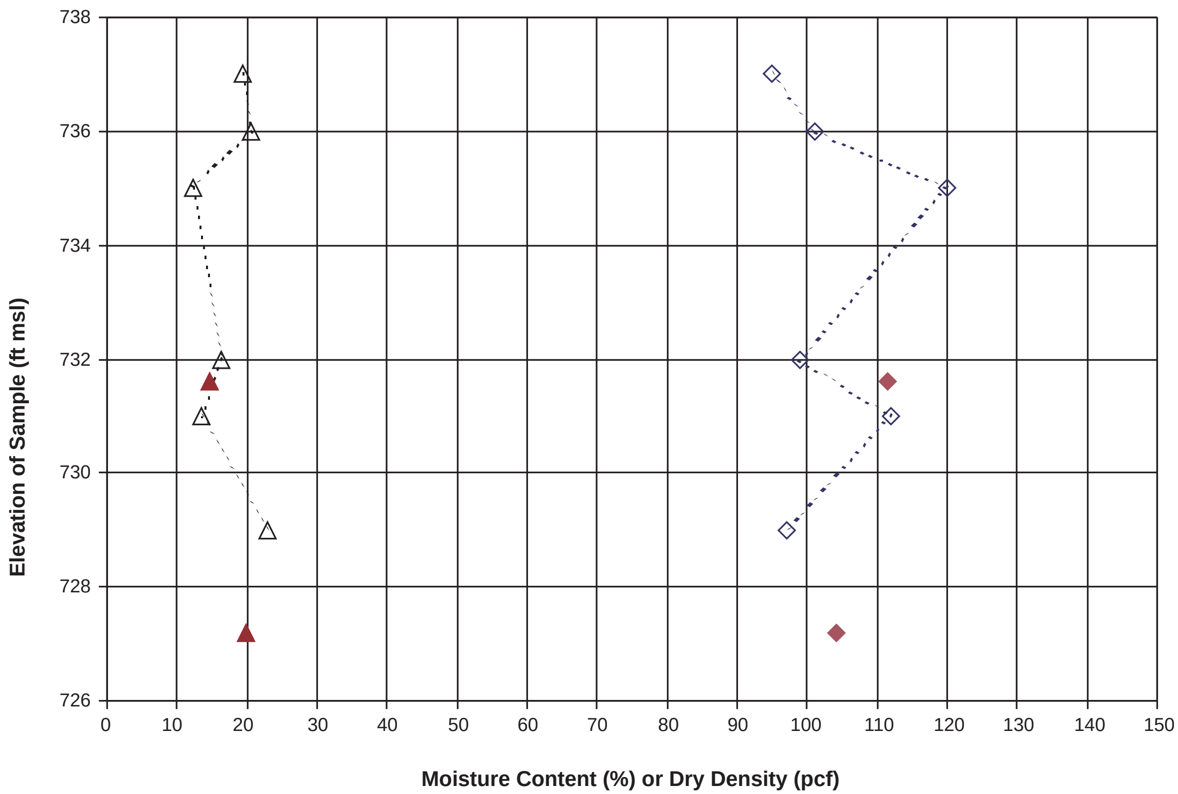
EGC ESP Site

- PL
- LL
- Moisture Content

Geotechnical Report for the EGC Early Site Permit

Figure 5-8

Richland Loess - Dry Density and Moisture Content



Legend

CPS Site (P-Series Boreholes)

- Dry Density
- Moisture Content

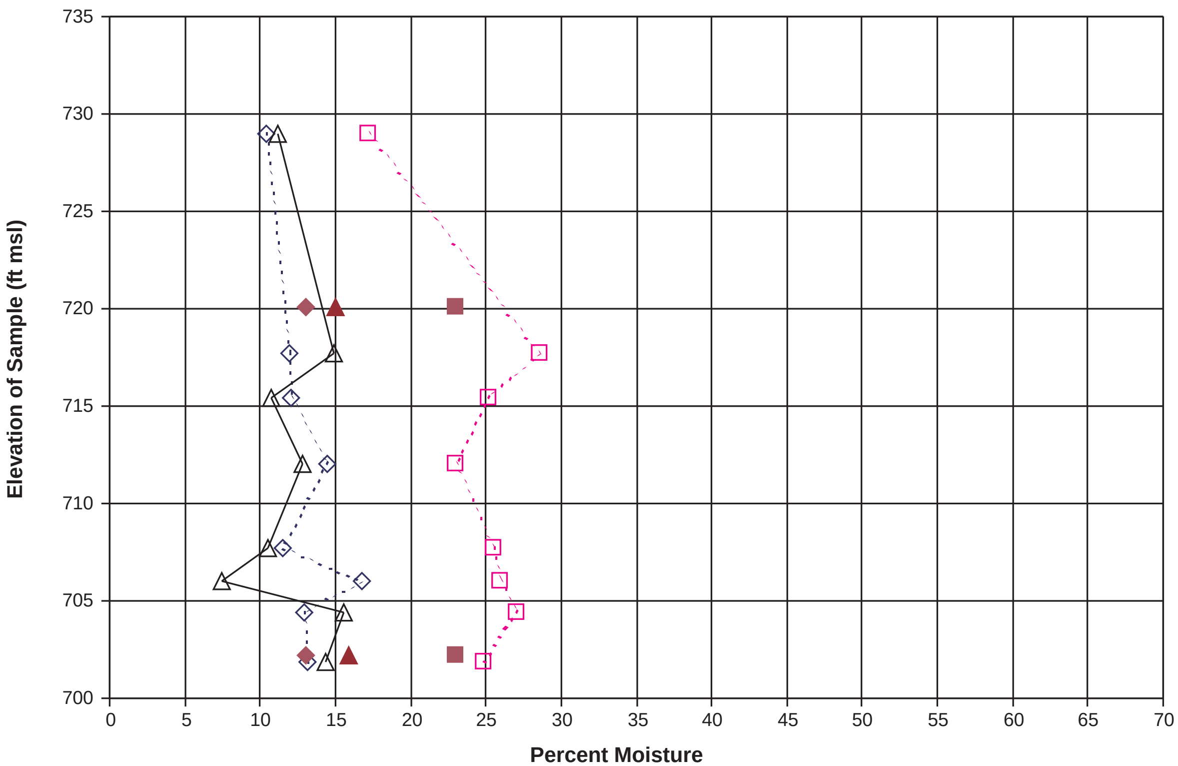
EGC ESP Site

- Dry Density
- Moisture Content

Geotechnical Report for the EGC Early Site Permit

Figure 5-9

Wisconsinan Till - Atterberg Limits (PL and LL) and Moisture Content



Legend

CPS Site (P-Series Boreholes)

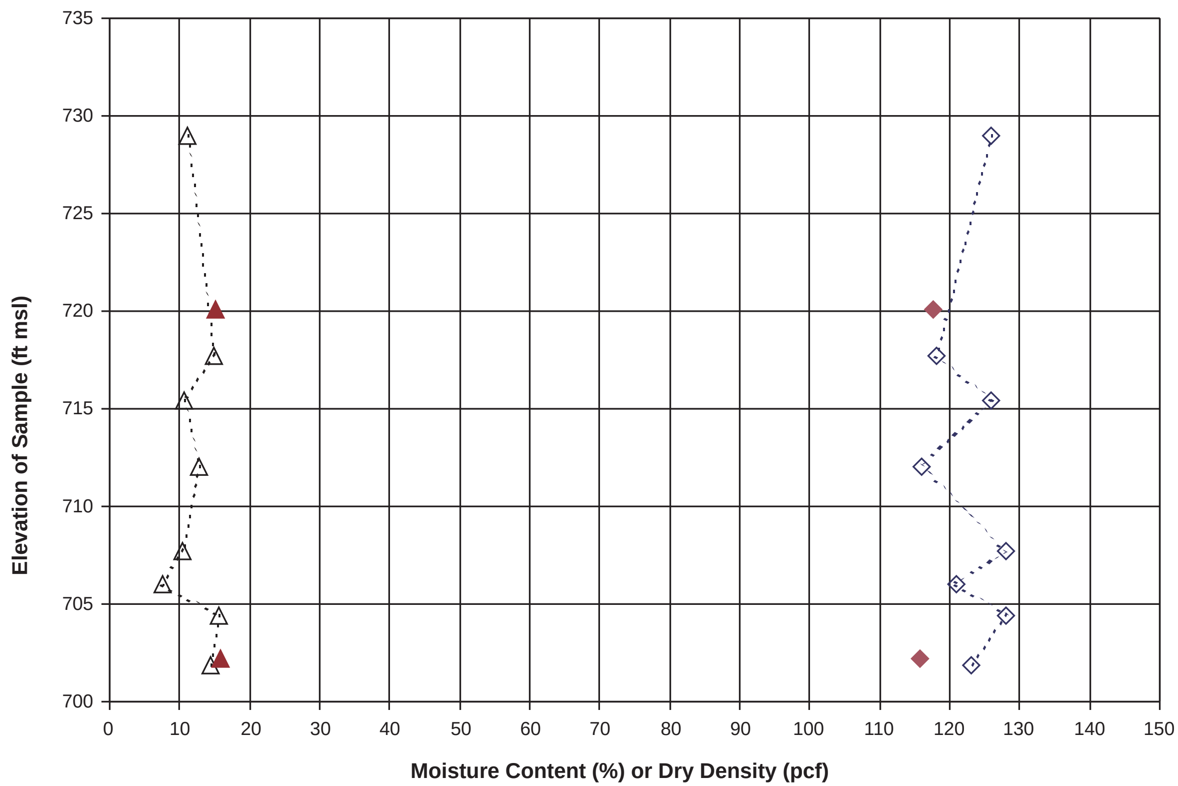
- PL
- LL
- Moisture Content

EGC ESP Site

- PL
- LL
- Moisture Content

Geotechnical Report for the EGC Early Site Permit

Figure 5-10
Wisconsinan Till - Dry Density and Moisture Content



Legend

CPS Site (P-Series Boreholes)

Dry Density

Moisture Content

EGC ESP Site

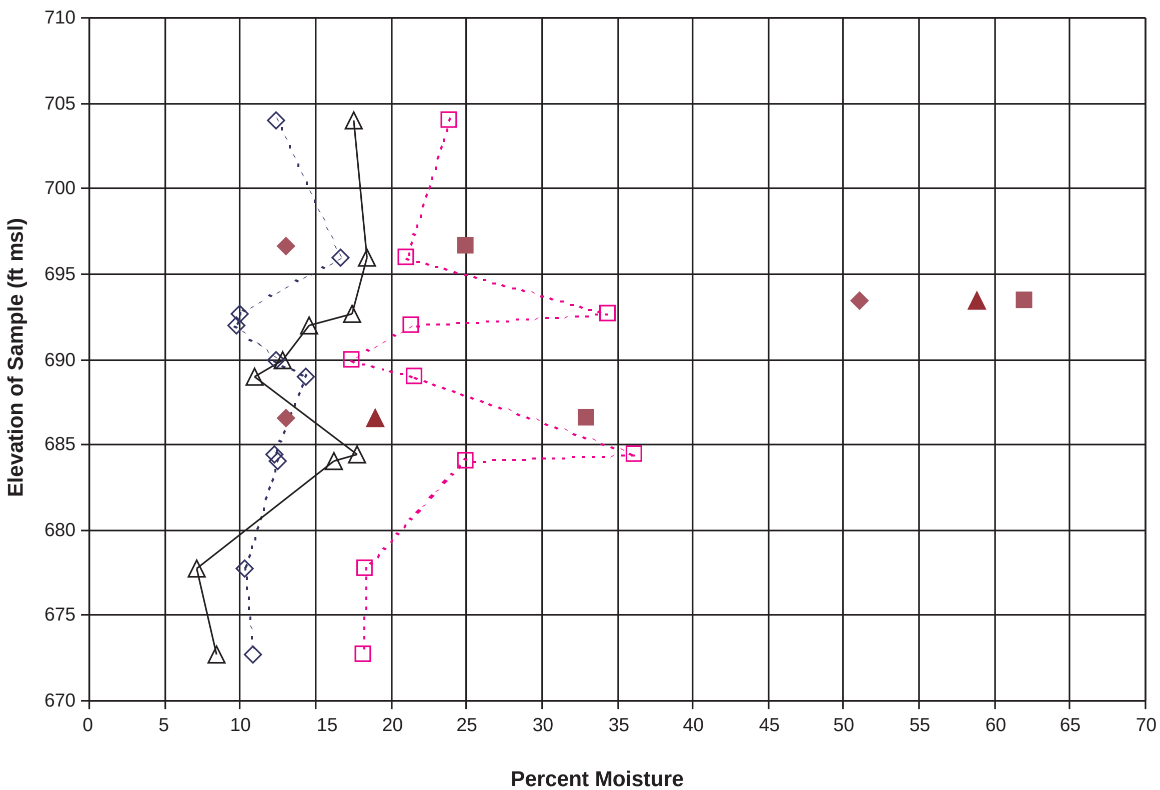
Dry Density

Moisture Content

Geotechnical Report for the EGC Early Site Permit

Figure 5-11

Interglacial Zone - Atterberg Limits (PL and LL) and Moisture Content



Legend

CPS Site (P-Series Boreholes)

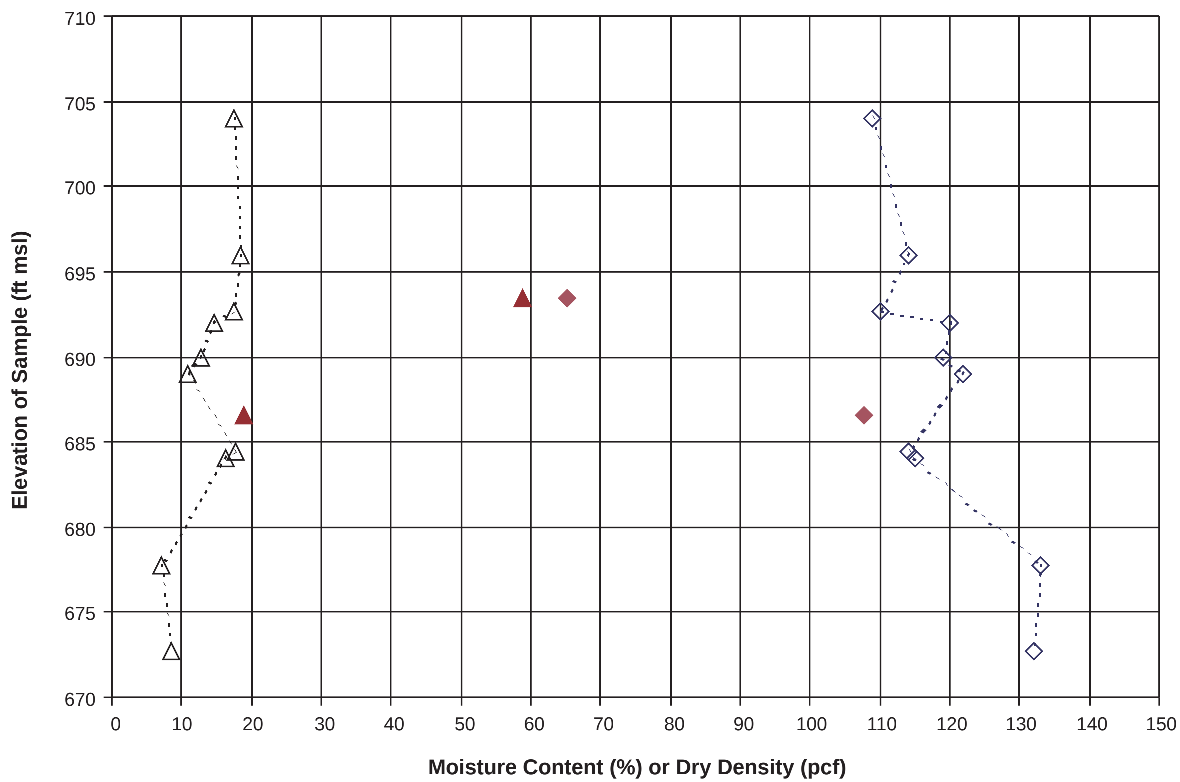
- PL
- LL
- Moisture Content

EGC ESP Site

- PL
- LL
- Moisture Content

Geotechnical Report for the EGC Early Site Permit

Figure 5-12
Interglacial Zone - Dry Density and Moisture Content



Legend

CPS Site (P-Series Boreholes)

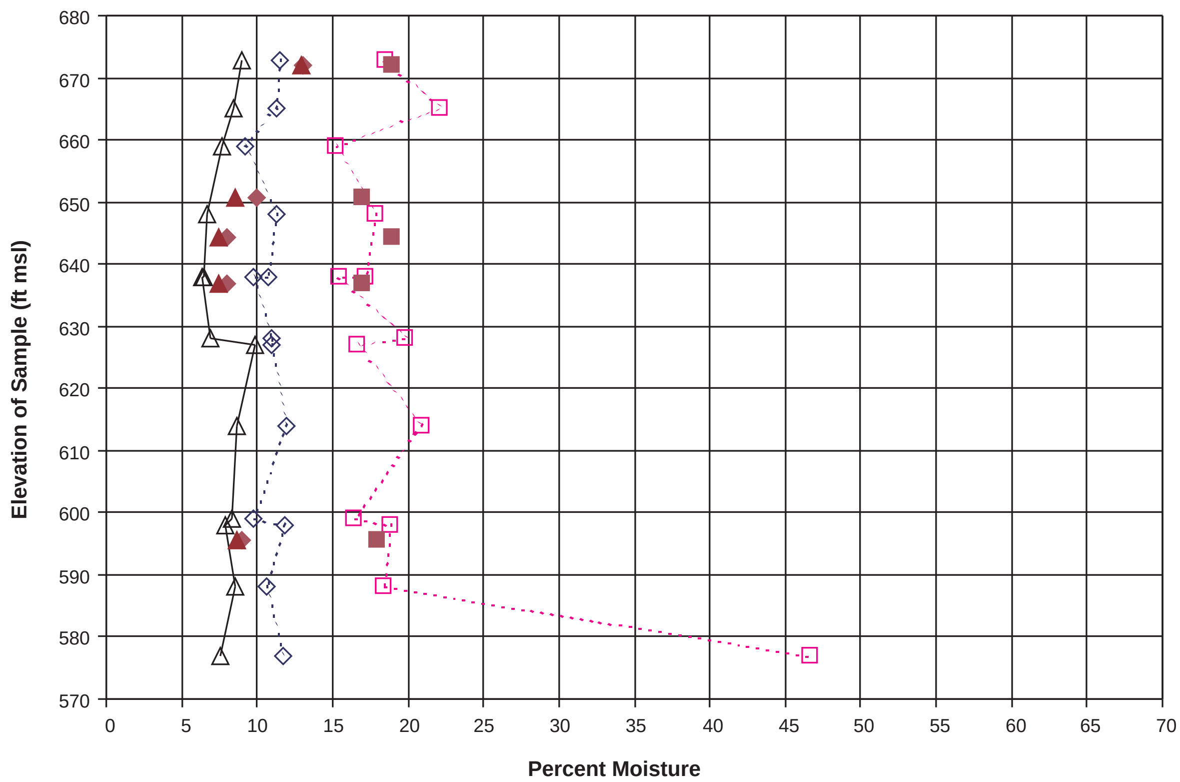
- Dry Density
- Moisture Content

EGC ESP Site

- Dry Density
- Moisture Content

Geotechnical Report for the EGC Early Site Permit

Figure 5-13
Illinoian Till - Atterberg Limits (PL and LL) and Moisture Content



Legend

CPS Site (P-Series Boreholes)

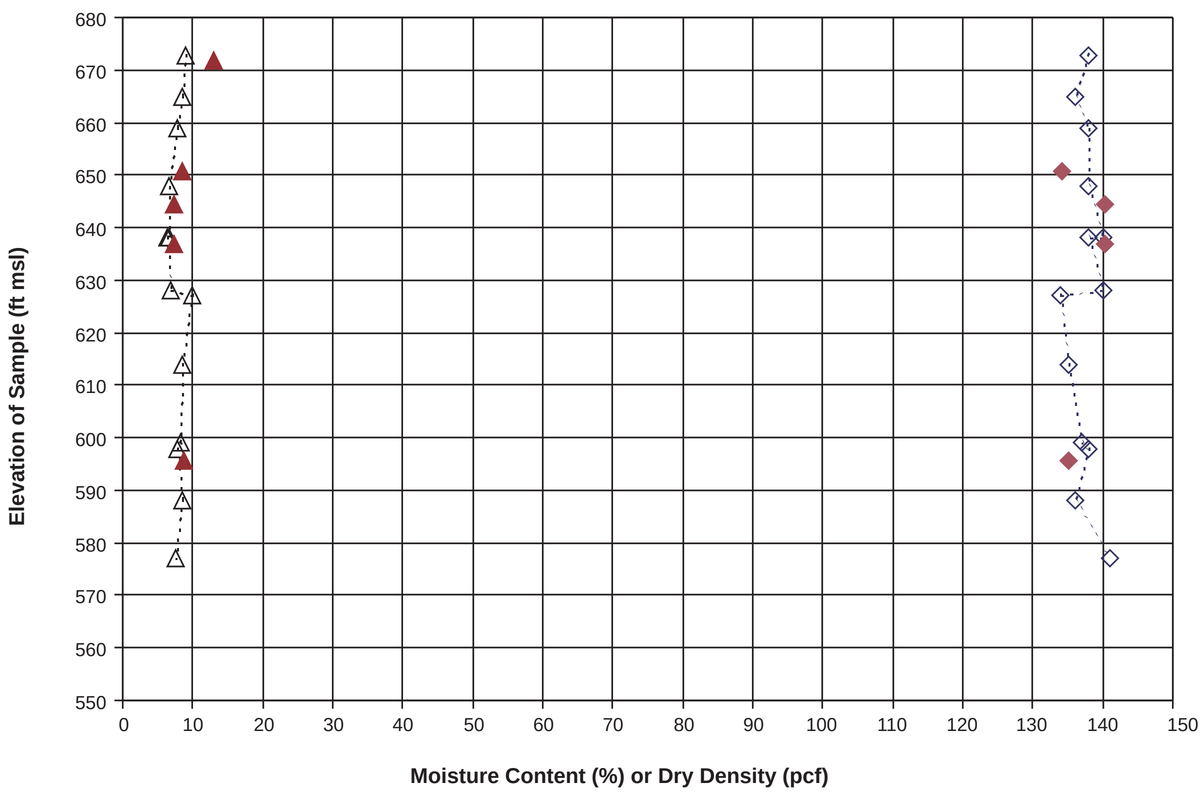
- PL
- LL
- Moisture Content

EGC ESP Site

- PL
- LL
- Moisture Content

Geotechnical Report for the EGC Early Site Permit

Figure 5-14
Illinoian Till - Dry Density and Moisture Content



Legend

CPS Site (P-Series Boreholes)

- Dry Density
- Moisture Content

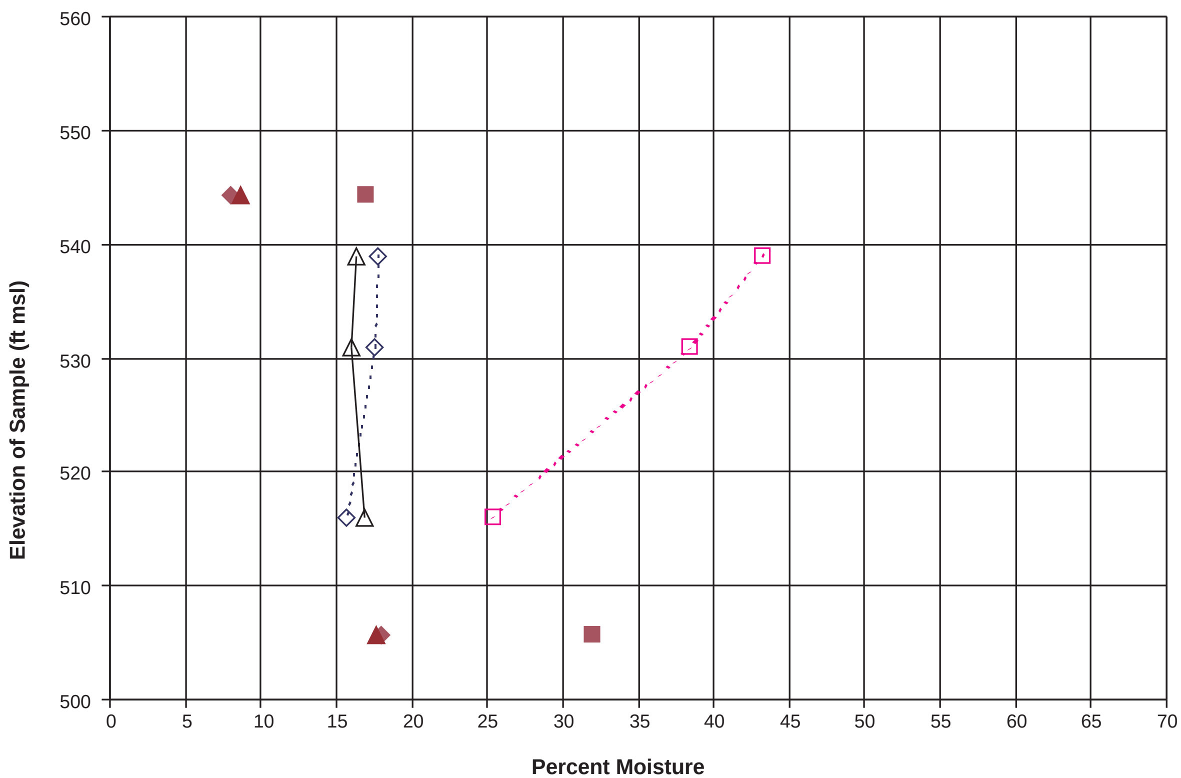
EGC ESP Site

- Dry Density
- Moisture Content

Geotechnical Report for the EGC Early Site Permit

Figure 5-15

Pre-Illinoian Till - Atterberg Limits (PL and LL) and Moisture Content



Legend

CPS Site (P-Series Boreholes)

- PL
- LL
- Moisture Content

EGC ESP Site

- PL
- LL
- Moisture Content

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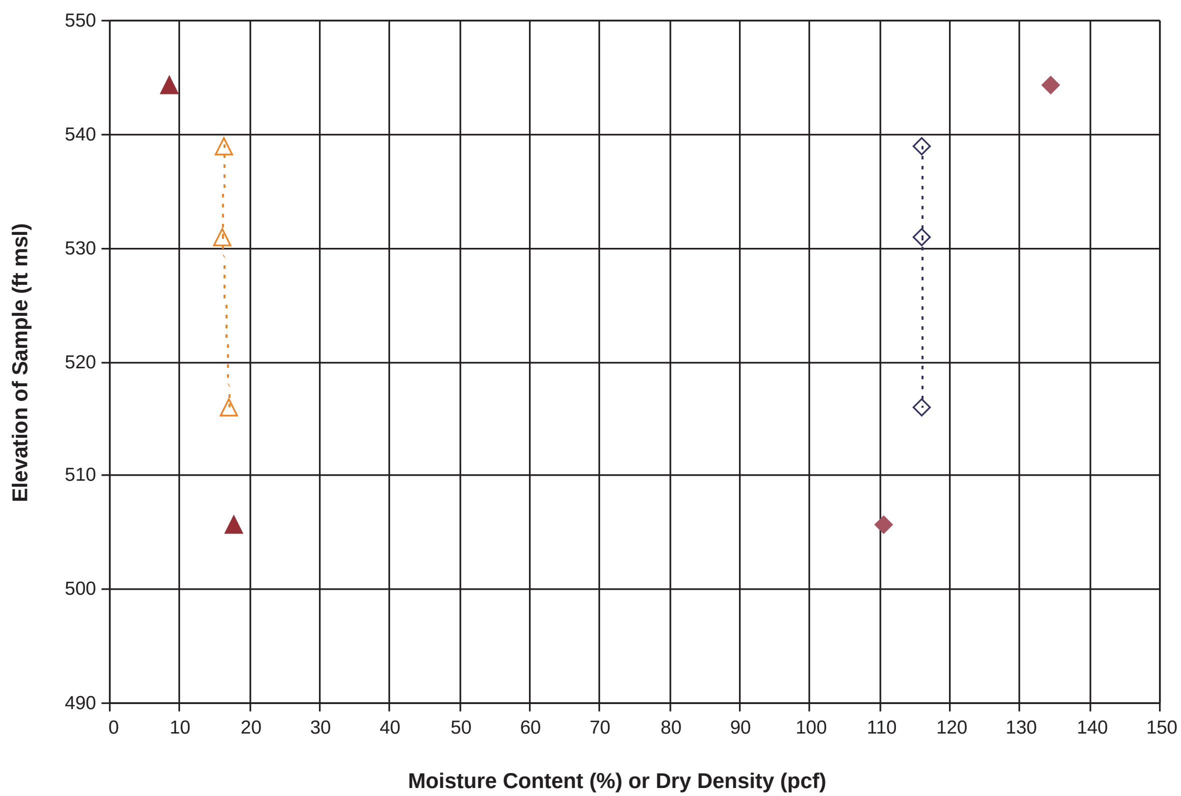
Figure 5-16
Pre-Illinoian Till - Dry Density and Moisture Content



Legend

CPS Site (P-Series Boreholes)

Dry Density

Moisture Content

EGC ESP Site

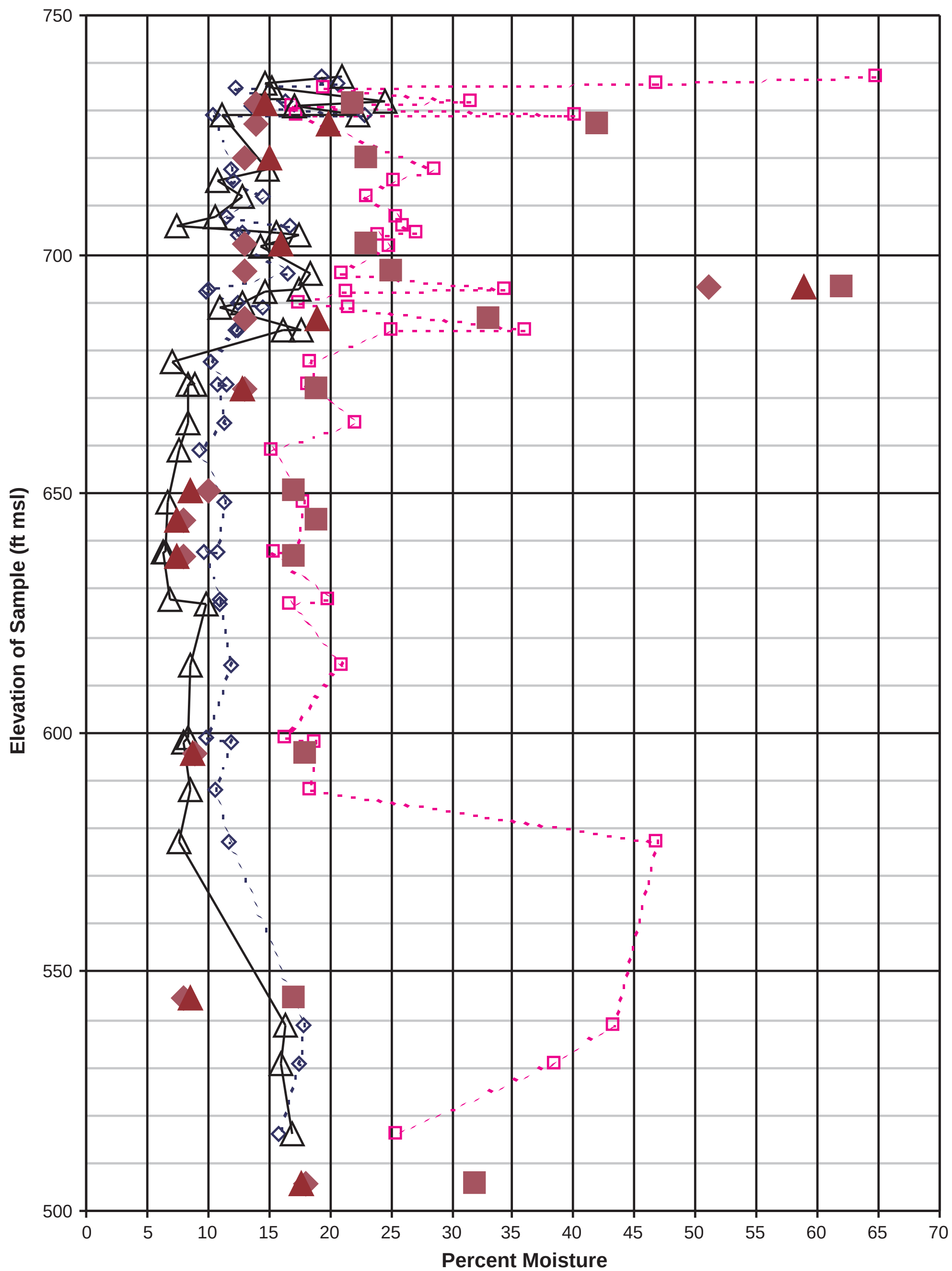
Dry Density

Moisture Content

Geotechnical Report for the EGC Early Site Permit

Figure 5-17

All Soils - Atterberg Limits (PL and LL) and Moisture Content



Legend

CPS Site (P-Series Boreholes)

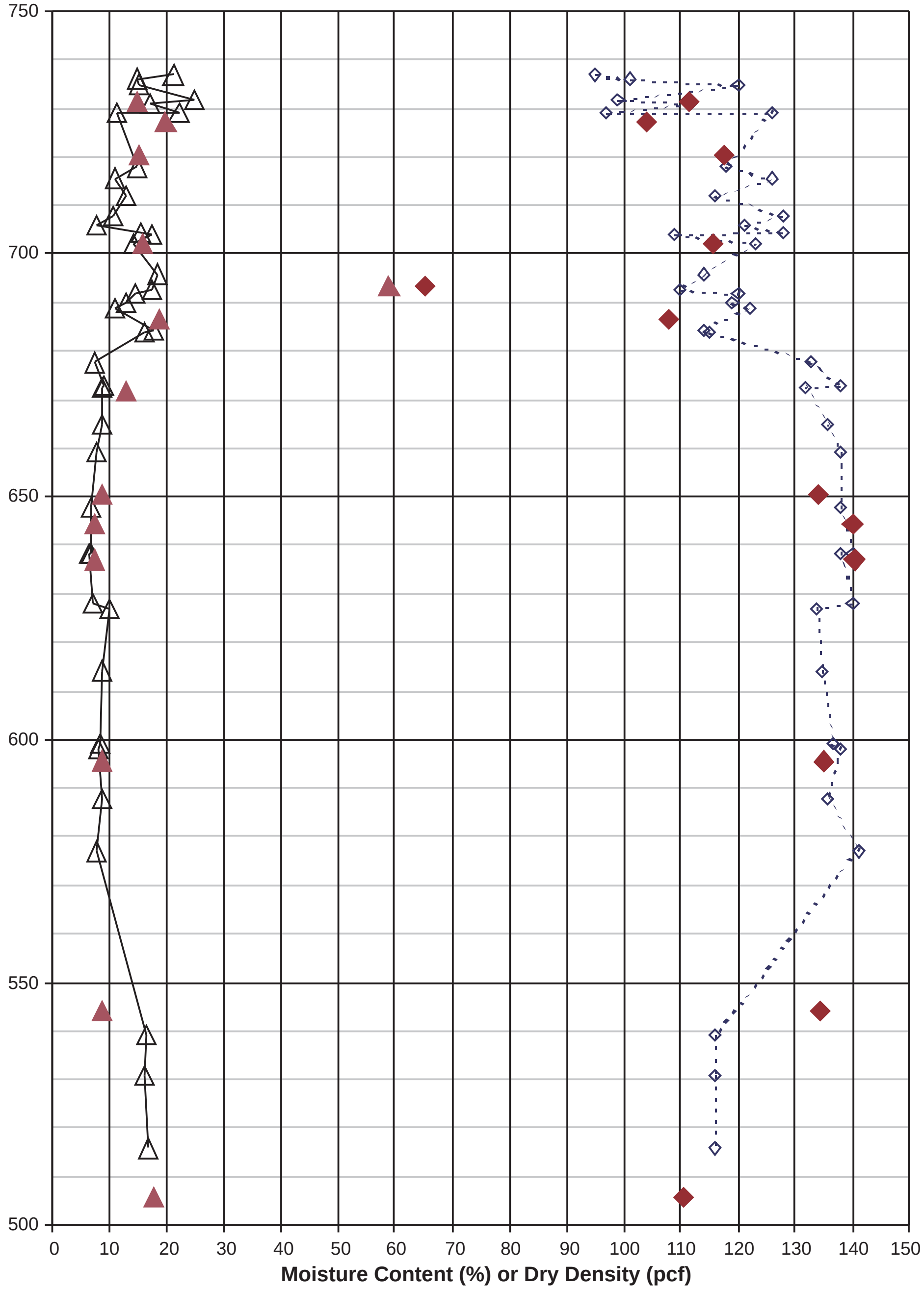
- PL
- LL
- Moisture Content

EGC ESP Site

- PL
- LL
- Moisture Content

Geotechnical Report for the EGC Early Site Permit

Figure 5-18
All Soils - Dry Density and Moisture Content



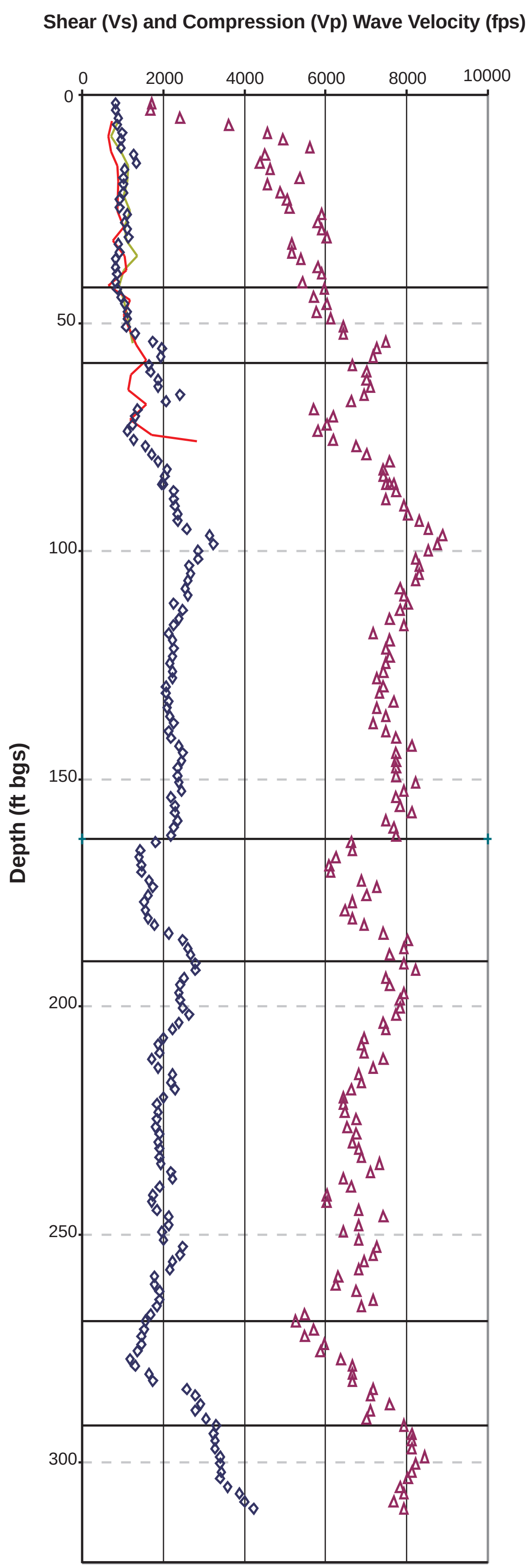
Legend

CPS Site (P-Series Boreholes)

- Dry Density
- Moisture Content

EGC ESP Site

- Dry Density
- Moisture Content



		Soil Properties - EGC ESP Site *(and CPS Site)*[1]					
Unit	**Depth (ft. bgs)**	**Moist Unit Wt. (pcf)**	**Moist. Cont. (%)**	**LL**	**PL**	**PI**	**Comments**
Loess & Wisconsinan Till	0 - 42	131 *(131)*	16 *(16)*	35 *(25)*	14 *(14)*	14 *(11)*	Perched water table at ~5 ft bgs
Interglacial	42 - 59	116 *(132)*	39 *(17)*	40 *(26)*	26 *(13)*	14 *(13)*	
Illinoian Till	59 - 163	148 *(147)*	8 *(9)*	18 *(18)*	9 *(11)*	9 *(7)*	
Lacustrine	163-190	133 *(140)*	13 *(11)*	28 *(19)*	11 *(12)*	17 *(7)*	
Pre-Illinoian Till	190 - 269	138 *(137)*	14 *(14)*	29 *(27)*	14 *(14)*	15 *(13)*	
Pre-Illinoian Alluvial/ Lacustrine	269 - 292	N.A. *(N.A.)*	23 *(N.A.)*	48 *(N.A.)*	17 *(N.A.)*	29 *(N.A.)*	
Bedrock	292-322	N.A. *(N.A.)*	N.A. *(N.A.)*	N.A. *(N.A.)*	N.A. *(N.A.)*	N.A. *(N.A.)*	Weathered rock contact at 292 ft bgs

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Figure 5-19

Shear and Compressional Wave Velocities and Other Soil Properties

Legend

- ◇ Vs at B-2
- △ Vp at B-2
- — Vs at CPT-02
- — Vs at CPT-04

Notes:

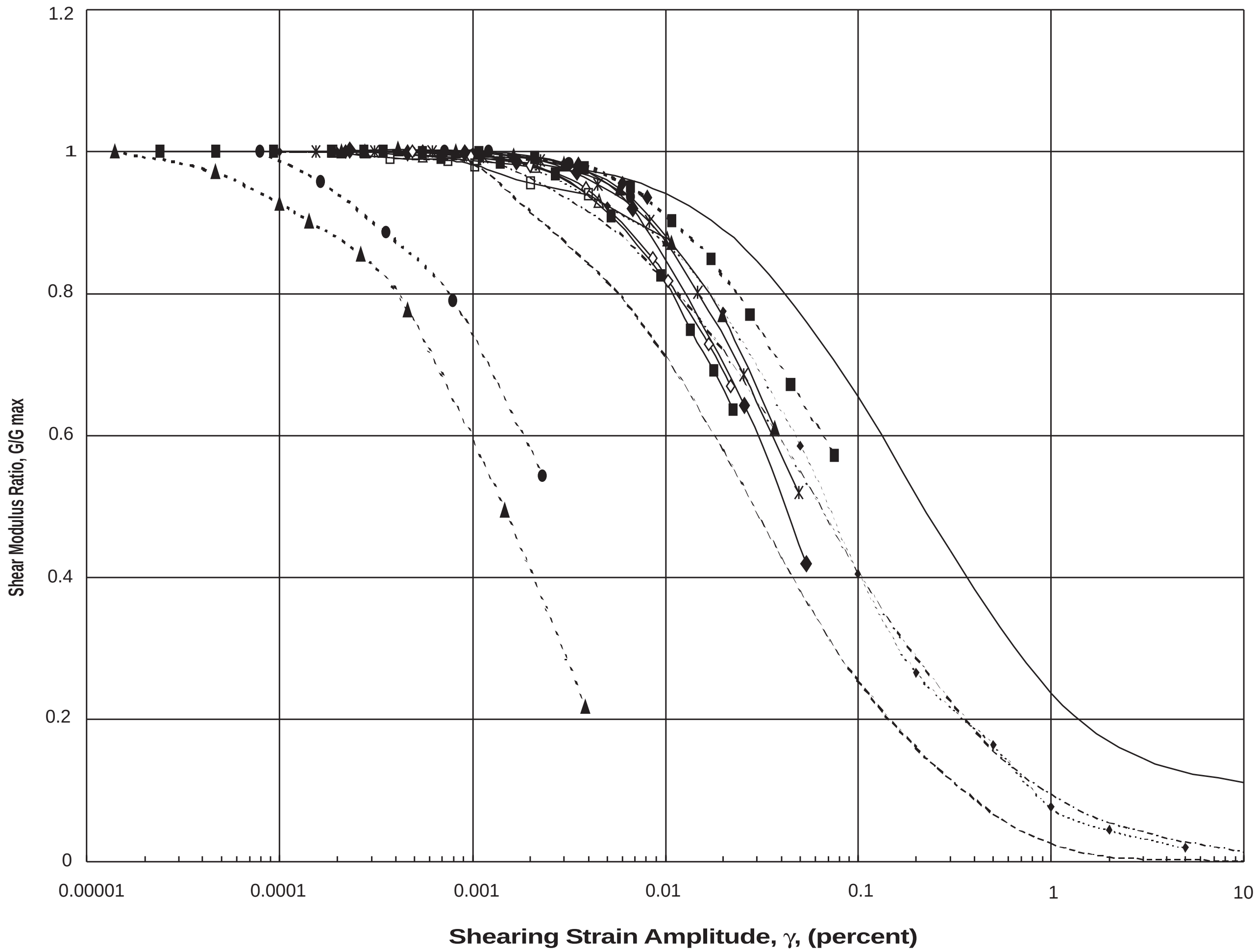
1 Soil properties shown are the arithmetic mean values for all available soil sample results for each stratigraphic unit. Top number is the mean value of applicable EGC ESP Site Investigation data.

(Italic) = Mean value of applicable data from CPS Site P-Series Soil Samples, as reported in Section 2.5 of CPS, 2002

N.A. = Results not available

Geotechnical Report for the EGC Early Site Permit

Figure 5-20
G/Gmax Plot
Resonant Column and Cyclic Torsion Test Results



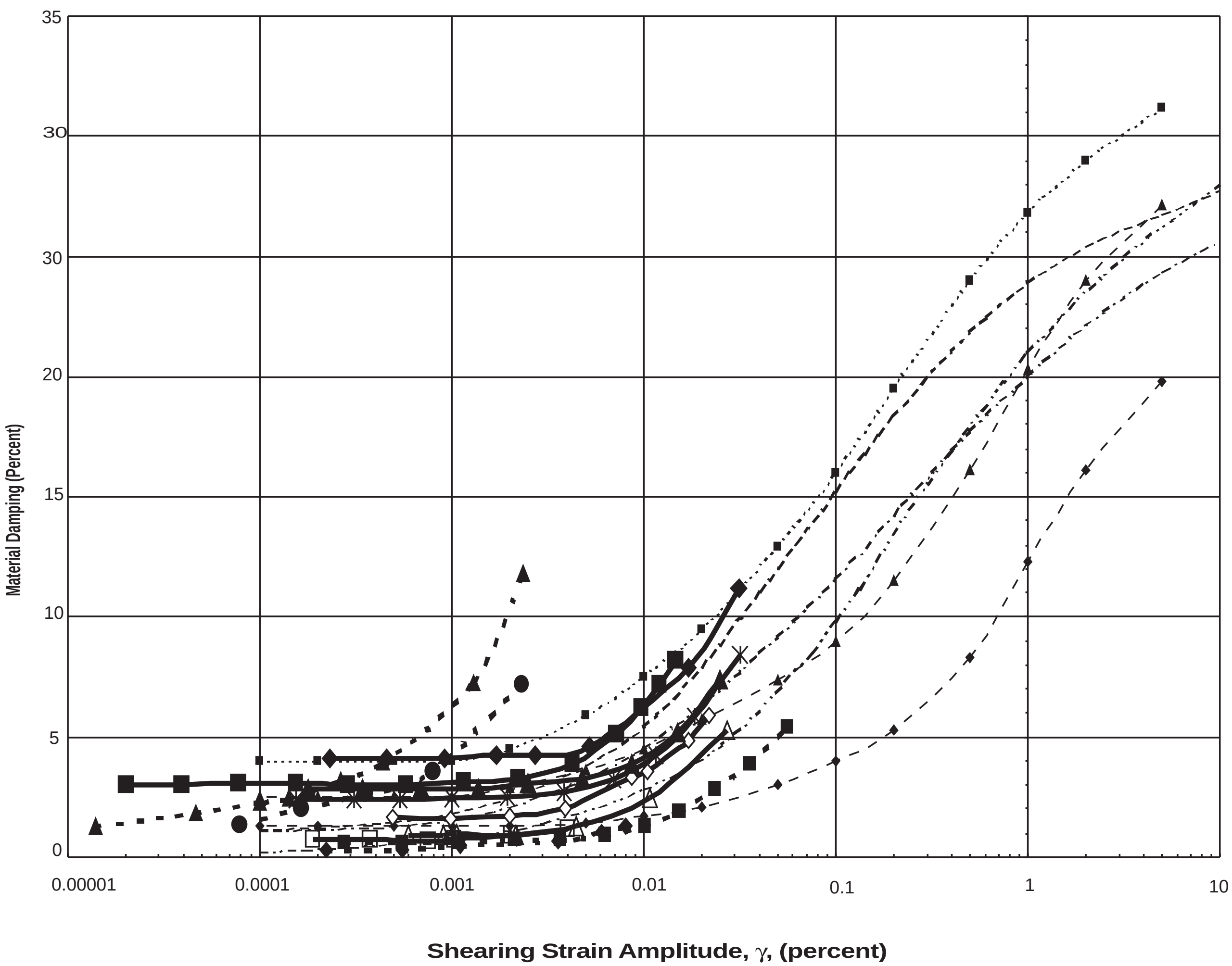
Legend

- V & D for PI = 0 (Vucetic and Dobry, 1991)
- V & D for PI = 15 (Vucetic and Dobry, 1991)
- Clay - PI = 10-20 (Sun et al., 1988)
- Clay (Seed and Sun, 1989)
- Sample A -- 33 ft depth -- Resonant Column
- Sample A -- 33 ft depth -- Cyclic Torsion
- Sample B -- 41.5 ft depth -- Resonant Column
- Sample B -- 41.5 ft depth -- Cyclic Torsion
- Sample C -- 171 ft depth -- Cyclic Torsion
- Sample C -- 171 ft depth -- Resonant Column
- Sample D -- 115 ft depth -- Resonant Column
- Sample D -- 115 ft depth -- Cyclic Torsion
- Sample E -- 208 ft depth -- Resonant Column
- Sample E -- 208 ft depth -- Cyclic Torsion
- Sample F -- 242 ft depth --Resonant Column
- Sample F -- 242 ft depth -- Cyclic Torsion

Note:
PI for EGC ESP soils typically 10

Figure 5-21

Material Damping Plot Resonant Column and Cyclic Torsion Test Results



Legend

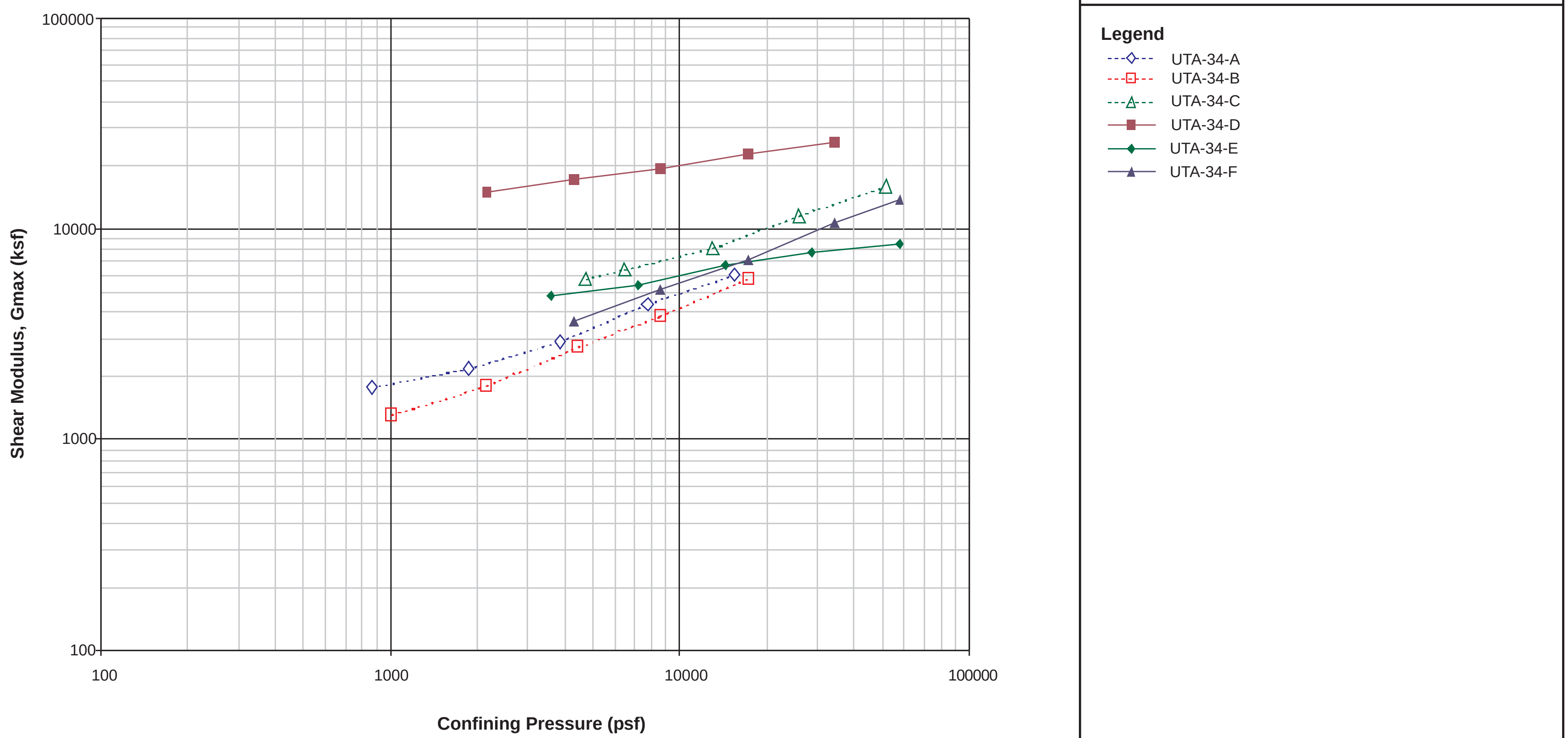
- V & D for PI = 0 (Vucetic and Dobry, 1991)
- V & D for PI = 15 (Vucetic and Dobry, 1991)
- Clay - Lower Bound (Sun et al., 1988)
- Clay - Average Bound (Sun et al., 1988)
- Clay - Upper Bound (Sun et al., 1988)
- Clay (Idriss, 1990)
- Sample A -- 33 ft depth -- Resonant Column
- Sample A -- 33 ft depth -- Cyclic Torsion
- Sample B -- 41.5 ft depth --Resonant Column
- Sample B -- 41.5 ft depth -- Cyclic Torsion
- Sample C -- 171 ft depth -- Cyclic Torsion
- Sample D -- 115 ft depth --Resonant Column
- Sample D -- 115 ft depth -- Cyclic Torsion
- Sample E -- 208 ft depth --Resonant Column
- Sample E -- 208 ft depth -- Cyclic Torsion
- Sample F -- 242 ft depth --Resonant Column
- Sample F -- 242 ft depth -- Cyclic Torsion

Note:
PI for EGC ESP soils typically 10

Geotechnical Report for the EGC Early Site Permit

Figure 5-22

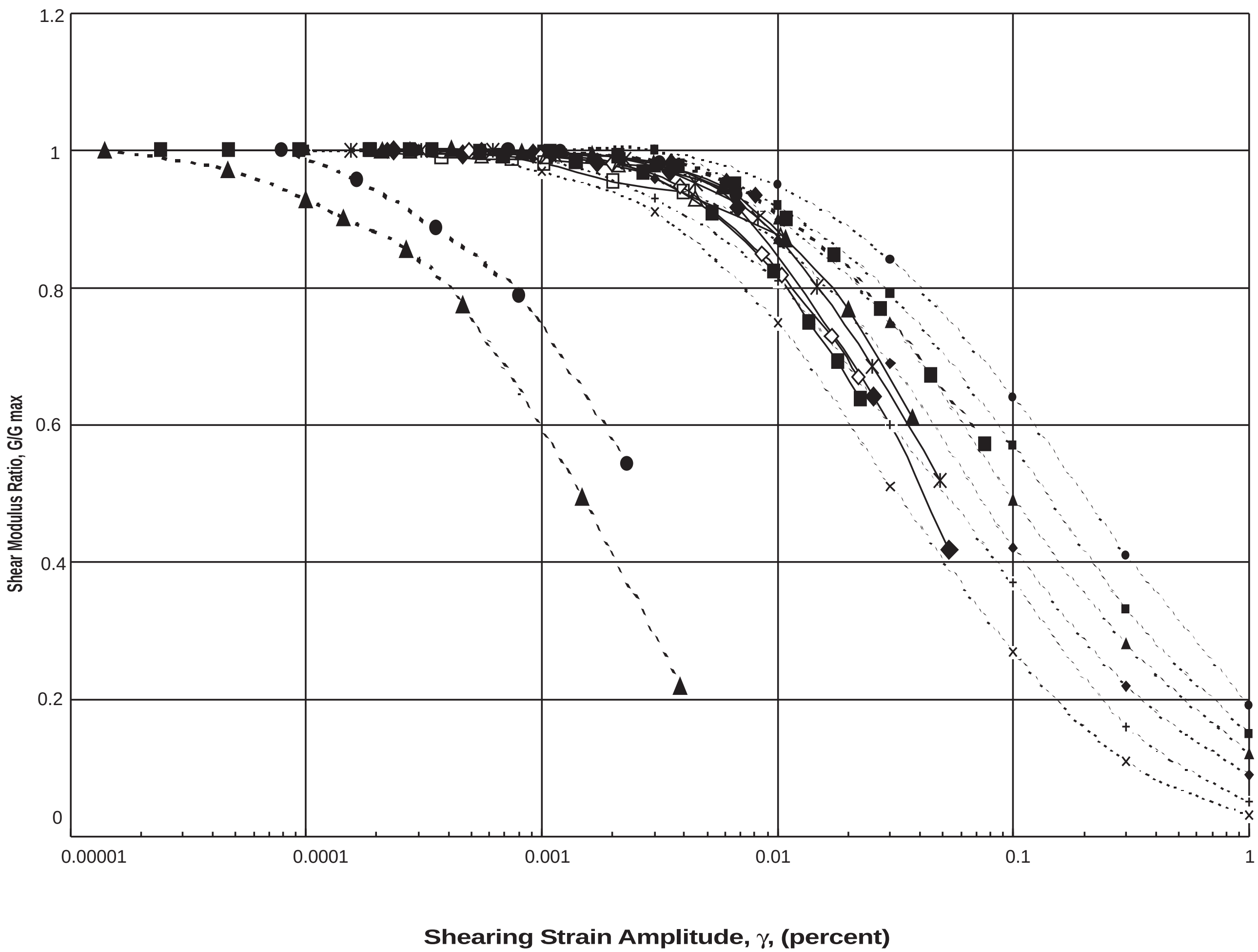
Gmax Variation with Confining Pressure-Resonant Column Test Results



Geotechnical Report for the EGC Early Site Permit

Figure 5-23

G/Gmax Plot Resonant Column and Cyclic Torsion Test Results Compared to EPRI Curves



Legend

- EPRI -- 0 to 20 ft
- EPRI -- 21 to 50 ft
- EPRI -- 51 to 120 ft
- EPRI -- 121 to 250 ft
- EPRI -- 251 to 500 ft
- EPRI -- 501 to 1000 ft
- Sample A -- 33 ft depth -- Resonant Column
- Sample A -- 33 ft depth -- Cyclic Torsion
- Sample B -- 41.5 ft depth --Resonant Column
- Sample B -- 41.5 ft depth -- Cyclic Torsion
- Sample C -- 171 ft depth --Resonant Column
- Sample C -- 171 ft depth -- Cyclic Torsion
- Sample D -- 115 ft depth --Resonant Column
- Sample D -- 115 ft depth -- Cyclic Torsion
- Sample E -- 208 ft depth --Resonant Column
- Sample E -- 208 ft depth -- Cyclic Torsion
- Sample F -- 242 ft depth --Resonant Column
- Sample F -- 242 ft depth -- Cyclic Torsion

Geotechnical Report for the EGC Early Site Permit

Figure 5-24

Material Damping Plot Resonant Column and Cyclic Torsion Test Results Compared to EPRI Curves