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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Atomic Safety and Licensing Board

In the Matter of	)	Docket Nos.
	)	
CONSUMERS POWER COMPANY	)	50-329 OM
	)	50-330 OM
(Midland Plant, Units 1 and 2)	)	50-329 OL
	)	50-330 OL
	)	

I, Alfred J. Hendron, Jr., being first duly sworn, state that my accompanying testimony concerning seismic shakedown is true and correct to the best of my knowledge and belief.

Alfred J. Hendron Jr.
Alfred J. Hendron, Jr.

SUBSCRIBED AND SWORN TO
before me this 8 day
of October , 1982.

Louise E. Ellis
Notary Public

DS03

TESTIMONY OF

DR. ALFRED J. HENDRON, JR.

This is the testimony of Dr. Alfred J. Hendron, Jr. My testimony is concerned with the evaluation of the seismic shakedown settlement of the Diesel Generator Building at the Midland nuclear power plant in the event of an earthquake. The seismic shakedown settlement of the DGB was evaluated for an intensity of motion which would correspond to an upper bound ground surface acceleration 0.19g. I have concluded that the north side of the DGB will settle about .25" ± .15" under an earthquake acceleration of 0.19g and the south side will settle about .05" ± .05". The North side of the building will settle more during the earthquake because there is a larger thickness of sand under the north side of the DGB. The building will tend to rotate slightly toward the north during seismic shaking just as it has tended to rotate south during static settlement due to the higher percentage of clay under the south side of the building.

QUALIFICATIONS AND EXPERIENCE

My detailed biographical, educational, and professional record is set forth in Attachment I. The following is a summary.

I completed the requirements for the degree of Bachelor of Science in Civil Engineering from the University of Illinois in June of 1959. In September of 1959 I enrolled in the Graduate College of the University of Illinois where I began full-time study on a University of Illinois Fellowship in the Department of Civil Engineering, specializing in Soil Mechanics and Foundation Engineering. I received the degree of Master of Science in Civil

Engineering from the University of Illinois in June of 1960. During the summer of 1960 I was employed by the consulting engineering firm of Shannon and Wilson, Inc. of Seattle, where I worked on foundations for the building complex which housed the World Fair in Seattle, and conducted an analysis of the stability of a 200 acre slope adjacent to the Pacific Ocean to be used in expert testimony of Mr. S. D. Wilson and Dr. A. Casagrande.

In the fall of 1960, I began full-time study at the University of Illinois toward a Ph.D. in Foundation Engineering and full minors in Geology and in Theoretical and Applied Mechanics. During this phase of my education, my academic adviser was Dr. Don U. Deere, under whom I studied engineering geology. I studied foundation engineering under Dr. R. B. Peck. My studies on the application of shear strength of cohesive soils to problems of slope stability and bearing capacity, problems usually analyzed by limit equilibrium methods, were in courses taught by Dr. R. B. Peck, Dr. Alan Bishop, and Dr. D. U. Deere.

In June of 1961, I became a full-time research associate at the University of Illinois where I conducted a research project in soil dynamics under Professor N. M. Newmark and I taught an undergraduate course in Soil Mechanics and Foundation Engineering under Dr. R. B. Peck. These duties continued until the completion of my Ph.D. thesis in the summer of 1963, when I became a 1st Lieutenant in the U. S. Army Corps of Engineers.

From September 1963 to September 1965 I was assigned to the U. S. Army Engineer Waterways Experiment Station as a research engineer. At the Waterways Experiment Station I worked in research in soil dynamics and structural dynamics as applied to problems in the design of protective structures. I was also instrumental in starting a rock mechanics research program at the

Waterways Experiment Station, and I served as a special consultant for the Office of the Chief of Engineers on construction problems associated with the Minute Man System in North Dakota and as a consultant to NATO in Norway on the construction of a large underground cavity in rock.

Since September of 1965 I have been employed in teaching and research at the University of Illinois in the Department of Civil Engineering, as an Assistant Professor from 1965 to 1968, an Associate Professor from 1968 to 1970, and as a Professor of Civil Engineering from 1970 until present. During this time I have taught graduate courses in soil and rock dynamics, applied foundation engineering, earth dams, rock mechanics, and rock engineering. I have also taught undergraduate courses in Introductory Soil Mechanics and Foundation Engineering. I have been active in research on slope stability in rock masses, design of tunnel linings in soil and rock, ground vibrations produced by construction blasting and by nuclear explosions, theoretical studies of inelastic and time-dependent stress distribution around tunnels in soil and rock, and compressibility of large sized granular materials such as rock fill materials.

While a staff member at the University of Illinois, I have been engaged by various public agencies, consulting engineering firms, utility companies, and foreign governments to consult on the design and construction of nuclear power plants, dams, tunnels, and slope stability problems. A number of these consulting assignments are listed in detail in Attachment I.

I have previous experience in the evaluation of foundations of dams and nuclear power plants for liquefaction potential. In those cases where liquefaction has been eliminated by means of dewatering, I have estimated

seismic shakedown by the methods used in this testimony.

Diesel Generator Building Description and Available Information Useful for Estimating Seismic Shakedown Settlement

The Diesel Generator Building for the Midland Nuclear Station is located to the south of the Turbine Building as shown in Figure 1. The building is founded on a 10 ft wide continuous wall footing around the perimeter of the structure; in addition three North-South wall footings, also 10 ft wide, support the walls which separate the four bays of the Diesel Generator Building. A plan view of the footings is shown in Figure 2. The strip footings analyzed and reported in this testimony are shown by the dark shaded areas in Figure 2. A cross-section taken from west to east through the Diesel Generator Building is shown in Figure 3. The base of the footings are founded at elevation 628 and the finished grade elevation is 634. The static water levels in the area of the diesel generator building will be dewatered to about elevation 600 to eliminate the possibility of liquefaction in the sands below the north side of the DGB. Thus the sands between elevation 600 and the base of the footings at elevation 628 will be partially saturated and will undergo some permanent vertical strain induced by the cyclic shear strains produced by the earthquake ground motions. The magnitude of the DGB settlement which results from the vertical "shakedown" strains is a function of the thickness of sand layers present between elevation 600 and 628, the relative density of the sands, and the magnitude of the cyclic shear strains produced by the earthquake.

The thickness and relative density of the sands present beneath the diesel generator footings must be obtained from soil boring information. The magnitude of the cyclic strains induced by the SSE can be calculated as illustrated later in this testimony.

Before surcharging in January of 1979, an exploratory program was conducted in the plant area by Bechtel from August 1978 to December 1978 which included borings in the series designated as DG borings. Borings were also made in 1979 after the surcharge removal and they are designated CH borings. The location of the borings is shown in Fig. 4. In some of the DG and CH borings standard penetration tests were obtained at intervals ranging from 1.5' to 3.5'. Those borings with complete enough information to estimate the thickness and relative density of the sand were used to estimate shakedown settlement. In these borings, listed in Table 1, samples were described closely enough to determine if the blow count was taken in sand or clay and the samples were obtained close enough to reasonably determine the thickness of clean sand. The boring logs of the borings shown in Table 1 are given in Attachment 2.

Consumers Power has subsequently conducted the additional boring and sampling program requested by the Corps of Engineers. Five of these borings, designated as COE 8, 10, 11, 12 and 13 were made in the area of DGB as shown in Fig. 4. These borings, which were continuously sampled except for boring COE-12, enabled an exact determination of the thickness of sand and clay at each boring location. In those instances where sand was encountered, the relative density of the sand was determined by Woodward-Clyde Consultants by several methods. The COE borings were taken after surcharging; the logs of COE borings 8, 10, 11, and 13 are shown in Attachment 3.

DESCRIPTION OF THE METHOD FOR CALCULATION OF "SHAKEDOWN" SETTLEMENT

The first step in the calculation of the "shakedown" settlement is to 1) obtain the thickness of each sand layer from the boring logs and to obtain the relative density for each sand layer. For the COE borings the relative density can be obtained from the Woodward-Clyde Consultants report of July 1981. For the DG and CH borings the relative density is determined from the Gibbs & Holtz relationship shown in Fig. 5 by using the standard penetration resistance for each layer and the "effective" stess at the location of the standard penetration test at the time of the boring.

The second step is to 2) determine the total vertical stress at the middle of each layer, σ_v, which consists of the soil overburden pressure and the distributed vertical stress from the load of the building.

The third step is to 3) determine the average cyclic shear stress which will be applied to the center of each sand layer by

$$\tau = (0.65)\ \frac{a\ max}{g}\ \sigma_v$$

where

τ is the average shear stress

a max. is the maximum acceleration associated with the earthquake,

g is the acceleration of gravity, and

σ_v is the total vertical stress at the center of the sand layer (Seed and Idriss 1971).

In the relationship above, the value of 0.65 is the commonly accepted value for reducing the peak shear stress to the average cyclic shear stress for the duration of shaking.

The fourth step is to 4) determine the average principal effective stress at the center of the sand layer, $\bar{\sigma}_m$, where

$$\bar{\sigma}_m = 1/3\ (\bar{\sigma}_v + 2Ko\bar{\sigma}_v)$$

and, Ko, the lateral earth pressure coefficient is taken as 0.7 for compacted soil.

The fifth step is to 5) calculate the shear modulus, G, using

$$G = 1000\ k_2\ (\bar{\sigma}_m)^{\frac{1}{2}}$$

where $\bar{\sigma}_m$ is in psf and K_2 is in $(psf)^{\frac{1}{2}}$ and is a function of relative density and shear strain, γ, as shown in Fig. 6.

The sixth step is to 6) determine the shear strain by taking $\gamma = \tau/G$. Since $G = f(\gamma)$, as shown in Figure 6, the shear strain, γ, is then recalculated in step 7. Step 6) and 7) must be repeated until the assumed shear strain γ and the computed shear strain are in close agreement. After the cyclic shear strain, γ, has been determined, the vertical "shakedown" strain can be obtained from Fig. 7. Note that the data points shown in Fig. 7 are for 10 cycles of strain which is conservative for the SSE postulated for the Midland plant; for relative densities different than those which correspond to the curves in Fig. 7, an interpolation is required. The vertical settlement for each boring location is then determined in step 8) by integrating the vertical strain in all sand layers between elevation 600 and 628. The values of settlement computed in step 8) are then multiplied by 3 in step 9) to account for 3 dimensional shaking as discussed in Pyke, Seed, and Chan (1975). It is significant that the procedure above, including the multiplication factor of 3, led to agreement between calculated and observed shakedown settlement at the Jensen Filtration Plant during the 1971 San Fernando Earthquake (Pyke, Seed & Chen 1975).

Calculation of "shakedown" settlement by the above procedures are given in Attachment 4 for the boring location shown in Table 1. The calculations given in Attachment 4 are for a ground surface acceleration of 0.19g and for a magnitude earthquake which would produce 10 significant cycles of average shear stess. The results of these calculations are shown in Table 2 and are illustrated on Fig. 8.

RESULTS OF "SHAKEDOWN" SETTLEMENT CALCULATIONS

It is felt that the most complete boring information which could be used to calculate the shakedown settlement is the information obtained from the COE boring 8, 10, 11, and 13. These indicate that the north side of the building (Fig. 8) could settle .17" and the south side of the building could settle .05". Then the building would tend to rotate toward the north during shaking just as it has rotated toward the south due to static settlements. Calculated settlements based on blow counts from the DG and CH borings are also shown on Fig. 8. The calculated settlements for the DG and CH boring locations ranged from .006" to .39". The pattern of settlement indicated by the DG and CH borings also indicate more shakedown settlement on the north side of the building. If the calculated settlements at the DG boring locations on the north side of the building are averaged, the average calculated settlement of the north side would be .19". It is my judgment that the settlement of the north side of the building should be considered to be .25" ± .15" and that the south side of the building should settle on the order of .05" ± .05" due to seismic shakedown. The building would tend to rotate as a rigid body about an east-west axis through the center of the building.

REFERENCES

Pyke, R.; Seed, B.; Chan, K. C., Settlements of Sands under Multidirectional Shaking, Journal of the Geotechnical Engineering Division, GT4, April 1975, pp. 379-397.

Seed, B.; and Idriss, M., Soil Moduli and Damping Factors for Dynamic Response Analyses, Earthquake Engineering Research Center, College of Engineering, University of California, Berkeley, California, December 1970.

Silver, M. L.; Seed, H. B., The Behaviour of Sands Under Seismic Loading Conditions, Earthquake Engineering Research Center, College of Engineering, University of California, Berkeley, California, December 1969.

TABLE 1

BORING INFORMATION USED IN SHAKEDOWN CALCULATIONS

DG - 8	DG - 27
DG - 12	DG - 28
DG - 14	CH - 13
DG - 15	CH - 14
DG - 17	CH - 15
DG - 18	COE - 8
DG - 19	COE - 10
DG - 20	COE - 11
DG - 22	COE - 13
DG - 24	

TABLE 2

SUMMARY OF SHAKEDOWN SETTLEMENT (Inches)

AT D. G. BUILDING FOR AN EARTHQUAKE ACCELERATION = 0.19g

Boring No.	Settlement, inches (.19g)
COE 8	.174
COE 10	.174
COE 11	.051
COE 13R	.036
DG 8	.39
DG 12	.048
DG 14	.006
DG 15	.084
DG 17	.003
DG 18	.171
DG 19	.393
DG 20	.270
DG 22	.324
DG 24	.006
DG 27	.033
DG 28	.126
CH 13	.090
CH 14	.171
CH 15	.198

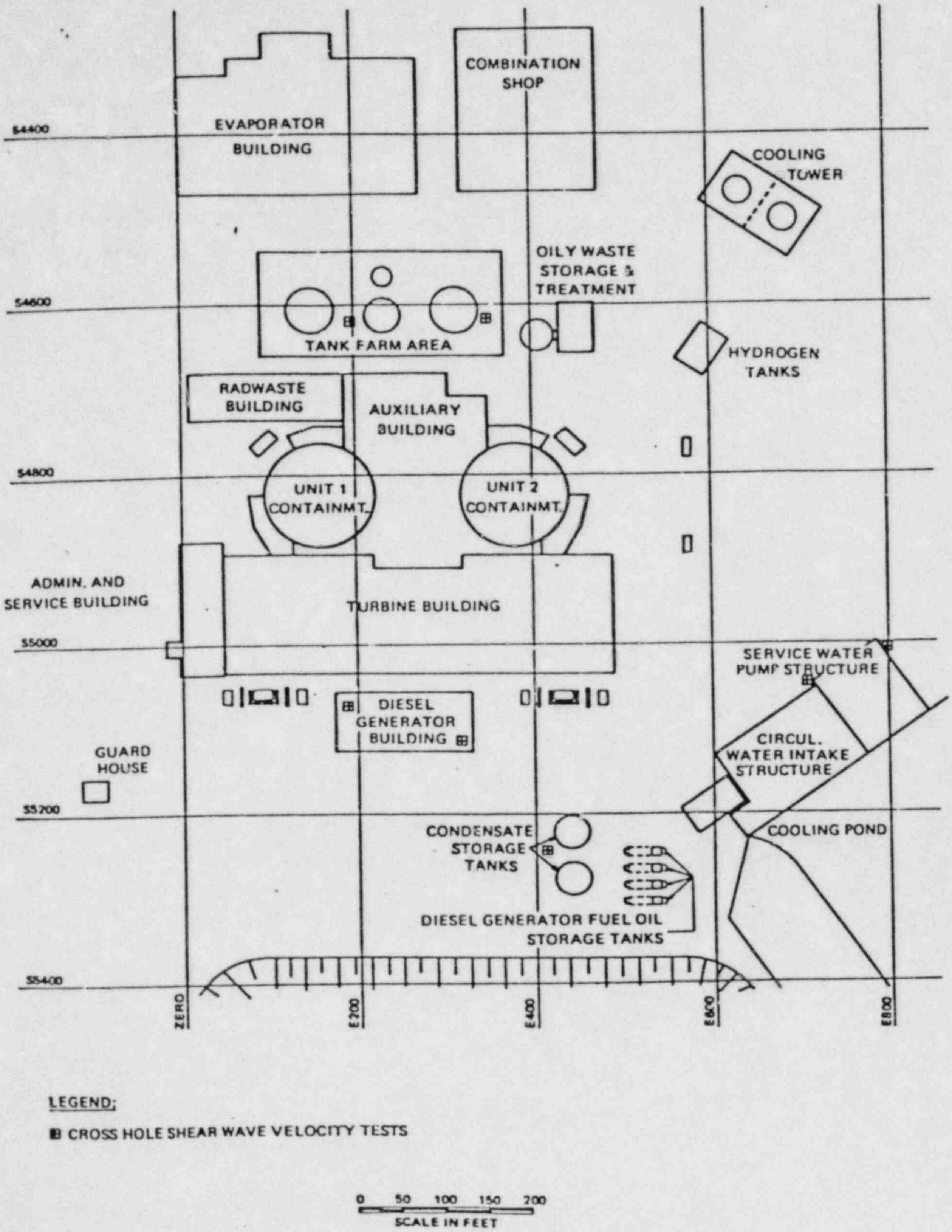

Figure 1. Plant view showing Diesel Generator Building Location

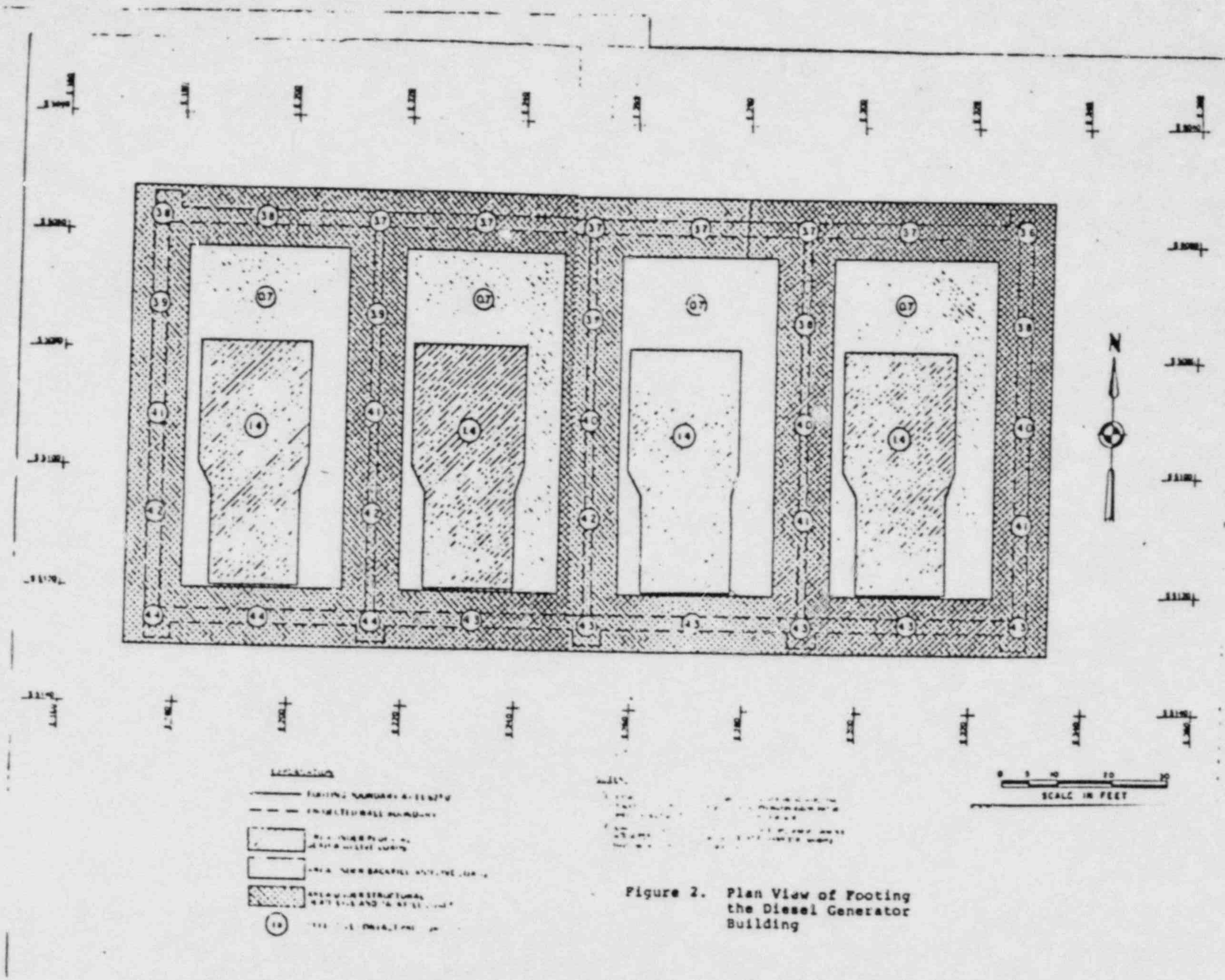

Figure 2. Plan View of Footing the Diesel Generator Building

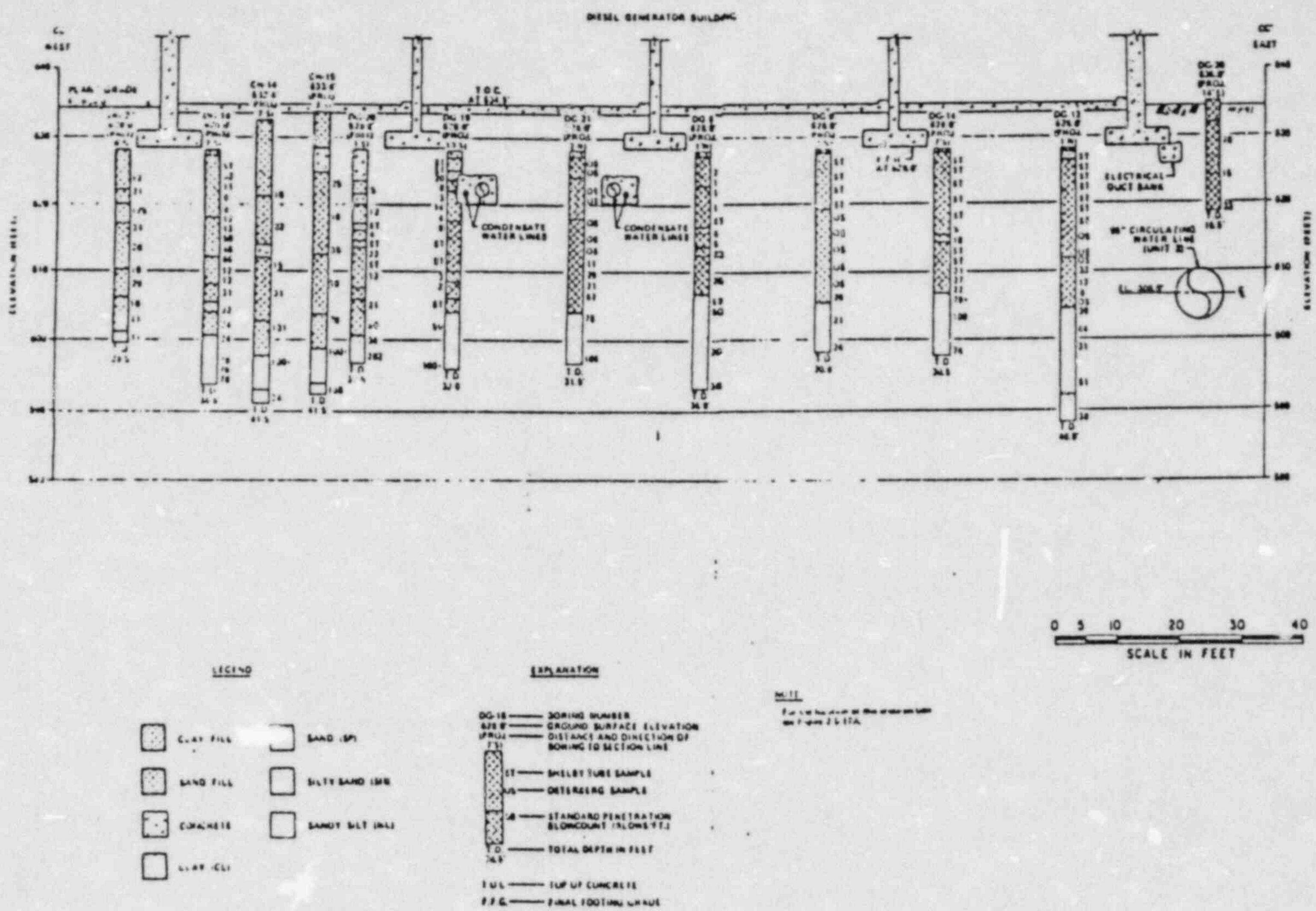

Figure 3. East-west Cross-section Through Diesel Generator Building Foundations

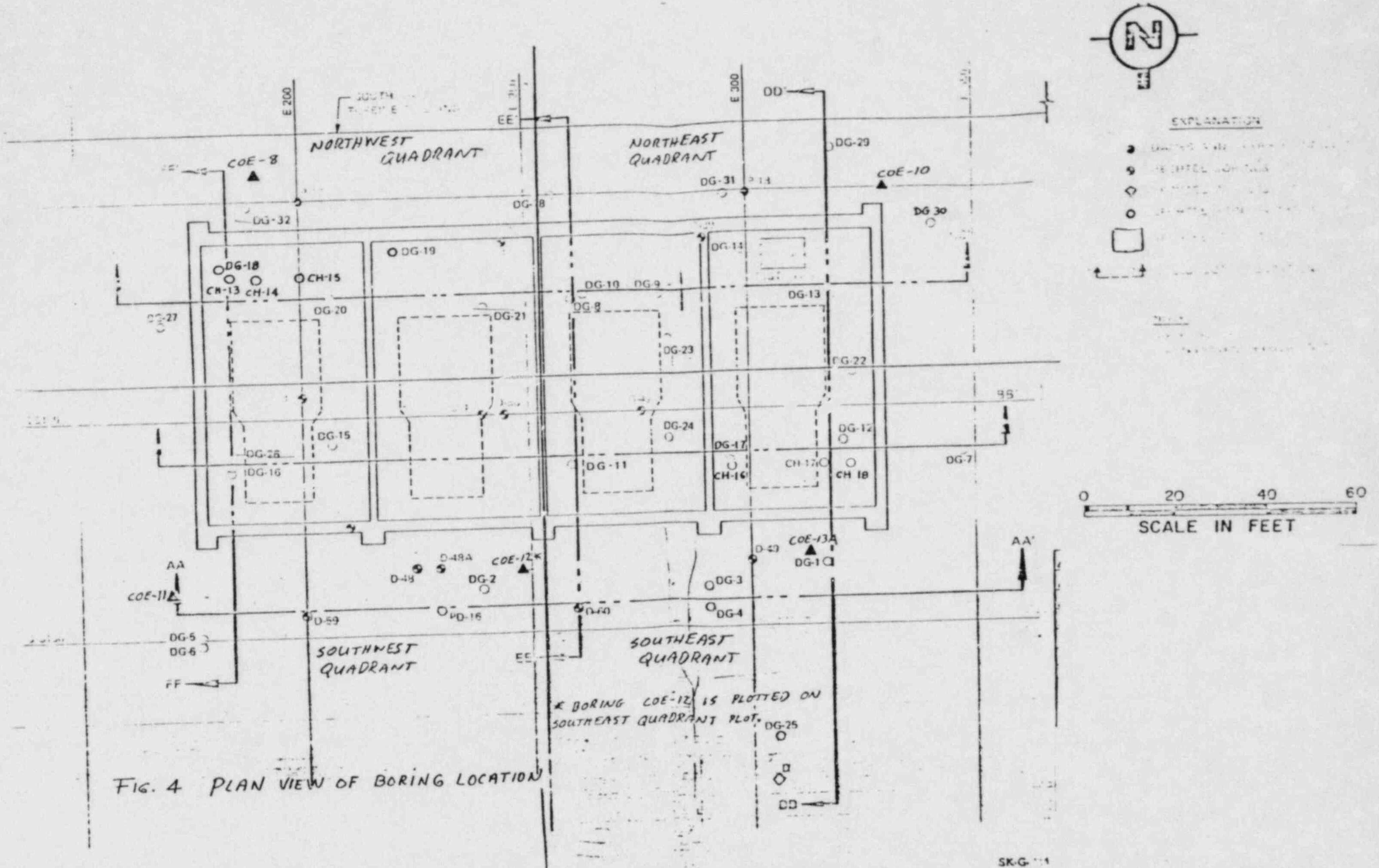

FIG. 4 PLAN VIEW OF BORING LOCATION

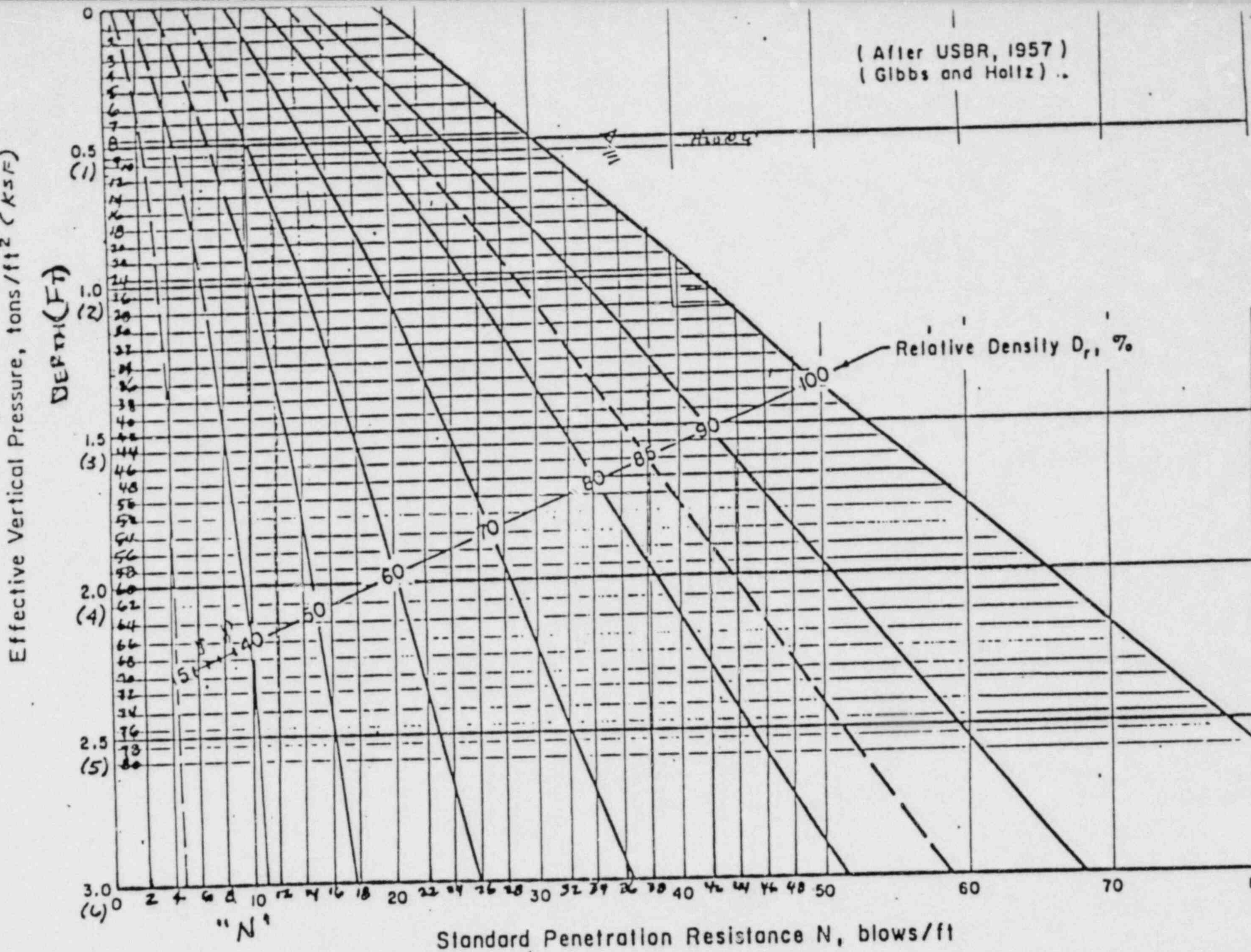

FIG. 5 RELATIVE DENSITIES CALCULATED FROM STANDARD PENETRATION RESISTANCES

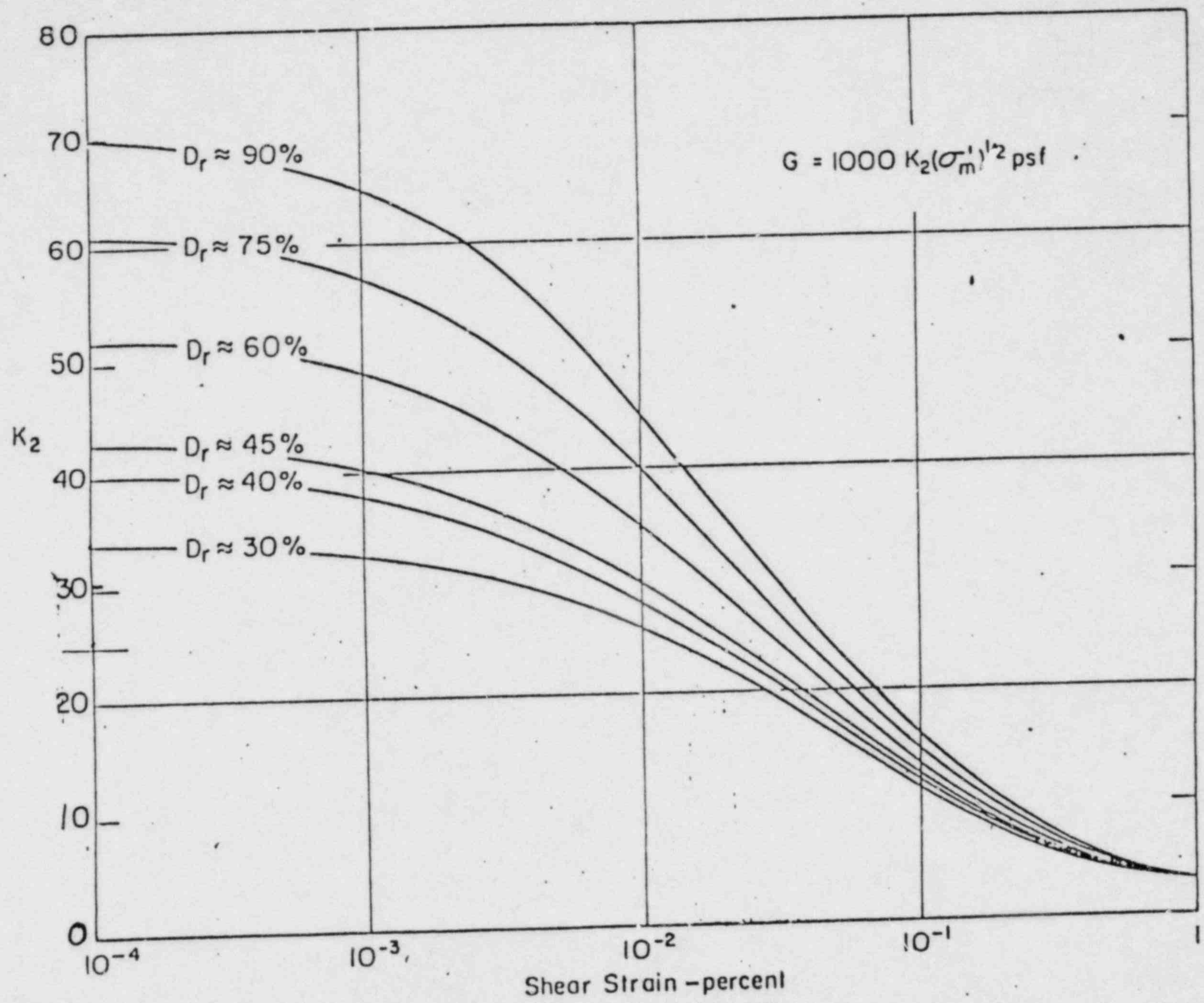

Fig. 6 SHEAR MODULI OF SANDS AT DIFFERENT RELATIVE DENSITIES.

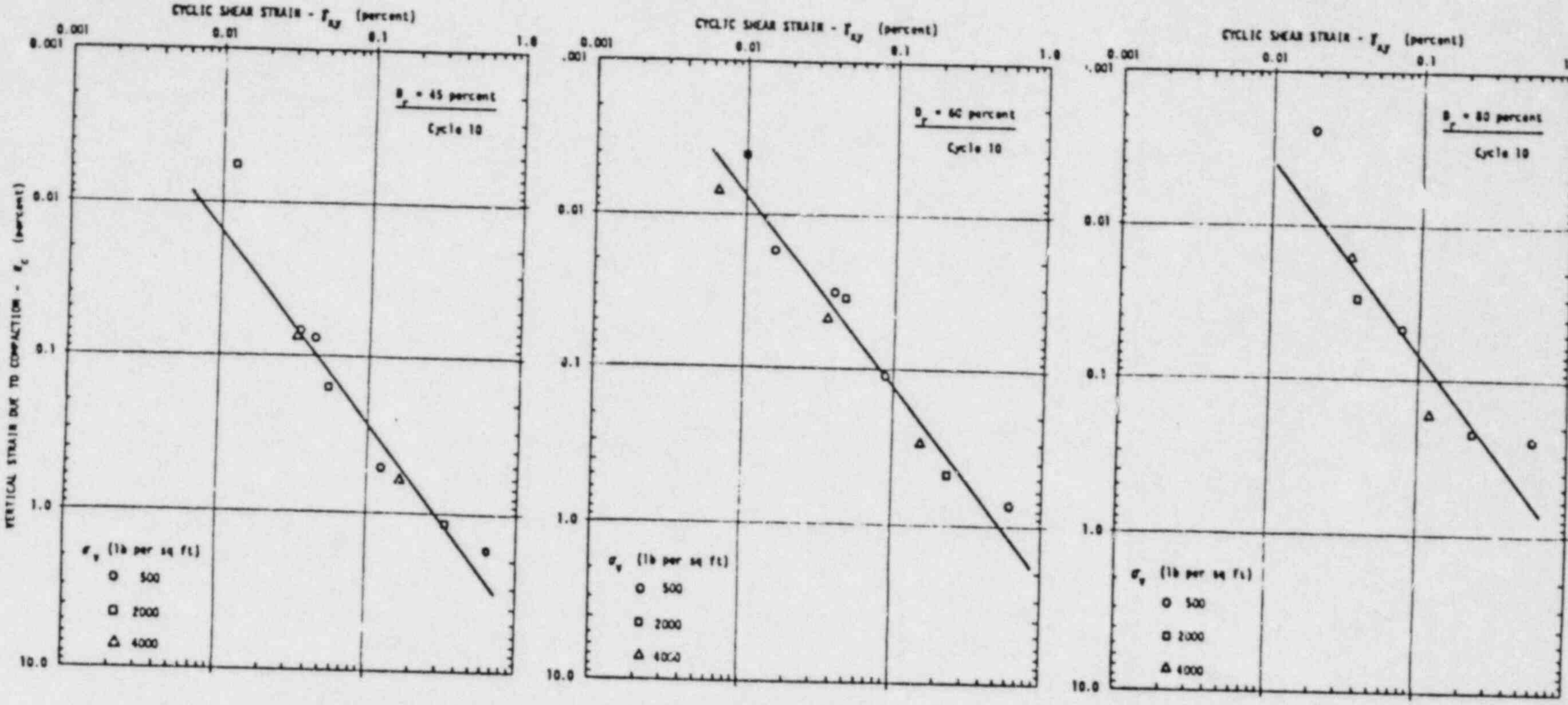

Fig. 7 Effect of Confining Pressure on Settlement in Ten Cycles at Smaller Shear Strain Amplitudes.

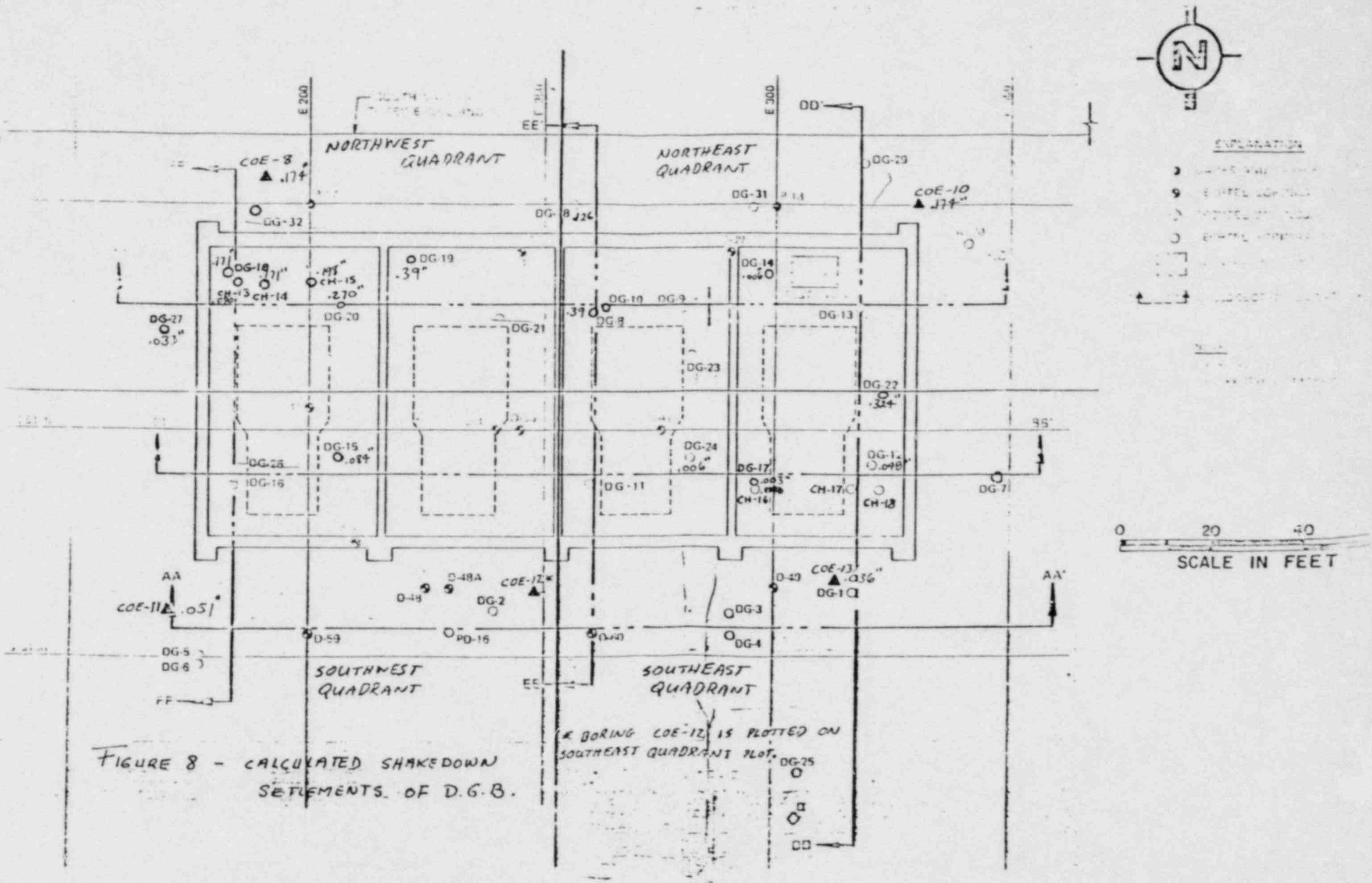

FIGURE 8 - CALCULATED SHAKEDOWN SETTLEMENTS OF D.G.B.

ATTACHMENT 1

RESUME

PROFESSIONAL BACKGROUND AND EXPERIENCE

Name: ALFRED J. HENDRON, JR.

Address: 2230c Newmark Civil Engineering Laboratory
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

Date of Birth: October 4, 1937

Marital Status: Married with 2 children

Citizenship: Natural Born - U. S.

EDUCATION

Ph.D.	1963	University of Illinois Urbana, Illinois	Major:	Soil Mechanics Foundations
			Minors:	Geology Theoretical and Applied Mechanics
M.S.	1960	University of Illinois Urbana, Illinois	Civil Engineering	
B.S.	1959	University of Illinois Urbana, Illinois	Civil Engineering (Bronze Tablet)	

NATIONAL AND INTERNATIONAL AWARDS OR RECOGNITIONS

Received American Society of Civil Engineers Walter L. Huber Research Prize, 1974

Invited to give 6th Nabor Carrillo Lecture, by Mexican Society for Soil Mechanics, November 1982

Listed in Who's Who in Engineering, 1980

POSITIONS HELD

September 1970 - Present	Professor of Civil Engineering, University of Illinois
September 1968 - September 1970	Associate Professor of Civil Enginering, University of Illinois
September 1965 - September 1968	Assistant Professor of Civil Engineering, University of Illinois
September 1963 - September 1965	1/Lt. U.S. Army Corps of Engineers Research Engineer U.S. Army Engineer Waterways Experiment Station

June 1961 - September 1963 — Research Associate
June 1960 - September 1960 — Engineer, Shannon & Wilson Soil Mechanics and Foundation Engineers, Seattle, Washington

TEACHING EXPERIENCE

Undergraduate Courses, University of Illinois

1961 - 1963 — Introductory Soil Mechanics

1965 - Present — Introductory Soil Mechanics
Foundation Engineering
Civil Engineering Design Course for Senior Honors Students

Graduate Courses, University of Illinois

1965 - Present — Earth Dams
Rock Mechanics
Applied Rock Mechanics
Applied Soil Mechanics
Soil Dynamics (including earthquakes effects)

RESEARCH EXPERIENCE

1961 - 1963 — Research Associate, University of Illinois
Conducted research on the high pressure compressibility of sands and measurement of the coefficient of earth pressure at rest.

1963 - 1965 — U.S. Army Engineer Waterways Experiment Station
Conducted research on stress wave propagation in soils, design of structures for dynamic loading, and developed a research program in rock mechanics.

1965 - Present — University of Illinois
Presently conducting research on the following specific topics:

(1) Ground vibrations produced from blasting tunnels and open cuts in rock.
(2) Compressibility of large sized granular materials such as that used in rock fill and rolled earth dams.
(3) Theoretical studies of inelastic and time dependent stress distribution around tunnels.
(4) Effect of pore pressures on the strength of rock.
(5) Three dimensional analysis of slope.
(6) Design of tunnel linings in soil and rock.
(7) Earth dam design.

OFFICES AND OTHER SERVICES TO PROFESSIONAL SOCIETIES

(1) Member of the Research Committee of the Soil Mechanics and Foundations Division of the American Society of Civil Engineers, 1967-69.

(2) Member of the Subcommittee 12 of Committee D-18, ASTM, Properties of Soil and Rock, 1965-1970.

(3) Co-chairman of Panel on "Stress Wave Propagation in Soils," International Symposium on Soil Dynamics, Albuquerque, New Mexico, sponsored by ASCE & NSF, August, 1967.

(4) Panel member for "Dynamic Loading," session of a National Specialty Conference on Placement and Improvement of Soil to Support Structures," sponsored by the Soil Mechanics and Foundations Division of the American Society of Civil Engineers, M.I.T., August, 1968.

(5) April, 1968 - Gave lectures on rock mechanics to Metropolitan Section ASCE, New York City.

(6) April 1969 - Gave lectures on rock mechanics to Metropolitan Section, Washington, D.C.

(7) Selected to give a lecture on "Field Instrumentation in the Design of Underground Structures in Rock," Metropolitan Section, ASCE, New York City, May, 1970.

(8) Panel member on "Dynamic Loadings and Deformations," session for ASCE, Soil Mechanics and Foundations Division Specialty Conference on "Lateral Streses in the Ground and the Design of Earth Retaining Structures," Cornell University, June, 1970.

(9) Panel member on "Deformation Modulus of Rock Foundations," ASTM Symposium on Deformation Properties of Rock, Denver, February, 1969.

(10) Selected by NSF as one of the U.S. members to Exchange Meeting with Japanese Engineers on the topic of Ground Motions Produced by Earthquakes, U. of California at Berkeley, August, 1969.

(11) Member of Committee on Soil Dynamics, Soil Mechanics Division, ASCE, 1970-1972.

(12) Member of Publications Committee for Journal of the Soil Mechanics and Foundations Division, ASCE, 1970-1972.

(13) Member of Committee on Rock Mechanics, ASCE, 1978-present.

(14) Member Corps of Engineer Advisory Board for Geotechnical Engineering Research, 1978-1981.

EXAMPLES OF FOUNDATION ENGINEERING AND EARTHQUAKE ENGINEERING EXPERIENCE

(1) Consultant to Williams Brothers Construction Company on slope stability problems encountered in construction of the Transandean Pipeline in southern Columbia, S.A.

(2) Consultant to Woodward-Clyde and Associates on the Foundation Design of Davis-Besse Nuclear Reactor for earthquake loadings.

(3) Consultant, as an associate of Dr. N.M. Newmark, on the foundations for a 40-story building in Vancouver, B.C., design for earthquake loading.

(4) Consultant to Waterways Experiment Station on the Earthquake Stability of Dam Slopes.

(5) Consultant to H.G. Acres Ltd. on seismic conditions for Nuclear Reactor Foundations as a part of a study for 6 New England States on Projected Power Needs.

(6) Consultant, as an associate of Dr. N.M. Newmark, to the Divisions of Reactor Licensing and Reactor Safety of the Atomic Energy Commission, on the adequacy of nuclear reactor foundations to resist earthquake loading, September 1967-1980. The following is a list of the Nuclear Power Station Foundations reviewed during this time:

Ft. Calhoun	Arnold
Cooper	Pilgrim #1
Surry	Crystal River
Shoreham	Prairie Island
Salem	Farley
Rancho Seco	Calvert Cliffs
Diablo Canyon	Oconee
Sequoyah	Indian Point
Hatch	D.C. Cook
Brunswick	Zimmer
Kewaunee	3 Mile Island
Fitzpatrick	Russellvile
Fermi	Easton
Turkey Point	LaSalle
Bell	

(7) Dynamic stability assessment of 3 TVA dams subjected to design earthquakes.

(8) Consultant on dynamic stability of Jackson Lake Dam to Bureau of Reclamation.

(9) Consultant on re-evaluation of foundations for the Olympic Tower and Stadium structures, Montreal, Quebec.

(10) Cerron Grande Dam, El Salvador, Consultant to Harza Engineering, liquefaction potential of foundation.

(11) Dynamic and static stability of both soil and rock slopes for Alyeska Pipe Line Service Company, Alaskan Pipe Line.

(12) Dynamic analysis of cooling pond dike for Skadgit Nuclear Station, Consultant to Bechntel Engineering.

(13) Assesment of the static and dynamic stability of Chatuge and Nottely Dams, Consultant to TVA.

(14) Kapong Hydroelectric Project, Ghana, assessment of dikes, Consultant to TVA.

(15) Suarez River Project, Colombia, S.A., Evaluation of four dam sites for dams ranging in heights from 500-600 ft in height.

(16) Pond Hill Dam, 100-ft high dam, Consultant to Tippetts, Abbett, McCarthy & Stratton (TAMS).

(17) Susitna Project, Consultant to H.G. Acres on 800-ft high earth dam and 600-ft high arch dam for Alaskan Power Authority.

(18) Remedial measures for Tarbela Dam, Service Spillway, Pakiston, Consultant to TAMS; static and dynamic slope stabilty.

(19) Libby Reregulating Dam, member of Board of Consultants, Seattle District, Corps of Engineers.

(20) Consultant to TAMS on Department of Interior study to evalute the design procedures of the Bureau of Reclamation for the design of earth dams; static and earthquake.

(21) Evaluation of site for Patia II Dam for Hidrostudies Company of Bogota, Colombia; 600-ft high dam on Patia River; static and dynamic stability.

EXAMPLES OF ROCK ENGINEERING EXPERIENCE

(1) Consultant to the American River Constructors on the stability of 300-ft high rock slopes for the spillway cut at Hell Hole Dam, American River Project.

(2) Consulted on rock mechanics problems related to the foundations of the World Trade Center Building, New York City (110-story office building).

(3) Consultant to New York Port Authority on Controlled Blasting Techniques to reduce damage to adjacent structures for Journal Square Subway Terminal.

(4) Consultant to Western Contracting Company on stability of 150-ft high vertical spillway cut, Stockton Dam, Stockton, Mo.

(5) Consultant to British Columbia Hydro Authority, Canada, on assessing stability to Portage Mountain Underground Powerhouse.

(6) Consultant to Fenix and Scisson on the design of a rock cavity and steel casing at a depth of 6,000 ft in weak rock on Amchitka Island.

(7) Slope stability problems along the Transandean Pipeline, Colombia, S.A., for Williams Brothers Construction Co.

(8) Consultant to Joseph S. Ward, Foundation Engineers, on the design of a school to resist blasting vibrations, Manchester, New Jersey.

(9) Consultant to Architect's Collaborative, Cambridge, Mass., on controlled blasting technques and blasting vibrations on IBM building complex, Fishkill, N.Y.

(10) Stability of rock slopes for Trans-Alaskan Pipeline Terminal, Valdez, Alaska, Alyeska Pipeline Service Company.

(11) Consultant to DeLeuw Cather & Co. on blasting specifications for Washington, D.C. Subway.

(12) Stability of open pit mine slope, Climax Molybdenum Co, Climax, Co.

(13) Consultant to British Columbia Hydro on the efects of a new reservoir on the stability of Downie Slied (1 billion cubic meter slide).

(14) Consultant to Gibbs & Hill on a slope adjacent to the Ohio River near Pittsburgh for sludge pipeline construction, slope 500-ft high.

(15) Consultant on effect of blasting on stability of slopes of Caue Mine, Itibira, Brazil, slope 800-ft high.

(16) Consultant to HydroQuebec on underwater rock blasting upstream on Manic #5 buttress arch dam.

(17) Contract study for Corps of Engineers to re-evaluate Vaiont Slide failure.

(18) Consultant, R&M Consultants, Pillar Mountain Slide, Kodiak City, Alaska.

EXPERIENCE ON DESIGN OF PROTECTIVE STRUCTURES AND NUCLEAR EFFECTS

(1) Consultant to TRW Systems, Redondo Beach, Ca., on dynamic soil properties pertinent to the hardnesss of the Minuteman System.

(2) Member of a panel in Dept. of Defense to review design of all safeguard structures for vulnerability and hardness.

(3) Consultant to Omaha District Corps of Engineering on the construction of underground protective structures in rock.

(4) Consultant to Air Force Space and Missle Systems Organization of Hardness of Minuteman Structures as an associate of Dr. N.M Newmark.

(5) Consultant on problems in soil dynamics and rock mechanics to the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

(6) A member of the "Decoupling Advisory Group," formed by the Defense Atomic Support Agency. Responsibility is to comment on stability problems which might be encountered in building underground cavities 100-360 ft in diameter and to give shear strength properties of rock masses which are important in determining the decoupling characteristics of cavities overdriven by the detonation of a nuclear device.

(7) Received Army Commendation Medal in 1965 for representing the Chief of the Corps of Engineers as a consultant to the Norwegian Government and NATO on the engineering of large underground facilities.

EXAMPLES OF UNDERGROUND - CONSTRUCTION EXPERIENCE

(1) Consultant to British Columbia Hydro on aspects of Portage Mountain Underground Powerhouse.

(2) Consultant to Duke Power Co., design of Bad Creek Underground Powerhouse.

(3) Consultant to ENEE, Honduras, El Cajon Underground Powerhouse.

(4) Consultant to ENEE, Honduras, El Nispero Pressure Tunnel.

(5) Consultant to Dominican Republic, Pressure Tunnel, Tavera Project.

(6) Consultant to Howard-Needles, Tammen & Bergandoff, Mt. Baker Ridge Highway Tunnel, Seattle, Wa.

(7) Consultant to Dames and Moore, City of San Francisco Sewer Tunnel, Fisherman's Wharf.

(8) Consultant to City of Rockford, Il., sewer tunnel in sands below the water table.

(9) Consultant to Metcalf & Eddy, design of sewer tunnel lining, Sao Paulo, Brazil.

(10) Consultant to Port of New York Authority, N.Y.C.:
Stability of Lincoln Tunnels
Stability of PATH Tubes

LIST OF PUBLICATIONS

Hendron, A. J., Jr., "The Behavior of Sand in One-Dimensional Compression," Ph.D. thesis, University of Illinois, Department of Civil Engineering, July, 1963.

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ATTACHMENT 2

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
MIDLAND POWER PLANT	7220-101	1 of 1	DG-8

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Diesel Generator Building	S 5074 E260	90°	

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
9/2/78	9/3/78	Raymond International	CME-45	2 7/8"			35.0'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
-		13		628.0	10.4' / 616.6'	

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140 lb. / 30 inches		A. S. Marshall

SAMPLE TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH OF CORE RUN (in.)	SAMPLE RECOVERY / CORE RECOVERY (in.)	SAMPLE BLOWS 1.0' / PERCENT CORE RECOVERY	PENETRATION BLOWS 1ST 6"	2ND 6"	3RD 6"	ELEVATION	DEPTH	SAMPLE
							628.0	0	
SS	18	17	[2] [25%]	1	1	1			1
SS	18	11	[1] [15%]	1	1/12"	-			2
SS	18	4	1	1/12"	-	1/10	622.5	5.5	3
SS	12	1	1	1/12"	0.5				4
ST 3"	22	22							5
SS	18	13	[6] [43]	1	3	3	616.5 [12'] 615.5	11.5 12.5	6
SS	18	10	[5] [53]	2	3	2	613.5	14	7
SS	18	18	[23]	6	9	14	[15']	15	8
SS	18	1	25	10	11	14			9
							606.5	21.5	
SS	18	12	[57] [100]	12	24	33	[22']		10
SS	18	18	[50] [100]	12	19	31	[24']	25	11
SS	18	12	[26] [78]	8	12	14	[30']	30	12
SS	18	12	[34] [86]	8	13	21	[34'] 593.0	35	13

DESCRIPTION AND CLASSIFICATION

0-21.5' Man-made fill (concrete to 9")

3/4-5.5' Clean Sand, brown, very loose, nonplastic, moist (SP) (Fill)

5.5-11.5' Silty Clay, brown, gray, very soft, low plasticity, wet, trace gravel (CL) (Fill)

11.5-12.5' Clean Sand, brown, loose nonplastic, moist (SP-SM)

12.5-21.5' Silty Clay, gray, medium stiff, low plasticity, wet (CL) (Fill) to 14.5', then very stiff to 21.5'.

Sand at 14.5-16' with some gravel

21.5-35' Clean Sand, brown, gray, medium dense to dense, wet (SP)

Bottom of hole at 35 feet

NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.

1. Drilled with 6" auger to 11', then 2 7/8" tricone bit and revert.

2. No significant water loss observed.

3. Hole grouted full depth.

4. 1/4" gap between mudmat and fill.

5. 2" split spoon and 3" Shelby tube samplers used.

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Diesel Generator Building	DG-8

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
MIDLAND POWER PLANT	7220-101	1 of 2	DG-12

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Diesel Generator Building	S 5108 E320	90°	

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
9/14/78	9/14/78	Raymond International	CME-45	4 3/4"			40.0'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
		17		628.0	Not Recorded	

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY
140 lb. / 30 inches		A. S. Marshall

Sample type and diameter	Sample advance length (in.)	Sample recovery (in.)	Sample blows per ft.	Penetration blows 0-6"	Penetration blows 6-12"	Penetration blows 12-18"	Elevation	Depth	Sample	Description and classification
							628.0	0		0-6" Concrete 0-25.5' Man-made fill
SS	18	10	2	1	1	1			1	Sandy Clay, gray, soft, low plasticity, moist (CL) (Fill)
O 3"	30	18							2	
SS	18	6	4	1	2	2		5	3	Sandy Clay, gray, soft, low plasticity, moist (CL) (Fill)
O 3"	30	16							4	7.2-9' Brown, clean Sand (SP-SM)
SS	18	5	3	1	1	2		10	5	Sandy Clay, gray, brown, soft, low plasticity, moist, trace gravel (CL) (Fill)
O 3"	24	18							6	
SS	18	18	15	3	8	7			7	
ST 3"	24	11						15	8	
SS	18	2	31	8	13	18			9	very stiff
SS	18	18	40	13	18	22			10	hard
SS	18	5	23	11	11	12		20	11	very stiff
SS	18	16	106	3	21	85			12	21-23' Slightly silty Sand, brown, very dense, nonplastic, wet, some silt and gravel (SP-SM) (Fill)
SS	18	16	39	25	19	20		25	13	23-25.5' Sandy Clay, mottled brown and gray, hard, low plasticity, wet, some wood (CL) (Fill)
SS	18	18	42	9	13	29	602.5	25.5	14	25.5-27.75' Silty Sand, brown, dense, low plasticity, moist, roots to 25.75; then silty Clay, gray, hard, low plasticity, moist (CL-ML)
							600.25	27.5		
SS	18	18	69	15	27	42		30	15	27.75-32' Clean, gravelly Sand, brown, very dense, nonplastic, wet (SP)
							596.0	32		32-34.5' Silty Clay, gray, hard, low plasticity, moist (CL)
SS	18	17	100+	13	30	100/5	593.5	34.5	16	34.5-38' Clean Sand, gray, very dense, nonplastic, wet (SP)
							593.0	35		

NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.

1. Drilled with 4" auger to 11', then 4 3/4" tri cone bit and revert.
2. No significant water loss observed.
3. Hole grouted full depth.

O-Osterberg Sampler

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENISON; P = PITCHER; O = OTHER

SITE	HOLE NO.
Diesel Generator Building	DG-12

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BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
MIDLAND POWER PLANT	7220-101	2 of 2	DG-12

Sampler type and diameter	Sampler advance length core run	Sample recovery core recovery	Sample blows per ft.	Percent core recovery	Penetration blows 1st 6"	2nd 6"	3rd 6"	Elevation	Depth	Graphic log	Sample	Description and classification	Notes on: water levels, water return, character of drilling, etc.
	in.	in.							35			Clean Sand, gray, very dense, nonplastic, wet (SP)	
								590.0	38				
SS	18	18	139		33	57	82	588.0	40		17	38-40' Very silty Sand, gray, very dense, nonplastic, wet (SM)	
												Bottom of hole at 40.0 feet	

SS = SPLIT SPOON; ST = SHELBY TUBE
D = DENNISON; P = PITCHER; O = OTHER

SITE: Diesel Generator Building

HOLE NO. DG-12

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BORING LOG

Project	Job No.	Sheet No.	Hole No.
MIDLAND POWER PLANT	7220-101	1 of 1	DG-14

Site	Coordinates	Angle from Horiz.	Bearing
Diesel Generator Building	S 5065 E298	90°	

Begun	Completed	Driller	Drill Make and Model	Hole Size	Overburden (Ft.)	Rock (Ft.)	Total Depth
9/19/78	9/20/78	Raymond International	CME-45	5"			30.5'

Core Recovery (Ft./%)	Core Boxes	Samples	El. Top of Casing	Ground El.	Depth/El. Ground Water	Depth/El. Top of Rock
		15		628.0	Not Recorded	

Sample Hammer Weight/Fall	Casing Left in Hole: Dia./Length	Logged By:
140 lb. / 30 inches		A. S. Marshall

Sample Type and Diameter	Sampler Advance Length Core Run	Sample Recovery Core Recovery	Sample Blows	Percent Core Recovery	Penetration Blows 1st 6"	2nd 6"	3rd 6"	Elevation	Depth	Graphic Log	Sample	Description and Classification	Notes on: Water Levels, Water Return, Character of Drilling, etc.
	in.	in.						628.0	0			Concrete to 6" 0-21.5' Man-made fill	1. Drilled with 4" auger to 11', then 5" tricone bit and revert.
ST 4.5"	24	18									1	Sandy Clay, gray, brown, soft, low plasticity, moist, occasional gravel (CL) (Fill)	2. No significant water loss observed.
ST 4.5"	24	18									2	stiff at 4'	3. Hole grouted full depth.
									5				
ST 4.5"	24	18									3	soft	
ST 4.5"	24	19									4	stiff	
ST 4.5"	24	15							10		5	stiff	
SS	18	3	5		3	2	3		13		6	soft	
SS	18	14	18		5	8	10	615.0	13		7	13-14' Slightly silty Sand, brown, medium dense, nonplastic, wet (SP-SM) (Fill)	
ST 3"	18	15						614.0	14 15		8	14-21.5' Sandy Clay, brown, low plasticity, soft (CL) (Fill)	
ST 3"	18	0									9		
SS	18	10	21		4	9	12				10	stiff	
SS	18	9	27		7	10	17				11	stiff	
SS	18	10	22		8	10	12		20		12	stiff	
SS	12	0	78/6"		30	78	-	606.5	21.5		13	21.5-30.5' Clean Sand, brown, very dense, nonplastic, wet occasional gravel (SP)	
SS	18	18	100		21	40	60		25		14		
SS	18	18	74		18	29	45		30		15		
								597.5	30.5			Bottom of hole at 30.5 feet	
									35				

SS = Split Spoon, ST = Shelby Tube, D = Dennison, P = Pitcher, O = Other	Site	Hole No.
	Diesel Generator Building	DG-14

BORING LOG

PROJECT	MIDLAND POWER PLANT
JOB NO.	7220-101
SHEET NO.	1 of 1
HOLE NO.	DG-15
SITE	Diesel Generator Building
COORDINATES	S 5106 E206
ANGLE FROM HORIZ.	90°
BEARING	
BEGUN	8/21/78
COMPLETED	8/22/78
DRILLER	Raymond International
DRILL MAKE AND MODEL	Acker Ace
HOLE SIZE	3 7/8"
OVERBURDEN (FT.)	
ROCK (FT.)	
TOTAL DEPTH	31.5'
CORE RECOVERY (FT./%)	
CORE BOXES	
SAMPLES	16
EL. TOP OF CASING	
GROUND EL.	628.0
DEPTH/EL. GROUND WATER	Not Recorded
DEPTH/EL. TOP OF ROCK	
SAMPLE HAMMER WEIGHT/FALL	140 lb. / 30 inches
CASING LEFT IN HOLE: DIA./LENGTH	
LOGGED BY	A. S. Marshall

Sample type and diameter	Sampler advance / length core run (in.)	Sample recovery / core recovery (in.)	Sample blows 6" / percent core recovery	Penetration blows 1st 6"	2nd 6"	3rd 6"	Elevation	Depth	Sample
							628.0	0	
ST 3"	18	17					626.5	1.5	1
SS	18	12	13	8	7	6	625.5 625.0	2.5 3	2
							623.0	5	
ST 3"	18	14							3
SS	18	12	46	6	22	24			4
SS	18	6	17	10	9	8			5
SS	12	6	5/6"	11	5			10	6
SS	18	6	17	9	9	8			7
SS	18	12	28	14	12	16			8
SS	18	15	38	30	21	17			9
SS	18	12	30	17	16	14		15	10
SS	18	10	30	12	14	16			11
SS	18	13	50	17	22	28			12
SS	18	12	45	15	20	25		20	13
SS	18	14	66	8	22	44	607.0	21	14
SS	18	12	165	42	82	83		25	15
SS	18	13	66	30	25	41	596.5	30	16
								35	

Description and Classification

0-1.5' Concrete
0-21' Man-made fill
Sandy Clay, gray, brown, stiff to hard, low plasticity, moist, occasional gravel and wood (CL) (Fill)
Slightly silty sand at 1.5 to 2.5 and 3.0 to 5.0'

wood fragments (sample 9)

21-31.5' Clean Sand, brown, dense to very dense, nonplastic, wet (SP)

Bottom of hole at 31.5 feet

Notes on: water levels, water return, character of drilling, etc.

1. Hole drilled with 3 7/8" tri-cone bit and revert, and grouted full depth.
2. No significant water loss observed.

SS = SPLIT SPOON; ST = SHELBY TUBE; D = DENNISON; P = PITCHER; O = OTHER

SITE: Diesel Generator Building HOLE NO. DG-15

BORING LOG

Project	Job No.	Sheet No.	Hole No.
MIDLAND POWER PLANT	7220-101	1 of 1	DG-17

Site	Coordinates	Angle from Horiz.	Bearing
Diesel Generator Building	S 5112 E295	90°	

Begun	Completed	Driller	Drill Make and Model	Hole Size	Overburden (ft)	Rock (ft)	Total Depth
9/22/78	9/23/78	Raymond International	Acker Ace	4 3/4"			34.5'

Core Recovery (ft/%)	Core Boxes	Samples	El. Top of Casing	Ground El.	Depth/El. Ground Water	Depth/El. Top of Rock
		18	630.0	628.0	See Notes	

Sample Hammer Weight/Fall	Casing Left in Hole: Dia./Length	Logged By
140 lb. / 30 inches	2"/34.5'	L. S. Marshall

Sample Type and Diameter	Sampler Advance Length (in.)	Sample Recovery (in.)	Sample Blows	1st 6"	2nd 6"	3rd 6"	Elevation	Depth	Sample	Description and Classification	Notes on: Water Levels, Water Return, Character of Drilling, etc.
							628.0	0		0-9" Concrete 0-20.5' Man-made fill Sandy Clay, gray, stiff, low plasticity, wet (CL) (Fill)	1. Drilled with 4" tricone bit and revert and later grouted full depth. 2. No significant water loss observed.
ST 3"	16	16							1		
SS	18	12	20	18	11	9			2		
								5	3		
SS	18	18	30	17	17	13			4		
SS	18	14	99	21	52	47			5		
SS	18	12	71	19	31	40			6	trace gravel	
SS	18	10	14	9	7	7		10	7		
ST 3"	18	0							8	trace gravel	
ST 3"	18	9							9		
SS	18	6	21	6	9	12		15	10		Water Levels Date: 10/11/78 Elevation: 621.0
SS	18	8*	0	0	0	0			11	Slightly sandy Silt, gray, very soft, low plasticity, wet (ML) (Fill)	
O 3"	24	17							12	Sandy Clay, gray, stiff, low plasticity, wet (CL) (Fill)	
SS	18	15	38	8	18	20		20	13		
SS	18	15	33/11" (77)	12	10	23/5"	607.5	20.5 (21')	14	20.5-22' Silty Sand, gray, very dense, nonplastic, moist, some gravel (SM) (Fill)	
							606.0	22		22-30' Clean Sand, brown, dense, nonplastic, wet, occasional silt, trace gravel (SP)	
SS	18	14	35	15	14	21		25	15		
SS	18	16	77	11	37	40			16		* Split-spoon penetrated under weight of the rods.
SS	18	14	52	21	22	30			17		
							598.0	30		30-34.5' Silty Clay, gray, hard, low plasticity, moist (CL)	O=Osterberg Sampler
SS	18	18	50	14	18	32	593.5	34.5	18	Bottom of hole at 34.5 feet	

SS = Split Spoon; ST = Shelby Tube; D = Denison; P = Pitcher; O = Other

Site: Diesel Generator Building — Hole No. DG-17

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BORING LOG

Project	Job No.	Sheet No.	Hole No.
MIDLAND POWER PLANT	7220-101	1 of 1	DG-18

Site	Coordinates	Angle from Horiz.	Bearing
Diesel Generator Building	S 5065 E183	90°	

Began	Completed	Driller	Drill Make and Model	Hole Size	Overburden (ft.)	Rock (ft.)	Total Depth
9/24/78	9/25/78	Raymond International	Acker Ace	4"			34.5'

Core Recovery (ft./%)	Core Boxes	Samples	El. Top of Casing	Ground El.	Depth/El. Ground Water	Depth/El. Top of Rock
		19	631.3	628.0	See Notes	

Sample Hammer Weight/Fall	Casing Left in Hole: Dia./Length	Logged By:
140 lb. / 30 inches	2"/34.5'	A. S. Marshall

				Penetration Blows		
	in.	in.				
ST 3-	18	18	~~ASSUMED OR I 20%~~			
SS	18	18	[illegible]	20	28	24
SS	18	18	[illegible]	10	6	5
SS	18	6	[illegible]	3	2	2
SS	18	6	[illegible]	3	2	2
SS	18	6	12	3	3	9
SS	18	6	13	1	7	6
SS	18	12	50	15	21	29
SS	18	10	46	12	15	31
SS	18	12	[illegible]	21	30	33
SS	18	12	[illegible]	6	7	5
SS	18	13	[illegible]	9	7	6
SS	18	12	31	12	11	20
SS	18	12	[illegible]	10	19	13
SS	18	14	24	11	14	10
SS	18	14	24	11	14	10
SS	18	18	78	24	30	48
SS	18	16	76	23	35	41
SS	18	12	78	20	34	44

Elevation	Depth	Description and Classification
628.0	0	0-9" Concrete 0-27.5' Man-made fill 9"-10' Clean Sand, brown, loose to dense, nonplastic, dry (SP) (Fill)
	10	10-16' Very sandy Clay, gray, brown, stiff to hard, low plasticity, wet, little gravel (CL) (Fill)
612.0	16	16-20' Clean Sand, brown, medium dense to dense, nonplastic, wet (SP) (Fill)
608.0	20	20-27.5' Sandy Clay, gray, hard, low plasticity, moist, some clean sand (CL) (Fill)
605.5	22.5	22.5-24.0' Silty Sand, gray, dense, nonplastic, wet (SM) (Fill)
604.0	24	24.0-27.5' Sandy Clay, gray, stiff, low plasticity, moist (CL) (Fill)
600.5	27.5	27.5-34' Silty Clay, brown, gray at 33', stiff to hard, low plasticity, moist (CL)
593.5	34.5	Bottom of hole at 34.5 feet

Notes on: Water levels, water return, character of drilling, etc.

1. Drilled with 4" tricone bit and revert.

2. No significant water loss observed.

Water Levels	
Date	Elevation
10/11/78	621.3

SS = Split Spoon; ST = Shelby Tube; D = Denison; P = Pitcher; O = Other

Site: Diesel Generator Building — Hole No.: DG-18

2A-210-137

Revision 18
2/79

BORING LOG

Project	Job No.	Sheet No.	Hole No.
MIDLAND POWER PLANT	7220-101	1 of 1	DG-19

Site	Coordinates	Angle from Horiz.	Bearing
Diesel Generator Building	S 5062 E221	90°	

Begun	Completed	Driller	Drill Make and Model	Hole Size	Overburden (Ft.)	Rock (Ft.)	Total Depth
9/23/78	9/26/78	Raymond International	CME-45	5 1/2"			32.0'

Core Recovery (Ft./%)	Core Boxes	Samples	El. Top of Casing	Ground El.	Depth/El. Ground Water	Depth/El. Top of Rock
		15	629.0	628.0	See Notes	

Sample Hammer Weight/Fall	Casing Left in Hole: Dia./Length	Logged By:
140 lb. / 30 inches	2"/32.0'	A. S. Marshall

Sample Type and Diameter	Sampler Advance / Length Core Run	Sample Recovery / Core Recovery	Sample Blows "N" / Percent Core Recovery	Penetration Blows 1st 6"	2nd 6"	3rd 6"	Elevation	Depth	Sample	Description and Classification	Notes on: Water Levels, Water Return, Character of Drilling, etc.
	in.	in.					628.0			0-1' Concrete 0-24' Man-made fill	1. Drilled with 6" auger to ', then 5 1/2" tri-cone bit and revert.
ST 5"	18	12							1	Sandy Clay, gray, very stiff, low plasticity, moist, trace gravel (CL) (Fill)	
ST 5"	6	0							2		
SS	18	13	91 (20)	4	11	9		3 – 4.5		3.0-4.5' Clean Sand, brown, medium dense, non-plastic, wet (SP) (FILL)	2. No significant water loss observed.
SS	18	0	8	3	4	4		5	4	Sandy Clay, gray, very stiff, low plasticity, moist, trace gravel (CL) (FILL)	
SS	18	1	39 (3)	1/12"	-	3	622.0	6		6-10.5' Clean Sand, brown, loose to very loose, nonplastic, wet (SP) (Fill) some gravel	
SS	18	10	69 (14)	5	9	5					
SS	18	2	35 (4)	3	2	2		10		Some sandy Clay	
SS	18	1/2"	0	0	0	0	617.5	10.5	8	10.5-18' Very sandy Silt, brown, very loose, nonplastic, wet (ML) (Fill)	
ST 3"	30	29							9	Sandy Clay, gray, soft, low plasticity, wet (CL) (Fill)	
								15			
ST 3"	30	28							10		
SS	18	2	15 (3)	1	2	1	610.0	18		18-19.5' Clean Sand, brown, very loose, nonplastic, wet (SP) (Fill)	
SS	18	4	2	1	1	1	608.5	19.5 – 20	12	19.5-22.0' Sandy Clay, gray, very soft, low plasticity, wet (CL) (Fill)	
ST 3"	30	30	Assume Dr = 45%				606.0	22		22.0-24.0' Clean Sand, brown, loose, non-plastic, wet (SP) (FILL)	Water Levels Date: 10/11/78 – Elevation: 621.3
							604.0	24		24-32' Clean Sand, brown, dense, nonplastic, wet (SP)	
SS	18	18	59	12	27	32		25	14		
								30			
SS	12	12	100+	50	103				15		
							596.0	32		Bottom of hole at 32 feet	
								35			

SS = Split Spoon; ST = Shelby Tube; D = Denison; P = Pitcher; O = Other

Site	Hole No.
Diesel Generator Building	DG-19

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2/79

BORING LOG

Project	MIDLAND POWER PLANT
Job No.	7220-101
Sheet No.	1 of 1
Hole No.	DG-20
Site	Diesel Generator Building
Coordinates	S 5072 E206
Angle from Horiz.	90°
Begun	9/26/78
Completed	9/26/78
Driller	Raymond International
Drill Make and Model	Acker Ace
Hole Size	4"
Total Depth	31.5'
Samples	13
Ground El.	628.0
Depth/El. Ground Water	Not Recorded
Sample Hammer Weight/Fall	140 lb. / 30 inches
Logged By	A. S. Marshall

Sample Type	Drive (in.)	Recovery (in.)	N	Blows 1st 6"	Blows 2nd 6"	Blows 3rd 6"
SS	18	2	5	2	2	3
SS	18	12	12	2	5	7
ST 3"	18	18				
SS	18	12	4	1	2	2
ST 3"	21	21				
SS	18	18	22	8	10	12
ST 3"	18	0				
SS	18	6	13	5	6	7
SS	18	18				
SS	18	12	21	2	7	14
SS	18	15	62	21	29	33
SS	18	12	34	15	16	18
SS	18	14	282	39	132	150

Elevation	Depth	Description and Classification
628.0	0	0-4.75 Concrete
623.25	4.75	4.75-6.8' Clean Sand, gray, loose, nonplastic, moist (SP) (Fill)
621.2	6.8	6.8-8' Concrete
620.0	8	8-20.5' Man-made fill. Clean Sand, brown, loose to medium dense, nonplastic, wet, some clay (SP,CL) (Fill). Clay at 11-12'. Clay at 13.5-14.5'
607.5	20.5	20.5-27.5' Very sandy Clay, brown, stiff, low plasticity, moist (CL) (Fill) (crimped tube at 22')
606.0	22	Clean Sand, brown, medium dense, nonplastic, wet (SP) (Fill)
600.5	27.5	27.5-31.5' Clean Sand, brown, very dense, nonplastic, wet, trace organics (SP)
596.5	31.5	Bottom of hole at 31.5 feet

Notes:

1. Drilled with 4" tricone bit and revert and grouted full depth.
2. No significant water loss observed below 8'. 100% loss at 4.75' (probable void at 4.75-5.5').
3. 2" split spoon and 3" Shelby tube samplers used.

Site: Diesel Generator Building — Hole No. DG-20

2A-210-139

Revision 18 2/79

BORING LOG

Project	Job No.	Sheet No.	Hole No.
MIDLAND POWER PLANT	7220-101	1 of 1	DG-22

Site	Coordinates	Angle from Horiz.	Bearing
Diesel Generator Building	S 5092 E323	90°	

Begun	Completed	Driller	Drill Make and Model	Hole Size	Overburden (ft.)	Rock (ft.)	Total Depth
9/11/78	9/12/78	Raymond International	CME-45	4 3/4"			33.5'

Core Recovery (ft./%)	Core Boxes	Samples	El. Top of Casing	Ground El.	Depth/El. Ground Water	Depth/El. Top of Rock
		14		628.0	Not Recorded	

Sample Hammer Weight/Fall	Casing Left in Hole: Dia./Length	Logged By:
140 lb. / 30 inches		A. S. Marshall

Sample Type	Sampler Advance (in.)	Sample Recovery (in.)	Blows/ft.	Penetration Blows 1st 6"	2nd 6"	3rd 6"	Elevation	Depth	Sample No.	Description and Classification
							628.0	0		Concrete to 1 foot 0-12': Silty to sandy Clay, gray, soft to stiff, low plasticity, moist wet, occasional gravel (CL) (Fill)
ST 5"	18	19							1	
ST 5"	18	12							2	
ST 5"	24	18						5	3	
ST 5"	24	19							4	
ST 5"	24	19						10	5	
ST 5"	18	18							6	
ST 5"	17	12					615.5	12.5	7	12.5-19' Clean Sand, brown, loose to very loose, nonplastic, wet (SP) (Fill)
SS	18	16	(7) 5	1	3	4				
SS	18	18	(2) 10	1	1	1		15		
SS	18	3	(15) 15	3	6	9				
							609.0	19		19-25.5' Silty Clay, gray, stiff, low plasticity, moist, little sand (CL) (Fill)
SS	18	16	17	6	8	9		20		
ST 5"	18	11								
							602.5	25.5		25.5-33.5' Very clayey Silt, gray, hard, low plasticity, moist, occasional sand and gravel (CL-ML)
SS	18	12	71	16	34	37			13	
								30		
SS	18	16	46	7	16	30	594.5	33.5	14	
										Bottom of hole at 33.5 feet

Notes on: water levels, water return, character of drilling, etc.

1. Drilled with 6-inch auger to 9 feet, then 4 3/4 inch tricone bit and revert.
2. No significant water loss observed.
3. Hole grouted full depth.

SS = Split Spoon; ST = Shelby Tube; D = Denison; P = Pitcher; O = Other

Site	Hole No.
Diesel Generator Buidling	DG-22

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BORING LOG

Project	Job No.	Sheet No.	Hole No.
MIDLAND POWER PLANT	7220-101	1 of 1	DG-24

Site	Coordinates	Angle from horiz.	Bearing
Diesel Generator Building	S 5106 E281	90°	

Begun	Completed	Driller	Drill make and model	Hole size	Overburden (ft)	Rock (ft)	Total depth
10/4/78	10/5/78	Raymond International	CME-45	4 3/4"			16.0'

Core recovery (ft/%)	Core boxes	Samples	El. top of casing	Ground El.	Depth/El. ground water	Depth/El. top of rock
		10		628.0	Not Recorded	

Sample hammer weight/fall	Casing left in hole: dia./length	Logged by
140 lb. / 30 inches		A. S. Marshall

	in.	in.		Penetration Blows			Elevation	Depth	Graphic Log	Samples	Description and Classification
							628.0	0			0-1' Concrete 1-16' Man-made fill Sandy to silty Clay, soft to very stiff, low plasticity, moist (CL) (Fill) with trace gravel
ST 5"	18	13.5								1	
ST 5"	18	10								2	
SS	18	16	34	8	14	20				3	
SS	18	16	25	10	12	13				4	
SS	18	0	5	6	3	2				5	
ST 3"	18	2						10		6	
SS	18	6	18	6	6	12				7	
SS	13	10	18	6	7	11				8	
SS	18	16	22	7	10	12				9	
SS	18	0	26	9	12	14	612.0	16		10	14.5-16': (Sand)
											Bottom of hole at 16 feet
								20			

Notes on: water levels, water return, character of drilling, etc.

1. Drilled with 4-inch auger and 4-inch casing to 8 feet, then 4 3/4-inch tri-cone bit and revert.
2. No significant water loss observed.
3. Hole grouted full depth.

	Site	Hole No.
	Diesel Generator Building	DG-24

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
MIDLAND POWER PLANT	7220-101	1 of 1	DG-27

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Diesel Genrator Building	S 5078 E169	90°	

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
10/8/78	10/8/78	Raymond International	CMI-45	3-15/16"			28.5'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
		10	630.5	628.0	Not Recorded	

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY
140 lb. / 30 inches	2"/28.5'	A. S. Marshall

Sample Type and Diameter	Sample Advance Length (in.)	Sample Recovery (in.)	Sample Blows	Penetration Blows 1st 6"	2nd 6"	3rd 6"	Elevation	Depth	Sample	Description and Classification
							628.0	0		0-27' Man-made fill Clean Sand, gray, medium dense, nonplastic, moist (SP) (Fill)
SS	18	16	17	3	7	10		5	1	
							622.0	6		6 - 8' Very sandy Clay, gray, stiff, low plasticity, moist (CL) (Fill)
SS	18	16	21	7	9	12			2	
							620.0	8		8-11' Clean Sand, gray, dense, nonplastic, moist (SP) (Fill)
SS	18	10	125	13	50	75		10	3	
							617.0	11		11-19.5' Sandy Clay, gray, stiff, low plasticity, moist (CL) (Fill) some sand.
SS	18	16	31	23	22	9			4	
SS	18	6	20	15	10	10		15	5	Sandy Clay, gray, stiff, low plasticity, moist (CL) (Fill)
SS	18	16	19	3	4	15	610.0	18	6	Sandy Clay as above and clean Sand
							608.5	19.5		
SS	18	16	29	20	16	19		20	7	18-22' Clean Sand, brown, medium dense, nonplastic, wet (SP) (Fill)
							606.0	22		22-27' Silty Clay, brown, stiff, low plasticity, moist (CL) (Fill)
SS	18	16	10	2	4	6			8	
SS	18	10	41	6	28	13		25	9	Some sand
							601.0	27		
SS	18	16	41	12	19	22			10	27-28.5' Silty Sand, brown, dense, nonplastic, wet (SM)
							599.5	28.5		Bottom of hole at 28.5 feet
								30		

Notes on: water levels, water return, character of drilling, etc.

1. Drilled with 4-inch casing to 13 feet then with auger then 3 15/16-inch tricone bit and revert.
2. No significant water loss observed.

SS = Split Spoon; ST = Shelby Tube; D = Denison; P = Pitcher; O = Other

SITE	HOLE NO.
Diesel Genrator Building	DG-27

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2/79

BORING LOG

Project	MIDLAND POWER PLANT
Job No.	7220-101
Sheet No.	1 of 1
Hole No.	DG-28
Site	Diesel Generator Building
Coordinates	S 5050 E256
Angle from Horiz.	90°
Bearing	
Begun	10/10/78
Completed	10/10/78
Driller	Raymond International
Drill Make and Model	CME-55
Hole Size	3-15/16"
Overburden (ft.)	
Rock (ft.)	
Total Depth	33.5'
Core Recovery (ft./%)	
Core Boxes	
Samples	12
El. Top of Casing	633.0
Ground El.	629.0
Depth/El. Ground Water	Not Recorded
Depth/El. Top of Rock	
Sample Hammer Weight/Fall	140 lb. / 30 inches
Casing Left in Hole: Dia./Length	2"/33.5'
Logged By	A. S. Marshall

Sample Type and Diameter	Sampler Advance / Length Core Run (in.)	Sample Recovery / Core Recovery (in.)	Sample Blows per ft.	Percent Core Recovery	Penetration Blows 6"	12"	18"	Sample
SS	18	16	(10)		3	4	6	
SS	18	10	(30)		12	14	16	
SS	18	4	5		5	3	2	3
SS	18	12	13		2	6	7	4
SS	18	8	5		2	2	3	5
SS	18	18	(15)		3	6	9	
SS	18	16	(33)		14	16	17	
SS	18	14	(16)		4	6	10	
SS	18	16	15		6	7	8	9
SS	18	17	(9)		3	3	6	
SS	18	12	(37)		6	16	21	
SS	18	16	(89)		24	36	53	

Elevation	Depth	Description and Classification
629.0	0	0-2' Clean Sand, brown, loose, nonplastic, moist (SP) (Fill)
	2	2-4.5' Concrete
624.5	4.5	4.5-9' Clean Sand, brown, loose, medium dense, nonplastic, moist (SP) (Fill)
620.0	9	9-17' Sandy Clay, gray, soft, low plasticity, moist (CL) (Fill)
		Trace gravel, wet
612.0	17	17-26' Clean Sand, brown, medium dense, nonplastic, wet (SP) (Fill)
		Sandy Clay, gray, stiff, low plasticity, wet (CL) (Fill)
	26	26-33.5' Clean Sand, brown, loose to 29 feet, then dense, nonplastic, wet (SP) (Fill)
595.5	33.5	Bottom of hole at 33.5 feet

Notes on: Water Levels, Water Return, Character of Drilling, etc.

1. Drilled with 6-inch tricone bit to 4.5 feet; 4-inch casing installed then drilled with 3-15/16" tricone bit and revert.
2. No significant water loss observed.

SS = Split Spoon; ST = Shelby Tube; D = Denison; P = Pitcher; O = Other

Site: Diesel Generator Building

Hole No.: DG-28

2A-210-148

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BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
MIDLAND POWER PLANT	7220	1 of 2	CH-15

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
CROSS-HOLE VELOCITY	S 5067 E 185	90°	—

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
11-15-79	11-15-79	RAYMOND INT'L	ACKER HILLBILLY	5 5/8"	—	NONE	41.5

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
N.A.	N.A.	7			NOT DETERMINED	N.A.

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY
140 LB/30 IN.	40' OF 4" PVC	W. KINZER

SAMPLE TYPE AND DIAMETER	SAMPLER ADVANCE LENGTH/CORE RUN	SAMPLE RECOVERY/CORE RECOVERY	SAMPLE BLOWS/PERCENT CORE RECOVERY	PENETRATION BLOWS 1st 6"	2nd 6"	3rd 6"	ELEVATION	DEPTH	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
							≈633	0	0-5.5' SAND: TAN FINE- TO COARSE-GRAINED, MOIST, TRACE OF FINE GRAVEL. (SW)	DRILLING WITH 5 5/8" TRI-CONE ROLLER BIT USING THICK BENTONITE MIX AND RECIRCULATION
							(628)	5	5.5-6.8' CONCRETE	
									6.8-8.8' SAND: TAN FINE- TO COARSE-GRAINED, TRACE OF FINE GRAVEL. (SW)	
									8.8-9.0' CONCRETE	
2" SS	18"	10"	18 (26)	8	9	9	EQUIVALENT DEPTH W/SURCHARGE OF 3KSF → 28	10	10-15.0' SAND: BROWN, MED. DENSE, MED. TO COARSE-GRAINED, WET, TRACE TO LITTLE FINE GRAVEL (SW)	
2" SS	18"	12"	22 (31)	8	9	13		33 / 15	15.0-25.0' SAND: TAN, MED DENSE, FINE-GRAINED, WET, TRACE OF MED SAND TO FINE GRAVEL (SP)	
2" SS	18"	10"	98 (100)	20	41	57		38 / 20	20-25' VERY DENSE.	
2" SS	18"	10"	23 (39)	7	7	16		43 / 25	25.0-26.0' SAND: BROWN, MED. DENSE, FINE- TO COARSE-GRAINED, WET (S	
									26.0-30.0 SILTY CLAY: BROWN, HARD, LOW PLASTICITY, MOIST, LITTLE FINE SAND. (CL)	
2" SS	18"	12"	95 (100)	18	42	55		48 / 30	30.0-35.0' SAND: TAN VERY DENSE, FINE-GRAINED, MOIST (SP)	
								35		F-

28

SITE	HOLE NO.
CROSS-HOLE VELOCITY SURVEY	CH-15

BORING LOG

PROJECT: MIDLAND POWER PLANT | JOB NO.: 7?2? | SHEET NO.: 2 of 2 | HOLE NO.: CH-15

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE LENGTH CORE RUN	SAMPLE RECOVERY CORE RECOVERY	SAMPLE BLOWS "N"	PERCENT CORE RECOVERY	PENETRATION BLOWS 1ST 6"	2ND 6"	3RD 6"	ELEVATION	DEPTH	GRAPHIC LOG	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
2" SS	18"	18"	66		24	32	34		35		6	35.0-41.5' SILTY CLAY: MED. GRAY, HARD, MED. PLASTICITY, MOIST, THIN LIGHT GRAY SILT SEAMS COMMON. (CL)	LACUSTRINE DEPOSIT
2" SS	18"	18"	83		22	33	50		40		7		
									41.5			BOTTOM OF HOLE: 41.5' 4" PVC PIPE INSTALLED & GROUTED IN PLACE.	

SS = SPLIT SPOON; ST = SHELBY TUBE
D = DENISON; P = PITCHER; O = OTHER

SITE: CROSS-HOLE VELOCITY SURVEY

HOLE NO.: CH-15

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
MIDLAND POWER PLANT	7220	1 of 2	CH-14

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
CROSS-HOLE SURVEY	S 5067.5 E 191	90°	—

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
11-19-79	11-20-79	RAYMOND INT'L	ACKER HILLBILLY	5 5/8"	—	NONE	41.5'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
N.A.	N.A.	7		632.4	NOT DETERMINED	N.A.

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140 LB / 30 IN	40' of 4" PVC	W. FINZER

SAMPLE TYPE AND DIAMETER	SAMPLER ADVANCE LENGTH CORE RUN	SAMPLE RECOVERY CORE RECOVERY	SAMPLE BLOWS 1 FT PERCENT CORE RECOVERY	PENETRATION BLOWS 1st 6"	2nd 6"	3rd 6"	ELEVATION	DEPTH	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
							632.4'	0		0-11.5' SAND: TAN, LOOSE, FINE- TO COARSE-GRAINED, MOIST, TRACE OF FINE GRAVEL (SW)	DRILLING WITH 5 5/8" TRI-CONE ROLLER BIT USING MED. WT. BENTONITE AND MIX AND RECIRCULATING.
							628.0	5			
SS 2"	18"	0"	10 (59)	5	5	5		10	1		
							620.9	11.5		11.5-18.9' SILTY CLAY: GRAY-BROWN, VERY STIFF, MED. PLASTICITY, MOIST, LITTLE FINE SAND, TRACE OF MED SAND TO FINE GRAVEL. (CL)	
2" SS	18"	6"	22	2	11	11		15	2		
							613.5	18.9		18.9-20.7' CONCRETE	
							611.7	20 / 20.7		20.7-30.0' SANDY CLAY: BROWN, STIFF, LOW PLASTICITY, WET, SOME FINE GRAVEL, SCATTERED COBBLES. (CL)	
2" SS	18"	6"	15	6	7	8			3		
2" SS	18"	8"	31	10	14	17		25	4	25.0-30.0' HARD.	
							602.4	30		30.0-35.0 SAND: TAN, VERY DENSE, FINE-GRAINED, MOIST. (SP)	
2" SS	18"	18"	100+ (100)	23	59	72			5		
							597.4	35			

FILL 30

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
MIDLAND POWER PLANT	7220	2 of 2	CH-14

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE / LENGTH CORE RUN	SAMPLE RECOVERY / CORE RECOVERY	SAMPLE BLOWS "N"	PERCENT CORE RECOVERY	PENETRATION BLOWS 1ST 6"	PENETRATION BLOWS 2ND 6"	PENETRATION BLOWS 3RD 6"	ELEVATION	DEPTH	GRAPHIC LOG	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: A. WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
								552.4	35				
2" SS	11"	16"	100+		39	86	100/4"				6	35.0-39.5' SILTY SAND: GLAY-BROWN, VERY DENSE, FINE-GRAINED, MOIST. (SP)	LACUSTRINE DEPOSITS
								552.9	39.5				
									40			39.5-41.5' SILTY CLAY: MED. GRAY, VERY STIFF, LOW PLASTICITY, MOIST, NUNEROUS [NUMEROUS] THIN LIGHT GLAY [GRAY] SILT SEAMS (CL)	
2" SS	18"	6"	24		10	12	12	550.9	41.5		7		
												BOTTOM OF HOLE: 41.5' 40' OF 4" PVC PIPE GROUTED IN HOLE FOR CROSS HOLE SURVEY.	

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SS = SPLIT SPOON, ST = SHELBY TUBE, D = DENISON, P = PITCHER, O = OTHER	SITE: CROSS-HOLE VELOCITY SURVEY	HOLE NO. CH-14

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
MIDLAND POWER PLANT	7220	1 of 2	CH-15

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
CROSS-HOLE SURVEY	S 5067 E 200	90°	—

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
11-27-79	11-29-79	RAYMOND INT'L	ACKER HILLBILLY	5 5/8"	—	NONE	41.5'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
N.A.	N.A.	7		633.8'	NOT DETERMINED	N.A.

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140 LB / 30 IN.	30' OF 4" PVC	W. KINZER

SAMPLE TYPE AND DIAMETER	SAMPLER ADVANCE LENGTH CORE RUN	SAMPLE RECOVERY CORE RECOVERY	SAMPLE BLOWS % RQD	PERCENT CORE RECOVERY	PENETRATION BLOWS 1ST 6"	2ND 6"	3RD 6"	ELEVATION	DEPTH	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
								633.8	0		0-5.5' SAND: TAN, FINE - TO COARSE - GRAINED, MOIST, TRACE OF FINE GRAVEL (SW)	DRILLING USING 5 5/8" TRI-CONE ROLLER BIT & RECIRCULATING MED. WT. BENTONITE MUD MIX.
								628.3	5.5		5.5-9.0' CONCRETE	
								624.8	9.0		9.0-21.5' SILTY CLAY & SAND: LAYERS OF GRAY-BROWN, MED. STIFF, LOW PLASTICITY, SILTY CLAY ALTERNATING WITH TAN, FINE-GRAINED, WET, MED. DENSE, SAND (CL & SP)	
2" SS	18"	9"	25 (70)		5	12	13		10	1		
2" SS	18"	10"	18 (63)		5	8	10		15	2		
2" SS	18"	14"	35 (85)		5	15	20		20	3	20-21.5' HARD.	
								612.3	21.5		21.5-30.0' SILTY CLAY: MED. GRAY & BROWN, VERY STIFF, LOW PLASTICITY, WET. (CL)	
2" SS	18"	12"	18		6	8	10		25	4		
2" SS	18"	12"	18 (58)		8	10	18	603.8	30	5	30.0-35.0' SAND: GRAY-BROWN, MED. DENSE, FINE-GRAINED, WET, TRACE OF SILT. (SP)	
								598.8	35			FILL

SS = SPLIT SPOON ST = SHELBY TUBE D = DENISON P = PITCHER O = OTHER	SITE	HOLE NO.
	CROSS-HOLE VELOCITY SURVEY	CH-15

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
MIDLAND POWER PLANT	7220	2-2	CH-15

SAMPLER TYPE AND DIAMETER	SAMPLER ADVANCE LENGTH CORE RUN	SAMPLE RECOVERY CORE RECOVERY	SAMPLE BLOWS "N" PERCENT CORE RECOVERY	PENETRATION BLOWS 1ST 6"	2ND 6"	3RD 6"	ELEVATION	DEPTH	GRAPHIC LOG	SAMPLE	DESCRIPTION AND CLASSIFICATION	NOTES ON: WATER LEVELS, WATER RETURN, CHARACTER OF DRILLING, ETC.
							598.8	35				
SS	10½	10"	100+	39	60/4½	—					35.0-40.0' SAND: TAN, VERY DENSE FINE-GRAINED, WET, TRACE OF SILT. (SP)	LACUSTRINE DEPOSITS
								40				
2" SS	18"	18"	100+	32	50	88	592.3	41.5			40.0-41.5' SILT: MED. GRAY, VERY DENSE LOW PLASTICITY TO NON-PLASTIC MOIST SOME TO LITTLE CLAY SILTY CLAY SEAMS COMMON (CL)	
											BOTTOM OF HOLE: 41.5' 40' OF 4" PVC PIPE INSTALLED.	

33

SS = SPLIT SPOON, ST = SHELBY TUBE, D = DENISON, P = PITCHER, O = OTHER

SITE: CROSS-HOLE VELOCITY SURVEY

HOLE NO. CH-15

ATTACHMENT 3

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIROMENTAL SCIENTISTS

Fig. A-9

SYNTHESIZED LOG OF BORING. COE: 8..

SHEET 1 ..OF..3...

project: MIDLAND NUCLEAR PLANT		project no. 81C 217	
location: MIDLAND, MICHIGAN		elevation & datum: + 634.2 (USGS)	COORDINATES: S 5044, E 191
drilling agency: D&G DRILLING		date started: 20 APRIL 81	date finished: 21 APRIL 81
drilling equipment: CME 55		completion depth: 40.4 FT	rock depth: NOT ENCOUNTERED
size & type of bit: 4" AUGER, 4 7/8" TRICONE ROLLER		no. samples: dist. 2	undist. 18, core 0
casing: 5" ID STEEL		water level: first N/A	compl. N/A, 24 hr. N/A
casing hammer: N/A	weight – drop –	driller: LARRY KOBITEK	prepared by: LUKE L. HEFFERNAN
sampler: OSTERBERG, HVORSLEV, PITCHER, SPLIT SPOON			
sampler hammer: No. 2	weight 140 lb drop 30 in.	supervisor: KEVIN O'DEA	reviewed by: 12 June 81 James Stanbora

ELEV. 634.2	DESCRIPTION	DEPTH SCALE ft	SAMPLES no. loc	type	recov.	penetr. resist	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING BLOWS
	BROWN, NONPLASTIC, SAND w/ SOME FINES, TRACE FINE GRAVEL (FINE - COARSE SAND) SM	0–4.5					SET UP RIG 0.4 FT EAST OF SURVEY NAIL. DONALD SIBBALD CPCO APPROVED BORING LOCATION. ADVANCED BORING w/ 4"ϕ CFA TO 4.5 FT. SET 5" ID CASING TO 3.5 FT. ADVANCE BORING WITH 4 7/8"ϕ TRICONE ROLLER BIT & REVERT DRILLING FLUID	N/A
629.2	V. STIFF, BROWN, LOW PLASTIC, SANDY CLAY - CLAYEY SAND, (FINE - COARSE SUBROUNDED POORLY GRADED SAND), MOIST (CL)	5	S-1	OS	0.6/0.7 FT	SEE REMARKS	S-1 REFUSAL AFTER 0.7 FT PUSH 86% RECOVERY	
	BROWN, LOW PLASTIC to NONPLASTIC CLAYEY SAND, WET (POSSIBLE SLOUGH)	6	S-2	SEE REMARKS			S-2 OSTERBERG PUSHED 0.7 FT. RECOVERY 0.1/0.7 FT (14% REC) NO PP ON GRANULAR MATL. SWITCHED TO HVORSLEV SAMPLER	
	BROWN w/ MIXED COLORS, NONPLASTIC SAND w/ TRACE OF FINES, FINE GRAVEL WET. (FINE - COARSE SUBROUNDED GRADED SAND) (SP)	7	S-3	HS	1.8/1.9 FT.	NO PP ON SAND	S-3 REFUSAL AFTER 1.9 FT PUSH 95% RECOVERY	
	MORE GRAVELLY	8.5	S-4	SEE REMARKS			S-4 HVORSLEV SAMPLER REFUSED AFTER 0.6 FT PUSH. BOTTOM OF TUBE IS BENT. RECOVERY 0.6/0.6 FT (100% REC) NO PP ON SAND.	
624.2	LESS GRAVEL BECOMING less GRADED.	9–10	S-5	HS	1.6/1.7 FT.	NO PP ON SAND	S-5 94% RECOVERY	
		11	S-6	HS	1.6/1.6 FT	NO PP ON SAND	S-6 100% RECOVERY	
	BECOMING WELL GRADED w/ NO FINES	12.5–13	S-7	HS	1.1/1.1 FT	NO PP ON SAND	S-7 100% RECOVERY	
620.2		14	S-8	HS	SEE REMARKS		END OF SHIFT 20 APRIL 81. S-8 RECOVERY 1.0/1.1 FT (91% REC) NO PP ON SAND.	

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Fig. A-9

HESIZED
OF BORING .COE-B...

SHEET. 2 .OF. 3 ...

DESCRIPTION	DEPTH SCALE ft	SAMPLES no. loc	type	recov.	penetr. resist bl/6in	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING BLOWS
BROWN NONPLASTIC, SAND, W/TRACE FINE GRAVEL, WET. (FINE-COARSE SUBROUNDED SAND) (SP)		S-9a			see p. 1 of 3	S-9 REFUSAL AFTER 0.5 FT PUSH OF HVORSLEV SAMPLER. RECOVERY 0.5/0.5 FT (100%). NO PP ON SAND	N/A
		S-9	SEE REMARKS				
	15–16	S-10	PS	1.8/2.5 FT	NO PP ON SAND	SWITCHED TO PITCHER SAMPLER DUE TO SHORT ADVANCE OF HVORSLEV SAMPLER S-10 72% RECOVERY	
	17–19	S-11	PS	2.5/2.5 FT	NO PP ON SAND	S-11 SAMPLER WAS DIFFICULT TO EXTRACT FROM BORING. 100% RECOVERY	
	20–22	S-12	PS	1.5/2.5 FT	NO PP ON SAND	S-12 0.5 FT OF SAMPLE SLIDES FROM TUBE UPON TUBE EXTRACTION. 60% RECOVERY.	
	23–24	S-13	PS	0.7/2.5 FT	NO PP ON SAND	S-13 28% RECOVERY NOTED LOSS OF DRILLING FLUID AT THIS DEPTH. EXCESSIVE AMOUNTS OF CUTTINGS WERE REMOVED FROM MUD TUB. CAVING NOTED IN BORING. (I.E. DRILL RODS WILL NOT SET AT BOTTOM OF BORING WHEN LIFTED. SAND SETTLING) REMOVED REVERT DRILLING FLUID AND REPLACED WITH BENTONITE DRILLING FLUID.	
BROWN, NONPLASTIC, SAND, W/ TRACE FINE GRAVEL, WET. (FINE-COARSE SUBROUNDED POORLY GRADED SAND) (SP)	25–27	S-14	PS	2.0/2.5 FT	NO PP ON SAND	DRILL W/ 4 7/8" ∅ TRICONE ROLLER BIT TO REMOVE SLOUGHED SAND S-14 80% RECOVERY	
	28–29	S-15	PS	1.0/2.5 FT	NO PP ON SAND	S-15 40% RECOVERY	
	30–31	S-16	PS	1.7/2.5 FT	NO PP ON SAND	S-16 68% RECOVERY NOTE: LOST ~ 25 GALLONS OF DRILLING FLUID IN THE BORE HOLE [illegible] DRILLING FLUID TO	

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Fig. A-9

SYNTHESIZED
LOG OF BORING .GOC-8...

ELEV.	DESCRIPTION	DEPTH SCALE ft	SAMPLES no. loc	SAMPLES type	SAMPLES recov.	SAMPLES penetr resist bl/6in	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING BLOWS
602.2	Brown, Non plastic, SAND, with trace F. Gravel (SP)							N/A
	LT. BROWN, NON PLASTIC, SAND, (FINE-MED, SUBROUNDED, POORLY GRADED), W/OCCASIONAL FINE GRAVEL, TRACE ORGANICS, WET. (SP)	33, 34	S-17	P3	1.6/2.0 FT	NO PP ON SAND	S-17 BOTTOM OF TUBE BENT. A PIECE OF STEEL WEDGE WAS FOUND IN TOP OF SAMPLE. 80% RECOVERY NOTE: DRILLING MUD VERY THICK, LADENED W/ SAND.	
	BECOMING MORE GRADED W/ MORE FINE GRAVEL. (SP)	35, 36	S-18	P3	1.5/2.5 FT	NO PP ON SAND	S-18 DRILLING INDICATES OCCASIONAL COBBLE OR GRAVEL. BOTTOM OF TUBE BENT. 60% RECOVERY	
597.2		37					SWITCH TO SPLIT SPOON SAMPLING	
	V. DENSE, LT GRAY-GRAY BROWN, NON PLASTIC, SILTY SAND, (V. FINE-FINE, POORLY GRADED SAND.) W/ LT BROWN LAYERING (Iron stains) (SM-ML)	38	S-19	SS	1.2/1.5 FT	26 66 78	S-19 80% RECOVERY N = 144	
	LIGNITE FRAGMENTS AT 38.5 FT	39, 40	S-20	SS	1.3/1.5 FT	43 72 135	S-20 87% RECOVERY 100 blows/0.3 ft at 40.2 ft	
593.8	LT GRAY NON PLASTIC SANDY SILT [illegible]							
	BOTTOM OF BORING 40.4 FT	41						
592.2		42					BORE HOLE BACKFILLED W/ BENTONITE CEMENT GROUT UP TO GROUND SURFACE	
		43, 44, 45, 46						
587.2		47						
		48, 49						
582.2		50						

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Fig. A-12

SIZED BORING COE-10 SHEET 3 OF 3

DESCRIPTION	DEPTH SCALE ft	SAMPLES no.loc	type	recov.	penetr resist bl/6in	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING BLOWS
HARD, BROWN AND GRAY, LOW-MED PLASTIC SILTY CLAY W/TRACE-SOME SAND, OCCASIONAL FINE GRAVEL, MOIST. (CL)	15	S-4 CONT.	PS	1.1/2.5 FT.	PP> 4.5TSF	S-4 DRILLING INDICATES SOFTER MATL. (INCREASED DRILLING RATE) FROM 15.2 - 15.7 FT. 44% RECOVERY.	
LESS SAND, BECOMES WET.	16						
BROWN, NONPLASTIC, SAND, FINE-MED, SUBROUNDED POORLY GRADED W/TRACE FINES, OCCASIONAL GRAVEL, WET. (SP) FILL	17	S-5	OS	2.5/2.5 FT SEE REMARKS	NO PP ON SAND	S-5 0.2 FT OF SAMPLE FALLS FROM TUBE UPON EXTRACTION. SAND MOVES TO BOTTOM OF TUBE BEFORE EXAMINATION OF SAMPLE. THE SAMPLE RETAINED ITS PLACE AT THE BOTTOM OF THE TUBE.	
NO RECOVERY	18–20	S-6A	OS	0.0/2.5	—	S-6A NO RECOVERY, UPON EXTRACTION, BROWN FLUID (SAND AND DRILL FLUID) RUNNING OUT OF BOTTOM OF TUBE, TUBE WAS NOT DAMAGED. S-6B SECOND ATTEMPT TO RETAIN SAMPLE FROM 18.5 TO 21.0 FT. (PUSH 0.3 FT BELOW PREVIOUS ATTEMPT) OSTERBERG SAMPLER USED. RECOVERY 0.7/2.5 FT (28%)	
BROWN, NONPLASTIC SAND, FINE-MED. SUBROUNDED; W/ TRACE FINES, WET. (SP)	21	S-6B	SEE REMARKS				
W/ OCCASIONAL GRAVEL.	22	S-7	OS	2.3/2.5 FT	NO PP ON SAND	S-7 TUBE BENT ON BOTTOM. OUT OF ROUND. 92% RECOVERY.	
W/TRACE ORGANICS	24–25	S-8	OS	SEE REMARKS	NO PP ON SAND	S-8 SAMPLE AT TOP OF TUBE AND BOTTOM OF TUBE. POSSIBLE SEPERATION OF SAMPLE IN TUBE. UNABLE TO ACCURATELY MEASURE RECOVERY BOTTOM OF TUBE IS BADLY CRIMPED.	N/A
SAND SIZE BECOMING VERY FINE, W/ OCCASIONAL FINE GRAVEL	26–27	S-9	OS	2.5/2.5 FT	NO PP ON SAND	S-9 100% RECOVERY	
MIXED COLORS, NON PLASTIC SAND; MED-COARSE, SUBANGULAR-SUB ROUNDED, WELL GRADED; W/ TRACE FINE GRAVEL, WET. (SW)	28–30	S-10	OS	2.1/2.5 FT.	NO PP ON SAND	S-10 BOTTOM OF TUBE BENT. 84% RECOVERY.	
SAND BECOMING FINER SIZED.	31	S-11	OS	2.2/2.5 FT.	NO PP ON SAND	S-11 88% RECOVERY	

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Fig. A-12

SYNTHESIZED LOG OF BORING COE-10

SHEET 1 OF 3

project: MIDLAND NUCLEAR PLANT	project no. 81C217
location: MIDLAND, MICHIGAN	elevation & datum: +633.9 FT (USGS); COORDINATES S 5050, E 330
drilling agency: D&G DRILLING	date started: 15 APRIL '81; date finished: 16 APRIL '81
drilling equipment: MOBILE A-56	completion depth: 42.5 FT; rock depth: NOT ENCOUNTERED
size & type of bit: 4" ø AUGER, 4 7/8 in TRICONE ROLLER	no. samples: dist. 3; undist. 13; core NONE
casing: 5 IN. ID STEEL	water level: first N/A; compl. N/A; 24 hr. N/A
casing hammer: N/A; weight N/A; drop N/A	driller: LARRY KOOITER
sampler: OSTERBERG, PITCHER, SPLIT SPOON	prepared by: LUKE L. HEFFERNAN
sampler hammer: 2; weight 140 lb; drop 30 in.	supervisor: KEVIN O'DEA; reviewed by: 15 Jun 81 James Stenborg

ELEV. 633.9	DESCRIPTION	DEPTH SCALE ft	SAMPLES no. loc	type	recov.	penetr. resist bl/6in	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING BLOWS
	BROWN, NONPLASTIC, SAND, FINE-COARSE SUBROUNDED W/ TRACE FINES, OCCASIONAL FINE GRAVEL, DRY-MOIST. (SP)	0–6	—	AUGER & TRICONE ROLLER BIT	SEE REMARKS	—	RIG SET UP 0.5 FT WEST AND 0.1 FT. SOUTH OF SURVEY NAIL. DONALD SIBBALD CPCo. APPROVED BORING LOCATION. ADVANCED BORE HOLE TO 4.5 FT W/ 4" ø CFA. SET 5 IN. ID. CASING TO 3.4 FT. CONTINUE ADVANCING BORE HOLE W/ 4 7/8 in. TRICONE ROLLER BIT AND REVERT DRILLING FLUID TO 60 FT.	N/A
628.9		5						
	BROWN, NONPLASTIC, SAND, FINE-COARSE SUBANGULAR-SUBROUNDED, WELL GRADED, MOIST. (SP)	6–8.8	S-1	OS	2.3/2.5 FT	NO PP ON SAND	S-1 0.2 FT OF SAMPLE FALLS FROM BOTTOM OF TUBE DURING EXAMINATION. 92% RECOVERY.	
	OCCASIONAL GRAVEL W/ BLACK OILY SLUDGE, FAINT ORGANIC ODOR	8.8–9.4	S-2	OS	0.8/0.9 FT	NO PP ON SAND	S-2 SAMPLER IS REFUSED AT 9.4 FT DEPTH. HIT HARD MATERIAL AT THIS DEPTH. CPCo. IDENTIFIES MATL AS MUD MAT AND REQUESTS DRILLER TO DRILL THROUGH IT. 89% RECOVERY	
623.9	CONCRETE	9.4–10.6	—	DRILLED W/ 4 7/8 in TRICONE		ROLLER BIT	DRILLED OUT WITH ROLLER BIT.	
	NO SAMPLE OBSERVED IN FIELD SEE REMARKS.	10.6–13.3	S-3	OS	SEE REMARKS	—	S-3 TUBE BADLY CRIMPED FROM ITS BOTTOM TO 1.4 FT UP. THE REST OF THE TUBE IS OUT OF ROUND. UNABLE TO CLEAN OUT SLOUGH ON TOP OF SAMPLE OR EXAMINE BOTTOM OF SAMPLE. UNABLE TO RECORD ACCURATE RECOVERY FIGURE.	
619.9	HARD, BROWN AND GRAY, LOW-MED PLASTIC SILTY CLAY W/ TRACE-SOME SAND, OCCASIONAL GRAVEL MOIST (CL)	13.3–14	S-4	↓	↓	↓		

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Fig. A-12

SYNTHESIZED LOG OF BORING LOG-10

ELEV.	DESCRIPTION	DEPTH SCALE ft	SAMPLES no. loc	type	recov.	penetr resist bl/6in	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING
601.9			S-11	CONT.			END OF SHIFT 15 APRIL 81 START OF SHIFT 16 APRIL 81	
	GREENISH-BROWN, NON PLASTIC SAND, (V FINE-FINE SUBROUNDED POORLY GRADED) W/ TRACE ORGANICS, FAINT ORGANIC ODOR, WET. (SP)	33–35	S-12	OS	2.1/2.5 FT.	NO PP ON SAND	S-12 BOTTOM OF TUBE BENT 84% RECOVERY	
	GRADES TO GRAY SILTY SAND (SM)	36	S-13	OS	2.4/2.5 FT	PP ON CLAY > 4.5 TSF	S-13 BOTTOM OF TUBE BENT 96% RECOVERY	N/A
596.9	HARD, GRAY, MEDIUM PLASTIC SILTY CLAY W/ TRACE ORGANICS, DRY LT GRAY SILT PARTINGS. (CL)	37						
		38	S-14	SS	1.2/1.5 FT	11 25 39	SWITCHED TO SPLITSPOON SAMPLING S-14 80% RECOVERY N=64	
	W/ THIN LAMINATIONS OF LT GRAY DRY SILT (ROCK FLOUR).	39						
		40	S-15	SS	1.4/1.5 FT	15 37 58	S-15 93% RECOVERY N=95	
591.9		41–42	S-16	SS	1.5/1.5 FT	14 26 45	S-16 100% RECOVERY N=71	
	BOTTOM OF BORING 42.5 FT	43					A MONITORING WELL WAS INSTALLED IN THIS BORE HOLE.	
		44–46						
586.9		47–49						
583.9		50						

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Fig. A-14

SHEET. 1..OF..3...

SYNTHESIZED LOG OF BORING. COE-11..

project MIDLAND NUCLEAR PLANT	project no. 81C217		
location MIDLAND, MICHIGAN	elevation & datum +633.5 FT (USGS)	COORDINATES S5790, E 171	
drilling agency D + G DRILLING	date started 13 APRIL 81	date finished 14 APRIL 81	
drilling equipment MOBILE B-56	completion depth 39.0 FT.	rock depth NOT ENCOUNTERED	
size & type of bit 4 in CFA ; 4 7/8 in TRICONE	no. samples dist. 2	undist. 15	core 0
casing 5 in ID STEEL	water level first N/A	compl. N/A	24 hr. N/A
casing hammer: N/A weight N/A drop N/A	driller LARRY KODITEK	prepared by KEVIN O'DEA	
sampler OSTERBERG (OS) PITCHER (PS) SPLITSPOON (SS)	supervisor KEVIN O'DEA	reviewed by 15 June James Stenborg 1981	
sampler hammer: No. 2 weight 140 lbs drop 30 in			

ELEV.	DESCRIPTION	DEPTH SCALE ft	SAMPLES no. loc	type	recov.	penetr. resist bl/6in	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING BLOWS
633.5								
	BROWN, NONPLASTIC, SAND, MED. TO COARSE w/ SOME FINES AND TRACE OF FINE GRAVEL, DRY TO MOIST (SP-SM)	0–4.8		NO SAMPLES RETAINED		DESCRIPTION FROM CUTTINGS	SET UP RIG WITHIN 0.1 FT OF SURVEY NAIL. ANCHOR RIG w/ 2 CONCRETE BLOCKS. APPROVAL TO ADVANCE BORING GIVEN BY DON SIBBALD OF CPCo. BORING WAS ADVANCED TO 4.5 FT w/ 4 in. CFA. SET 5 in. ID STEEL CASING to 3.6 FT. MIX DRILLING FLUID. - 20 lbs BENTONITE to 50 GALS. WATER. DRILL w/ 4 7/8 in TRICONE TO 5.3 FT. OBSTRUCTION ENCOUNTERED AT 4.8 FT. CPCo AUTHORIZES WCC TO DRILL THROUGH (4.8-5.3 FT) OBSTRUCTION (CONCRETE MUD MAT).	N/A
628.5	CONCRETE	5						
	MIXED COLORS, NONPLASTIC SAND MED. TO COARSE w/ TRACE OF FINES, TRACE OF FINE GRAVEL, WET (SP)	5.3–7.8	S-1	OS	2.1/2.5	NO PP ON SAND	S-1 84% RECOVERY	
		7.8–10.3	S-2	OS	2.4/2.5	PP = 1.25 TSF	S-2 96% RECOVERY	
623.5	STIFF, BROWN, MED. PLASTIC, SILTY CLAY w/ TRACE TO SOME SAND AND OCCASIONAL FINE GRAVEL, MOIST (CL)	9–10						
	BROWN AND GRAY	10.3–11.9	S-3	OS	1.4/1.6	PP: 3.5 TSF	S-3 88% RECOVERY CHAIN AND BINDER BREAK AFTER 1.6 FT. PUSH	
		11.9–12.9	S-4	OS	0.9/1.0	UNABLE TO TEST w/ PP	S-4 90% RECOVERY TUBE BADLY BENT.	
	BECOMES HARD	12.9–14	S-5	↓	↓	↓	S-5 76% RECOVERY	

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Fig. A

SYNTHESIZED
LOG OF BORING COE-11.

SHEET. 2 .OF.

ELEV.	DESCRIPTION	DEPTH SCALE ft	SAMPLES no.loc	SAMPLES type	SAMPLES recov.	SAMPLES penetr resist bl/6in	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)
618.5	V. STIFF TO HARD, BROWN AND GRAY, MED. PLASTIC, SILTY CLAY w/ TRACE OF SAND, MOIST (CL)	15	S-5 cont	OS	1.9/2.5	PP> 4.5 TSF	S-5 76% RECOVERY
		16–17	S-6	PS	1.0/2.5	PP = 3.25 - >4.5 TSF	S-6 40% RECOVERY
		18	S-7	OS	0.2/0.5	N/R	S-7 0.2 ft Rec., placed in Jar. STOP TEST AFTER 0.5 FT PUSH BECAUSE OF EXCESSIVE LEAKAGE THROUGH DRILL ROD JOINTS
613.5		19–20	S-8	OS	SEE REMARKS		S-8 NO RECOVERY, FIRST ATTEMPT PUSH OS AGAIN FROM 18.4 to 20.9. RECOVER 1.8 FT. SAMPLE POSSIBLY DISTURBED.
		21	S-9	OS	[illegible]		S-9 NO RECOVERY. CHAIN AND BINDER BREAK AFTER 0.2 FT PUSH, STOP TEST. TUBE BENT. SMALL AMOUNT OF DISTURBED SAMPLE RECOVERED. DRILL to 21.2 FT w/ 4 7/8 in TRICONE TO REMOVE COBBLE FROM 21.0-21.2 FT.
	LT. BROWN, NONPLASTIC, SAND FINE TO MED., SUBROUNDED, POORLY GRADED w/ TRACE OF FINES and COARSE SAND, wet (SP-SM)	22–23	S-10	OS	1.1/2.2	NO PP ON SAND	S-10 50% RECOVERY. STOP SAMPLER ADVANCE AT 23.2 FT. BECAUSE CIRCULATION IS BLOCKED. REAM BORING TO 23.4 FT w/ TRICONE. ENCOUNTER COBBLE. DRILL THROUGH to 23.8 FT to REMOVE.
608.5		24–26	S-11	OS	2.2/2.5	NO PP ON SAND	S-11 88% RECOVERY
	BROWN, LOW PLASTIC, SANDY CLAY w/ TRACE OF GRAVEL, WET (CL)	27–28	S-12	OS	1.9/2.5	—	S-12 76% RECOVERY * * TUBE BENT AND CRIMPED. SAMPLE POSSIBLY DISTURBED. NOT ABLE TO MEASURE RECOVERY ACCURATELY. NOT ABLE TO TEST w/ PP.
603.5	LT. BROWN, NONPLASTIC, SAND, V. FINE TO FINE, SUBROUNDED, POORLY GRADED, w/ SOME FINES AND TRACE OF ORGANICS, WET (SM)	29–30	S-13	OS	*/1.5	NO PP ON SAND	S-13 *NOT ABLE TO MEASURE RECOVERY ACCURATELY AS ~0.2 ft OF SAMPLE SLIDES FROM TUBE DURING EXAMINATION.
		31–32	S-14	OS	2.3/2.5	NO PP ON SAND	S-14 92% RECOVERY

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Fig. A-14

SYNTHESIZED

LOG OF BORING ..CQE-11. SHEET 3 OF 3

ELEV.	DESCRIPTION	DEPTH SCALE ft	SAMPLES no. loc	type	recov.	penetr resist bl/6in	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING BLOWS
	LT. BROWN, NONPLASTIC, SAND, V. FINE TO FINE, SUBROUNDED, POORLY GRADED W/ SOME FINES AND TRACE FINE GRAVEL		S-14	CONT				
		33	S-15	OS	2.1/2.4	NO PPON SAND	S-15 88 % RECOVERY BOTTOM OF TUBE BADLY BENT	
	V. DENSE, GRAY, NONPLASTIC, SAND, V. FINE TO FINE SUBROUNDED, POORLY GRADED W/ 30 TO 50% FINES AND TRACE OF LIGNITE FRAGMENTS, WET (SM)	34					ON N. RAMANUJAM'S DIRECTION, SPLIT SPOON SAMPLING BEGAN AT 35.3 FT.	
598.5		35	S-16	SS	0.9/1.0	24 102	S-16 90% RECOVERY N = 102/0.5 FT. (R)	N/A
	37.3 - 37.7 V. DENSE, GRAY, NONPLASTIC SANDY SILT, V. FINE SAND, MOIST (ML)	36 37	S-17	SS	0.7/0.7	75 100	S-17 100% RECOVERY N = 100/0.2 FT (R)	
595.5	BOTTOM OF BORING 38.0 FT.	38					RAMANUJAM OF CPCO INSTRUCTS K. O'DEA TO TERMINATE BORING AT 38.0 FT.	
		39 40					BORING IS BACKFILLED W/ CEMENT - BENTONITE GROUT.	

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Fig. A-21

SYNTHESIZED LOG OF BORING. COE-13A

SHEET..1..OF..3...

project: MIDLAND NUCLEAR PLANT		project no.: 81C217	
location: MIDLAND MICHIGAN		elevation & datum: +633.5 FT (USGS)	COORDINATES S 5134, E 317
drilling agency: D & G DRILLING		date started: 1 MAY 81	date finished: 1 MAY 81
drilling equipment: MOBILE B-61		completion depth: 47.5 FT.	rock depth: NOT ENCOUNTERED
size & type of bit: 6 IN DIA. CFA, 4¾ IN DIA. TRICONE ROLLER		no. samples dist. 0 undist. 12	core NONE
casing: 5 IN ID STEEL		water level first N/A compl. N/A	24 hr N/A
casing hammer: N/A	weight — drop —	driller: BARRY THOMASSON	prepared by: LUKE L. HEFFERNAN
sampler: OSTERBERG (OS), PITCHER (PS)		supervisor: GEORGE K. HESS	reviewed by: JAMES STENBORG 16 JUNE 1981
sampler hammer: N/A	weight — drop —		

ELEV. 632.5	DESCRIPTION	DEPTH SCALE ft	SAMPLES no. loc	type	recov.	penetr. resist bl/6in	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING BLOWS
	-, GRAY, FINE-MED, POORLY GRADED GRAVEL, w/ TRACE FINE-MED SAND, CLAY. (GP).	0–1					APPROVAL TO ADVANCE COE-13A WAS GIVEN BY DONALD SIBCALD (CPCo).	N/A
628.5	LT. BROWN, FINE-MED GRAINED, POORLY GRADED SAND, w/ TRACE COARSE SAND, SILT, MOIST. (SP)	1–7					CENTER OF BORING STARTED 2.2 FT SOUTH OF COE-13B. BORING WAS ADVANCED WITH 6 IN. DIA. CFA TO 8.0 FT.	
623.5	HARD, GRAY BROWN, LOW PLASTIC SILTY CLAY w/ SOME FINE-MED SAND, TRACE COARSE SAND, FINE GRAVEL, MOIST. (CL)	7–10					BORING CONTINUED w/ 4¾ IN. DIA. TRICONE ROLLER BIT, w/ REVERT DRILLING FLUID.	
	BECOMING V. STIFF w/ LESS SAND. (CL)	10–12.5	S-1	OS	1.3/2.5 FT.	PP= 2.3 TSF	S-1 52% RECOVERY	
619.5		12.5–14	S-2	OS	1.4/2.5 FT	PP= 4.25 to >4.5 TSF	S-2 SAMPLE TUBE PUSHED ALONGSIDE GRAVEL. BOTTOM 0.6 FT OF TUBE IS GROOVED. 56% RECOVERY	

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Fig. A-21

SYNTHESIZED LOG OF BORING . COE-13A

ELEV.	DESCRIPTION	DEPTH SCALE ft	SAMPLES no. loc	type	recov.	penetr. resist bl/6in	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING BLOWS
619.5	HARD, GRAY, LOW PLASTIC, SILTY CLAY W/ SOME FINE-MED SAND, TRACE FINE GRAVEL & COARSE SAND, MOIST. (CL)		S-2 Cont.	↑	↑	↑		
		15 – 17	S-3	OS	1.4/2.5 FT	PP: 2.5 TO >4.5 TSF	S-3 56% RECOVERY	
	V. STIFF - HARD W/ LESS SAND (CL)	17						
		17.5 – 19.5	S-4	OS	1.4/2.5 FT	PP 2.5 TO >4.5 TSF	S-4 56% RECOVERY	
614.5	GRAY - GRAY BROWN IN COLOR, W/ OCCASIONAL TAN - LT BROWN, HIGHLY PLASTIC CLAY ZONES. (CL)	19						
	BECOMES BROWN W/ OUT PLASTIC CLAY ZONES.	20 – 21.5	S-5	OS	1.3/1.5 FT	PP>4.5 TSF	S-5 87% RECOVERY	
		21.5 – 22.7	S-6	OS	1.1/1.2 FT	PP>4.5 TSF	S-6 92% RECOVERY	
		22.7 – 23.7	S-7	OS	0.9/1.0 FT	PP: 4.5 TSF	S-7 90% RECOVERY	
		23.7 – 26.2	S-8	PS	0.9/2.5 FT	PP > 4.5 TSF	SWITCH TO PITCHER SAMPLER S-8 36% RECOVERY	N/A
609.5	GRAY - BROWN COLOR	24 – 25						
		26.2 – 27.4	S-9	OS	1.2/1.2 FT	PP>4.5 TSF	S-9 100% RECOVERY	
	POSSIBLE COBBLE	27.4 – 27.8	SEE REMARKS				S-10 REFUSAL AFTER 0.4 FT PUSH WITH OSTERBERG SAMPLER. BOTTOM OF TUBE WAS MODERATELY BENT. NO RECOVERY. DRILLED OUT TO 27.8 FT WITH 4 3/4 IN TRICONE ROLLER BIT TO REMOVE POSSIBLE COBBLE	
		27.8 – 28.3	S-11	OS	SEE REMARKS		S-11 REFUSAL AFTER 0.5 FT PUSH. 100% RECOVERY.	
604.5	HARD, GRAY-BROWN, LOW PLASTIC SILTY CLAY W/ TRACE - SOME FINE-MED SAND, TRACE FINE GRAVEL, COARSE SAND, MOIST. (CL)	28.3 – 30.8	S-12	PS	1.4/2.5 FT	NO PP ON SAND	SWITCH TO PITCHER SAMPLER S-12 56% RECOVERY	
	LT BROWN, FINE-MED GRAINED POORLY GRADED SAND, W/ TRACE FINE SAND, MOIST. (SP)	30 – 31					BORING CONTINUED TO 47.5 FT FOR THE PURPOSE OF INSTALLING AN OBSERVATION WELL. NO SAMPLES WERE TAKEN BELOW 30.8 FT.	↓

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Fig. A-21

SYNTHESIZED LOG OF BORING COE-13A

SHEET 3 OF 3

ELEV. 601.5	DESCRIPTION	DEPTH SCALE ft	SAMPLES no.loc	type	recov.	penetr resist bl/6in	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING BLOWS
		33					BORING CONTINUED TO 47.5 FT W/ 4¾ in. TRICONE ROLLER BIT	
	LT BROWN SAND NOTED IN CUTTINGS.	34						
		35						
		36						
596.5		37						
		38						
		39						
		40						N/A
		41						
591.5		42						
		43						
		44						
		45						
		46					AN OBSERVATION WELL WAS INSTALLED IN THIS BORE HOLE PER THE DIRECTION OF CPCo.	
586.5		47						
	BOTTOM OF BORING 47.5 FT.	48						
		49						
		50						

ATTACHMENT 4

BORING DG-8

REL. DENSITY, Dr	LAYER THICKNESS, H, (IN)	MID-LAYER DEPTH, D, (FT)	$\sigma = \underline{3} + .13D$ (KSF)	AVG. SHEAR STRESS, τ, (KSF)(1)	$\sqrt{1000\,\sigma'_m}$ (2)	K_{21}	$G_1 = K_{21}\sqrt{1000\sigma'_m}$ (KSF)	$\gamma_{AVG_1} = \tau/G_1 \times 100$ (10^{-2}%)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (KSF)	$\gamma_{AVG_2} = \tau/G_2 \times 100$ (10^{-2}%)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (IN)
20	56	3.2	3.42	.42	52.3	28	1464	2.87	18	941	4.46	15	.83	.183	.102
43	12	12	4.56	.56	60.4	42	2537	2.21	23	1389	4.03	19	.83	.092	.011
83	18	15.3	4.99	.62	63.2	66	4108	1.51	37	2338	2.65	30	.81	.011	.002
91	162	28.3	6.68	.82	73.1	71	5190	1.58	38	2778	2.95	30	.79*	~~.006~~	~~.0097~~
"	"	"	"	"	"	46	3363	2.44	33	2413	3.40	29	.88	.009	.015

3 × .130 = .390

* SINCE THIS IS NOT > .80, I WILL RE-START THE ITERATION PROCESS AT A HIGHER SHEAR STRAIN VALUE - I.E. 1×10^{-2} INSTEAD OF 1×10^{-4} - TO ATTEMPT TO GET K_{23}/K_{22} AS CLOSE TO UNITY AS POSSIBLE. (THIS IS SHOWN ON THE FOLLOWING LINE)

(1) $\tau = \underline{.19}(.65)\sigma = \underline{.19}(.65)(\underline{3} + .13D) = \underline{.1235}\,\sigma$ (KSF)

(2) $\sqrt{1000\,\sigma'_m} = \sqrt{(1000/3)(\sigma + .7\sigma + .7\sigma)} = \sqrt{800\,(\underline{3} + .13D)} = 28.28\sqrt{\sigma}$ (KSF)

BORING DG-12

REL. DENSITY, D_r	LAYER THICKNESS, H, (IN)	MID-LAYER DEPTH, D, (FT)	$\sigma = 3 + .13D$ (KSF)	AVG. SHEAR STRESS, τ, (KSF)(1)	$\sqrt{1000\,\sigma'_m}$ (2)	K_{21}	$G_1 = K_{21}\sqrt{1000\,\sigma'_m}$ (KSF)	$\gamma_{AVG_1} = \tau/G_1 \times 100$ (10^{-2} %)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (KSF)	$\gamma_{AVG_2} = \tau/G_2 \times 100$ (10^{-2} %)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (in)	
45	21	8	4.04	.50	56.8	43	2442	2.05	25	1420	3.52	21	.84	.076	.016	
100	24	22	5.86	.72	68.5	75	5138	1.41	43	2946	2.44	34	.79*	—	—	
"	"	"	"	"	"	48	3288	2.19	37	2535	2.84	34	.92	—	—	

*SINCE THIS IS NOT >.80, I WILL RESTART THE ITERATION PROCESS AT A HIGHER SHEAR STRAIN VALUE - ie. 1×10^{-2} INSTEAD OF 1×10^{-4} — TO ATTEMPT TO GET K23/K22 AS CLOSE TO UNITY AS POSSIBLE. (THIS IS SHOWN IN THE FOLLOWING LINE).

3 × .016 = .048

(1) $\tau = .19(.65)\sigma = .19(.65)(3 + .13D) = .1235\,\sigma$ (KSF)

(2) $\sqrt{1000\,\sigma'_m} = \sqrt{(1000/3)(\sigma + .7\sigma + .7\sigma)} = \sqrt{800(3 + .13D)} = 28.28\sqrt{\sigma}$ (KSF)

BORING DG-15

REL. DENSITY, D_r	LAYER THICKNESS, H, (IN)	MID-LAYER DEPTH, D, (FT)	$\sigma = 3 + .13D$ (KSF)	AVG. SHEAR STRESS, τ, (KSF)(1)	$\sqrt{1000\,\sigma_m'}$ (2)	K_{21}	$G_1 = K_{21}\sqrt{1000\,\sigma_m'}$ (KSF)	$\gamma_{AVG_1} = \tau / G_1 \times 100$ (10^{-2} %)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (KSF)	$\gamma_{AVG_2} = \tau / G_2 \times 100$ (10^{-2} %)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (IN)
45	42	3	3.39	.42	52.1	43	2240	1.88	25	1302	3.23	21	.84	.066	.028

3 × .028 = .084

(1) $\tau = .19(.65)\sigma = .19(.65)(3 + .13D) = .1235\,\sigma$ (KSF)

(2) $\sqrt{1000\,\sigma_m'} = \sqrt{(1000/3)(\sigma + .7\sigma + .7\sigma)} = \sqrt{800(3 + .13D)} = 28.28\sqrt{\sigma}$ (KSF)

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BORING DG-17

REL. DENSITY, D_r	LAYER THICKNESS, H, (IN)	MID-LAYER DEPTH, D, (FT)	$\sigma = \underline{3} + .13D$ (KSF)	AVG. SHEAR STRESS, τ, (KSF)(1)	$\sqrt{1000\,\sigma'_m}$ (2)	K_{21}	$G_1 = K_{21}\sqrt{1000\,\sigma'_m}$ (KSF)	$\gamma_{AVG_1} = \tau/G_1 \times 100$ (10^{-2}%)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (KSF)	$\gamma_{AVG_2} = \tau/G_2 \times 100$ (10^{-2}%)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (IN)
93	18	21.3	5.77	.71	67.9	72	4889	1.45	40	2716	2.61	33	.83	.006	.001

3 × .001 = .003

(1) $\tau = \underline{.19}(.65)\sigma = \underline{.19}(.65)(\underline{3} + .13D) = \underline{.1235}\,\sigma$ (KSF)

(2) $\sqrt{1000\,\sigma'_m} = \sqrt{(1000/3)(\sigma + .7\sigma + .7\sigma)} = \sqrt{800(\underline{3} + .13D)} = 28.28\sqrt{\sigma}$ (KSF)

BORING DG-18

REL. DENSITY, Dr	LAYER THICKNESS, H, (IN)	MID-LAYER DEPTH, D, (FT)	$\sigma = \underline{3} + .13D$ (KSF)	AVG. SHEAR STRESS, τ, (KSF)(1)	$\sqrt{1000\,\sigma'_m}$ (2)	K_{21}	$G_1 = K_{21}\sqrt{1000\,\sigma'_m}$ (KSF)	$\gamma_{AVG_1} = \tau/G_1 \times 100$ (10^{-2}%)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (KSF)	$\gamma_{AVG_2} = \tau/G_2 \times 100$ (10^{-2}%)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (IN)	
55	110	5.4	3.7	.46	54.4	47	2557	1.80	28	1523	3.02	24	.86	.039	.043	
90	18	23.2	6.02	.74	69.4	70	4853	1.52	39	2707	2.73	32	.82	.007	.001	
72	48	18	5.34	.66	65.4	39*	2551	2.59	28	1831	3.60	24	.86	.028	.013	

* TAKEN AT A SHEAR STRAIN-PERCENT OF 1×10^{-2}

3 × .057 = .171

(1) $\tau = \underline{.19}(.65)\sigma = \underline{.19}(.65)(\underline{3} + .13D) = .1235\,\sigma$ (KSF)

(2) $\sqrt{1000\,\sigma'_m} = \sqrt{(1000/3)(\sigma + .7\sigma + .7\sigma)} = \sqrt{800(\underline{3} + .13D)} = 28.28\sqrt{\sigma}$ (KSF)

BORING DG-19

REL. DENSITY, D_r	LAYER THICKNESS, H, (IN)	MID-LAYER DEPTH, D, (FT)	$\sigma = 3 + .13D$ (KSF)	AVG. SHEAR STRESS, τ, (KSF)(1)	$\sqrt{1000\sigma'_m}$ (2)	K_{21}	$G_1 = K_{21}\sqrt{1000\sigma'_m}$ (KSF)	$\gamma_{AVG_1} = \tau/G_1 \times 100$ (10^{-2}%)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (KSF)	$\gamma_{AVG_2} = \tau/G_2 \times 100$ (10^{-2}%)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (IN)	
91	18	3.8	3.49	.43	52.8	70	3696	1.16	44	2323	1.85	37	.84	.004	.001	
15	18	18.8	5.44	.67	65.9	25	1648	4.07	15	989	6.77	13	.87	.35	.063	
45	24	23	5.99	.74	69.2	43	2976	2.5	23	1592	4.65	22	.95	.10	.024	
45	48	8	4.04	.50	56.84	43	2444	2.04	25	1421	3.52	21	.84*	.09	.043	

3 × .131 = .393

* $G_3 = 1193$; $\gamma_3 = 4.2 \times 10^{-3}$ % ; $K_{24} = 20$; $\frac{K_{24}}{K_{23}} = .96$

(1) $\tau = .19(.65)\sigma = .19(.65)(3 + .13D) = .1235\,\sigma$ (KSF)

(2) $\sqrt{1000\,\sigma'_m} = \sqrt{(1000/3)(\sigma + .7\sigma + .7\sigma)} = \sqrt{800(3 + .13D)} = 28.28\sqrt{\sigma}$ (KSF)

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BORING DG-20

REL. DENSITY, D_r	LAYER THICKNESS, H, (IN)	MID-LAYER DEPTH, D, (FT)	$\sigma = \underline{3} + .13D$ (KSF)	AVG. SHEAR STRESS, τ, (KSF)(1)	$\sqrt{1000\,\sigma_m'}$ (2)	K_{21}	$G_1 = K_{21}\sqrt{1000\,\sigma_m'}$ (KSF)	$\gamma_{AVG_1} = \tau/G_1 \times 100$ (10^{-2}%)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (KSF)	$\gamma_{AVG_2} = \tau/G_2 \times 100$ (10^{-2}%)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (IN)
30	18	12.5	4.63	.57	60.9	34	2071	2.75	20	1218	4.68	16	.80	.150	.027
70	72	17.5	5.28	.65	65.0	58	3770	1.72	32	2080	3.12	25	.78*	~~.023~~	~~.017~~
88	90	25.5	6.32	.78	71.1	68	4835	1.61	38	2702	2.89	30	.79*	~~.008~~	~~.007~~
44	25	6	3.78	.47	55.0	43	2365	1.99	25	1375	3.42	20	.80	.076	.019
64	36	9.5	4.24	.52	58.2	56	3259	1.60	32	1862	2.79	25	.78*	~~.024~~	~~.009~~
70	72	17.5	5.28	.65	65.0	38	2470	2.63	28	1820	3.57	25	.89	.029	.021
88	90	25.5	6.32	.78	71.1	44	3128	2.49	31	2204	3.54	27	.87	.013	.012
64	36	9.5	4.24	.52	58.2	37	2153	2.42	27	1571	3.31	24	.89	.031	.011

$3 \times .090 = .270$

*SINCE THIS IS NOT > .80, I WILL RESTART THE ITERATION PROCESS AT A HIGHER SHEAR STRAIN VALUE – I.E. 1×10^{-2} INSTEAD OF 1×10^{-3} – TO ATTEMPT TO GET K_{23}/K_{22} AS CLOSE TO UNITY AS POSSIBLE. (THIS IS SHOWN IN THE FOLLOWING LINES.)

(1) $\tau = \underline{.19}(.65)\sigma = \underline{.19}(.65)(\underline{3} + .13D) = \underline{.1235}\,\sigma$ (KSF)

(2) $\sqrt{1000\,\sigma_m'} = \sqrt{(1000/3)(\sigma + .7\sigma + .7\sigma)} = \sqrt{800(\underline{3} + .13D)} = 28.28\sqrt{\sigma}$ (KSF)

BORING DG-22

REL. DENSITY, D_r	LAYER THICKNESS, H, (IN)	MID-LAYER DEPTH, D, (FT)	$\sigma = \underline{3} + .13D$ (KSF)	AVG. SHEAR STRESS, τ, (KSF)(1)	$\sqrt{1000\sigma'_m}$ (2)	K_{21}	$G_1 = K_{21}\sqrt{1000\sigma'_m}$ (KSF)	$\gamma_{AVG_1} = \tau/G_1 \times 100$ (10^{-2}%)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (KSF)	$\gamma_{AVG_2} = \tau/G_2 \times 100$ (10^{-2}%)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (IN)
40	78	15.8	5.05	.62	63.6	40	2544	2.44	22	1399	4.43	17	.77*	~~.117~~	~~.091~~
"	"	"	"	"	"	28	1781	3.48	19	1209	5.13	17	.89	.139	.108

3 × .108 = .324

* SINCE THIS IS NOT ≥.80, I WILL RESTART THE ITERATION PROCESS AT A HIGHER SHEAR STRAIN VALUE - ie 1×10^{-2} INSTEAD OF 1×10^{-4} TO ATTEMPT TO GET K_{23}/K_{22} AS CLOSE TO UNITY AS POSSIBLE. (THIS IS SHOWN IN THE FOLLOWING LINE).

(1) $\tau = \underline{.19}(.65)\sigma = \underline{.19}(.65)(\underline{3} + .13D) = \underline{.1235}\,\sigma$ (KSF)

(2) $\sqrt{1000\,\sigma'_m} = \sqrt{(1000/3)(\sigma + .7\sigma + .7\sigma)} = \sqrt{800(\_ + .13D)} = 28.28\sqrt{\sigma}$ (KSF)

BORING DG-24

REL. DENSITY, D_r	LAYER THICKNESS, H, (IN)	MID-LAYER DEPTH, D, (FT)	$\sigma = \underline{3} + .13D$ (KSF)	AVG. SHEAR STRESS, τ, (KSF)(1)	$\sqrt{1000\sigma'_m}$ (2)	K_{21}	$G_1 = K_{21}\sqrt{1000\sigma'_m}$ (KSF)	$\gamma_{AVG_1} = \tau/G_1 \times 100$ (10^{-2}%)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (KSF)	$\gamma_{AVG_2} = \tau/G_2 \times 100$ (10^{-2}%)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (IN)	
86	18	15.3	4.99	.62	63.2	69	4361	1.42	39	2465	2.52	31	.79*			
"	"	"	"	"	"	44	2781	2.23	33	2086	2.97	29	.88	.009	.002	

3 × .002 = .006

* SINCE THIS IS NOT > .80, I WILL RESTART THE ITERATION PROCESS AT A HIGHER SHEAR STRAIN VALUE - ie. 1×10^{-2} INSTEAD OF 1×10^{-4} - TO ATTEMPT TO GET K_{23}/K_{22} AS CLOSE TO UNITY AS POSSIBLE. (THIS IS SHOWN IN THE FOLLOWING LINE).

(1) $\tau = \underline{.19}(.65)\sigma = \underline{.19}(.65)(\underline{3} + .13D) = \underline{.1235}\sigma$ (KSF)

(2) $\sqrt{1000\,\sigma_m'} = \sqrt{(1000/3)(\sigma + .7\sigma + .7\sigma)} = \sqrt{800(\underline{3} + .13D)} = 28.28\sqrt{\sigma}$ (KSF)

BORING DG-27

REL. DENSITY, D_r	LAYER THICKNESS, H, (IN)	MID-LAYER DEPTH, D, (FT)	$\sigma = \frac{3}{} + .13D$ (KSF)	AVG. SHEAR STRESS, τ, (KSF)[1]	$\sqrt{1000\sigma'_m}$ (2)	K_{21}	$G_1 = K_{21}\sqrt{1000\sigma'_m}$ (KSF)	$\gamma_{AVG_1} = \tau/G_1 \times 100$ (10^{-2}%)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (KSF)	$\gamma_{AVG_2} = \tau/G_2 \times 100$ (10^{-2}%)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (IN)	
85	72	45	3.59	.44	53.58	68	3643	1.21	41	2197	2.00	29	.71*	~~.007~~	~~.005~~	
100	36	9.5	4.24	.52	58.23	75	4367	1.19	46	2678	1.94	38	.83	.001		
87	48	20	5.60	.69	66.92	69	4617	1.49	39	2610	2.64	32	.82	.009	.004	
97	18	28	6.64	.82	72.87	74	5392	1.52	42	3060	2.68	32	.76*			
85	72	45	3.59	.44	53.58	44	2358	1.87	35	1876	2.35	32	.91	.009	.006	
97	18	28	6.64	.82	72.87	47	3425	2.39	35	2551	3.21	31	.89	.004	.001	

*SINCE THIS IS NOT >.80, I WILL RESTART THE ITERATION PROCESS AT A HIGHER SHEAR STRAIN VALUE - i.e. 1×10^{-2} INSTEAD OF 1×10^{-4} - TO ATTEMPT TO GET K_{23}/K_{22} AS CLOSE TO UNITY AS POSSIBLE. (THIS IS SHOWN IN THE FOLLOWING LINES)

3 × .011 = .033

(1) $\tau = .19(.65)\sigma = .19(.65)(\frac{3}{}+.13D) = .1235\sigma$ (KSF)

(2) $\sqrt{1000\sigma'_m} = \sqrt{(1000/3)(\sigma + .7\sigma + .7\sigma)} = \sqrt{800(\frac{3}{}+.13D)} = 28.28\sqrt{\sigma}$ (KSF)

BORING DG-28

REL. DENSITY, D_r	LAYER THICKNESS, H, (IN)	MID-LAYER DEPTH, D, (FT)	$\sigma = \underline{3} + .13D$ (KSF)	AVG. SHEAR STRESS, τ, (KSF)(1)	$\sqrt{1000\,\sigma'_m}$ (2)	K_{21}	$G_1 = K_{21}\sqrt{1000\,\sigma'_m}$ (KSF)	$\gamma_{AVG_1} = \tau/G_1 \times 100$ (10^{-2}%)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (KSF)	$\gamma_{AVG_2} = \tau/G_2 \times 100$ (10^{-2}%)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (IN)	
80	90	30	6.9	.85	74.29	64	4755	1.79	35	2600	3.27	28	.80	.016	.014	
82	54	7	3.91	.48	55.92	65	3635	1.32	38	2125	2.26	32	.84	.009	.005	
74	90	21	5.73	.71	67.70	60	4062	1.75	32	2166	3.28	25	.78*			
"	"	"	"	"	"	39	2640	2.69	28	1895	3.75	24	.86	.025	.023	

3 × .042 = .126

* SINCE THIS IS NOT ≥ .80, I WILL RESTART THE ITERATION PROCESS AT A HIGHER SHEAR STRAIN VALUE – i.e. 1×10^{-2} INSTEAD OF 1×10^{-4} – TO ATTEMPT TO GET K_{23}/K_{22} AS CLOSE TO UNITY AS POSSIBLE. (THIS IS SHOWN IN THE FOLLOWING LINE).

(1) $\tau = \underline{.19}(.65)\sigma = \underline{.19}(.65)(\underline{3} + .13D) = \underline{.1235}\,\sigma$ (KSF)

(2) $\sqrt{1000\,\sigma'_m} = \sqrt{(1000/3)(\sigma + .7\sigma + .7\sigma)} = \sqrt{800(\underline{3} + .13D)} = 28.28\sqrt{\sigma}$ (KSF)

BORING CH-13

REL. DENSITY, D_r	LAYER THICKNESS, H, (IN)	MID-LAYER DEPTH, D, (FT)	$\sigma = \underline{3} + .13D$ (KSF)	AVG. SHEAR STRESS, τ, (KSF)(1)	$\sqrt{1000\sigma_m'}$ (2)	K_{21}	$G_1 = K_{21}\sqrt{1000\sigma_m'}$ (KSF)	$\gamma_{AVG_1} = \tau/G_1 \times 100$ (10^{-2}%)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (KSF)	$\gamma_{AVG_2} = \tau/G_2 \times 100$ (10^{-2}%)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (IN)
66	60	9.3	4.21	.52	58.0	55	3190	1.63	32	1856	2.80	25	.78*	~~.022~~	~~.013~~
71	60	14.3	4.86	.60	62.3	58	3613	1.66	33	2056	2.92	28	.85	.020	.012
100	60	32.5	7.22	.89	76.0	75	5700	1.56	42	3192	2.79	34	.81	.002	.001
100	98	20.9	5.72	.71	67.6	75	5070	1.40	42	2839	2.50	35	.83	.001	.001
66	60	9.3	4.21	.52	58.0	37	2146	2.42	28	1624	3.20	25	.89	.026	.016

*SINCE THIS IS NOT >.80, I WILL RESTART THE ITERATION PROCESS AT A HIGHER SHEAR STRAIN VALUE - ie. 1×10^{-2} INSTEAD OF 1×10^{-4} - TO ATTEMPT TO GET K_{23}/K_{22} AS CLOSE TO UNITY AS POSSIBLE. (THIS IS SHOWN IN THE FOLLOWING LINE).

3 × .030 = .090

(1) $\tau = \underline{.19}(.65)\sigma = \underline{.19}(.65)(\underline{3} + .13D) = \underline{.1235}\,\sigma$ (KSF)

(2) $\sqrt{1000\,\sigma_m'} = \sqrt{(1000/3)(\sigma + .7\sigma + .7\sigma)} = \sqrt{800(\underline{3} + .13D)} = 28.28\sqrt{\sigma}$ (KSF)

BORING CH-14

REL. DENSITY, D_r	LAYER THICKNESS, H, (IN)	MID-LAYER DEPTH, D, (FT)	$\sigma = \underline{3} + .13D$ (KSF)	AVG. SHEAR STRESS, τ, (KSF)(1)	$\sqrt{1000\,\sigma'_m}$ (2)	K_{21}	$G_1 = K_{21}\sqrt{1000\sigma'_m}$ (KSF)	$\gamma_{AVG_1} = \tau/G_1 \times 100$ (10^{-2}%)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (KSF)	$\gamma_{AVG_2} = \tau/G_2 \times 100$ (10^{-2}%)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (IN)
47	84	8	4.04	.50	56.8	44	2499	2.00	25	1420	3.52	21	.84	.068	.057
100	60	32.5	7.22	.89	76.0	75	5700	1.56	42	3192	2.79	34	.81	—	—

3 × .057 = .171

(1) $\tau = \underline{.19}(.65)\sigma = \underline{.19}(.65)(\underline{3} + .13D) = \underline{.1235}\,\sigma$ (KSF)

(2) $\sqrt{1000\,\sigma'_m} = \sqrt{(1000/3)(\sigma + .7\sigma + .7\sigma)} = \sqrt{800(\underline{3} + .13D)} = 28.28\sqrt{\sigma}$ (KSF)

BORING CH-15

REL. DENSITY, D_r	LAYER THICKNESS, H, (IN)	MID-LAYER DEPTH, D, (FT)	$\sigma = \underline{3} + .13D$ (KSF)	AVG. SHEAR STRESS, τ, (KSF)(1)	$\sqrt{1000\,\sigma'_m}$ (2)	K_{21}	$G_1 = K_{21}\sqrt{1000\,\sigma'_m}$ (KSF)	$\gamma_{AVG_1} = \tau/G_1 \times 100$ (10^{-2}%)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (KSF)	$\gamma_{AVG_2} = \tau/G_2 \times 100$ (10^{-2}%)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (IN)
58	60	32.5	7.23	.89	76.0	51	3876	2.30	26	1976	4.50	20	.77*	~~.0549~~	~~.033~~
75	60	11.5	4.50	.56	60.0	61	3654	1.53	35	2097	2.67	29	.83	.016	.010
75	90	17.8	5.31	.66	65.2	61	3977	1.66	34	2217	2.98	28	.82	.019	.017
58	60	32.5	7.23	.89	76.0	34	2584	3.44	23	1748	5.09	19	.83	.065	.059

3 × .066 = .198

*SINCE THIS IS NOT >.80, I WILL RESTART THE ITERATION PROCESS AT A HIGHER SHEAR STRAIN VALUE – I.E. 1×10^{-2} INSTEAD OF 1×10^{-4} – TO ATTEMPT TO GET K_{23}/K_{22} AS CLOSE TO UNITY AS POSSIBLE. (THIS IS SHOWN IN THE FOLLOWING LINE).

(1) $\tau = \underline{.19}(.65)\sigma = \underline{.19}(.65)(\underline{3} + .13D) = \underline{.1235}\,\sigma$ (KSF)

(2) $\sqrt{1000\,\sigma'_m} = \sqrt{(1000/3)(\sigma + .7\sigma + .7\sigma)} = \sqrt{800(\underline{3} + .13D)} = 28.28\sqrt{\sigma}$ (KSF)

Boring COE-8

$a = 0.19g$

Rel. Dens., D_r	Layer Thickness, H, (in)	Mid-Layer Depth, D, (ft)	$\sigma = \frac{3}{} + 0.13D$ (ksf) (1)	Ave. Shear Stress, τ, (ksf)	$\sqrt{1000\,\sigma_m'}$ (2)	K_{21} (First Assmpt'n at $\gamma = 10^{-2}\%$)	$G_1 = K_{21}\sqrt{1000\,\sigma_m'}$ (ksf)	$\gamma_{AVE_1} = \tau/G_1 \times 100$ ($10^{-2}\%$)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (ksf)	$\gamma_{AVE_2} = \tau/G_2 \times 100$ ($10^{-2}\%$)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (in)
75	72	9.4	4.22	.52	58.1	40	2324	2.23	32	1859	2.80	28	0.88	.017	0.012
85	31	13.7	4.78	.59	61.8	44	2719	2.17	34	2101	2.81	30	0.88	.011	0.003
92	60	17.5	5.28	.65	65.0	47	3055	2.13	36	2340	2.78	32	0.89	.006	0.004
77	60	22.5	5.93	.74	68.9	41	2825	2.62	29	1998	3.70	25	0.86	.022	0.013
79	60	27.5	6.58	.82	72.5	40	2900	2.83	29	2103	3.90	25	0.86	.021	0.013
85	36	31.5	7.10	.88	75.4	44	3318	2.65	32	2413	3.65	27	0.84	.015	0.005
85	53	35.2	7.58	.94	77.9	44	3428	2.74	31	2415	3.89	27	0.87	.015	0.008

3 × 0.058 = 0.174

(1) $\tau = \underline{0.19}\,(.65)\,\sigma = 0.124\,\sigma$ (ksf)

(2) $\sqrt{1000\,\sigma_m'} = \sqrt{1000\left(\frac{\sigma + 0.7\sigma + 0.7\sigma}{3}\right)} = 28.28\sqrt{\sigma}$ (ksf)

BORING COE-10

$a = 0.19g$

Rel. Dens., D_r	Layer Thickness, H, (in)	Mid-Layer Depth, D, (ft)	$\sigma = \underline{3} + 0.13D$ (ksf) (1)	Ave. Shear Stress, τ, (ksf)	$\sqrt{1000\,\sigma_m'}$ (2)	K_{21} first assumption at $10^{-2}\% = \gamma$	$G_1 = K_{21}\sqrt{1000\,\sigma_m'}$ (ksf)	$\gamma_{AVE_1} = \tau/G_1 \times 100$ ($10^{-2}\%$)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (ksf)	$\gamma_{AVE_2} = \tau/G_2 \times 100$ ($10^{-2}\%$)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (in)
71	41	7.7	4.0	.50	56.6	39	2207	2.27	30	1698	2.94	27	0.90	.020	0.008
91	137	22.3	5.9	.73	68.7	45	3092	2.36	34	2336	3.13	30	0.88	.007	0.010
68	103	32.3	7.2	.89	75.9	38	2884	3.09	26	1973	4.51	22	0.85	.039	0.040

3 × 0.058 = 0.174

(1) $\tau = \underline{0.19}\,(.65)\,\sigma = \underline{0.124}\,\sigma$ (ksf)

(2) $\sqrt{1000\,\sigma_m'} = \sqrt{1000\left(\frac{\sigma + 0.7\sigma + 0.7\sigma}{3}\right)} = 28.28\sqrt{\sigma}$ (ksf)

BORING COE-11

$a = 0.19g$

Rel. Dens., D_r	Layer Thickness, H, (in)	Mid-Layer Depth, D, (ft)	$\sigma = \underline{3} + 0.13 D$ (ksf) (1)	Ave. Shear Stress, τ, (ksf)	$\sqrt{1000\,\sigma_m'}$ (2)	K_{21} Assume at $10^{-2}\% = \gamma$	$G_1 = K_{21}\sqrt{1000\,\sigma_m'}$ (ksf)	$\gamma_{AVE_1} = \tau/G_1 \times 100$ $(10^{-2}\%)$	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (ksf)	$\gamma_{AVE_2} = \tau/G_2 \times 100$ $(10^{-2}\%)$	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (in)
115	46	7.1													—
88	65	23.7	6.1	0.76	69.8	44	3071	2.47	33	2303	3.30	29	0.88	.011	0.007
83	60	31.5	7.10	0.88	75.4	43	3242	2.71	30	2262	3.89	26	0.87	.017	0.010

3 x | .017 | = | .051

(1) $\tau = \underline{0.19}\,(.65)\,\sigma = \underline{0.124}\,\sigma$ (ksf)

(2) $\sqrt{1000\,\sigma_m'} = \sqrt{1000\left(\frac{\sigma + 0.7\sigma + 0.7\sigma}{3}\right)} = 28.28\sqrt{\sigma}$ (ksf)

BORING COE-13R

$a = 0.19g$

Rel. Dens., D_r	Layer thickness, H, (in)	Mid-layer depth, D, (ft)	$\sigma = 3 + 0.13D$ (ksf)	Ave. shear stress, τ, (ksf) (1)	$\sqrt{1000\,\sigma_m'}$ (2)	K_{21} First assumpt'n at $10^{-2}\% = 8$	$G_1 = K_{21}\sqrt{1000\,\sigma_m'}$ (ksf)	$\gamma_{AVE_1} = \tau/G_1 \times 100$ ($10^{-2}\%$)	K_{22}	$G_2 = \frac{K_{22}}{K_{21}} G_1$ (ksf)	$\gamma_{AVE_2} = \tau/G_2 \times 100$ ($10^{-2}\%$)	K_{23}	K_{23}/K_{22}	ϵ (%)	$\delta = \frac{\epsilon H}{100}$ (in)
88	103	321	7.2	.89	75.9	44	3340	2.66	32	2429	3.66	28	0.88	.012	0.012

$3 \times$ | 0.012 | = | 0.036 |

(1) $\tau = \underline{0.19}\,(.65)\,\sigma = \underline{0.124}\,\sigma\,(KSF)$

(2) $\sqrt{1000\,\sigma_m'} = \sqrt{1000\left(\frac{\sigma + 0.7\sigma + 0.7\sigma}{3}\right)} = 28.28\sqrt{\sigma}\,(KSF)$