Harding Lawson Associates
Engineers, Geologists
& Geophysicists

Volume II

Point Thomson Development Project Winter 1982 Geotechnical Investigation

prepared for
EXXON COMPANY, U.S.A.
Production Department Western Divison

№ 012

VOLUME II

POINT THOMSON DEVELOPMENT PROJECT
WINTER 1982 GEOTECHNICAL INVESTIGATION
EXXON COMPANY, U.S.A

HLA JOB NO. 9612,031.08

A Report Prepared for

EXXON COMPANY, U.S.A.
1800 Avenue Of The Stars
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by

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JUNE, 1982

REPORT COPY № 012

This is a proprietory report prepared for Exxon Company USA for the Point Thomson Development Project.

APPENDIX A
EXISTING INFORMATION

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EXISTING INFORMATION

Previous soil investigations for the development of the Point Thomson Development (PTD) area have produced a collection of geotechnical data. This chapter summarizes the available onshore and offshore geotechnical information sources pertinent to development of the PTD area.

The studies cited were performed for either government agencies or partners in the PTD area. The list is limited to data available to Harding Lawson Associates (HLA) and used in the current investigation. The locations of the studies along with the boring locations for this study are shown on Plate A-1.

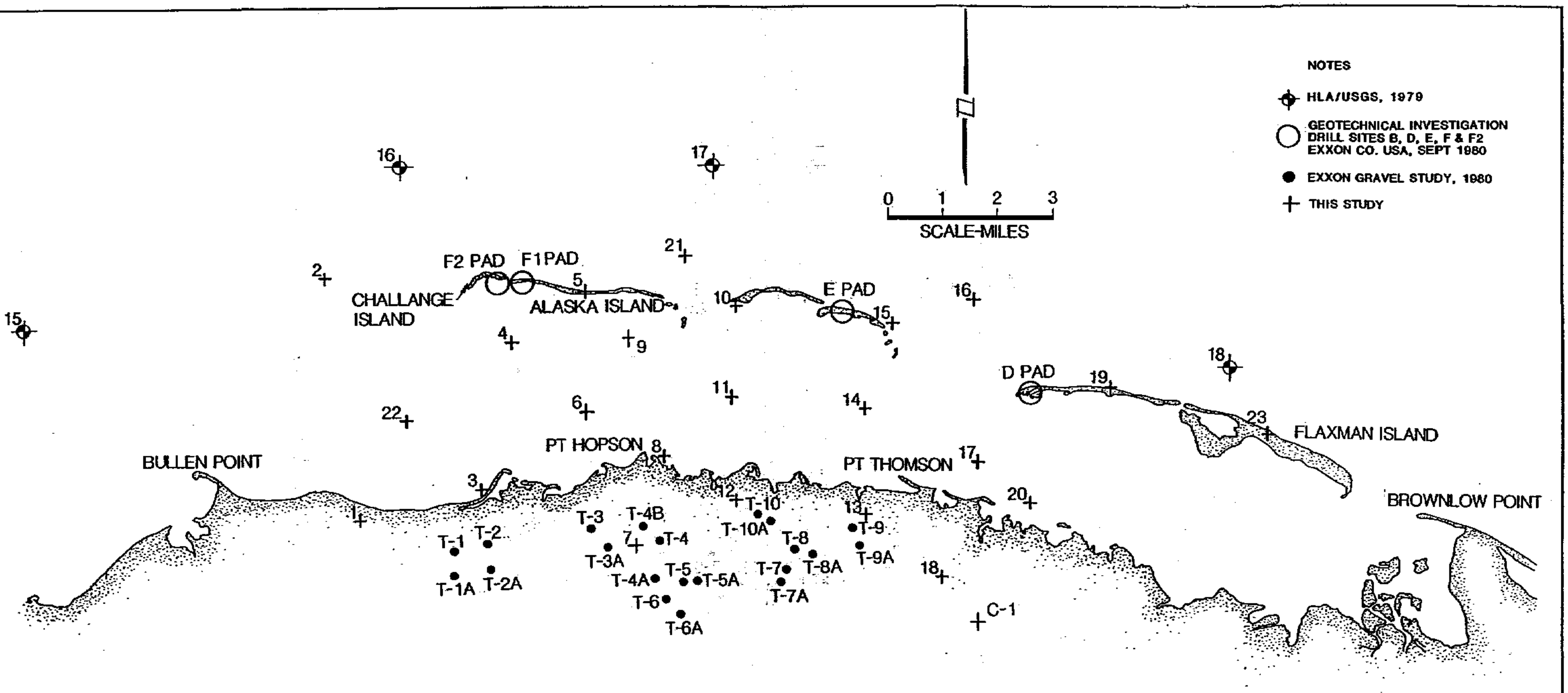
A. Offshore Soil Investigations

1. Geotechnical Investigation Beaufort Sea

HLA performed this investigation in February and March, 1979 for the United States Geological Survey (USGS). Four borings for this USGS investigation were drilled within the proposed PTD area to depths of 42 to 103 feet below mudline. Logs for these four borings were generalized in the Alaska Oil and Gas Association study and are shown on Plates A-2 through A-5.

2. Interpretation of Geophysical, Geologic and Engineering Data Beaufort Sea, Alaska

This study was performed in November, 1979 for eight oil companies by HLA. This paper presented an interpretation of geophysical and geotechnical data available in the Prudhoe Bay-Point Thomson region from 1971-1977 and involved the geotechnical data generated in the 1979 USGS investigation.



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Locations of Area Studies
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

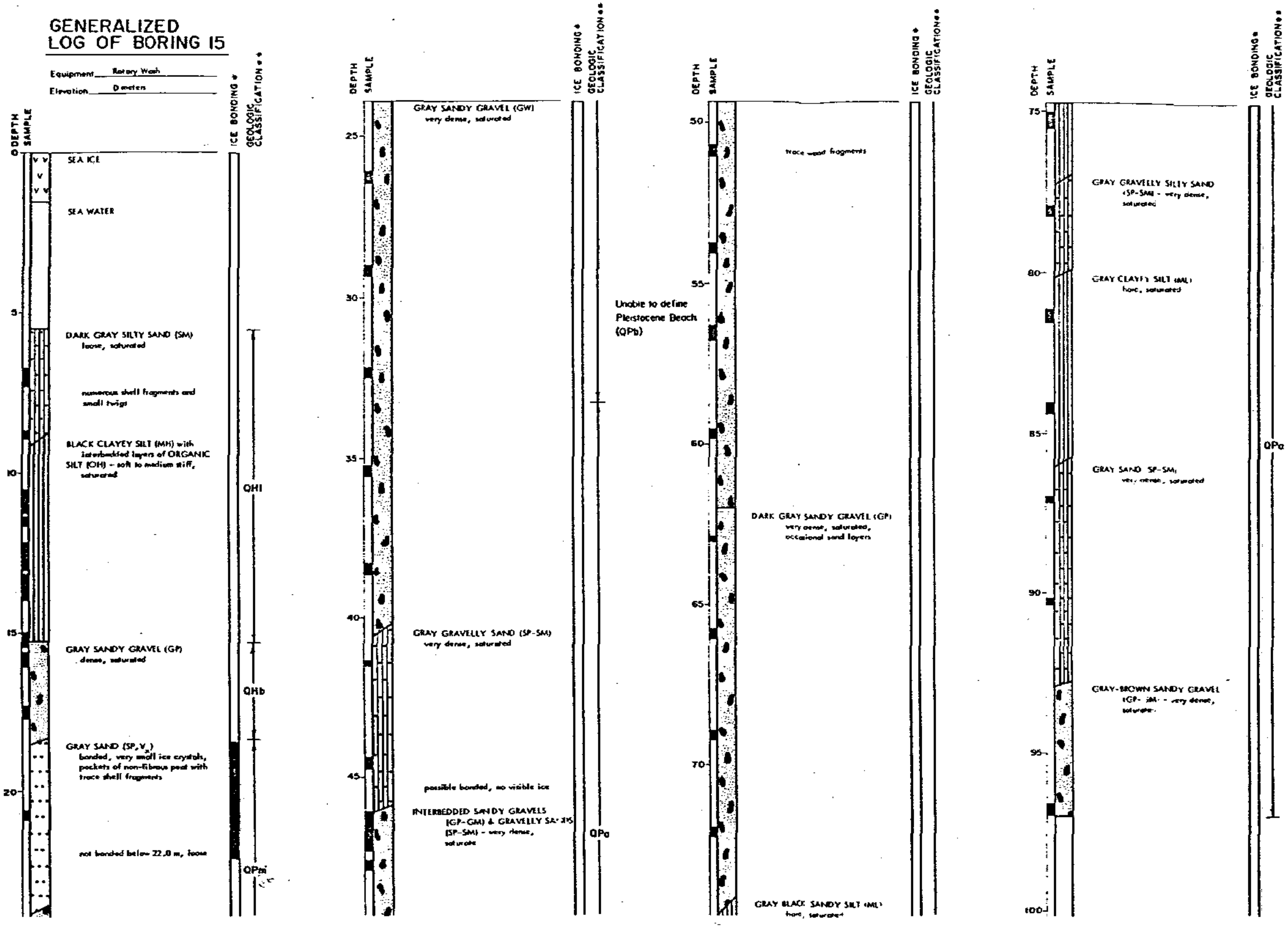
PLATE
A-1

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DKB	4/82		

GENERALIZED LOG OF BORING 15

Equipment Rotary Wash

Elevation 0 meters



Reference:

Interpretation of Geophysical, Geologic and Engineering Data Beaufort Sea, Alaska, HLA 1979

* Refer to Plate A2L Bonding index

** Refer to Plate 11, Explanation of Geologic Map Symbols

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USGS/HLA Boring 15
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
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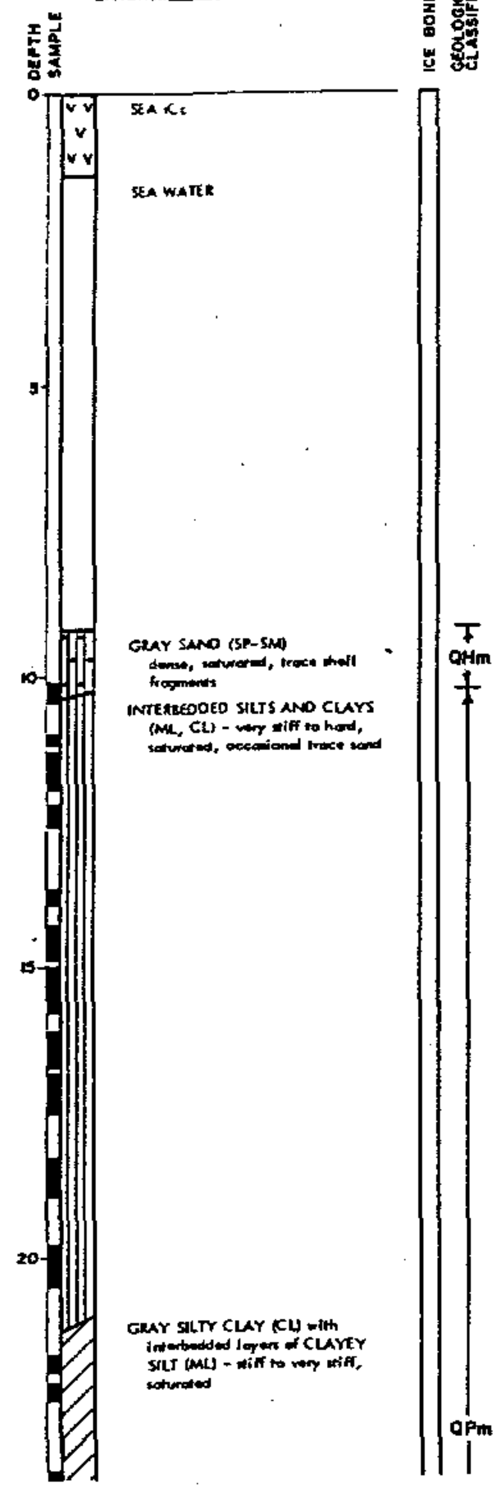
PLATE
A-2

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		

GENERALIZED LOG OF BORING 16

Equipment Rotary Wash

Elevation 0 meters



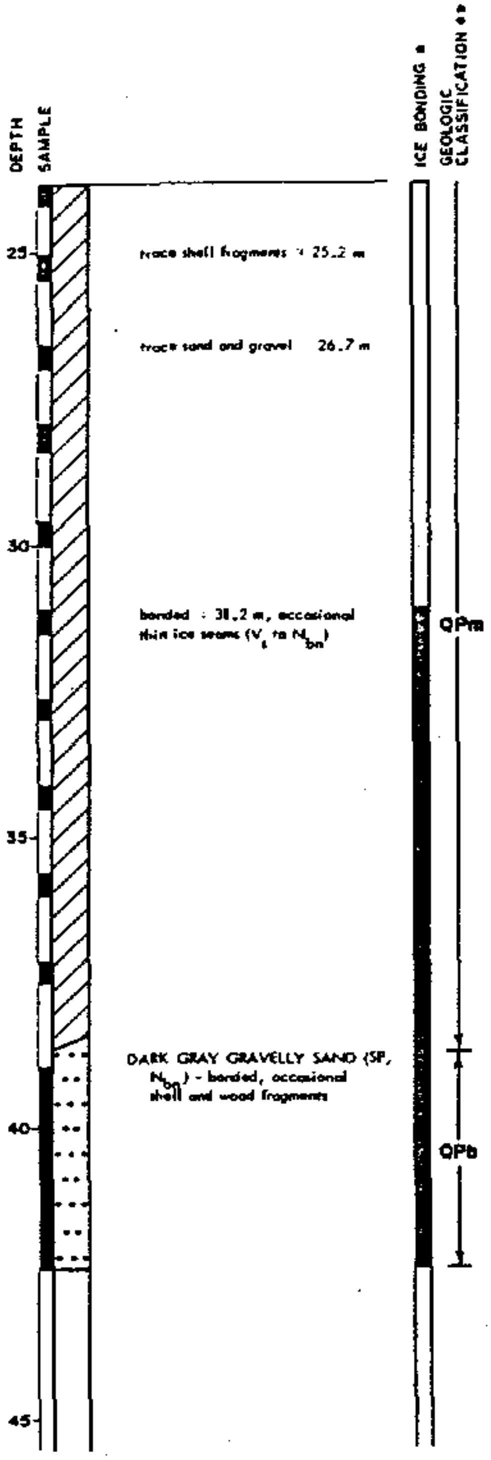
SEA ICE

SEA WATER

GRAY SAND (SP-SM) dense, saturated, trace shell fragments

INTERBEDDED SILTS AND CLAYS (ML, CL) - very stiff to hard, saturated, occasional trace sand

GRAY SILTY CLAY (CL) with interbedded layers of CLAYEY SILT (ML) - stiff to very stiff, saturated



trace shell fragments ÷ 25.2 m

trace sand and gravel 26.7 m

bonded ÷ 31.2 m, occasional thin ice seams (V_s to N_{bn})

DARK GRAY GRAVELLY SAND (SP, N_{bn}) - bonded, occasional shell and wood fragments

Reference:

Interpretation of Geophysical, Geologic and Engineering Data Beaufort Sea, Alaska, HLA 1979

* Refer to Plate A21, Bonding index

** Refer to Plate II, Explanation of Geologic Map Symbols

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USGS/HLA Boring 16
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
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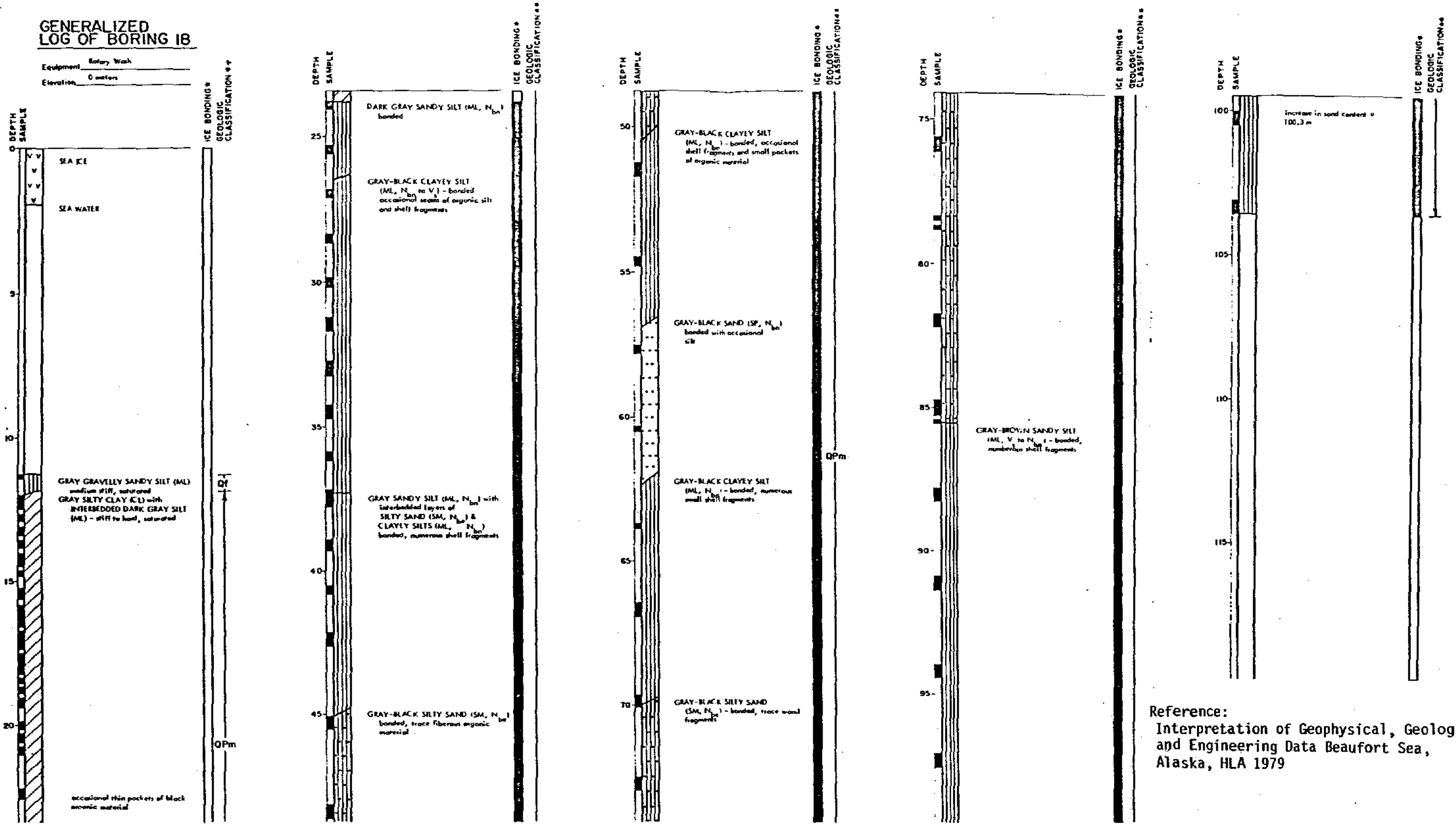
PLATE
A-3

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DAB	4/82		

GENERALIZED LOG OF BORING 18

Equipment Rotary Wash

Elevation 0 meters



SEA ICE

SEA WATER

GRAY GRAVELLY SANDY SILT (ML) medium stiff, saturated

GRAY SILTY CLAY (CL) with INTERBEDDED DARK GRAY SILT (ML) - stiff to hard, saturated

occasional thin pockets of black organic material

DARK GRAY SANDY SILT (ML, N_{bn}) bonded

GRAY-BLACK CLAYEY SILT (ML, N_{bn} to V_s) - bonded occasional seams of organic silt and shell fragments

GRAY SANDY SILT (ML, N_{bn}) with interbedded layers of SILTY SAND (SM, N_{be}) & CLAYEY SILTS (ML, N_{bn}) bonded, numerous shell fragments

GRAY-BLACK SILTY SAND (SM, N_{be}) bonded, trace fiberous organic material

GRAY-BLACK CLAYEY SILT (ML, N_{bn}) - bonded, occasional shell fragments and small pockets of organic material

GRAY-BLACK SAND (SP, N_{bn}) bonded with occasional silt

GRAY-BLACK CLAYEY SILT (ML, N_{bn}) - bonded, numerous small shell fragments

GRAY-BLACK SILTY SAND (SM, N_{be}) - bonded, trace wood fragments

GRAY-BROWN SANDY SILT (ML, V_s to N_{bn}) - bonded, numberous shell fragments

increase in sand content @ 100.3 m

Reference:
Interpretation of Geophysical, Geologic and Engineering Data Beaufort Sea, Alaska, HLA 1979

* Refer to Plate A21, Bonding index
** Refer to Plate 11, Explanation of Geologic Map Symbols

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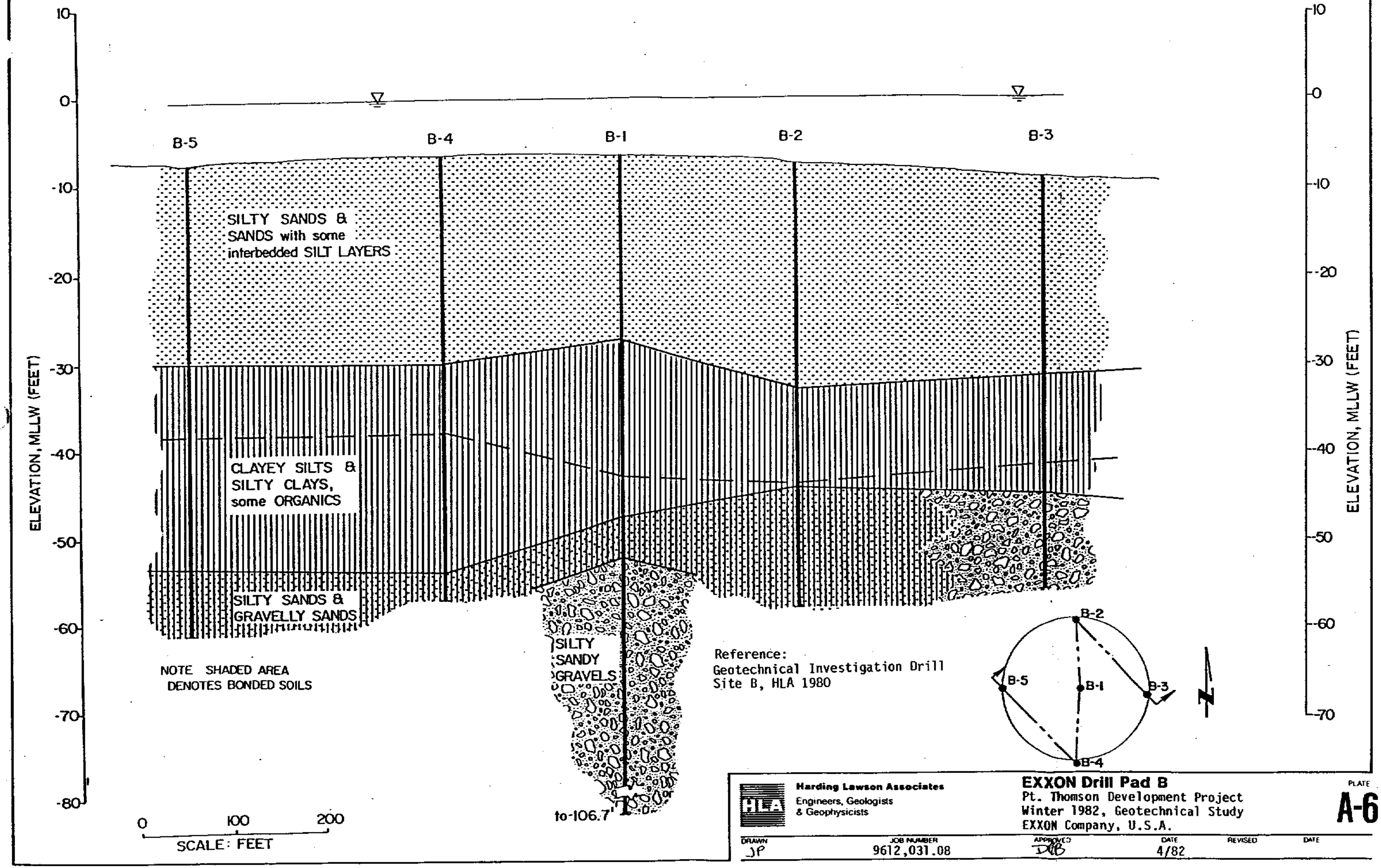
USGS/HLA Boring 18
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
A-5

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DGB	4/82		



NOTE SHADED AREA DENOTES BONDED SOILS

Reference:
Geotechnical Investigation Drill Site B, HLA 1980

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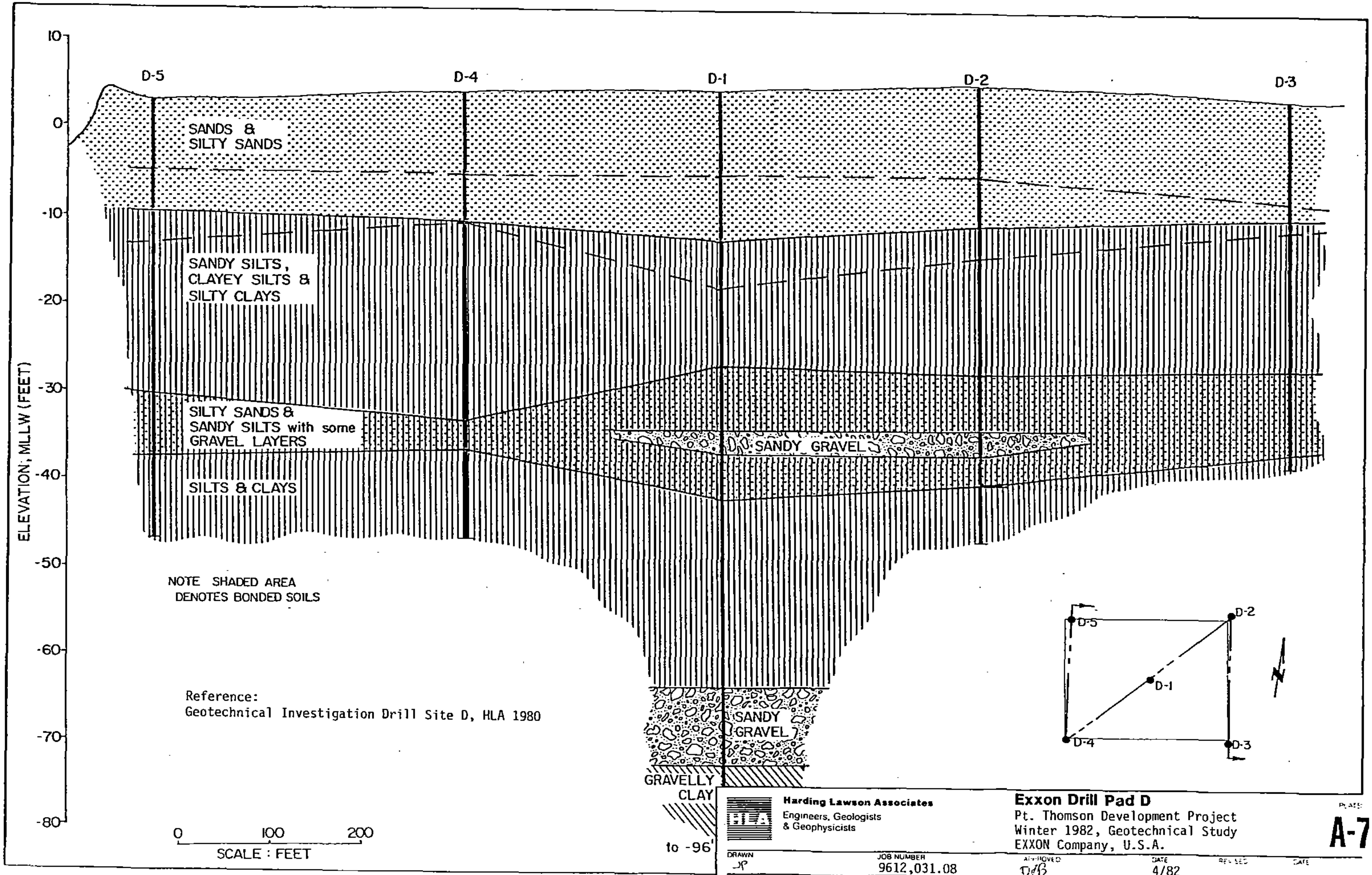
EXXON Drill Pad B
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
A-6

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DLB	4/82		



NOTE SHADED AREA DENOTES BONDED SOILS

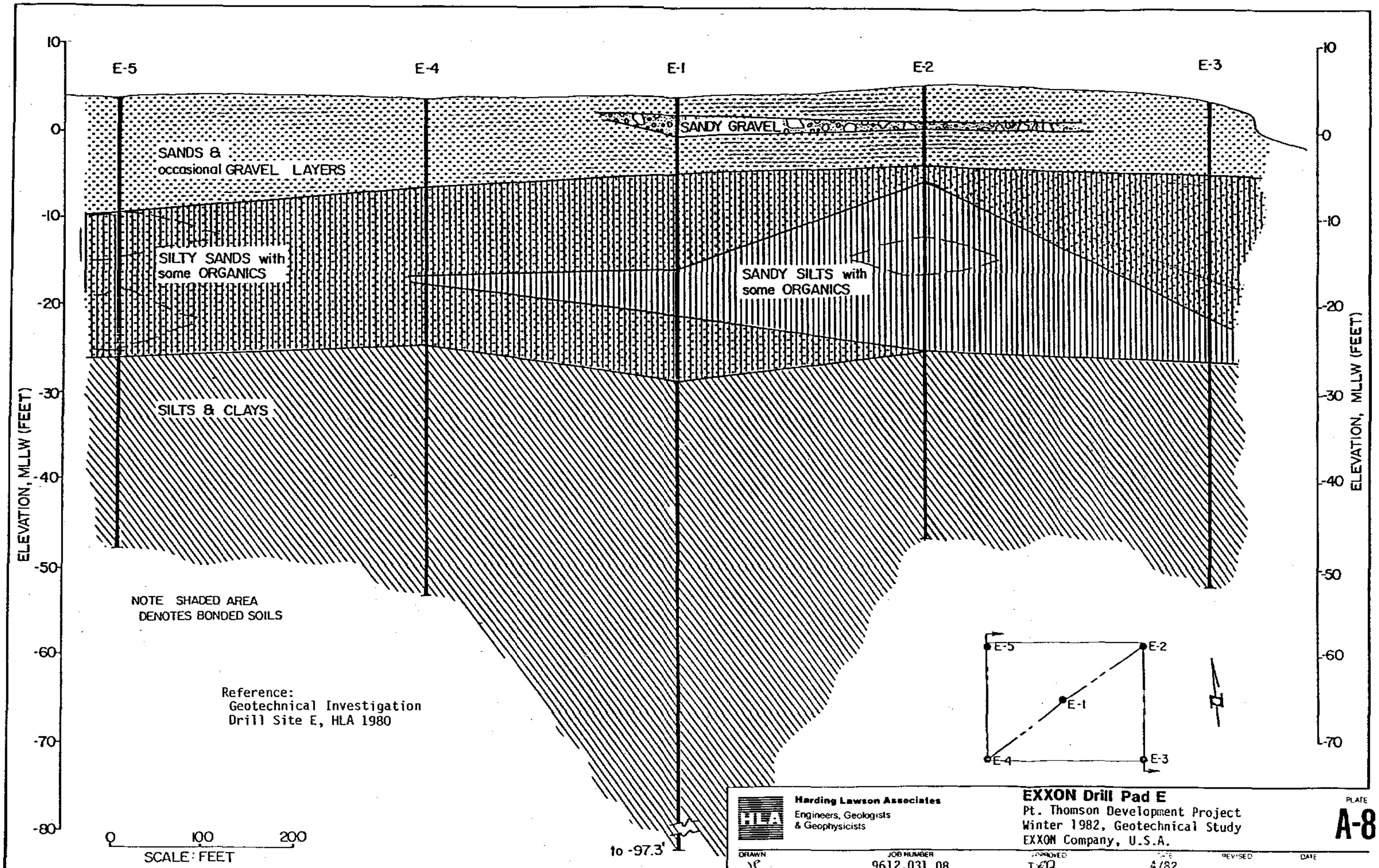
Reference:
Geotechnical Investigation Drill Site D, HLA 1980

Harding Lawson Associates
Engineers, Geologists
& Geophysicists

Exxon Drill Pad D
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08		4/82		

PLATE
A-7



NOTE SHADED AREA
DENOTES BONDED SOILS

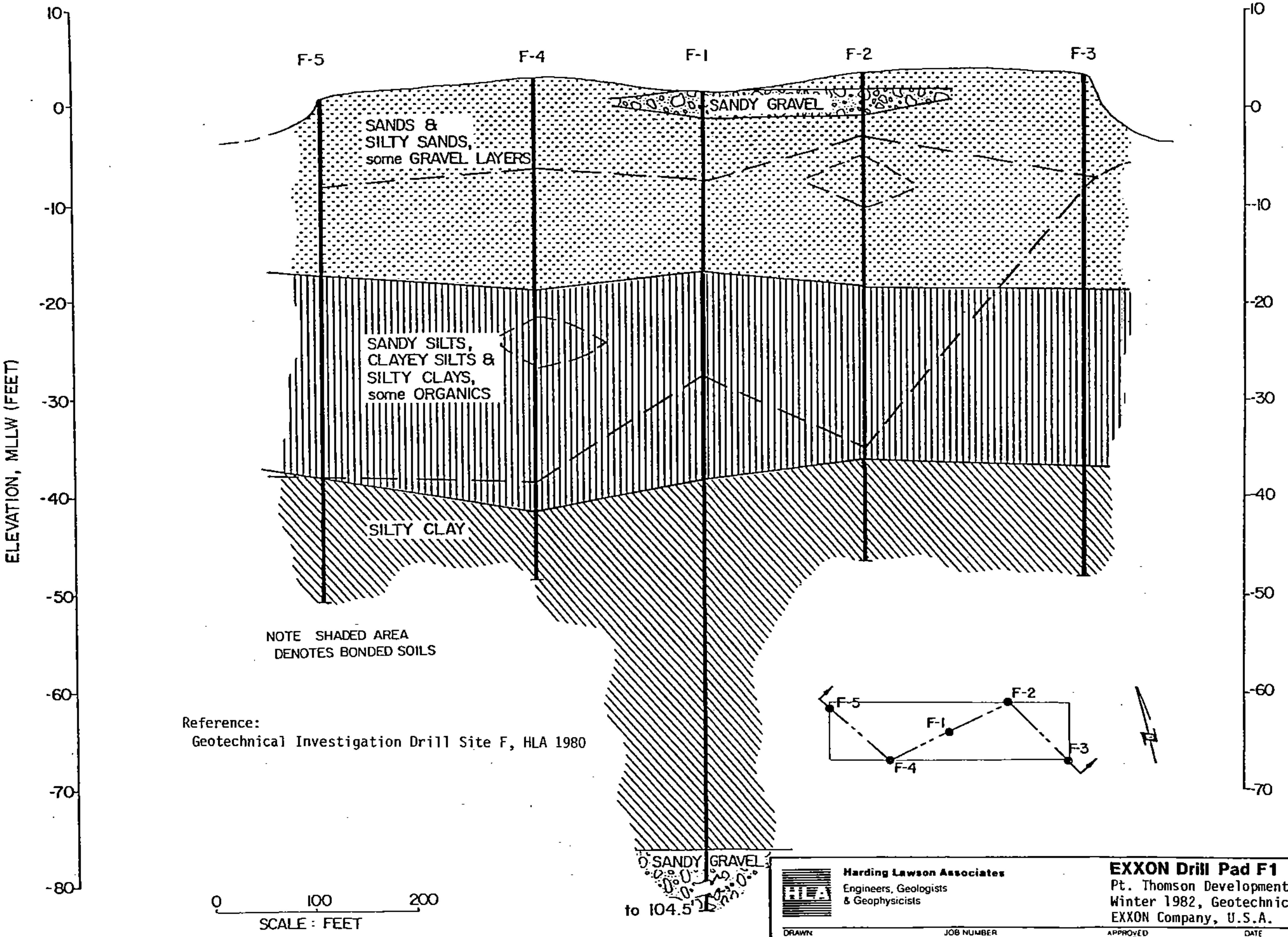
Reference:
Geotechnical Investigation
Drill Site E, HLA 1980

Harding Lawson Associates
Engineers, Geologists
& Geophysicists

EXXON Drill Pad E
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
A-8

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08		4/82		



NOTE SHADED AREA
DENOTES BONDED SOILS

Reference:
Geotechnical Investigation Drill Site F, HLA 1980

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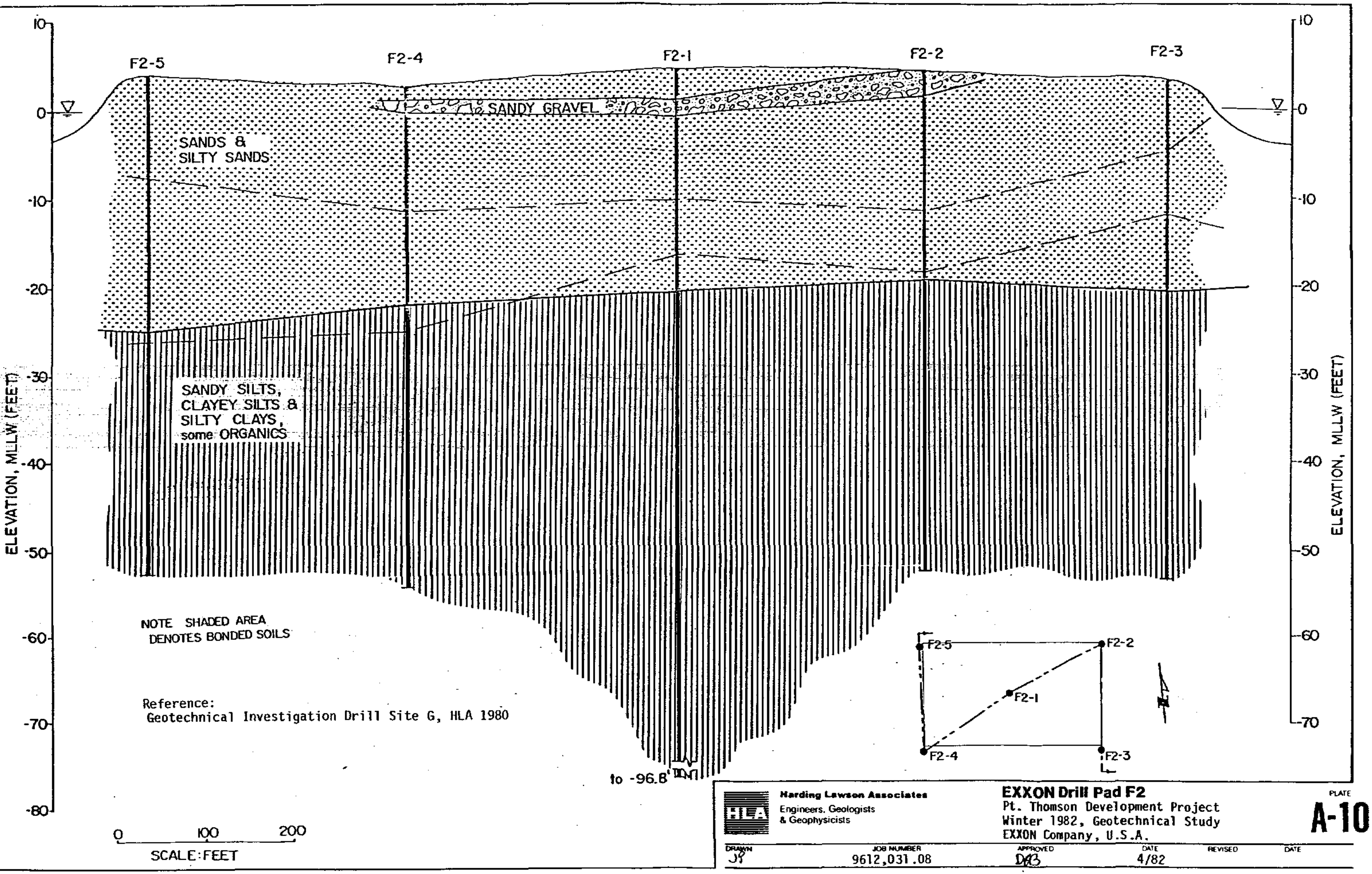
EXXON Drill Pad F1
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
A-9

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08		4/82		



NOTE SHADED AREA
DENOTES BONDED SOILS

Reference:
Geotechnical Investigation Drill Site G, HLA 1980

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& Geophysicists

EXXON Drill Pad F2
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
A-10

DRAWN JF
JOB NUMBER 9612,031.08
APPROVED DAB
DATE 4/82
REVISED
DATE

3. Drill Sites B, D, E, F1, F2 - Soil Investigation

These five sites were investigated in February and March, 1980 by HLA for Exxon Company, U.S.A. Several borings were drilled at each site. Generalized subsurface profiles of conditions encountered at each site are presented on Plates A-6 through A-10 and are described below.

a. Drill Site B

Drilling operations were conducted on the ice from February 29 through March 2, 1980. Five test borings were drilled at the locations shown on Plate A-6. Ice thickness at boring locations varied from 4.0 to 4.8 feet and the water depth (top of ice to mudline) ranged from 6.6 to 9.4 feet. The test borings ranged in depth from 47.0 to 100.3 feet below mudline. A generalized subsurface profile of the site is presented on Plate A-6.

The upper stratum extending from the mudline to a depth of 20 to 25 feet is a Holocene unit. This unit is comprised of sand, silty sand and thin interbedded layers of sandy and clayey silt. The sand is fine-grained and loose to medium dense. The silt layers are medium stiff and have medium plasticity.

A late Pleistocene stratum of silt and clay underlies the surficial Holocene deposit. This stratum extends to depths of 35 to 46 feet and ranges in thickness from 14 to 24 feet. The stratum contains occasional, discontinuous silty sand and gravel lenses, some organic silt layers, and occasional thin seams of peat. The silt and clay are overconsolidated and medium stiff to stiff.

The silt and clay are underlain by a glaciofluvial Pleistocene deposit of silty sand and gravel. This deposit extended to the depths penetrated by the borings.

At the time of our investigations, the soils were unbonded(*) from the mudline to depths ranging from 31 to 36 feet. Below these depths the soil is bonded.

The ground temperatures were measured in Boring B-1 using downhole thermistors. The ground temperatures measured approximately 44 hours after completion of the boring ranged from -1.6°C to -0.6°C.

b. Drill Site D

Drilling operations were conducted at the "D" site from March 3 through 6, 1980. The island is approximately 430 feet in width (bank-to-bank) at the proposed drill pad location. Surface elevations vary across the drill pad site from 2.6 to 4.3(**). Five test borings were drilled at the locations shown on Plate A-7 to depths of 41.5 to 100.0 feet. A generalized subsurface profile of the site is presented on Plate A-7.

A Holocene unit consisting of sand and silty sand extends from the ground surface to depths of 12 to 17 feet. The sand is fine to medium grained with occasional fine gravel and thin gravel lenses. The unbonded sand is medium dense to dense.

The surficial sand is underlain by a late Pleistocene deposit consisting predominantly of clayey silt with some silty clay layers. Generally, the silt and clay have medium plasticity and the unbonded soils are medium stiff to stiff. At depths ranging from 30 to 45 feet the silt and clay contain interbedded silty sand and gravel.

(*) "Unbonded" soil denotes soils which exhibit temperatures below 0°C but behave in a thawed manner due primarily to saline concentrations in the pore water. "Bonded" soil denotes soils which exhibit temperatures below 0°C and behave as an ice-cemented soil mass having frozen pore water.

(**) All elevations refer to feet above Mean Lower Low Water (MLLW).

In Boring D-1 sandy gravel, gravelly clay, and sand were encountered beginning at a depth of 68 feet and extending to the 100-foot depth penetrated by the boring.

At the time of our investigation the soils were bonded from the ground surface to depths ranging 8 to 11 feet. Underlying the surficial bonded soils is an unbonded zone ranging in thickness from 3 feet in Boring D-3 to 13 feet in Boring D-1. Ground-water seepage occurred in several of these unbonded zones. Beneath this zone the soils were bonded to a depth of approximately 79 feet. From 79 to 100 feet the soil was unbonded. The bonded soils encountered during our investigation are denoted on the boring logs and on the design and subsurface profiles.

The ground temperatures were measured in Borings D-1 and D-2 using down-hole thermistors. In Boring D-1 the ground temperatures, measured approximately 84 hours after the boring was completed, varied from -9.2°C at a depth of 5.7 feet to -2.5°C at a depth of 51.7 feet. In Boring D-2 the ground temperatures, measured approximately 71 hours after completion of the boring, varied from -13.3°C at a depth of 4.0 feet to -3.4°C at a depth of 49 feet.

c. Drill Site E

Drilling operations were conducted at the "E" site from March 6 through 8, 1980. At the proposed drill pad site the island varies in width (bank-to-bank) from approximately 480 to 600 feet. The surface elevation varies across the pad from 3.2 to 5.3 feet. Five test borings were drilled at the locations shown on Plate A-8 to depths of 51.5 to 101.5 feet. A generalized subsurface profile of the site is presented on Plate A-8.

The borings encountered Holocene deposits extending from the ground surface to depths of 28 to 33 feet. The surficial 9 to 13 feet of this deposit consists of fine to medium grained sand with occasional thin gravel layers in the upper five feet. The lower portion of the deposit consists of silty sand and sandy silt with some organics. The deeper sand is also fine to medium grained and the silt has a low plasticity.

The Holocene unit is underlain by late Pleistocene silt and clay which extend to the depths penetrated by the borings with the exception of a sand pocket or layer encountered in Boring E-1 at a depth of 86 feet.

In Borings E-1, E-3, and E-4 the subsurface soils were bonded from the ground surface to the depth penetrated by the borings. In Boring E-2 an unbonded zone was encountered from approximately 18 to 22 feet; seepage water was also encountered in this zone. In Boring E-5, unbonded zones were encountered from 13 to 18 feet and 22 to 29 feet.

The ground temperatures were measured in Boring E-1 using down-hole thermistors. The ground temperatures, measured approximately 50 hours after completion of the boring, varied from -19.4°C at the ground surface to -4.2°C at a depth of 50.5 feet.

d. Drill Site F

Drilling operations were conducted at the "F" site from March 9 through 12, 1980. The island is approximately 150 feet in width (bank-to-bank) at the proposed drill pad location. Surface elevations vary across the drill pad site from 0.9 to 4.9 feet. Five test borings drilled at the site ranged in depth from 50.0 to 104.5 feet at the locations shown on Plate A-9. A generalized subsurface profile of the site is presented on Plate A-9.

A Holocene unit consisting of sand and silty sand extends from the ground surface to a depth of approximately 20 feet. The sand is fine to medium grained and the unbonded sand is dense to very dense. A gravel layer 1.5 to 3.0 feet thick was encountered in the upper 5 feet of several test borings.

The sand is underlain by late Pleistocene deposits consisting of interbedded silt, clay and organic silt to a depth of approximately 40 feet, and gray silty clay below a depth of 40 feet. The silt and clay generally have medium to low plasticity and the unbonded materials are soft to medium stiff. The gray silty clay extended to the depths penetrated by Borings F-2 through F-5 and to a depth of 77 feet in Boring F-1. Below 77 feet and extending to the depth penetrated, Boring F-1 encountered a later to middle Pleistocene stratum of gray sandy silty gravel.

The surficial soils were bonded to depths of 6 to 10 feet. Beneath the surficial bonded zone, an unbonded zone was encountered. The thickness of the unbonded zone varied from 3 feet in Boring F-3 to 33 feet in Boring F-2.

The ground temperatures were measured in Boring F-1 using down-hole thermistors. The ground temperatures measured approximately 156 hours after completion of the boring ranged from -21.1°C at the ground surface to -2.7°C at a depth of 53 feet.

e. Drill Site F2

Drilling operations were conducted at the "F2" site from March 12 through 14, 1980. At the proposed drill pad location the width of the island varies from approximately 290 to 340 feet (bank-to-bank). Surface elevations vary across the drill pad site from 2.6 to 4.9 feet. Five test borings were drilled at the locations shown on Plate A-10 to depths of 56.5 to 101.5 feet. A generalized subsurface profile of the site is presented on Plate A-10.

A Holocene unit consisting of sand and silty sand extends from the ground surface to a depth of approximately 24 feet. The sand is fine to medium grained and medium dense in the unbonded zones. A thin gravel layer was encountered in the upper five feet of several of the borings.

Underlying the sand is late Pleistocene silt and clay. The silt has a plasticity ranging from low to medium, while the clay plasticity ranges from medium to high. The upper portion of the stratum contains some organics. The silt and clay extended to a depth of 90 feet in Boring F2-1 where a sandy gravel was encountered to the depth penetrated by the boring.

The surficial soils were bonded from the ground surface to depths of 8 to 16 feet. The bonded soils are underlain by an unbonded zone varying in thickness from 6 feet in Borings F2-1 to 16 feet in Boring F2-5. Below this zone the soils were bonded to the depth penetrated by the borings.

The ground temperatures were measured in Boring F2-5 using down-hole thermistors. The ground temperatures, measured approximately 28 hours after the boring was completed, ranged from -20.8°C at the ground surface to -2.6°C at a depth of 55.8 feet.

B. Onshore Soil Investigations

1. Gravel Study - Field Exploration and Laboratory Tests

This onshore study was performed in March, April and May 1980 by HLA for Exxon Company, U.S.A. The purpose of the study was to locate sources of gravel material which could be used as construction material. A total of 118 borings were drilled. Various laboratory tests were performed on samples recovered from the borings.

The test borings drilled in the Point Thomson area in general encountered a surficial layer of organic soil (peat). Beneath the organic soil, a thin layer of sandy silt and silty sand were generally present. Usually, the silt and silty sand were common in the three to six-foot depth range. Beneath the silt and silty sand, gravelly sand and sandy gravel with variable amounts of silt were encountered to the depths explored.

In general, the ice content was greatest in the borings between the 3-foot and 10-foot depth and decreased below 15 feet. Massive ice layers were encountered in the 3 to 15-foot range in 22 of the borings. Ground ice constituted as much as 50 percent of the total soil volume in the upper 10 to 15 feet where fine-grained soils, such as silt, were present.

2. Field Density Tests - Field construction observation of frozen gravel fill placement at three drill sites in the Point Thomson area

HLA performed testing in March and April, 1980 for Exxon Company, U.S.A. in the project area. Field density and water content tests were performed on frozen gravel hauled from the Point Thomson C-1 material source located as shown on Plate A-1. Test results indicate that this material had an average dry density of 70 pounds per cubic foot and a water (ice) content of 25 percent.

APPENDIX B
DRILLING INVESTIGATION

LIST OF TABLES

LIST OF ILLUSTRATIONS

APPENDIX B
DRILLING INVESTIGATION

A. Surveying

Besse, Epps & Potts of Anchorage, Alaska provided horizontal control for the test boring program using a Motorola Mini Ranger III system. This system includes a range console, a receiver/transmitter, two reference stations, and peripheral equipment for data recording and range computations. One surveyor assisted occasionally by HLA personnel completed the survey program.

1. Horizontal Control

The position of each test boring was fixed relative to the positions of benchmarks and known survey locations near the project area. Initially, battery-powered remote stations were established at these sites. The distance between each test boring and the various control points were determined using the Mini Ranger III system. Given these known distances, and using the method of resection, the locations and coordinates of the test borings were established.

As each remote station answers to interrogations from the range console, the two-way travel time of radar frequency pulses is used to compute the distance between points. The system is accurate to ± 3 meters for a station separation of up to 40 nautical miles. The measured distances are continuously displayed on LED read-outs on the range console. Additionally, the information is supplied to peripheral equipment that provides hard copy records of time and distance data and computes the XY coordinates of the station.

2. Survey Program

The survey program was conducted in three phases. During the first phase, remote stations were established at the five survey control points listed in Table B-1. In phase two, the test borings were located and staked. Test Borings 1 to 17, 21, and 22 were located with a helicopter-mounted range console prior to the commencement of the drilling program. The remaining four sites, Test Borings 18, 19, 20, and 23, were established using the range console and data recording system mounted in a Rolligon. The final phase of the program involved determining the as-drilled locations of the test borings. The Rolligon-mounted unit was used to determine these locations, which are summarized in Table B-2.

TABLE B-1. UTM ZONE 6 COORDINATES FOR THE SURVEY CONTROL POINTS

Control Point	East (X, feet)	North (Y, feet)
Hopson	1 699 321.65	25 542 594.67
Nygren	1 741 125.23	25 532 682.12
Thin	1 694 111.09	25 563 542.99
Point Thomson 4	1 688 925.76	25 543 214.63
Point Thomson 3	1 733 219.53	25 541 585.22

TABLE B-2. AS-DRILLED UTM ZONE 6 COORDINATES

Test Boring	East (X, feet)	North (Y, feet)
1	1 672 981	25 541 221
2	1 670 030	25 565 015
3	1 685 051	25 544 025
4	1 687 992	25 558 492
5	1 695 221	25 563 165
6	1 695 409	25 551 822
7	1 699 991	25 538 242
8	1 702 499	25 546 772
9	1 702 473	25 558 836
10	1 709 962	25 562 119
11	1 709 919	25 552 762
12	1 710 000	25 542 511
13	1 722 914	25 540 930
14	1 722 995	25 551 633
15	1 725 699	25 559 893
16	1 733 529	25 562 005
17	1 733 344	25 546 035
18	1 730 229	25 534 749
19	1 747 696	25 552 953
20	1 739 000	25 541 749
21	1 705 180	25 566 788
22	1 677 694	25 551 551
23	1 763 017	25 548 668

B. Offshore Drilling Investigation

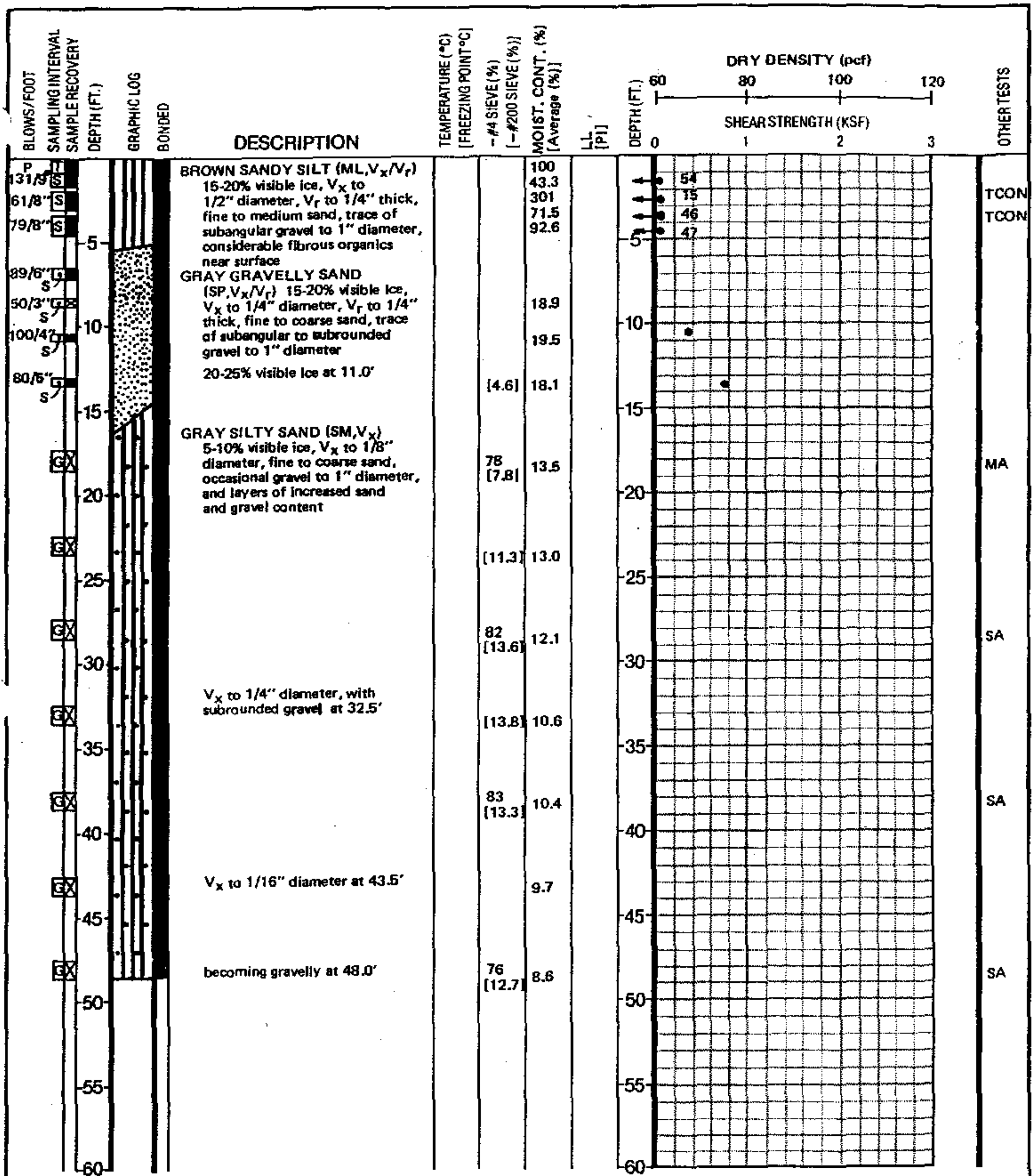
The soil conditions within the offshore area were investigated between March 3 and March 15, 1982 by drilling 18 test borings, ranging in depth from 25 to 80 feet. Additionally, pipe for ground temperature monitoring was installed in five test borings, as described in Appendix C.

The locations of the offshore test borings are shown on Plate II-2; the test boring logs are presented as Plates B-1 through 23 with the explanation of the symbols used on the test boring logs presented on Plate B-24.

HLA personnel involved in the offshore drilling included a geologist, a soil engineer, a drilling foreman, two drillers, and two drill helpers. Two drill crews, consisting of a geologist or engineer, a driller, and a drill helper, worked alternate 12-hour shifts to maintain around-the-clock drilling. The engineer or geologist directed the drilling operation, logged the soils encountered, and obtained representative samples for laboratory testing. The drilling foreman served as a Cat operator, back-up driller and a mechanic.

The offshore test borings were drilled using a sled-mounted Mobile Drill B-61 that was fully enclosed in a heated and insulated framed structure. The drill rig was equipped with casing, drill rods, and a mud pump for rotary wash rilling. Additionally, eight-inch O.D. hollow stem auger and a mud pit were available. Extra support equipment, including a 5 kw generator and a survival shed, was mounted on a support sled.

A Rolligon with a water-shack and driver was provided by Crowley All-Terrain Corporation (CATCO) to support the drilling operations. The Rolligon was used to transport crews, drag trails, and carry the surveying equipment.



BROWN SANDY SILT (ML,V_x/V_r)
15-20% visible ice, V_x to 1/2" diameter, V_r to 1/4" thick, fine to medium sand, trace of subangular gravel to 1" diameter, considerable fibrous organics near surface

GRAY GRAVELLY SAND (SP,V_x/V_r) 15-20% visible ice, V_x to 1/4" diameter, V_r to 1/4" thick, fine to coarse sand, trace of subangular to subrounded gravel to 1" diameter

20-25% visible ice at 11.0'

GRAY SILTY SAND (SM,V_x)
5-10% visible ice, V_x to 1/8" diameter, fine to coarse sand, occasional gravel to 1" diameter, and layers of increased sand and gravel content

V_x to 1/4" diameter, with subrounded gravel at 32.5'

V_x to 1/16" diameter at 43.5'

becoming gravelly at 48.0'

UTM Coordinates: N 25 541 221
E 1 672 981

Water Depth: ---
Equipment: Mobile B-61, 8" Hollow Stem Auger

SHEAR STRENGTH
▲ — Torvane
△ — Compression Test

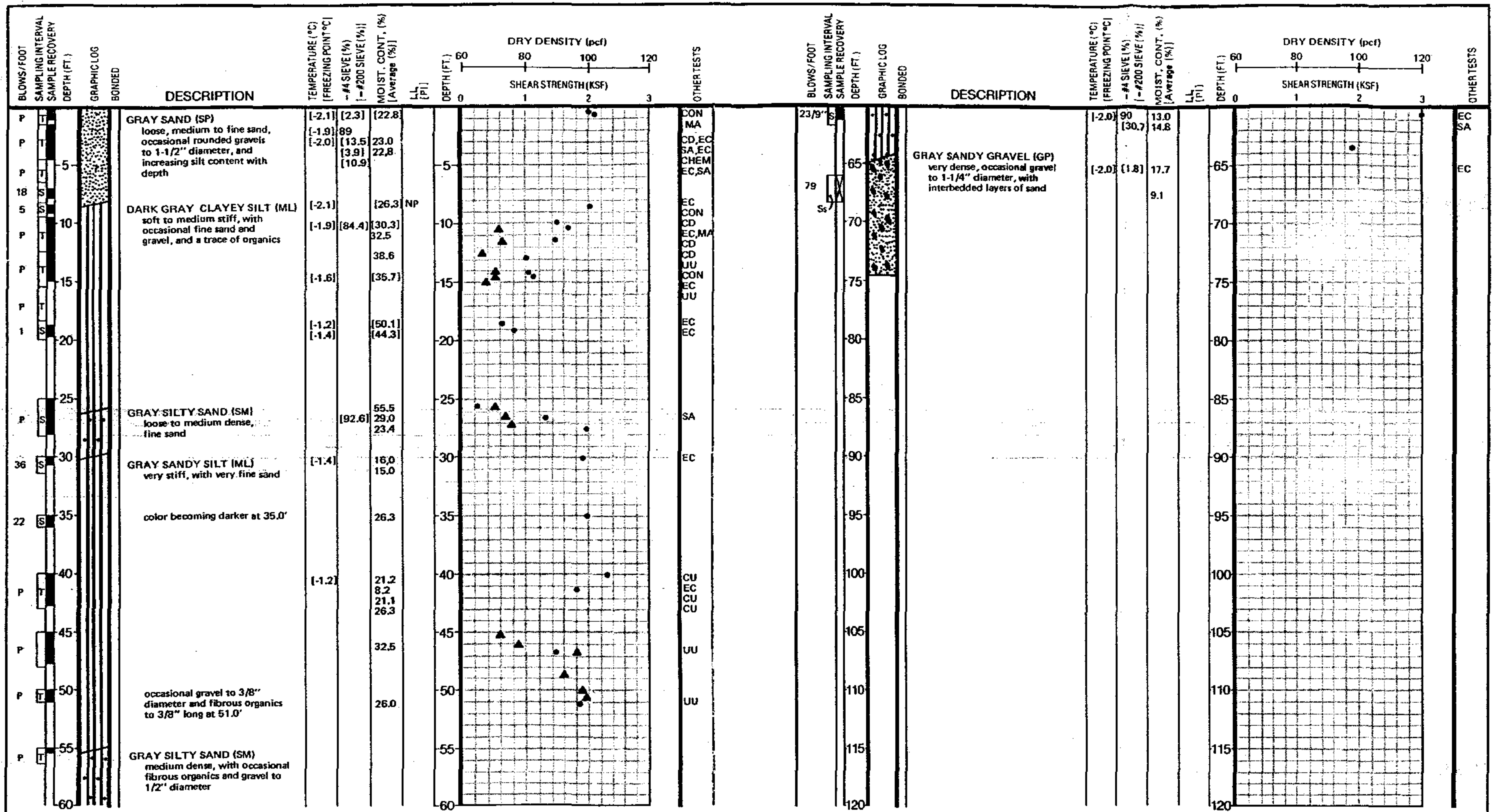
Date Completed: 3-5-82
Logged By: P.J. Ondra

Job Number: 9612,031.08

Approved: DEB
Date: 4-82

LOG OF BORING NO. 1
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-1



GRAY SAND (SP)
loose, medium to fine sand, occasional rounded gravels to 1-1/2" diameter, and increasing silt content with depth

DARK GRAY CLAYEY SILT (ML)
soft to medium stiff, with occasional fine sand and gravel, and a trace of organics

GRAY SILTY SAND (SM)
loose to medium dense, fine sand

GRAY SANDY SILT (ML)
very stiff, with very fine sand

color becoming darker at 35.0'

occasional gravel to 3/8" diameter and fibrous organics to 3/8" long at 51.0'

GRAY SILTY SAND (SM)
medium dense, with occasional fibrous organics and gravel to 1/2" diameter

GRAY SANDY GRAVEL (GP)
very dense, occasional gravel to 1-1/4" diameter, with interbedded layers of sand

UTM Coordinates: N 25 565 015
E 1 670 030

Water Depth: 12.3'

Equipment: Mobile B-61, Rotary Wash

SHEAR STRENGTH
▲ — Torvane
△ — Compression Test

HLA

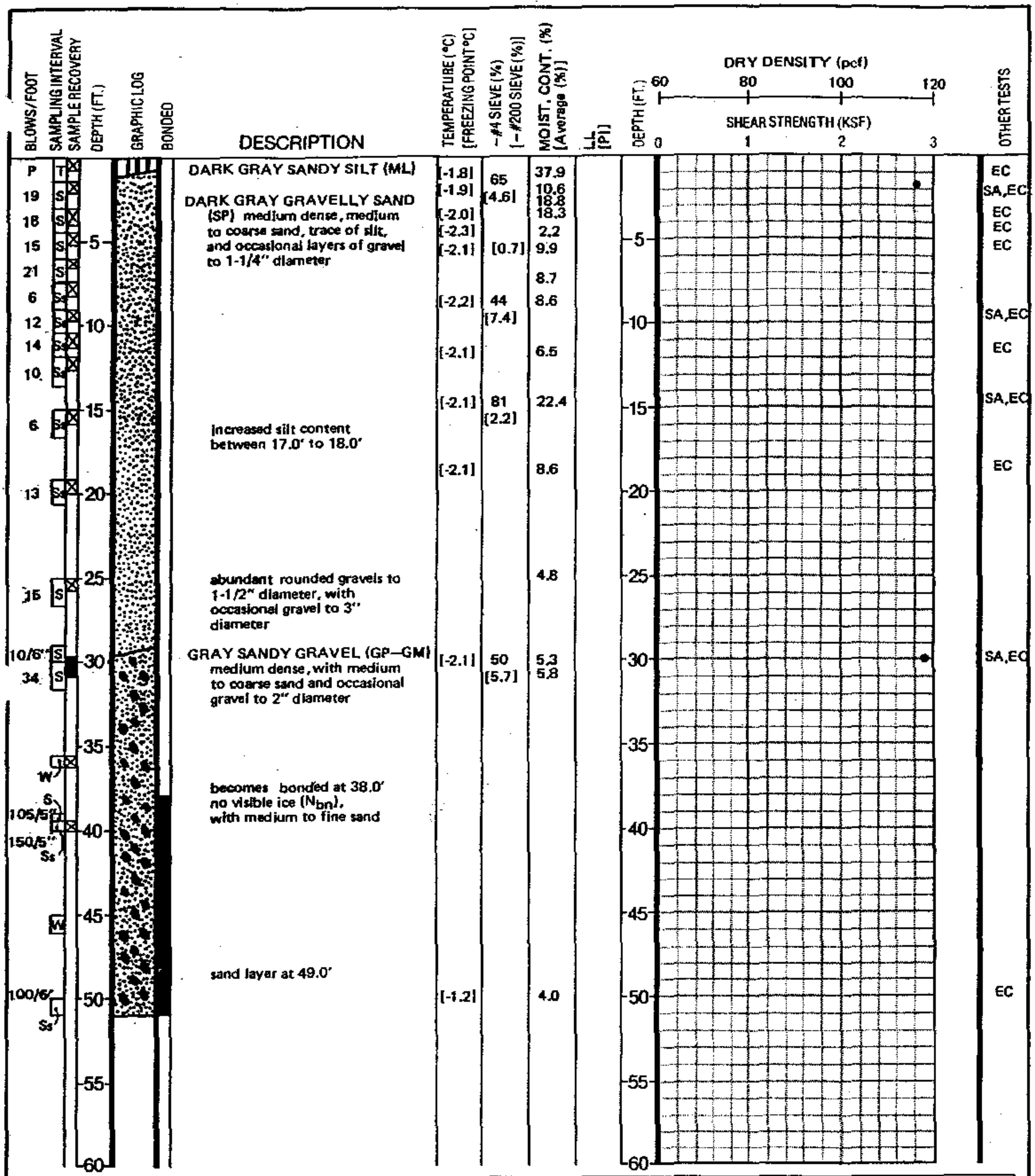
Date Completed: 3-7-82
Logged By: M.R. Musial
R.H. Prescott

Job Number: 9612,031.08

Approved: PEB
Date: 4-82

LOG OF BORING NO. 2
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-2



BLOWS/FOOT	SAMPLING INTERVAL	DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	-#4 SIEVE (%) [-#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	OTHER TESTS
P	T	DARK GRAY SANDY SILT (ML)	[-1.8]	65	37.9	EC
19	S	DARK GRAY GRAVELLY SAND (SP) medium dense, medium to coarse sand, trace of silt, and occasional layers of gravel to 1-1/4" diameter	[-1.9]	[4.6]	10.6 18.8	SA,EC
18	S		[-2.0]		18.3	EC
15	S		[-2.3]		2.2	EC
			[-2.1]	[0.7]	9.9	EC
21	S				8.7	
6	S		[-2.2]	44 [7.4]	8.6	SA,EC
12	S					
14	S		[-2.1]		6.5	EC
10	S					
6	S		[-2.1]	81 [2.2]	22.4	SA,EC
		increased silt content between 17.0' to 18.0'	[-2.1]		8.6	EC
13	S					
35	S	abundant rounded gravels to 1-1/2" diameter, with occasional gravel to 3" diameter			4.8	
10/6"	S	GRAY SANDY GRAVEL (GP–GM) medium dense, with medium to coarse sand and occasional gravel to 2" diameter	[-2.1]	50 [5.7]	5.3 5.8	SA,EC
34	S					
	W					
105/5"	S	becomes bonded at 38.0' no visible ice (N$_{bn}$), with medium to fine sand				
150/5"	Ss					
	W					
100/6"	Ss	sand layer at 49.0'	[-1.2]		4.0	EC

UTM Coordinates: N 25 544 025
E 1 685 051

Water Depth: 5.8'

Equipment: Mobile B-61, Rotary Wash

SHEAR STRENGTH
▲—Torvane
△—Compression Test

Date Completed: 3-5-82
Logged By: M.R. Musial
R.H. Prescott

Approved: DEB
Date: 4-82

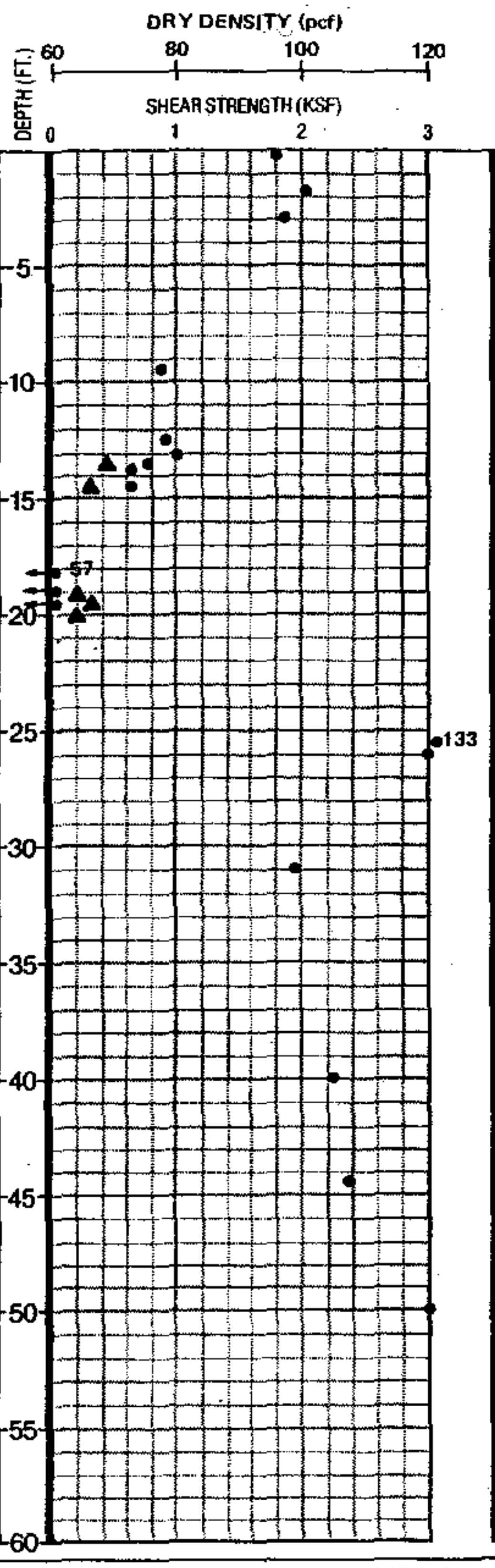
Job Number: 9612,031.08

HLA

LOG OF BORING NO. 3
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-3

BLOWS/FOOT	SAMPLING INTERVAL	DEPTH (FT.)	DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	–#4 SIEVE (%) [–#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	LL [PI]	OTHER TESTS
P	T		GRAY SANDY SILT (ML) soft		[21.4 [2.0]	26.4 22.7		SA, DS
P P	S T		DARK GRAY SAND (SP) loose, fine sand	[-1.9]		27.1	NP	EC CON
		5	GRAY SILT (ML) soft, with a trace of fine sand					
P	T							
			trace of clay at 9.5'	[-1.8]		43.8 41.6		EC
P P	S T	10						
P	T		occasional shell fragments at 12.0'	{-1.8]	90.1	[40.0] 36.3	33 [6]	EC TC CON
		15	becoming medium stiff and clayey at 14.5'			[46.6 45.5	33 [6]	CU CU CON
P	T		trace of organics at 18.0'			[72.8] [71.6 69.0	44 [18]	UU CU CON CU EC
		20		[-1.9]				
		25	organics (peat) encountered at 25.0'			25.9		EC
36	S		GRAY SILTY SAND (SM) medium dense, medium sand, with rounded gravel to 1-1/2" diameter, and abundant gravel to 1/2" diameter	[-1.8]	93 [40.2]	9.7 12.9		SA
18	S	30			[65.9]	22.3 22.8		
			DARK GRAY SILT (ML) very stiff, becoming gravelly at 34.5', gravel to 1/2" diameter					
139	S	35						
W								
			decreasing gravel content at 39.0'					
18	S	40				24.4 23.1	27 [5]	
					99 [74.9]	22.5		SA
74	S	45	GRAY SAND (SP) dense, medium to coarse sand, becoming gravelly between 45.0' to 49.0'					
37	S	50		[-2.2]	[2.8]	21.9 13.7		EC
		55						
		60						



UTM Coordinates: N 25 558 492
E 1 687 992

Water Depth: 11.8'

Equipment: Mobile B-61, Rotary Wash

SHEAR STRENGTH

▲ — Torvane

△ — Compression Test

Date Completed: 3-7-82
Logged By: M.R. Musial
R.H. Prescott

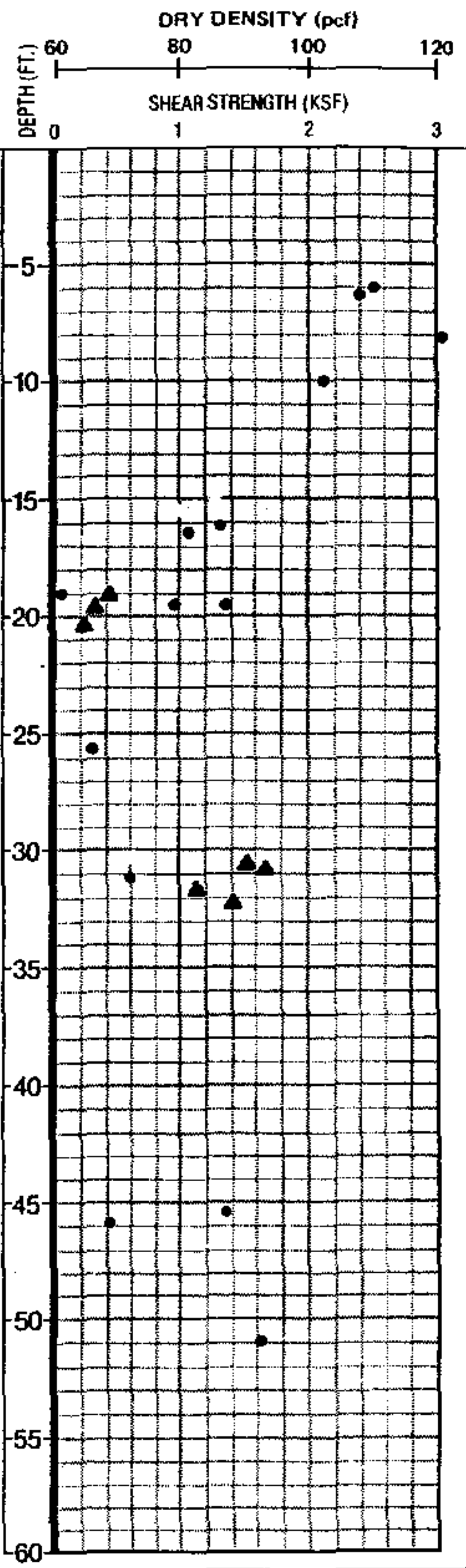
Approved: DEB
Date: 4-82

Job Number: 9612,031.08

LOG OF BORING NO. 4
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-4

BLOWS/FOOT	SAMPLING INTERVAL / SAMPLE RECOVERY	DEPTH (FT.)	DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	−#4 SIEVE (%) [−#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	LL [PI]	OTHER TESTS
180	Ss		**BROWN GRAVELLY SAND** (SP-SM, V_x/V_c) up to 5% visible ice, occasional subrounded gravel to 3/4" diameter	-19.4 [-2.5]	86 [9.6	27.1 16.2		EC. SA
113	Ss			[-2.2] -12.9		14.0		CHEM
25	Ss	5		[-1.0] -11.6	[3.5]	36.4		EC
23	S		**GRAY SILTY SAND** (SM, N_f/N_{bn}) fine sand	[-4.0]	[22.0	18.0 18.3		EC
-18	S			-10.1 [-5.0]		18.9 13.5		EC CHEM
19	S	10	**BROWN GRAVELLY SAND** (SP) medium dense, abundant rounded to subrounded fine gravel	-9.0 [-0.8]	[1.1	6.9 6.2		EC
10	S			-7.6				
P P 11	S T S	15	**DARK GRAY SILT** (ML) soft to medium stiff, with a trace of gravel and occasional lenses of organic silt	-6.6 [-3.4]		33.0 34.8 52.0		EC EC
P	T	20	clay seam at 19.0'	[-0.7] -6.1 -5.9 [-3.2]		35.5 39.5 36.6 42.3	31 (10)	UU TC CON
	W							
P P	S T	25	V_r to 1/4" diameter and a trace of clay at 26.0'	-6.0		52.4		
P	T	30	Vs/Vx with occasional gravel to 1-1/2" diameter at 30.0'	-6.1 [-1.7]		43.6 46.3		EC
P	T	35	**GRAY SILTY CLAY** (CL, N_{bn})	-6.1				
P	T	40		-6.1				
P	S T	45	V_r to 1/16" thick at 45.5'	-6.0 [-1.1]	[98.4] [99.0]	41.9 33.6 36.2		EC TCON MA TCON MA
D	T	50		-5.9 [-1.6]		27.0 28.8		EC
		55	Temperature measurements recorded on 4-17-82					
		60						



UTM Coordinates: N 25 563 165
E 1 695 221

Water Depth: 3.5'

Equipment: Mobile B-61, Rotary Wash

SHEAR STRENGTH
▲ — Torvane
△ — Compression Test

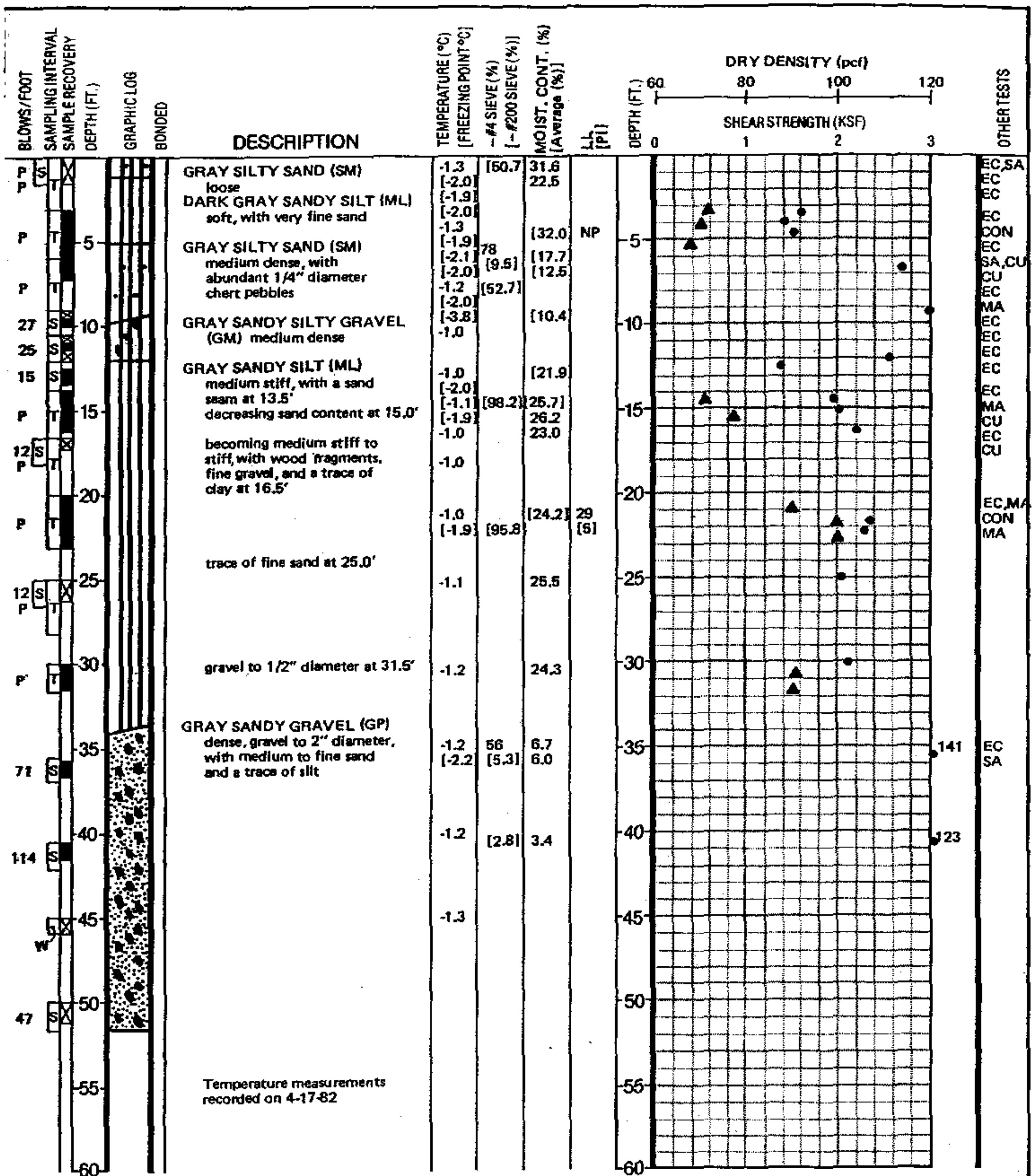
Date Completed: 3-8-82
Logged By: M.R. Musial
R.H. Prescott

Job Number: 9612,031.08

Approved: DEB
Date: 4-82

LOG OF BORING NO. 5
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-5



BLOWS/FOOT	SAMPLING INTERVAL	DEPTH (FT.)	DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	−#4 SIEVE (%) [−#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	L.L. [PI]	OTHER TESTS
P	S		GRAY SILTY SAND (SM)	-1.3	[50.7	31.6		EC,SA
P	T		loose	[-2.0]		22.5		EC
			DARK GRAY SANDY SILT (ML)	[-1.9]				EC
			soft, with very fine sand	[-2.0]				EC
				-1.3		[32.0	NP	CON
P	T	5	GRAY SILTY SAND (SM)	[-1.9]				EC
			medium dense, with	[-2.1]	78	[17.7		SA,CU
			abundant 1/4" diameter	[-2.0]	[9.5]	[12.5		CU
P	T		chert pebbles	-1.2	[52.7]			EC
				[-2.0]				MA
27	S	10	GRAY SANDY SILTY GRAVEL	[-3.8]		[10.4		EC
			(GM) medium dense	-1.0				EC
25	S							EC
15	S		GRAY SANDY SILT (ML)	-1.0		[21.9		EC
			medium stiff, with a sand	[-2.0]				EC
			seam at 13.5'	[-1.1]	[98.2]	25.7]		MA
P	T	15	decreasing sand content at 15.0'	[-1.9]		26.2		CU
				-1.0		23.0		EC
12	S		becoming medium stiff to					CU
P	T		stiff, with wood fragments,	-1.0				
			fine gravel, and a trace of					
		20	clay at 16.5'					
P	T			-1.0		[24.2]	29	EC,MA
				[-1.9]	[95.8		[5]	CON
								MA
			trace of fine sand at 25.0'					
12	S	25		-1.1		25.5		
P	T							
P'	T	30	gravel to 1/2" diameter at 31.5'	-1.2		24.3		
			GRAY SANDY GRAVEL (GP)					
		35	dense, gravel to 2" diameter,	-1.2	56	6.7		EC
			with medium to fine sand	[-2.2	[5.3]	6.0		SA
71	S		and a trace of silt					
		40		-1.2	[2.8]	3.4		
114	S							
	S	45		-1.3				
W'								
47	S	50						
		55	Temperature measurements recorded on 4-17-82					
		60						

UTM Coordinates: N 25 551 822
E 1 695 409
Water Depth: 16.2'
Equipment: Mobile B-61, Rotary Wash

SHEAR STRENGTH
▲ — Torvane
△ — Compression Test

Date Completed: 3-4-82
Logged By: M.R. Musial
R.H. Prescott

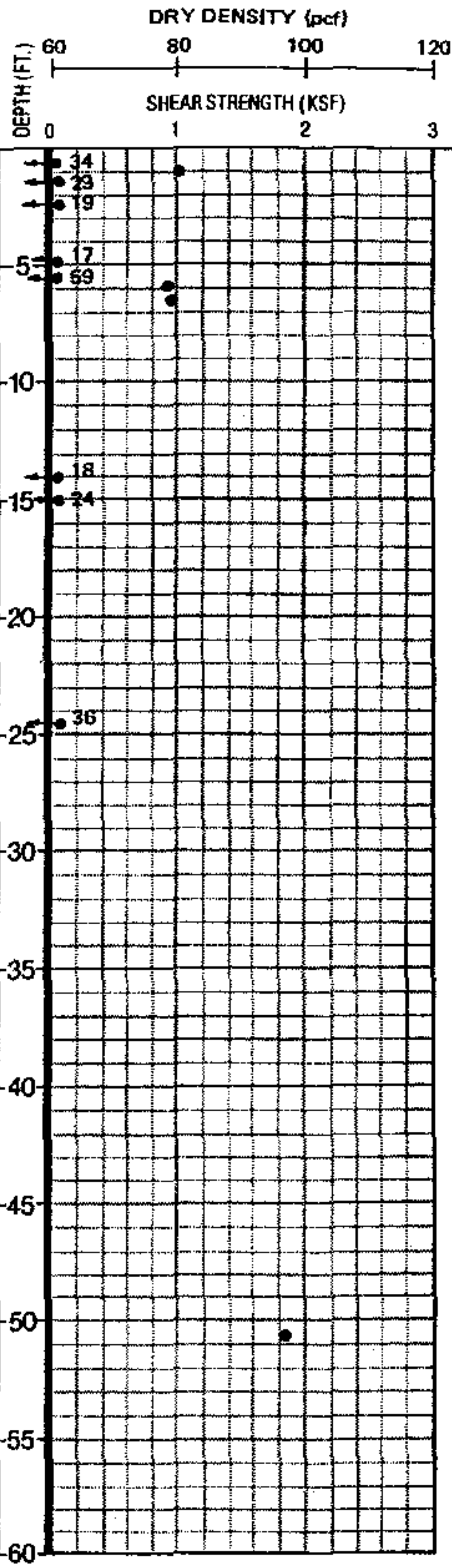
Approved: DGB
Date: 4-82

Job Number: 9612,031.08

LOG OF BORING NO. 6
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-6

BLOWS/FOOT	SAMPLING INTERVAL SAMPLE RECOVERY	DEPTH (FT.)	DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	−#4 SIEVE (%) [−#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	LL [PI]	OTHER TESTS
P 114/7"	S S		**BROWN ORGANIC SILT** (OL,V_x/V_r) V_x to 1/4" diameter, V_r to 1/8" thick, with fibrous organics and a trace of gravel to 1/4" diameter	-15.4		108 31.3 138 260		TCON TCON
100/5"	S	5	**MASSIVE ICE (ICE)**	-14.4		220 43.1		
115/9"	S	10	**GRAY GRAVELLY SAND** (SP-SM, V_x) 5% V_x to 1/4" diameter, fine to medium sand, with occasional subrounded gravel to 1/2" diameter	-13.3 -12.4 -12.1	92 [21.7]	23.6		SA
99	S	15	**ICE with GRAVELLY SAND** (ICE + SP,V_x/V_r) up to 70% visible ice, V_x to 1/2" diameter, V_r to 1/2" thick	-11.2		245 190		
50/3"	U S	20	**GRAY GRAVELLY SAND** (SP-SM,V_x) V_x to 1/4" diameter, fine to medium sand, with a trace of gravel to 1" diameter	-10.3 -9.9		12.9		
51/9"	S	25	**BROWN SILT** (ML,V_x/V_r) 20 to 30% visible ice, V_x to 1/2" diameter, V_r to 1/4" thick, with a trace of fine sand	-8.9		114		
50/1"	U S	30	**BROWN GRAVELLY SILTY SAND** (SM,V_x) 10% visible ice, V_x to 1/16" diameter, fine to coarse sand, with occasional subrounded gravel to 1" diameter	-8.4		7.3		
50/3"	U S	35	V_x to 1/4" diameter at 34.0'	-8.5	[7.4]	12.8		
	G	40		-8.4	76 [17.7]	16.6		SA
	G	45	V_x to 1/8" diameter at 43.0'	-8.5	[19.4	14.8		
	G	50		-8.6	59 [15.6]	11.9		SA
		55	Temperature measurements recorded on 4-17-82					
		60						



UTM Coordinates: N 25 538 242
E 1 699 991

Water Depth: - - -

Equipment: Mobile B-61, 8" Hollow Stem Auger

SHEAR STRENGTH
▲ — Torvane
△ — Compression Test

Date Completed: 3-4-82
Logged By: P.J. Ondra

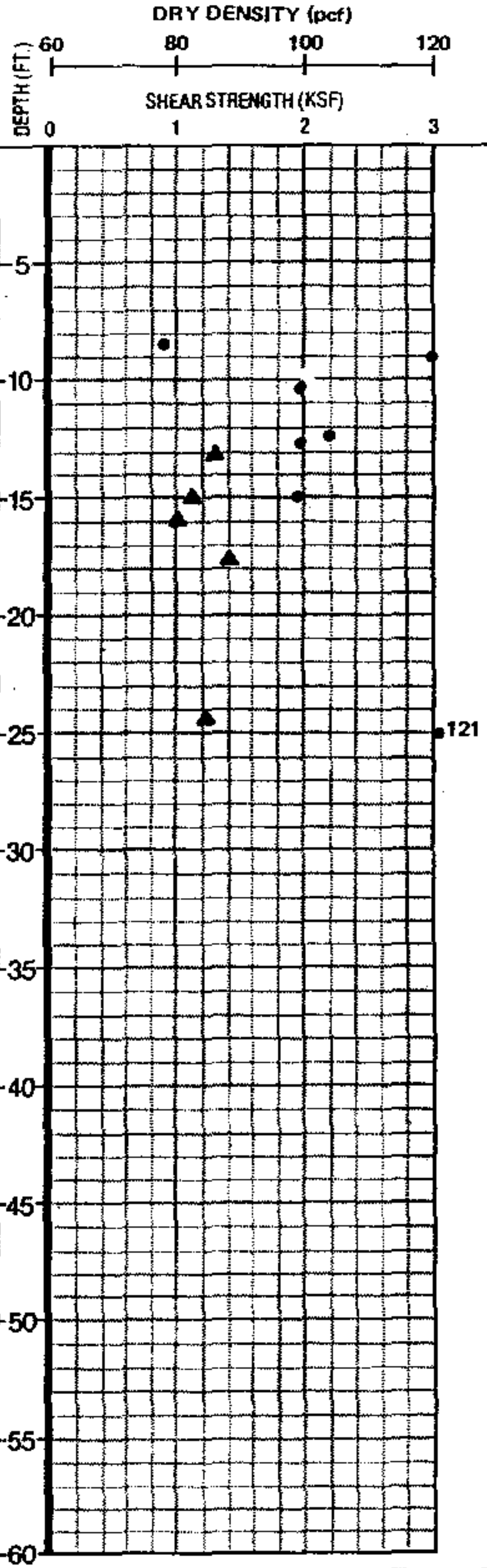
Job Number: 9612,031.08

Approved: DEB
Date: 4-82

LOG OF BORING NO. 7
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-7

BLOWS/FOOT	SAMPLING INTERVAL / SAMPLE RECOVERY	DEPTH (FT.)	DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	−#4 SIEVE (%) [−#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	LL [PI]	OTHER TESTS
P	S		**BROWN SILTY SANDY GRAVEL**	[-2.0]	56	23.8		EC,
			(GM) Loose, gravel to 2"		[29.3]	31.8		SA
P	T		diameter	[-2.1]	85			EC,
8	S		**GRAY GRAVELLY SAND (SP)**		[4.6]	15.4		SA
		5	loose, medium to fine sand,		60	9.5		EC,
10	S		gravel to 2" diameter, gravel	[-2.3]	[3.6]			SA
			content increasing with depth	[-2.2]		8.0		EC
7	S							
				[-3.0]		9.2		
12	S					6.7		EC
		10				15.3		
12	S			[-3.2]		[24.9]		EC
P	T		**GRAY SILT (ML)**			[24.3]		TC
			stiff to very stiff, with	[-3.2]		25.3		CON
			occasional fine gravel					EC
		15	becoming clayey at 14.0'	[-2.1]		28.8		EC
P	T					26.4		UU
			becoming sandy at 15.5'					
				[-2.6]		23.3		EC
P	T		becoming clayey at 17.5'					
		20						
			increasing sand content					
			with depth		90			SA
P	T				[47.0]	18.7		
		25	**GRAY GRAVELLY SAND (SP)**		[36.4]	14.0		
104	S		coarse to fine sand, with					
			occasional gravel to 1" diameter					
10	Ss	30						
			silt layer, with occasional					
	W		fibrous organics at 33.0'					
		35						
	W							
67	Ss		bonded (N_{be}) beginning at 37.0', occasional silt and gravel layers		60 [7.1]	13.9		SA
	W	40						
	W	45						
41	Ss	50	N_{bn} at 50.0'					
		55						
		60						



UTM Coordinates: N 25 546 772
E 1 702 499

Water Depth: 8.5'

Equipment: Mobile B-61, Rotary Wash

SHEAR STRENGTH

▲ — Torvane

△ — Compression Test

Date Completed: 3-11-82

Logged By: M.R. Musial
R.H. Prescott

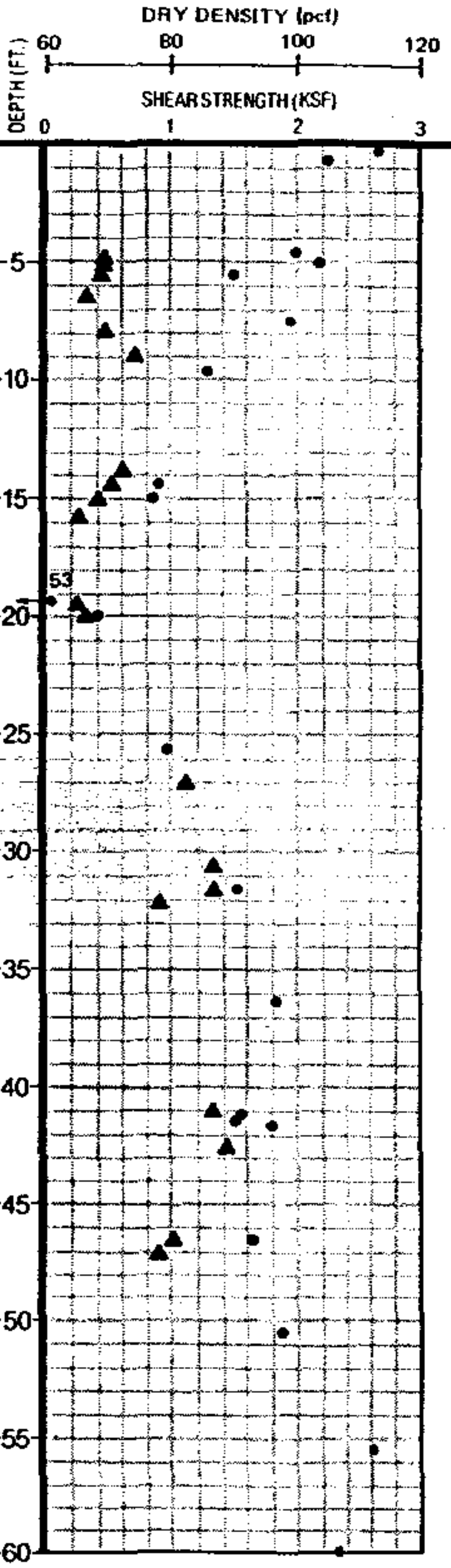
Job Number: 9612,031.08

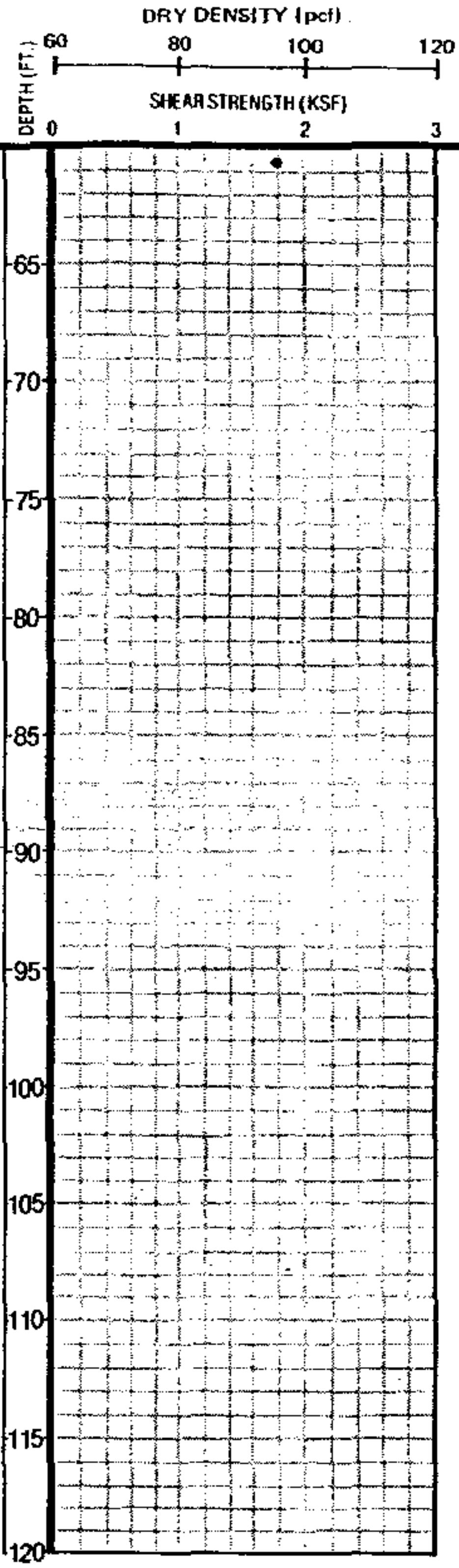
Approved: DEB
Date: 4-82

LOG OF BORING NO. 8
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-8

BLOWS/FOOT	SAMPLING INTERVAL SAMPLE RECOVERY	DEPTH (FT.)	DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	−#4 SIEVE (%) [−#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	LL [PI]	OTHER TESTS
P	S		**DARK GRAY SILTY SAND (SM)** loose, fine sand	[-2.1]	[36.5]	[22.7]		EC TC
P	T	5	**DARK GRAY SILT (ML)** soft to medium stiff, with a trace of sand, and occasional wood fragments at 7.0'	[-2.1] [-2.1] [-2.0] [-2.2]	[59.4]	[23.1] 32.1 28.2		EC CHEM CU EC CU
P	T			[-1.6] [-2.2]		[29.3 27.4 35.0 28.2		EC CON EC EC CU
P	T	10						EC
P	T			[-2.1]		37.0 41.8 40.7		CU CU EC, CON
P	T	15	occasional shell fragments to 1/8" diameter at 16.0'					EC EC
P	T	20	increasing sand content at 19.0'	[-1.9]		80.4 51.3 37.0		UU UU CON UU EC
			GRAY SILTY SAND (SM) medium dense, · sand					
P	T	25		[-1.7]	[67.4	33.2 35.7		EC
P	T	30	sand layer at 30.0' 1 foot clayey silt layer with occasional fibrous organics at 31.0'		[38.8	30.2		UU
P	T	35			[23.6]	27.8		
			DARK GRAY SILTY CLAY (CL) stiff to hard					
P	T	40		[-1.5]	[98.2]	[31.8]	35 [8]	EC CON MA UU UU
P	T	45				29.3		TC
P	S	50	**DARK GRAY SANDY SILT (ML)** stiff, with occasional gravel to 1/2" diameter becoming clayey at 51.5' increasing sand content at 53.0'			25.1		
91	S	55	**GRAY SANDY GRAVEL (GP)** dense to very dense, gravel to 2" diameter, with medium to coarse sand			16.5 2.8		
118	S	60			96 [0.2]	6.2		SA





UTM Coordinates: N 25 558 836
E 1 702 473

Water Depth: 9.5'

Equipment: Mobile B-61, Rotary Wash

SHEAR STRENGTH

▲ — Torvane

△ — Compression Test

Date Completed: 3-10-82

Logged By: M.R. Musial
R.H. Prescott

Job Number: 9612,031.08

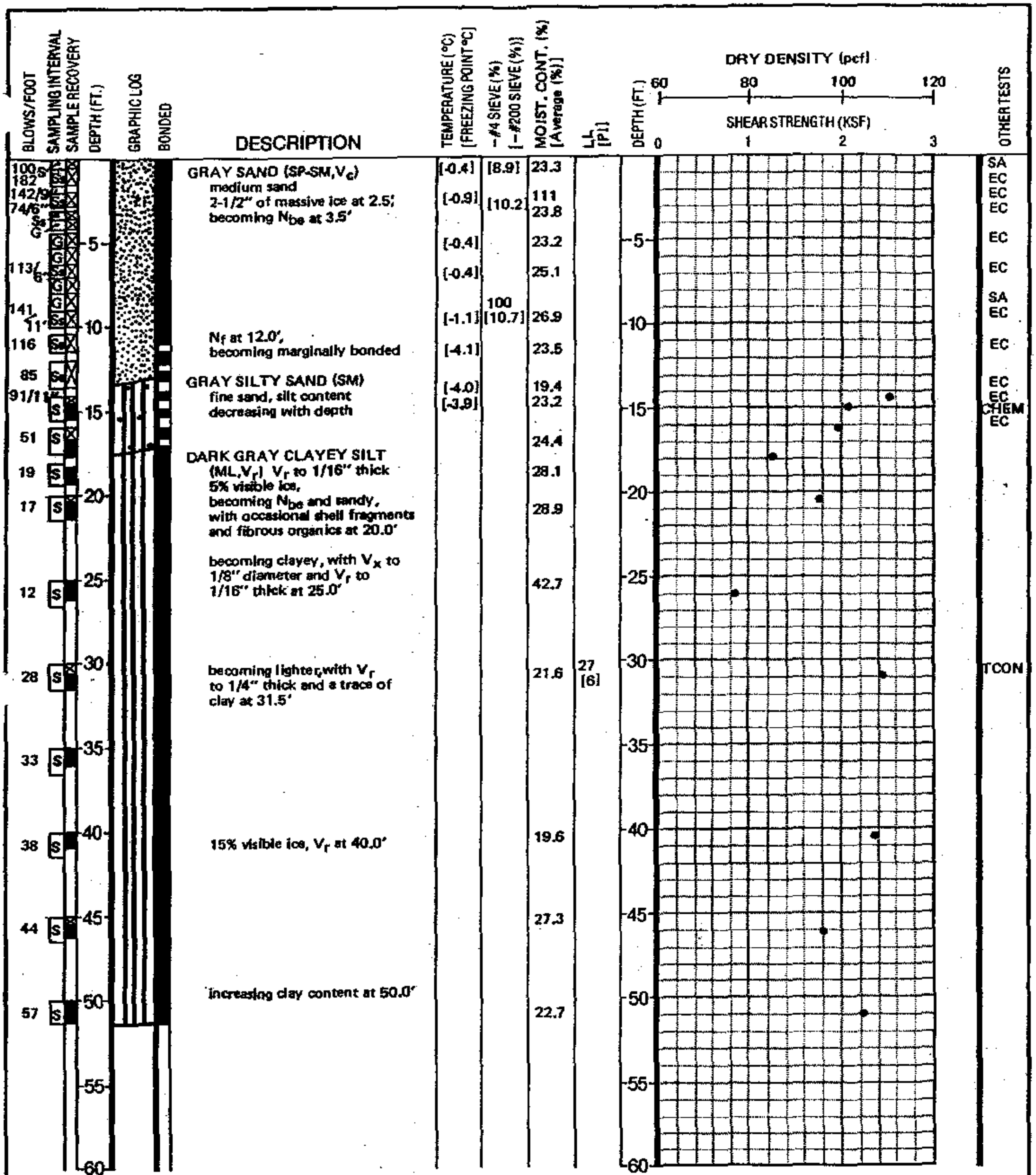
Approved: DEB

Date: 4-82

LOG OF BORING NO. 9
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE

B-9



BLOWS/FOOT	SAMPLING INTERVAL	DEPTH (FT.)	DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	–#4 SIEVE (%) [–#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	LL [PI]	OTHER TESTS
100/6" 182			**GRAY SAND (SP-SM,V_c)**	[-0.4]	[8.9]	23.3		SA EC
142/9" 74/6" Ss			medium sand 2-1/2" of massive ice at 2.5'; becoming N_{be} at 3.5'	[-0.9]	[10.2]	111 23.8		EC EC
G	G	5		[-0.4]		23.2		EC
113/6"	G			[-0.4]		25.1		EC
141/11"	G Ss	10		[-1.1]	100 [10.7]	26.9		SA EC
116	Ss		N_f at 12.0', becoming marginally bonded	[-4.1]		23.5		EC
85	Ss		**GRAY SILTY SAND (SM)** fine sand, silt content decreasing with depth	[-4.0] [-3.9]		19.4 23.2		EC EC CHEM EC
91/11"	S	15						
51	S					24.4		
19	S		**DARK GRAY CLAYEY SILT** (ML,V_r) V_r to 1/16" thick 5% visible ice,			28.1		
17	S	20	becoming N_{be} and sandy, with occasional shell fragments and fibrous organics at 20.0'			28.9		
12	S	25	becoming clayey, with V_x to 1/8" diameter and V_r to 1/16" thick at 25.0'			42.7		
28	S	30	becoming lighter, with V_r to 1/4" thick and a trace of clay at 31.5'			21.6	27 [6]	TCON
33	S	35						
38	S	40	15% visible ice, V_r at 40.0'			19.6		
44	S	45				27.3		
57	S	50	increasing clay content at 50.0'			22.7		
		55						
		60						

UTM Coordinates: N 25 562 119
E 1 709 962

Water Depth: ---

Equipment: Mobile B-61, 8" Hollow Stem Auger

SHEAR STRENGTH
▲ – Torvane
△ – Compression Test

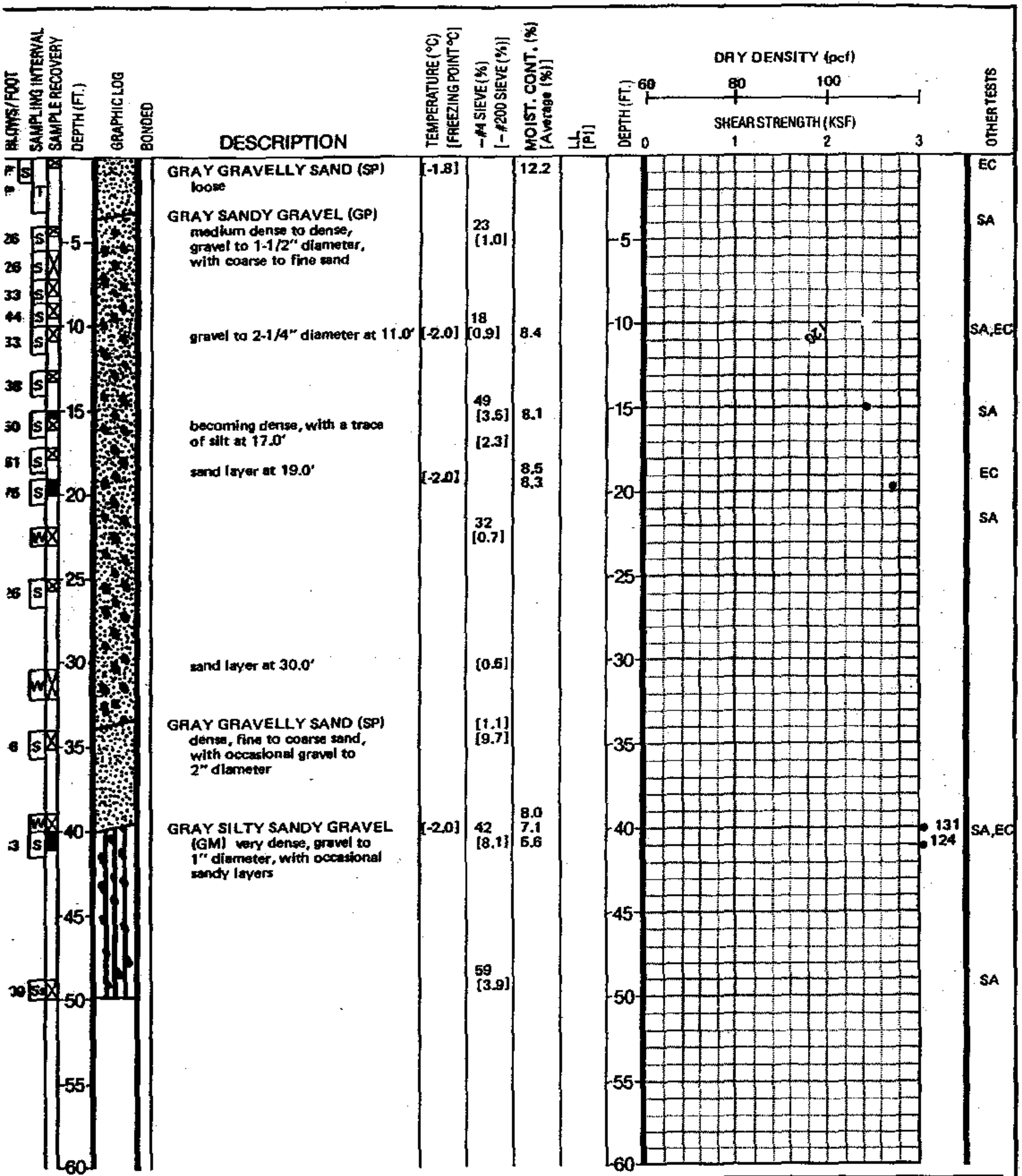
Date Completed: 3-9-82
Logged By: R.H. Prescott

Job Number: 9612,031.08

Approved: DGB
Date: 4-82

LOG OF BORING NO. 10
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-10



GRAY GRAVELLY SAND (SP)
loose

GRAY SANDY GRAVEL (GP)
medium dense to dense,
gravel to 1-1/2" diameter,
with coarse to fine sand

gravel to 2-1/4" diameter at 11.0'

becoming dense, with a trace of silt at 17.0'

sand layer at 19.0'

sand layer at 30.0'

GRAY GRAVELLY SAND (SP)
dense, fine to coarse sand,
with occasional gravel to
2" diameter

GRAY SILTY SANDY GRAVEL
(GM) very dense, gravel to
1" diameter, with occasional
sandy layers

SHEAR STRENGTH

▲ — Torvane

△ — Compression Test

JTM Coordinates:	N	25 552 762
	E	1 709 919

Water Depth: 9.5'
Equipment: Mobile B-61, Rotary Wash

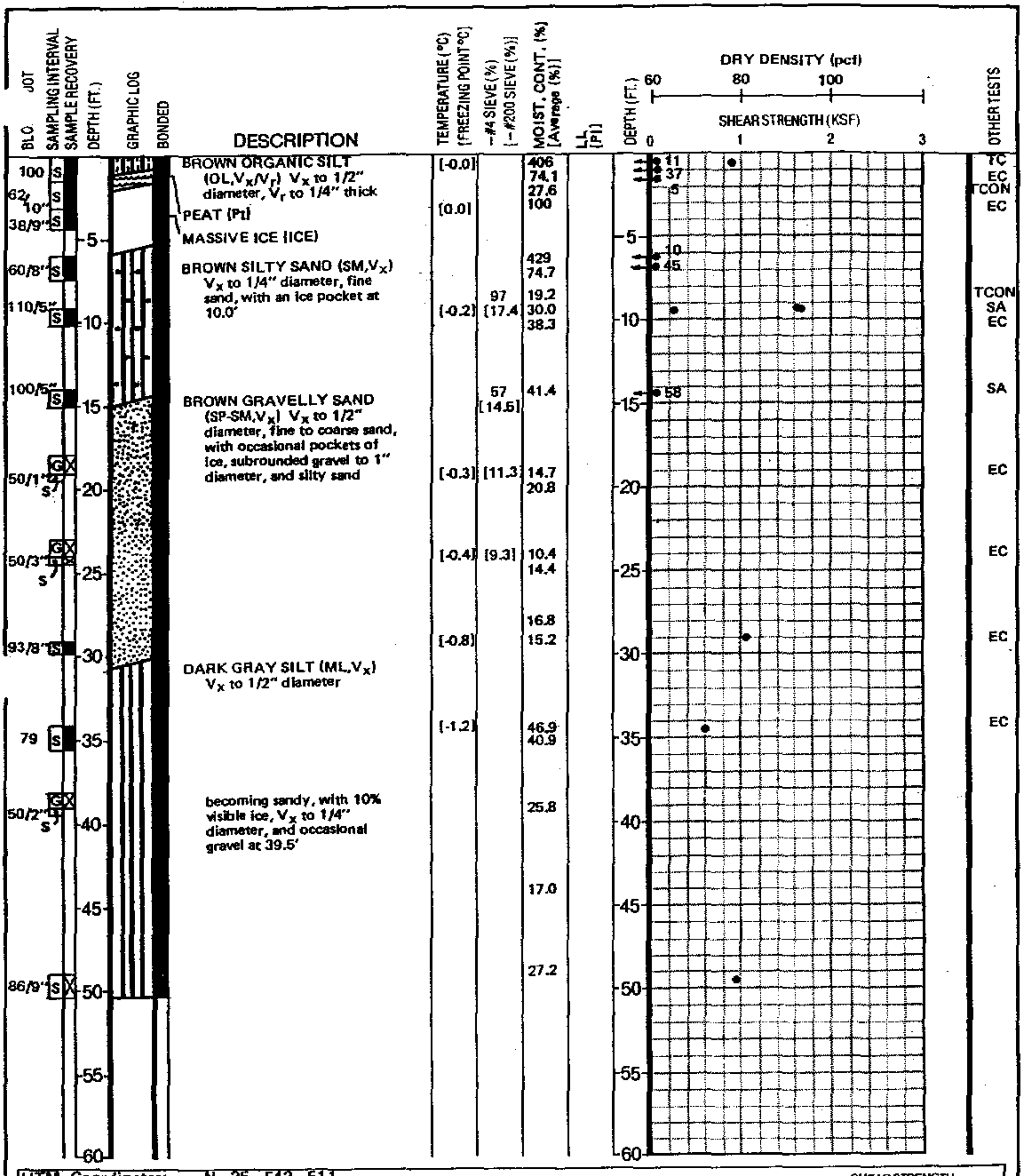
Date Completed: 3-11-82
Logged By: M.R. Musial
R.H. Prescott

Approved: DGB
Date: 4-82

Job Number: 9612,031.08

LOG OF BORING NO. 11
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-11



DESCRIPTION

BROWN ORGANIC SILT (OL,V_x/V_r) V_x to 1/2" diameter, V_r to 1/4" thick

PEAT (Pt)

MASSIVE ICE (ICE)

BROWN SILTY SAND (SM,V_x) V_x to 1/4" diameter, fine sand, with an ice pocket at 10.0'

BROWN GRAVELLY SAND (SP-SM,V_x) V_x to 1/2" diameter, fine to coarse sand, with occasional pockets of ice, subrounded gravel to 1" diameter, and silty sand

DARK GRAY SILT (ML,V_x) V_x to 1/2" diameter

becoming sandy, with 10% visible ice, V_x to 1/4" diameter, and occasional gravel at 39.5'

BLO.	TEMPERATURE (°C) [FREEZING POINT °C]	−#4 SIEVE (%) [−#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	OTHER TESTS
100	[-0.0]		406	TC
			74.1	EC
62/10"			27.6	TCON
	[0.0]		100	EC
38/9"				
			429	
60/8"			74.7	
		97	19.2	TCON
110/5"	[-0.2]	[17.4	30.0	SA
			38.3	EC
100/5"		57	41.4	SA
		[14.6]		
50/1"	[-0.3]	[11.3]	14.7	EC
			20.8	
50/3"	[-0.4]	[9.3]	10.4	EC
			14.4	
			16.8	
93/8"	[-0.8]		15.2	EC
	[-1.2]		46.9	EC
79			40.9	
50/2"			25.8	
			17.0	
86/9"			27.2	

UTM Coordinates: N 25 542 511
E 1 710 000

Water Depth: - - -

Equipment: Mobile B-61, 8" Hollow Stem Auger

SHEAR STRENGTH

▲ — Torvane

△ — Compression Test

Date Completed: 3-6-82

Logged By: P.J.Ondra

Approved:

Date: 4-82

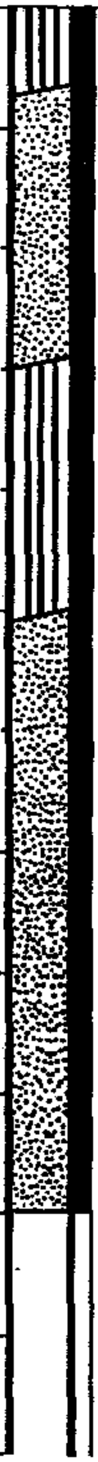
Job Number: 9612,031.08

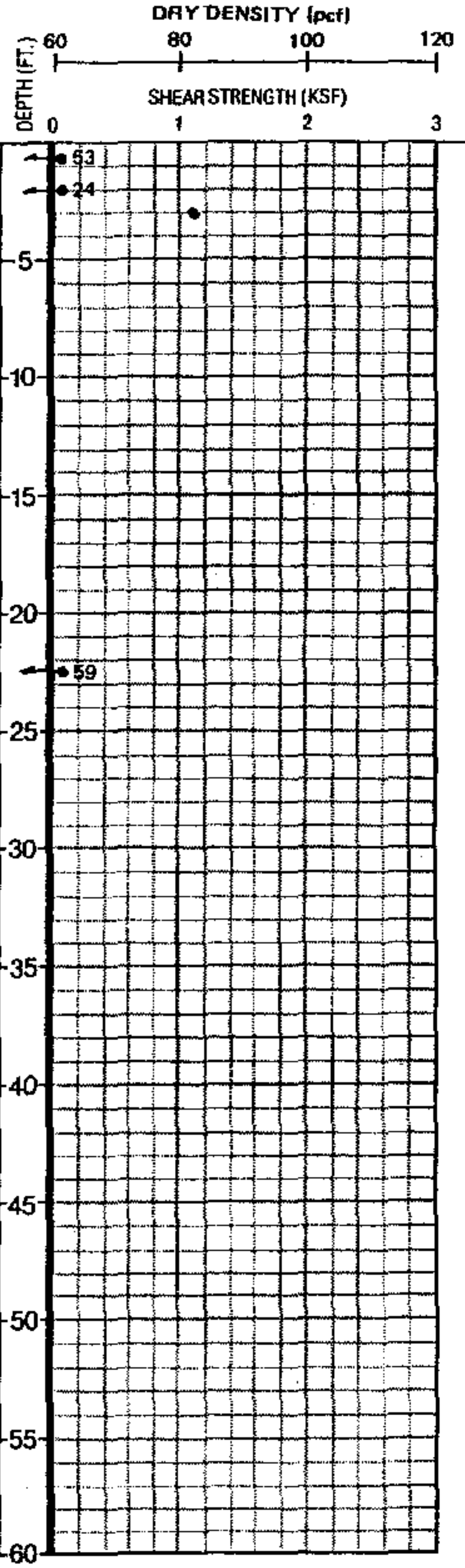
LOG OF BORING NO. 12
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE

B-12

BLOWS/FOOT	SAMPLING INTERVAL SAMPLE RECOVERY	DEPTH (FT.)	DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	−#4 SIEVE (%) [−#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	LL [PI]	OTHER TESTS
79/8"	S		**BROWN SANDY SILT** (ML,V_x/V_r) V_x to 1/4" diameter, with massive ice at 2.0', fibrous organics near surface	[-0.0] -19.4		60.1 54.9 153		TCON EC
50/4"	S			-15.0	51			
50/3"	S				[7.2]	21.0		SA, TCON EC
50/2"	G S	5	**GRAY GRAVELLY SAND** (SP-SM,V_x) 10-20% visible ice V_x to 1/2" diameter, fine to coarse sand, with occasional gravel to 1" diameter	[-0.3] -13.4		8.3		
50/4"	G S				[16.1]			
50/3"	S			-13.1				
	G							
50/3"	S	10		[-0.2] -12.5	78 [12.5]	15.8		SA,EC
50/3"	G S			[-0.2] -12.1		20.0		EC
		15	**DARK GRAY SANDY SILT** (ML,V_x/V_r) 20% visible ice, V_x to 1/2" diameter, V_r to 1/4" thick, with fine sand	-11.4				
61	S			-10.7		76.1 154	34 [9]	TCON TC
		20		-10.2				
			pockets of massive ice at 22.5'					
50/3"	S			[-1.2]		48.8 58.6		EC
		25		-9.0				
			BROWN GRAVELLY SAND (SP-SM,V_x) 10% visible ice, V_x to 1/16" diameter, fine to coarse sand, with occasional subrounded gravel to 2" diameter					
50/2"	G S				[11.5]	6.9		
		30		-8.3				
50/2"	G S			[-0.9]	55 [13.3]	12.9		SA, EC
		35		-8.5				
50/2"	G S		V_x to 1/4" diameter at 37.0'			11.0		
		40		-8.3				
50/2"	G G S				[12.6]	9.8		
		45		-8.4				
	G	50		[-0.6] -8.5	66 [10.9]	9.6		SA, EC
			Temperature measurements recorded on 4-17-82					
		55						
		60						





UTM Coordinates: N 25 540 930
E 1 722 914

Water Depth: ---

Equipment: Mobile B-61, 8" Hollow Stem Auger

SHEAR STRENGTH

▲ — Torvane

△ — Compression Test

Date Completed: 3-8-82

Logged By: P.J. Ondra

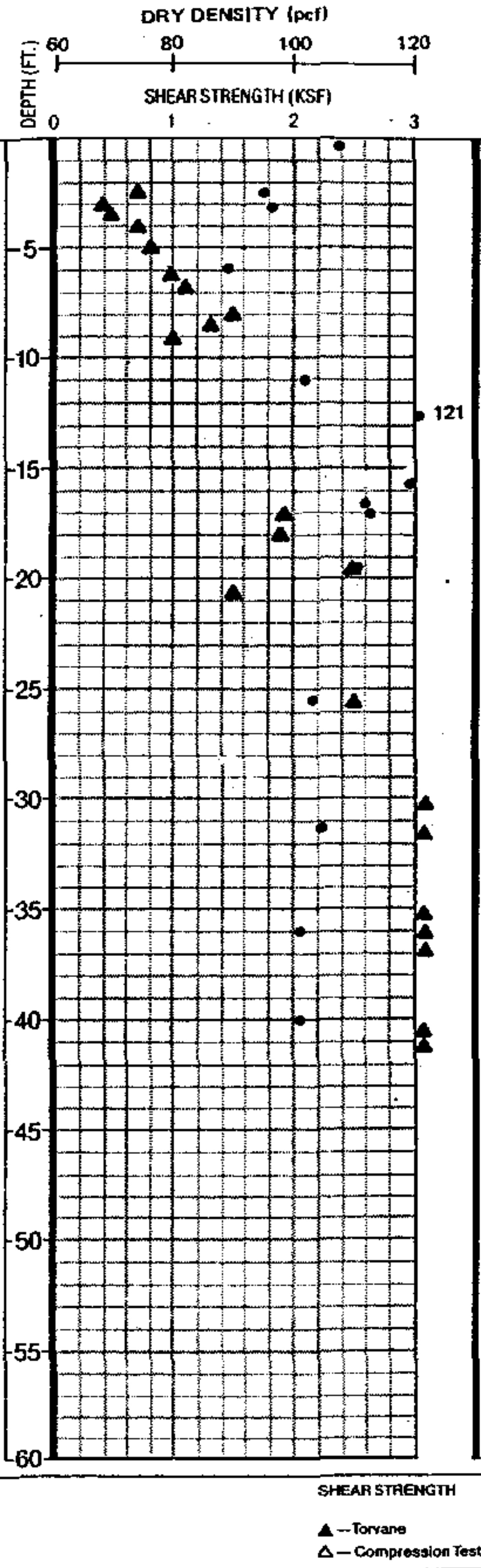
Job Number: 9612,031.08

Approved: DGB

Date: 4-82

LOG OF BORING NO. 13
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

BLOWS/FOOT	SAMPLING INTERVAL	DEPTH (FT.)	DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	-#4 SIEVE (%) [-#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	L.L. [PI]	OTHER TESTS
P	S		**GRAY SILTY SAND (SM)**	[-1.9]	98	21.7		EC
			loose, fine sand	[-1.9]	[27.5]	21.6		SA
						27.1		EC
P	T		**DARK GRAY SILT (ML)**			26.7		CU
			soft to medium stiff					CU
		5						
P	T			[-1.8]		31.1	32	EC
				[-1.8]		33.1	[6]	CON
						31.1		EC
P	T		**GRAY SILTY SAND (SM)** loose, with occasional gravel to 3/4" diameter					
		10						
P	S			[-2.1]	89	25.2		SA,
			GRAY GRAVELLY SAND (SP)		[27.9]	23.6		EC
33	S		medium dense, rounded	[-2.0]		16.1		EC
			gravel to 1" diameter			14.2		
22	S					6.2		
		15				9.5		
25	S		**GRAY CLAY (CL)**			15.1		
			stiff to hard			19.5	33	CON
P	T					18.1	[14]	UU
		20				20.4		
P	T							
		25						UU
P	T							
		30	**DARK GRAY CLAYEY SILT (ML)**					
P	T		stiff to hard			22.8		TC
		35				25.1	40	
P	T					25.1	[14]	UU
			becoming sandy, with occasional gravel to 3/8" diameter at 40.0'					
P	T	40				25.1		UU
	S				53			
44/6" 84/6"	S	45	**DARK GRAY GRAVEL (GM)** very dense, gravel to 1" diameter		[31.4]	18.9		SA
			becoming sandy at 48.0'		36			
60/5"	Ss	50			[2.0]	8.7		SA
		55						
		60						



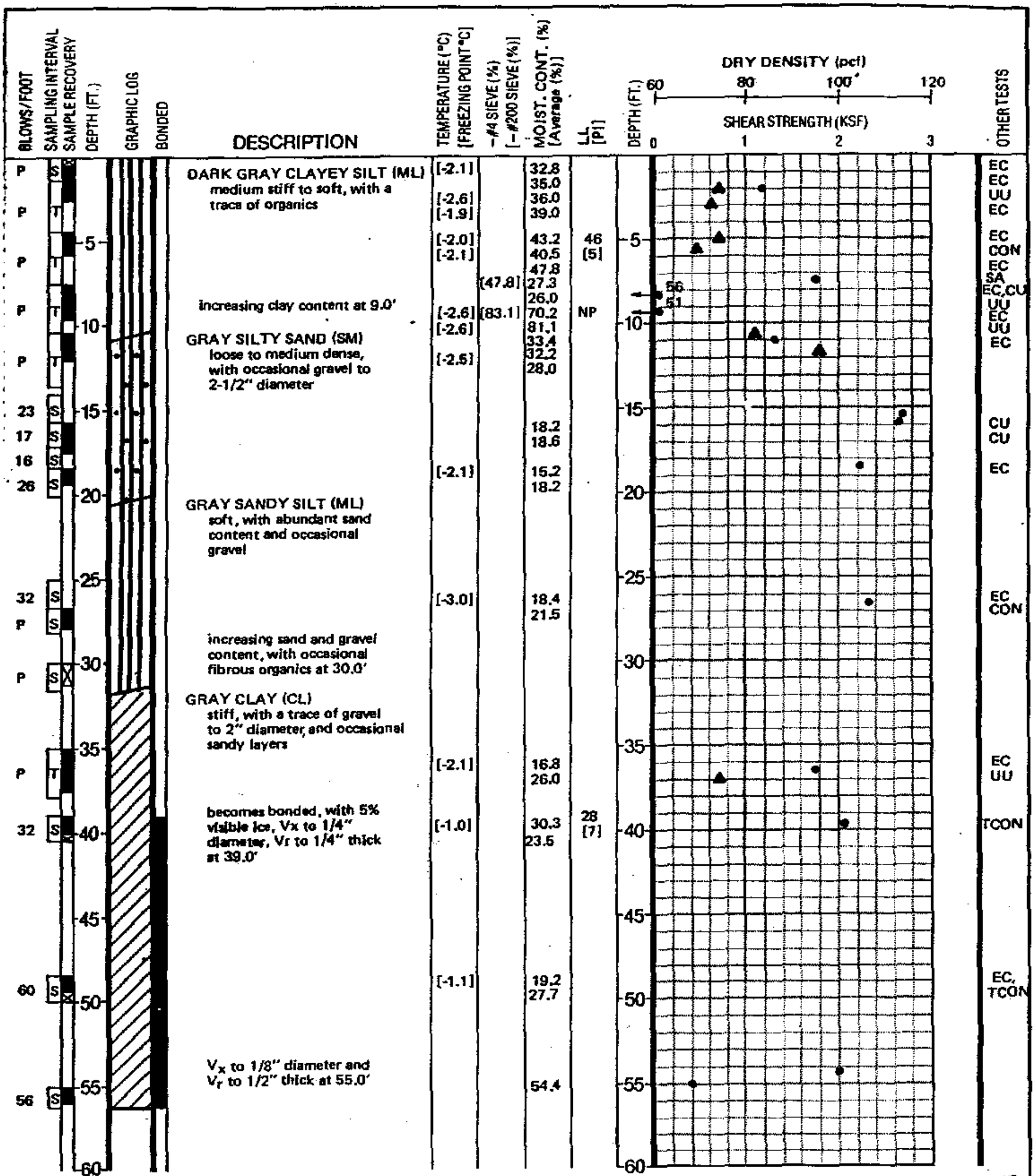
UTM Coordinates: N 25 551 633
E 1 722 995
Water Depth: 9.6'
Equipment: Mobile B-61, Rotary Wash

Date Completed: 3-12-82
Logged By: M.R. Musial
Job Number: 9612,031.08

Approved: DEB
Date: 4-82

LOG OF BORING NO. 14
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-14



UTM Coordinates: N 25 559 893
E 1 725 699
Water Depth: 16.5'
Equipment: Mobile B-61, Rotary Wash

SHEAR STRENGTH
▲ — Torvane
△ — Compression Test

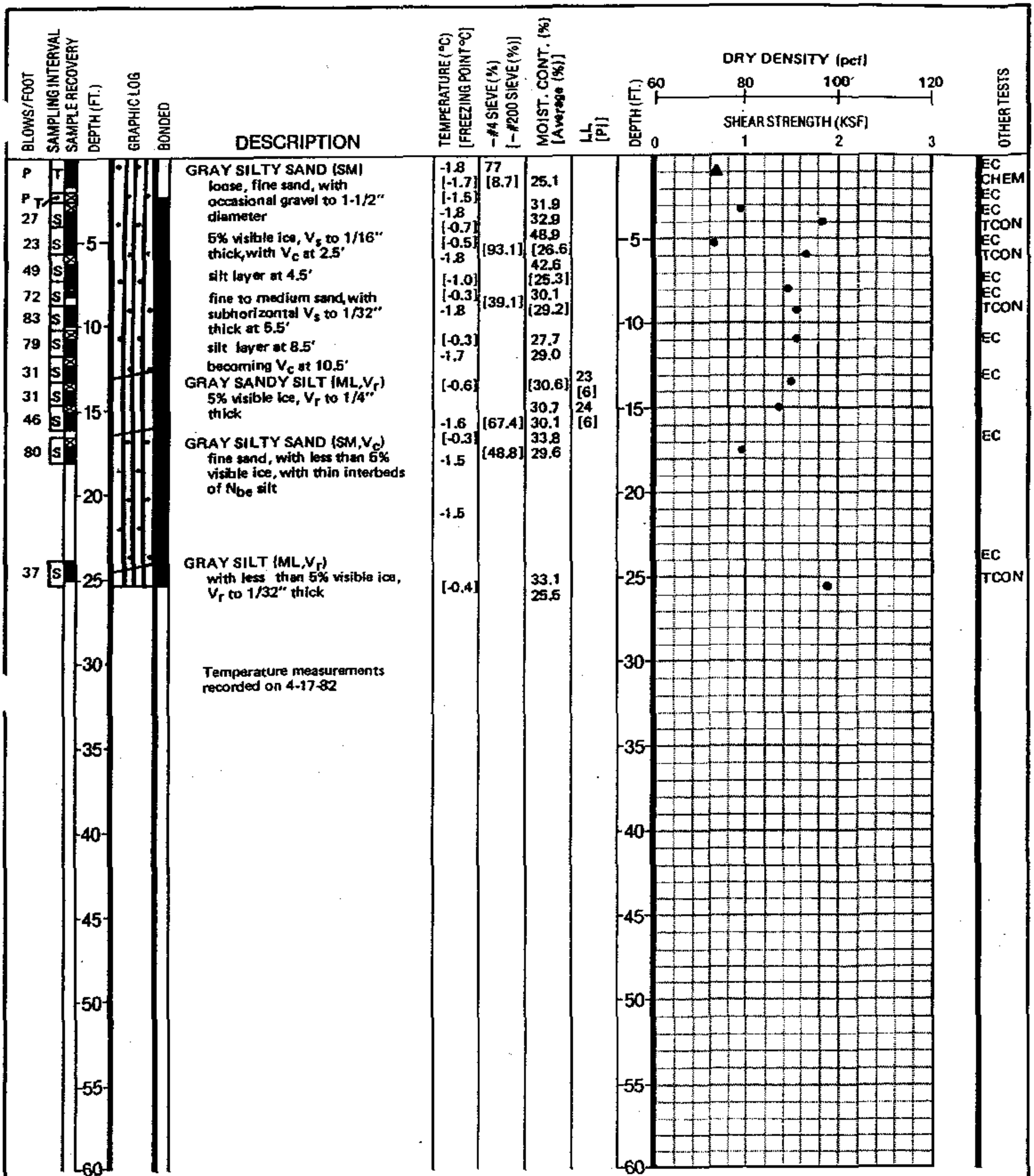
Date Completed: 3-13-82
Logged By: M.R. Musial
R.H. Prescott

Job Number: 9612,031.08

Approved: DGB
Date: 4-82

LOG OF BORING NO. 15
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-15



GRAY SILTY SAND (SM)
loose, fine sand, with occasional gravel to 1-1/2" diameter

5% visible ice, V_s to 1/16" thick, with V_c at 2.5'

silt layer at 4.5'

fine to medium sand, with subhorizontal V_s to 1/32" thick at 5.5'

silt layer at 8.5'

becoming V_c at 10.5'

GRAY SANDY SILT (ML,V_r)
5% visible ice, V_r to 1/4" thick

GRAY SILTY SAND (SM,V_c)
fine sand, with less than 5% visible ice, with thin interbeds of N_{be} silt

GRAY SILT (ML,V_r)
with less than 5% visible ice, V_r to 1/32" thick

Temperature measurements recorded on 4-17-82

UTM Coordinates: N 25 562 005
E 1 733 529

Water Depth: 31.0'

Equipment: Mobile B-61, Rotary Wash

SHEAR STRENGTH
▲ — Torvane
△ — Compression Test

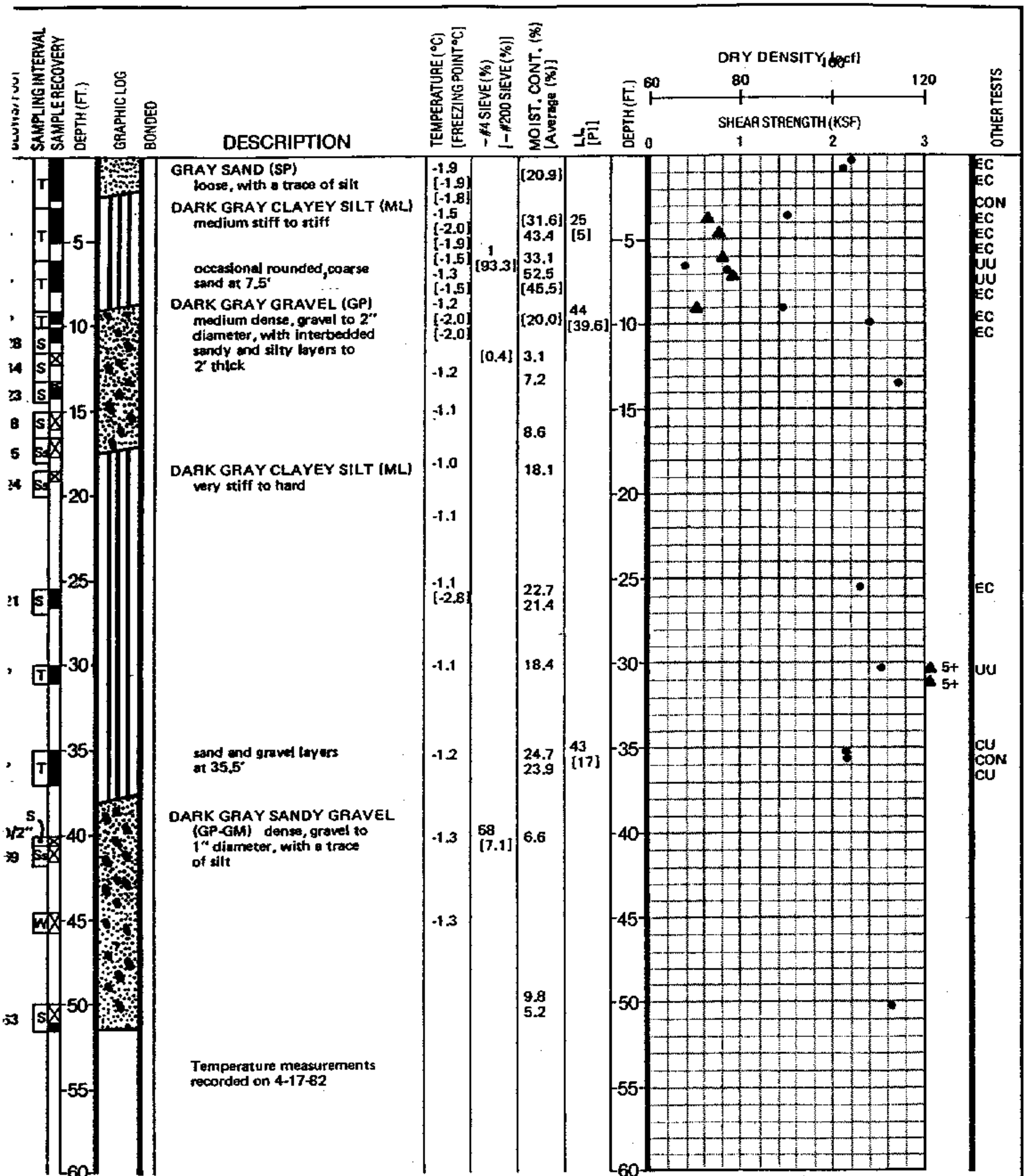
Date Completed: 3-12-82
Logged By: M.R. Musial
R.H. Prescott

Job Number: 9612,031.08

Approved: DGB
Date: 4-82

LOG OF BORING NO. 16
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-16



DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	-#4 SIEVE (%) [-#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	LL [PI]	OTHER TESTS
GRAY SAND (SP)	-1.9		[20.9]		EC
loose, with a trace of silt	[-1.9]				EC
	[-1.8]				CON
DARK GRAY CLAYEY SILT (ML)	-1.5				
medium stiff to stiff			[31.6]	25	EC
	[-2.0]		43.4	[5]	EC
	[-1.9]	1			EC
	[-1.5]	[93.3]	33.1		UU
occasional rounded, coarse	-1.3		52.5		UU
sand at 7.5'	[-1.5]		[46.5]		EC
DARK GRAY GRAVEL (GP)	-1.2			44	
medium dense, gravel to 2"	[-2.0]		[20.0]	[39.6]	EC
diameter, with interbedded	[-2.0]				EC
sandy and silty layers to		[0.4]	3.1		
2' thick	-1.2		7.2		
	-1.1				
			8.6		
DARK GRAY CLAYEY SILT (ML)	-1.0		18.1		
very stiff to hard					
	-1.1				
	-1.1		22.7		EC
	[-2.8]		21.4		
	-1.1		18.4		UU
sand and gravel layers	-1.2		24.7	43	CU
at 35.5'			23.9	[17]	CON CU
DARK GRAY SANDY GRAVEL					
(GP-GM) dense, gravel to	-1.3	58	6.6		
1" diameter, with a trace		[7.1]			
of silt					
	-1.3				
			9.8		
			5.2		
Temperature measurements recorded on 4-17-82					

UTM Coordinates: N 25 546 035
E 1 733 344
Water Depth: 9.0'
Equipment: Mobile B-61, Rotary Wash

SHEAR STRENGTH
▲ —Torvane
△ — Compression Test

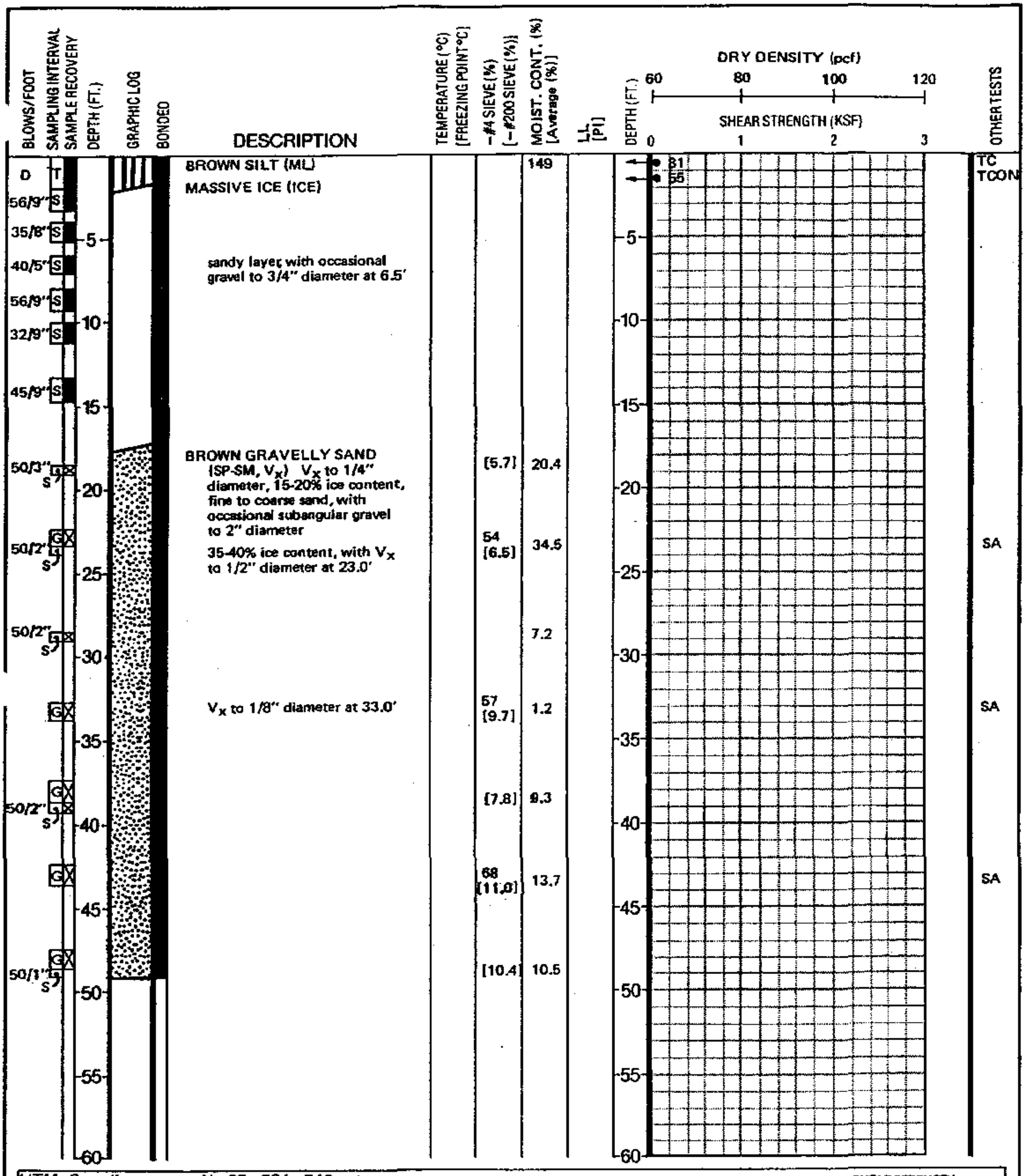
Date Completed: 3-13-82
Logged By: M.R. Musial
R.H. Prescott

Approved: DCB
Date: 4-82

Job Number: 9612,031.08

LOG OF BORING NO. 17
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-17



BLOWS/FOOT	SAMPLING INTERVAL	DESCRIPTION	-#4 SIEVE (%) [-#200 SIEVE (%)]	MOIST. CONT. (%)	OTHER TESTS
D	T	BROWN SILT (ML)		149	TC TCON
		MASSIVE ICE (ICE)			
56/9"	S				
35/8"	S				
40/5"	S	sandy layer with occasional gravel to 3/4" diameter at 6.5'			
56/9"	S				
32/9"	S				
45/9"	S				
50/3"	G S	BROWN GRAVELLY SAND (SP-SM, V_x) V_x to 1/4" diameter, 15-20% ice content, fine to coarse sand, with occasional subangular gravel to 2" diameter	[5.7]	20.4	
50/2"	G S	35-40% ice content, with V_x to 1/2" diameter at 23.0'	54 [6.5]	34.5	SA
50/2"	S			7.2	
	G	V_x to 1/8" diameter at 33.0'	57 [9.7]	1.2	SA
50/2"	G S		[7.8]	9.3	
	G		68 [11.0]	13.7	SA
50/1"	G S		[10.4]	10.5	

UTM Coordinates: N 25 534 749
E 1 730 229

Water Depth: - - -

Equipment: Mobile B-61, 8" Hollow Stem Auger

SHEAR STRENGTH

▲ — Torvane

△ — Compression Test

Date Completed: 3-9-82

Logged By: P.J. Ondra

Approved: DEG

Date: 4-82

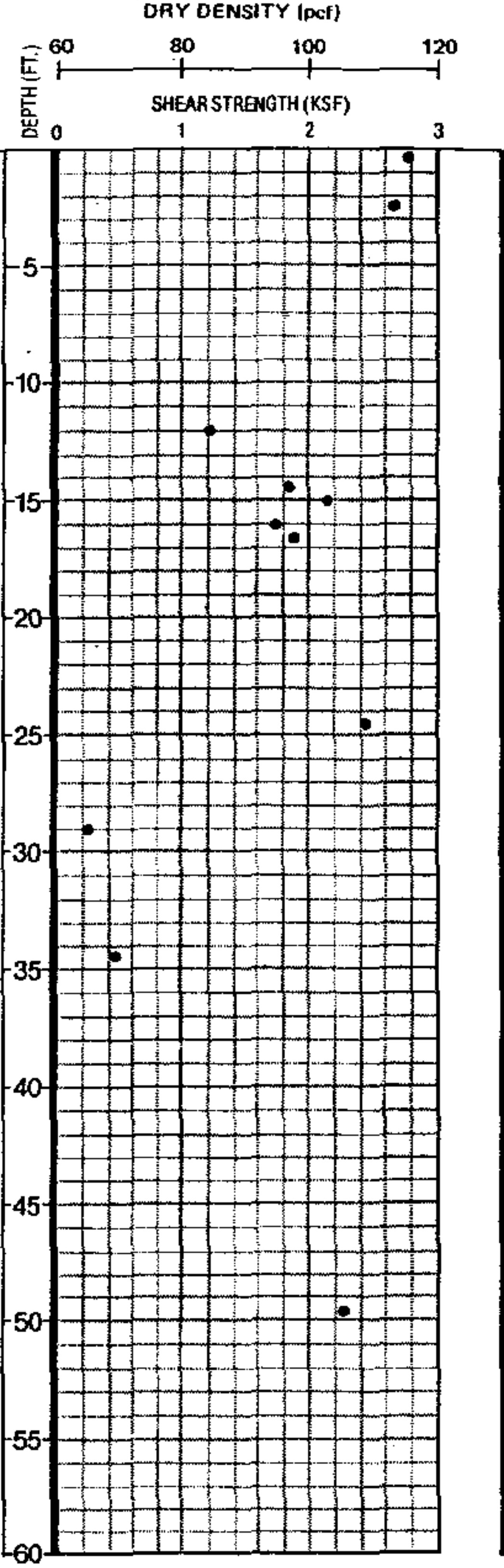
Job Number: 9612,031.08

LOG OF BORING NO. 18
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE

B-18

BLOWS/FOOT	SAMPLING INTERVAL / SAMPLE RECOVERY	DEPTH (FT.)	DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	−#4 SIEVE (%) [−#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	LL [PI]	OTHER TESTS
24	S		BROWN SAND (SP,N_f/N_{bn})	-19.4	91	2.8		
			medium to coarse sand,		[1.1]			
107/8"	S		gravelly, with occasional	[-0.4]		2.2		EC CHEM
	G		subrounded gravel to 3/4"	-13.2	14			
80/5"	S		diameter at 2.5'	[-0.1]	[3.0]	8.8		EC
		5		-12.8		15.0		EC
50/3"	G S		V_x to 1/16" diameter at 4.0'	[-0.3]		22.6		
			silt layer, with V_x to 1/8"	[-3.3]				
97/10"	S		diameter at 8.0'	-12.1		24.8		EC
	S		becoming gray, with	[-1.9]		28.3		EC
50/4"	G	10	increasing silt content at 8.5'	-11.5		20.2		EC
						21.3		
50/4"	S			[-3.6]	[5.5]	24.8		
	G			-10.3		41.2		
				[-3.7]				EC
			marginally bonded 14' to 16',	-9.1		[23.1]		EC
29	S	15	saturated	[-4.3]				EC
				[-4.1]		[28.6]		EC
15	S		GRAY SANDY SILT (ML,V_r)	[-4.1]				
			5% visible ice,	-7.8				
			V_r to 1/8" thick, with					
	S	20	fine sand	-7.4				
				[-3.0]				TCON
				-7.3		21.6	38	EC
16	S	25				[36.7]	[12]	
			V_x to 1/8" diameter at 29.0'	[-2.6]		[51.9]		EC
				-7.2				
24	S	30						
			organic material to 1/8"					
			diameter at 34.0'			51.1		
18	S	35		-7.0				
			pockets of fibrous organics					
			and wood pieces at 39.5'					
23	S	40		-6.6				
			gravelly, with occasional					
70/6"	G S		gravel to 3/4" diameter at 44.0'			12.1		
		45		-6.3				
			V_x to 1/4" diameter, with					
			30% ice content at 49.5'	[-2.5]		21.8		EC
61	S	50		-6.1		21.0		
			Temperature measurements recorded on 4-17-82					
		55						
		60						



UTM Coordinates: N 25 552 953
E 1 747 696

Water Depth: ---

Equipment: Mobile B-61, 8" Hollow Stem Auger

SHEAR STRENGTH

▲—Torvane

△—Compression Test

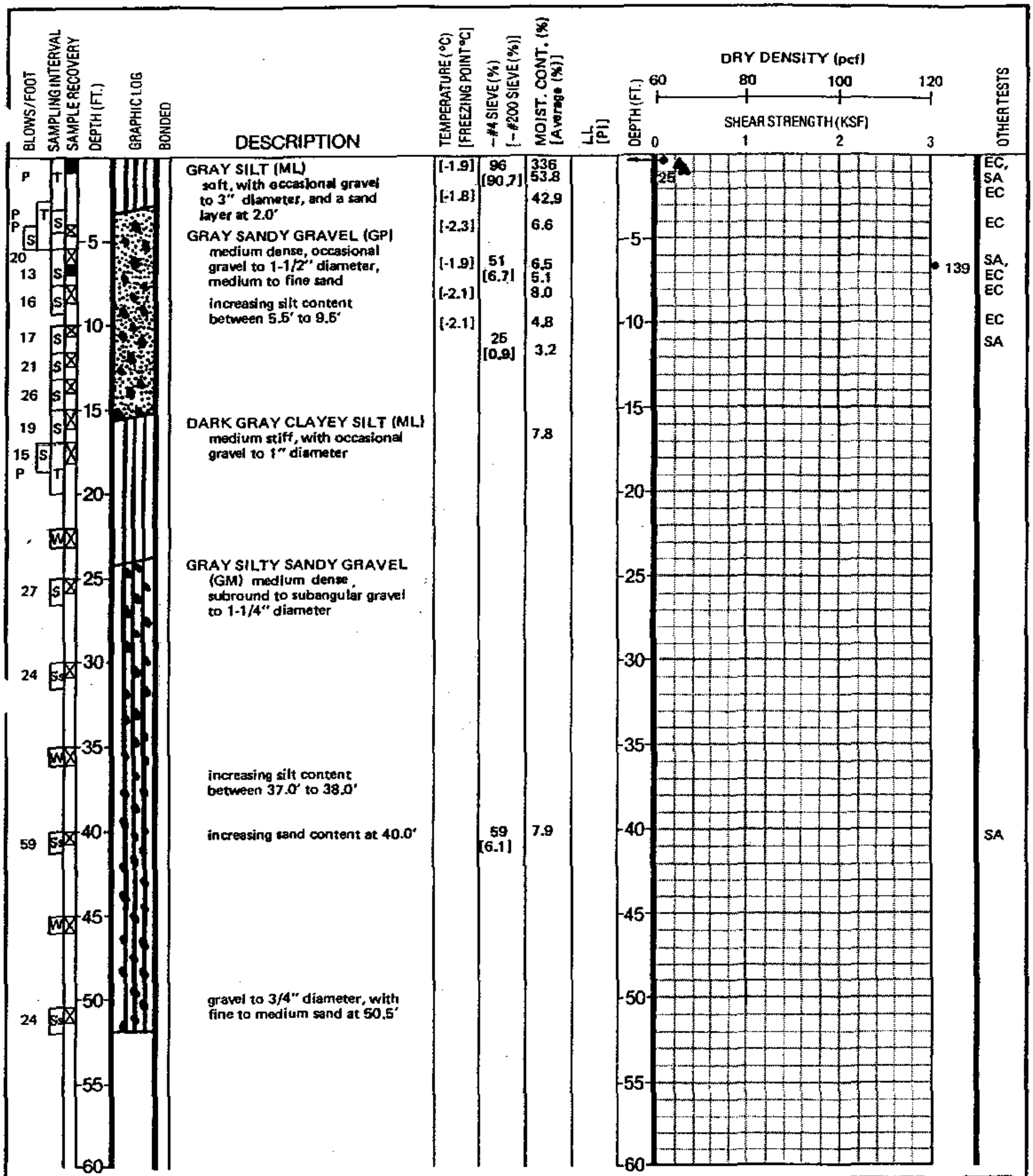
Date Completed: 3-10-82
Logged By: P.J. Ondra

Job Number: 9612,031.08

Approved: DGB
Date: 4-82

LOG OF BORING NO. 19
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-19



GRAY SILT (ML)
soft, with occasional gravel to 3" diameter, and a sand layer at 2.0'

GRAY SANDY GRAVEL (GP)
medium dense, occasional gravel to 1-1/2" diameter, medium to fine sand

increasing silt content between 5.5' to 9.5'

DARK GRAY CLAYEY SILT (ML)
medium stiff, with occasional gravel to 1" diameter

GRAY SILTY SANDY GRAVEL
(GM) medium dense, subround to subangular gravel to 1-1/4" diameter

increasing silt content between 37.0' to 38.0'

increasing sand content at 40.0'

gravel to 3/4" diameter, with fine to medium sand at 50.5'

BLOWS/FOOT	SAMPLING INTERVAL	TEMPERATURE (°C) [FREEZING POINT °C]	-#4 SIEVE (%) [-#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	DRY DENSITY (pcf)	OTHER TESTS
P	T	[-1.9]	96 [90.7]	336 53.8	25	EC, SA
		[-1.8]		42.9		EC
P P	T S	[-2.3]		6.6		EC
	S					
20						
13	S	[-1.9]	51 [6.7]	6.5 5.1	139	SA, EC
16	S	[-2.1]		8.0		EC
17	S	[-2.1]		4.8		EC
			25 [0.9]	3.2		SA
21	S					
26	S					
19	S			7.8		
15	S					
P	T					
	W					
27	S					
24	Ss					
	W					
59	Ss		59 [6.1]	7.9		SA
	W					
24	Ss					

UTM Coordinates: N 25 541 749
E 1 739 000

Water Depth: 8.8'

Equipment: Mobile B-61, Rotary Wash

SHEAR STRENGTH
▲ — Torvane
△ — Compression Test

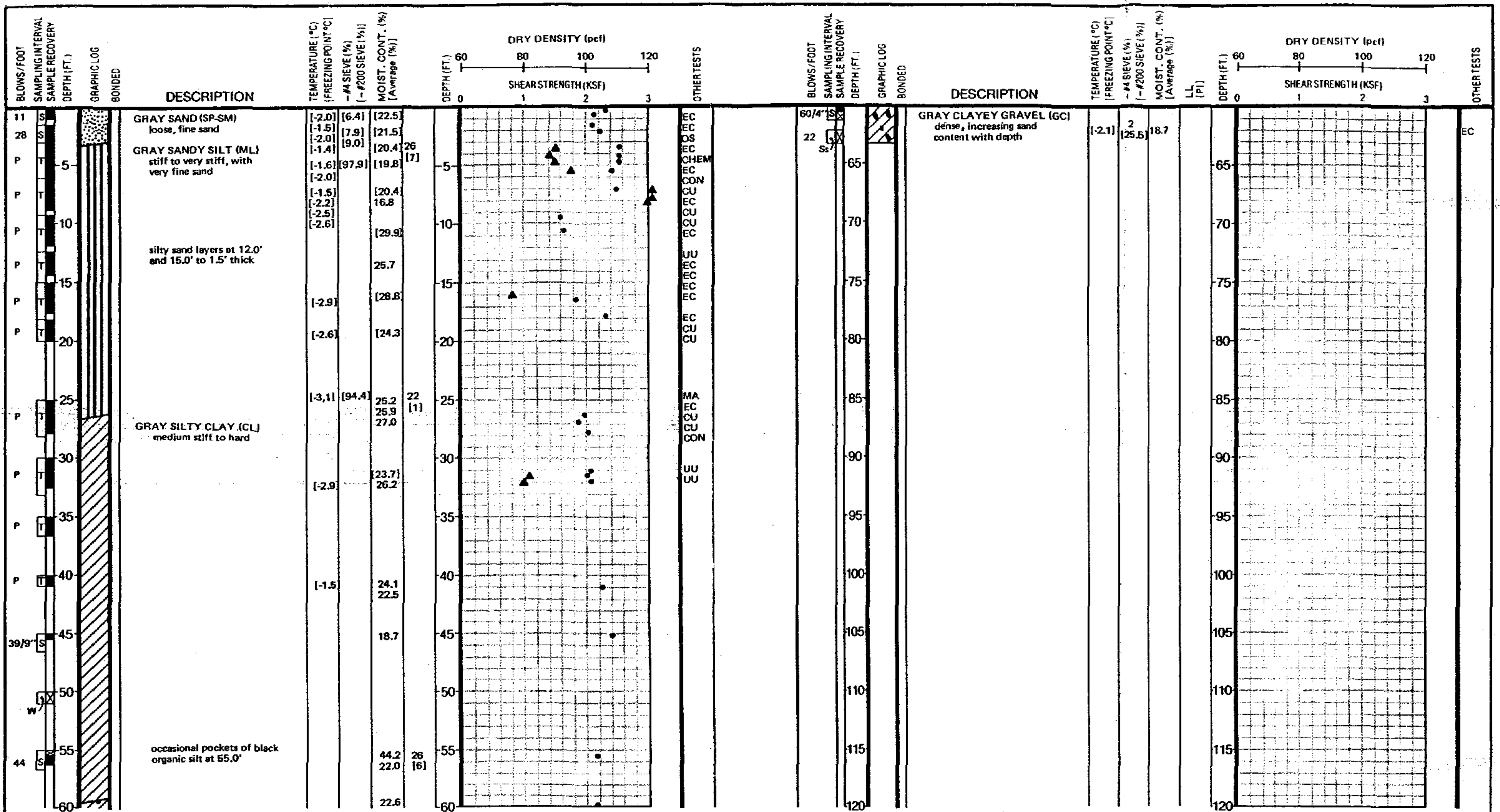
Date Completed: 3-15-82
Logged By: M.R. Musial
R.H. Prescott

Job Number: 9612,031.08

Approved: DGB
Date: 4-82

LOG OF BORING NO. 20
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-20



BLOWS/FOOT	SAMPLING INTERVAL	DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	−#4 SIEVE (%) [−#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]		OTHER TESTS
11	S	**GRAY SAND (SP-SM)**	[-2.0]	[6.4]	[22.5]		EC
		loose, fine sand	[-1.5]	[7.9]	[21.5]		EC
28	S		[-2.0]	[9.0]			DS
		GRAY SANDY SILT (ML)	[-1.4]		[20.4]	26	EC
P	T	stiff to very stiff, with				[7]	CHEM
		very fine sand	[-1.6]	[97.9]	[19.8]		EC
			[-2.0]				CON
P	T		[-1.5]		[20.4]		CU
			[-2.2]		16.8		EC
			[-2.5]				CU
			[-2.6]				CU
P	T				[29.9]		EC
		silty sand layers at 12.0'					UU
P	T	and 15.0' to 1.5' thick			25.7		EC
							EC
							EC
							EC
P	T		[-2.9]		[28.8]		
							EC
P	T		[-2.6]		[24.3]		CU
							CU
			[-3,1]	[94.4]	25.2	22	MA
P	T				25.9	[1]	EC
		GRAY SILTY CLAY (CL)			27.0		CU
		medium stiff to hard					CU
							CON
P	T				[23.7]		UU
			[-2.9]		26.2		UU
P	T						
P	T		[-1.5]		24.1		
					22.5		
39/9"	S				18.7		
44	S	occasional pockets of black			44.2	26	
		organic silt at 55.0'			22.0	[6]	
					22.6		

BLOWS/FOOT	SAMPLING INTERVAL	DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	−#4 SIEVE (%) [−#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	LL [PI]	OTHER TESTS
60/4"	S	**GRAY CLAYEY GRAVEL (GC)**					
22	S	dense, increasing sand content with depth	[-2.1]	2 [25.5]	18.7		EC

UTM Coordinates: N 25 566 788
E 1 705 180

Water Depth: 25.0'

Equipment: Mobile B-61, Rotary Wash

SHEAR STRENGTH

▲ — Torvane

△ — Compression Test

Date Completed: 3-9-82

Logged By: M.R. Musial
R.H. Prescott

Job Number: 9612,031.08

Approved: DEG

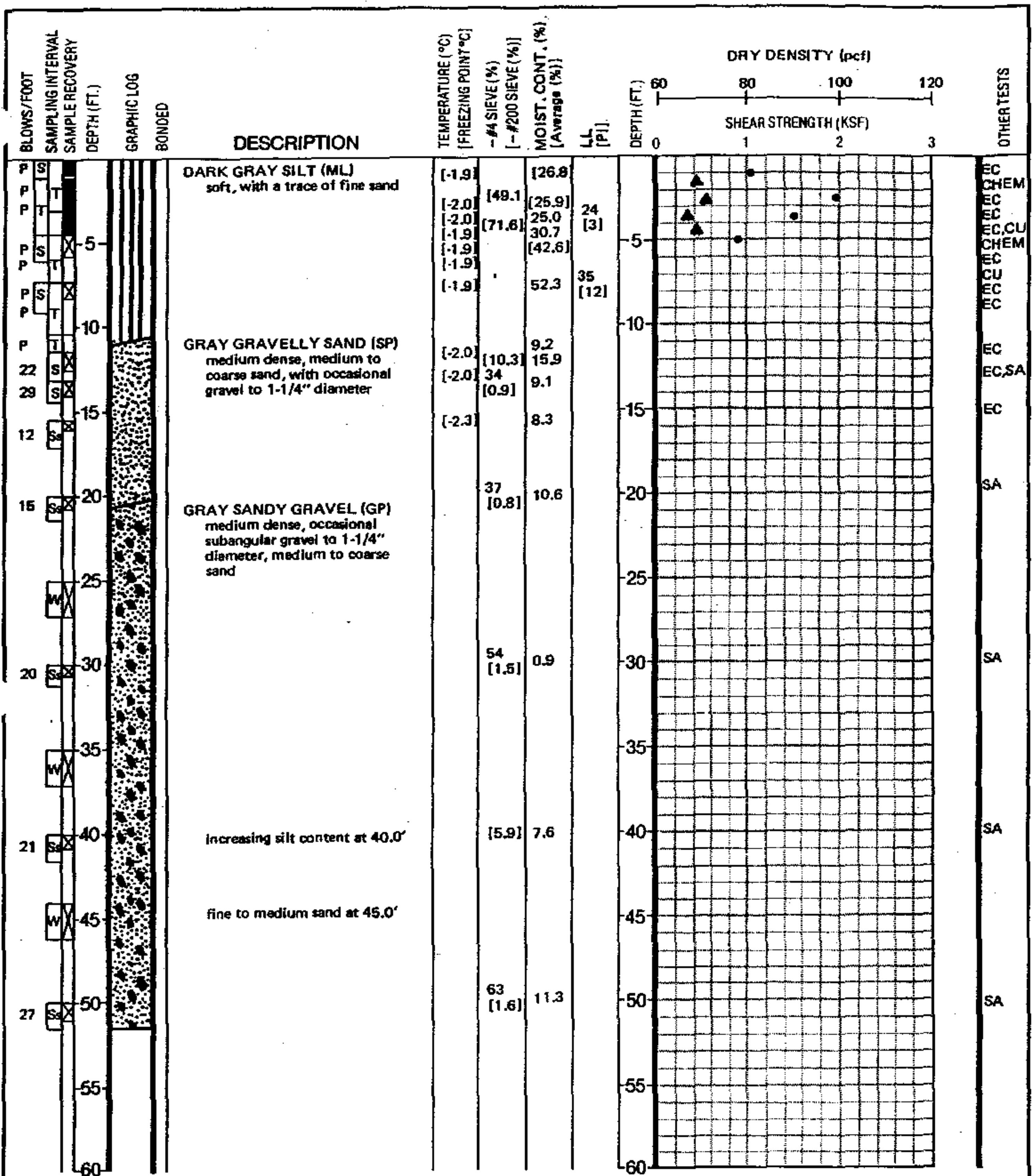
Date: 4-82

LOG OF BORING NO. 21

Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE

B-21



BLOWS/FOOT	SAMPLING INTERVAL	SAMPLE RECOVERY	DEPTH (FT.)	DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	-#4 SIEVE (%) [-#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	LL [PI]	OTHER TESTS
P P P P P P P	S T T S T S T		5 10	**DARK GRAY SILT (ML)** soft, with a trace of fine sand	[-1.9] [-2.0] [-2.0] [-1.9] [-1.9] [-1.9] [-1.9]	[49.1 [71.6]	[26.8] [25.9] 25.0 30.7 [42.6] 52.3	24 [3] 35 [12]	EC CHEM EC EC EC,CU CHEM EC CU EC EC
P 22 29 12	T S S Ss		15	**GRAY GRAVELLY SAND (SP)** medium dense, medium to coarse sand, with occasional gravel to 1-1/4" diameter	[-2.0] [-2.0] [-2.3]	[10.3] 34 [0.9]	9.2 15.9 9.1 8.3		EC EC,SA EC
15	Ss		20	**GRAY SANDY GRAVEL (GP)** medium dense, occasional subangular gravel to 1-1/4" diameter, medium to coarse sand		37 [0.8]	10.6		SA
	W		25						
20	Ss		30			54 [1.5]	0.9		SA
	W		35						
21	Ss		40	increasing silt content at 40.0'		[5.9]	7.6		SA
	W		45	fine to medium sand at 45.0'					
27	Ss		50			63 [1.6]	11.3		SA
			55 60						

UTM Coordinates: N 25 551 551
E 1 677 694

Water Depth: 15.0'

Equipment: Mobile B-61, Rotary Wash

SHEAR STRENGTH

▲ — Torvane

△ — Compression Test

Date Completed: 3-6-82
Logged By: M.R. Musial
R.H. Prescott

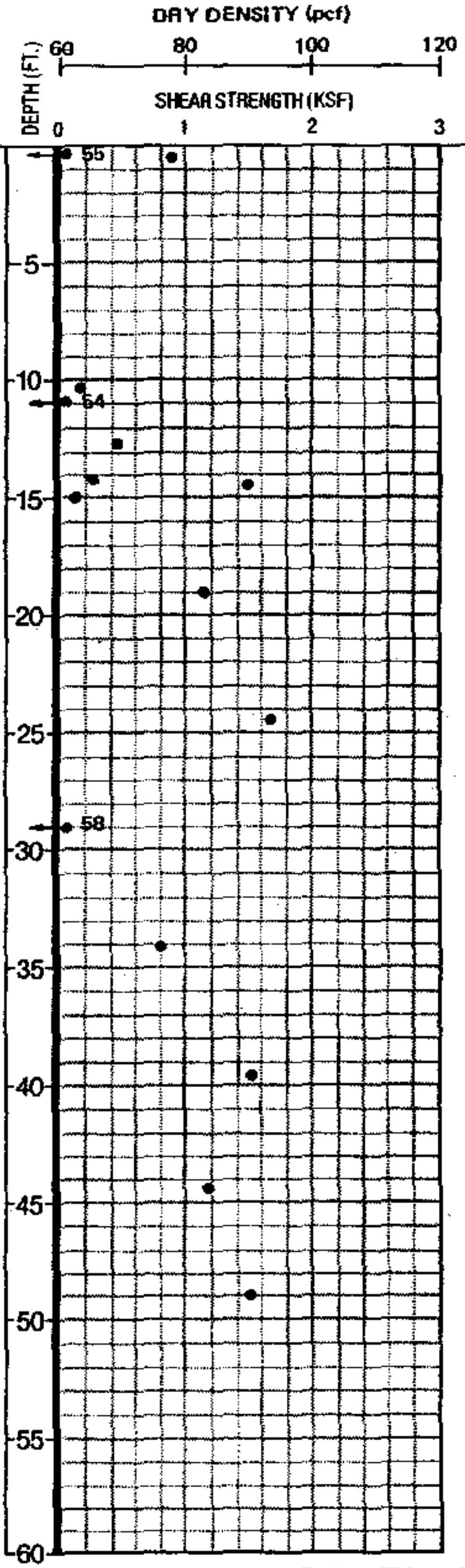
Job Number: 9612,031.08

Approved: DGB
Date: 4-82

LOG OF BORING NO. 22
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-22

BLOWS/FOOT	SAMPLING INTERVAL	DEPTH (FT.)	DESCRIPTION	TEMPERATURE (°C) [FREEZING POINT °C]	–#4 SIEVE (%) [–#200 SIEVE (%)]	MOIST. CONT. (%) [Average (%)]	LL [PI]	OTHER TESTS
133	S		**BROWN SILT (ML,V_x)** V_x to 1/4" diameter, 20-25% visible ice	[-0.1]		42.9 29.5 30.3 23.2	21 [8]	TCON TC,EC TCON
83/9"	S							
67/9"	S	5	**MASSIVE ICE (ICE)**					
34/9"	S			[0.0]				EC
47/9"	S			[0.0]				EC
		10	**BROWN SANDY SILT (ML,V_x)** 15-20% visible ice content, V_x to 1/4" diameter	[0.6]	[88.4	41.6 47.4 64.6		EC TCON
102/9"	S							
100	S		**GRAY SILTY CLAY (CL,V_r)** V_r to 1" thick, with 20-40% visible ice				33 [11]	TC
80	S	15		[-1.5]		49.1 30.8 37.8 56.7		EC
83	S	20				31.9		
			less ice below 20 feet					
102	S	25						
107/6"	S	30	**BROWN SILTY SAND (SM,N_{be})** fine to medium sand	[-0.4]	[15.5	23.7 22.8		EC
			GRAY SILTY CLAY (CL,V_x/V_r) V_x to 1/4" diameter, V_r to 1/4" thick, 5-10% visible ice					
98	S	35				32.5		
76	S	40	V_r to 1/8" thick at 39.0'			27.7	27 [7]	TCON
30/10"	S	45				27.2		
56	S	50		[-1.4]		29.3 25.5		EC
		55						
		60						



UTM Coordinates: N 25 548 668
E 1 763 017
Water Depth: - - -
Equipment: Mobile B-61, 8" Hollow Stem Auger

SHEAR STRENGTH
▲—Torvane
△—Compression Test

Date Completed: 3-11-82
Logged By: P.J. Ondra

Approved: DEB
Date: 4-82

Job Number: 9612,031.08

LOG OF BORING NO. 23
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
B-23

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS				TYPICAL NAMES
COARSE GRAINED SOILS MORE THAN HALF IS LARGER THAN #200 SIEVE	GRAVELS MORE THAN HALF COARSE FRACTION IS LARGER THAN NO. 4 SIEVE SIZE	CLEAN GRAVELS WITH LITTLE OR NO FINES	GW	WELL GRADED GRAVELS, GRAVEL - SAND MIXTURES
			GP	POORLY GRADED GRAVELS, GRAVEL - SAND MIXTURES
		GRAVELS WITH OVER 12% FINES	GM	SILTY GRAVELS, POORLY GRADED GRAVEL - SAND - SILT MIXTURES
			GC	CLAYEY GRAVELS, POORLY GRADED GRAVEL - SAND - CLAY MIXTURES
	SANDS MORE THAN HALF COARSE FRACTION IS SMALLER THAN NO. 4 SIEVE SIZE	CLEAN SANDS WITH LITTLE OR NO FINES	SW	WELL GRADED SANDS, GRAVELLY SANDS
			SP	POORLY GRADED SANDS, GRAVELLY SANDS
		SANDS WITH OVER 12% FINES	SM	SILTY SANDS, POORLY GRADED SAND - SILT MIXTURES
			SC	CLAYEY SANDS, POORLY GRADED SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN HALF IS SMALLER THAN #200 SIEVE	SILTS AND CLAYS LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS, OR CLAYEY SILTS WITH SLIGHT PLASTICITY
			CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
			OL	ORGANIC CLAYS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACIOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS
			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
			OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS			Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS

KEY TO TEST DATA

CON	-	Consolidation
TCON	-	Thaw Consolidation
LL	-	Liquid Limit (in %)
PL	-	Plastic Limit (in %)
G_s	-	Specific Gravity
SA	-	Sieve Analysis
MA	-	Mechanical Analysis
UU	-	Unconsolidated Undrained Triaxial
CU	-	Consolidated Undrained Triaxial
CD	-	Consolidated Drained Triaxial
UC, F	-	Unconfined Compression, frozen
EC	-	Electrical Conductivity
TC	-	Thermal Conductivity
PI*	-	Nonplastic

KEY TO SAMPLE TYPE

T	-	Shelby Tube
S	-	3" Split Spoon
S_s	-	2" Split Spoon
W	-	Rotary Wash
G_b	-	Driven Thickwalled Tube
G	-	Grab
P	-	Pushed
■	-	"Undisturbed" Sample
⊠	-	Bulk or Grab Sample

ICE DESCRIPTIONS

GROUP SYMBOL	ICE VISIBILITY AND CONTENT	SUBGROUP			
		DESCRIPTION		SYMBOL	
N	Segregated ice not visible by eye	Poorly bonded or friable		N_f	
		Well bonded	No Excess Ice	N_b	N_{bn}
			Excess ice microscopic		N_{be}
V	Segregated ice is visible by eye, ice one inch or less in thickness	Individual ice crystals or inclusions		V_x	
		Ice coatings on particles		V_c	
		Random or irregularly oriented ice formations		V_r	
		Stratified or distinctly oriented ice formations		V_s	
ICE	Ice greater than one inch in thickness	Ice with soil inclusions		ICE + soil type	
		Ice without soil inclusions		ICE	

Harding Lawson Associates
Engineers, Geologists
& Geophysicists

Unified Soil Classification and
Key to Test Data
Pt. Thomson Development Project, Winter 1982
Geotechnical Study, EXXON Company, U.S.A.

PLATE
B-24

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DSB	4/82		

It was also used on occasion to move the drill rig between test borings. Because rough ice conditions necessitated slow travel time, most rig moves were accomplished using the D-6 Cat. A Tucker "Sno-cat" was occasionally used to transport crews.

The drill crews were quartered in a 16-person sled-camp stationed on the ice at Point Hopson. The camp was equipped with sleeping units, kitchen, shower, water shack, and a diesel generator for electrical power. Communications were maintained between the camp and drilling enclosure and between the camp and CATCO operations office using radios.

1. Drilling Methods

With the exception of Borings 19 and 23, the offshore test borings were drilled with rotary wash techniques utilizing sea water drilling fluid. The criteria for determining the total depth of drilling were as follows:

1. In all cases, a minimum depth of 50 feet below the ground surface or mudline
2. Five feet into coarse-grained soil (gravels or gravelly soil)
3. Fifteen feet into ice-bonded soil

Each test boring was cased with 4-inch I. D. casing from the enclosure deck to at least 10 feet below mudline. Additional casing was used when the test boring would not stay open during either the drilling or sampling operations. The casing was advanced and retracted using a 300-pound safety drop hammer. Borings 19 and 23 were drilled with 8-inch O.D. hollow stem auger and a Nodwell-mounted B-61 drill rig as described in Section C of this Appendix.

2. Sampling Methods

Sampling was performed continuously to at least 15 feet below mudline and at 5 to 10 foot intervals throughout the remaining depth of the test borings. The four types of samples and the procedures used to obtain samples are discussed in the following sections. The symbol in parentheses following the sample type appears on the test boring logs and designates the sampling method used. The symbol corresponds to those presented on the Test Boring Key Sheet, Plate B-24.

a. Undisturbed Samples (T)

Undisturbed samples were taken with Shelby tubes in accordance with ASTM Test Method D 1587-74. The Shelby sampler was a 2.87-inch I.D. by 36-inch long steel tube. The tube was placed at the bottom of the test boring and pushed (P) by the hydraulic system of the drill rig approximately 34 inches into the soil or to refusal. This method was used in soft to stiff silts and clays and in loose to medium dense sands.

b. Drive Samples (S) and (Ss)

Drive sampling was performed by driving a split-spoon sampler either 18 inches into the soil or to refusal. Two sizes of split-spoon were used depending upon the soil conditions. A 2.4-inch I.D. by 3.0-inch O.D. sampler (S), containing three 6.0-inch brass liners to retain the sample, was primarily used to sample coarse-grained soil and hard silts and clays that could not be sampled using a Shelby tube. The 2.4-inch I.D. sampler was also used to recover disturbed specimens that were not recovered when using a Shelby tube. Where dense or ice-bonded coarse-grained soils were encountered, drive samples were taken with a 1.4-inch I.D. by 2.0-inch O.D. (Ss) split-spoon sampler.

Both sizes of samplers were advanced by either a 300-pound hammer falling 30 inches, or by the hydraulic system of the drill rig. When the hammer was used, the number of blows required to drive each 6-inch increment was recorded. This driving information is presented on the test boring logs as the number of blows required to drive the sampler the last 12 inches, or fraction thereof.

c. Grab Samples (G)

Grab samples were occasionally taken during auger drilling on the barrier islands. Samples were either taken from the auger cuttings or directly from the augers as they were pulled from the hole.

d. Rotary Wash Samples (W)

Rotary wash samples consist of soil particles that have settled out of the circulating wash water after it has been run through a sieve. This technique was primarily used if representative samples of gravel could not be obtained by using the split-spoon sampler. The wash technique was also used to obtain intermediate samples when the sampling interval was greater than five feet. Since the grinding action of the bit within the casing breaks down the larger gravel particles, the in situ materials are probably more coarsely graded than these specimens indicate.

C. Onshore Drilling Investigation

Five test borings were drilled to explore the onshore soil conditions between March 4 and 8, 1982. The depths drilled varied between 48.5 to 50.5 feet; the conditions encountered are shown on the Test Boring Logs. Thermistor wells were installed in Test Borings 7 and 13.

The onshore borings and the two borings on Flaxman Island were drilled with a Mobile Drill B-61 rig that was equipped with eight-inch O.D. hollow-stem auger and mounted on a Nodwell carrier. A Tucker Sno-cat was used to transport the crew to the rig, as a work station for the geologist, and as a shelter from the weather.

The onshore drill crew worked a single 12-hour shift and consisted of a geologist, a driller, and a drill helper. The geologist directed the drilling operation, logged the soils encountered in the borings, and obtained representative samples for laboratory testing.

The majority of the samples that were taken were either type (S) or type (G), as discussed in the offshore investigation section. Modified Shelby tubes (T) were also used occasionally. These samplers are standard Shelby tubes with hardened cutting teeth. They are drilled (D) into bonded, fine-grained soil by slowly rotating the sampler while applying pressure by the drill rig hydraulic system.

D. Sample Handling

The soil samples were visually examined, classified and logged in the field by our engineer/geologist. Whenever possible, sample temperatures as well as torvane and/or pocket penetrometer readings were taken. Shelby tubes and split-spoon liners were sealed with electrical tape to prevent moisture loss and then tagged. Bulk and grab samples were placed in heavy-duty plastic bags, sealed, and tagged. In the field, unbonded samples were protected against freezing by storing them in either a cooler chest or heated enclosure. Bonded samples were kept frozen by storing them in either a cooler chest that was packed with blue-ice or a chest freezer.

All of the samples from the onshore borings were returned to our operations base at Deadhorse on a regular basis. The bonded samples from the offshore borings were stored in a chest freezer at -10^{0}C until the end of the drilling program. Unbonded offshore samples were transported daily to the camp, where they were stored in a heated room until they could be transferred to Deadhorse. In Deadhorse, all of the bonded samples were stored in a chest freezer for a minimum amount of time until they could be shipped via air freight to our laboratory in Anchorage. To protect the bonded specimens from thermal shock, they were shipped in insulated containers and stored in our laboratory cold room at -6^{0}C until tested.

E. Drilling Operations Diary

Date	Activity
3/03/82	Moved drill rigs, sled-camp and crew to PTD project area, offshore rig began drilling Test Boring 6 (TB 6).
3/04/82	Completed TB 6 and installed a thermistor string. Moved to and began drilling TB 3. Onshore rig (Nodwell) moved to and completed TB 7 and installed thermistor well.
3/05/82	Completed TB 3. Moved to and began drilling TB 22. Nodwell moved to and completed TB 1.
3/06/82	Completed TB 22. Moved to and began drilling TB 2. Nodwell moved to and completed TB 12.
3/07/82	Completed TB 2. Moved to and completed TB 4. Moved to TB 5. Nodwell - mechanical standby - starter malfunctioned.
3/08/82	Completed TB 5 and installed thermistor well. Moved to and began drilling TB 21. Nodwell moved to and completed TB 13 and installed thermistor well.
3/09/82	Completed TB 21. Moved to and completed TB 10. Moved to and began drilling TB 9. Nodwell moved to and completed TB 18.
3/10/82	Completed TB 9. Moved to and began drilling TB 8. Nodwell moved to and completed TB 19 and installed thermistor well.

E. Drilling Operations Diary (continued)

3/11/82	Completed TB 8. Moved to and completed TB 11. Moved to and began drilling TB 14. Nodwell moved to and completed TB 23.
3/12/82	Completed TB 14. Moved to and began drilling TB 16. TB 16 terminated at 25.5 feet due to ice movement and high winds. Installed thermistor string. Moved to and began drilling TB 15. Nodwell drill rig and crews demobilized.
3/13/82	Completed TB 15. Moved to and began drilling TB 17.
3/14/82	Completed TB 17 and installed thermistor string. Moved to and began drilling TB 20.
3/15/82	Completed TB 20. Demobilized enclosed drill rig, sled-camp and crews.

APPENDIX C
GROUND TEMPERATURE MEASUREMENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

APPENDIX C
GROUND TEMPERATURE MEASUREMENTS

A. General

Three thermistor strings and four thermistor wells were installed in the test borings listed in Table C-1.

TABLE C-1. THERMISTOR INSTALLATIONS

Test Boring	Location of Installation	Depth of Test Boring (ft)	Date Boring Completed	Total Depth of Temperature Data (ft)
5	Barrier Island	51.5	03/08/82	50.0
6	Offshore	51.5	03/04/82	45.0
7	Onshore	49.0	03/04/82	49.0
13	Onshore	50.0	03/08/82	50.0
16	Offshore	25.5	03/12/82	21.0
17	Offshore	50.5	03/13/82	45.0
19	Barrier Island	50.5	03/10/82	50.0

B. Equipment

1. Offshore

Hard-wired thermistor strings were used to obtain ground temperature measurements in the offshore test borings. The strings were constructed using 20-gauge, 52-conductor cable and YSI Model 44034 bead-in-glass thermistors. The Model 44034 thermistor has an interchangeability of $\pm 0.1^{\circ}C$ between $-10^{\circ}C$ to $80^{\circ}C$, a resistance of 5000 ohms at $25^{\circ}C$, and exhibits a resistance change of approximately 860 ohms per degree centigrade.

Each thermistor string was 175 feet long, including a 75-foot leadwire, and contained 24 thermistors spaced at 3-foot intervals for the first 21 feet and 5-foot intervals to 100 feet. The thermistors were installed through an incision in the cable sheath and individually grounded. They were then sealed into the cable with heat shrink tubing, and silicone caulk and the incision was covered with heat-shrink tubing. Finally, a 41-pin, male plug was installed on the lead-out end of the thermistor string and covered with a waterproof cap. The thermistors were placed in an ice bath held at a constant $0^{o}C$ and the corresponding resistance was compared to the manufacturers' values.

2. Onshore and Barrier Islands

Ground temperature measurements for the barrier islands and onshore test borings were recorded using a retractable probe that contained a YSI Model 44007 thermistor and a Victory, Serial No. 50 thermistor. The interchangeability of the YSI thermistor is $\pm 0.2^{o}C$ for the temperature range $0^{o}C$ to $80^{o}C$. Also, it has a resistance of 5000 ohms at $25^{o}C$ and exhibits a resistance change of approximately 860 ohms per degree centigrade. The precision calibrated Victory thermistor has an interchangeability of $\pm 0.05^{o}C$ and a resistance of 4560 ohms at $0^{o}C$ and exhibits a resistance change of approximately 220 ohms per degree centigrade.

The thermistors were placed side by side at the bottom of a six-inch-long probe that was attached to a four-conductor lead-out wire manufactured by Berk-Teck Company (Model BTONX-734-2F-Q). One conductor was used for a common ground, one for measuring lead-wire resistance, and the remaining two for measuring the thermistors. The calibration of the probe was performed by Dr. Robert I. Lewellen of Lewellen Arctic Research and can be traced back to the National Bureau of Primary Standards.

C. Thermistor Installation

1. Offshore

The procedure for installing the offshore thermistor strings was as follows:

1. After washing the test boring to remove all of the cuttings, the boring was sounded with a weighted line to confirm that it was open for its entire depth.
2. A length of 1-inch I.D. steel pipe, equal to the total depth of the hole, was attached to flexible hose whose length was equal to the depth from the mudline to the top of the ice. This entire assembly was then set on the bottom of the hole and filled with propylene glycol.
3. The thermistor string and lead-out assembly were trimmed to a length so that the first of the 3-foot interval thermistors was located at the mudline when placed down the pipe. The string was then lowered to the bottom of the steel pipe. An additional 25 feet of flexible hose was attached to the installed hose. This was done so that small ice movement would not destroy the temperature well.
4. The drill casing was pulled from around the thermistor installation and the drill sled was moved off of the site.

2. Onshore and Barrier Islands

The onshore and barrier islands thermistor wells consist of 1-1/4-inch I.D. PVC pipe that is filled with propylene glycol. First, PVC pipe was installed in a completed test boring which was then backfilled. The pipe was then filled with propylene glycol and capped until ground temperature readings are taken.

D. Thermistor Readings and Data Reduction

The resistance values were reduced to ground temperatures using the following relationship:

1. Offshore

The thermistor strings were allowed to equilibrate for periods ranging from 10 days to 4 weeks before the ground temperatures were recorded. These readings were obtained using a switchbox and a Data Precision Model 248 multi-meter. The multi-meter displays 4.5 digits and is capable of measuring and resolving resistance to 1 ohm. When combined, the YSI thermistors and the multi-meter have a precision of $\pm 0.1^{\circ}C$ and an accuracy of $\pm 0.2^{\circ}$.

2. Onshore and Barrier Islands Ground Temperatures

The thermistor wells were allowed to equilibrate for up to 4 weeks before the final ground temperatures were measured. The resistance readings were taken by using a Data Precision Model 248 multi-meter, as described above. When combined, the calibrated bead-in-glass thermistors and the Model 248 multi-meter have a precision of $\pm 0.05^{\circ}C$ and an accuracy of $\pm 0.1^{\circ}C$.

Resistance readings were taken at 2-foot to 5-foot intervals from the ground surface to the bottom of the thermistor well. All of the depths were referenced to the ground surface surrounding the thermistor well. The thermistors were monitored at each depth until a stabilized reading was obtained. Stabilization time varied from up to 30 minutes in the upper 10 feet and 1 to 3 minutes in the lower portion of the boring. To avoid inducing heating in the thermistors, the multi-meter was turned off between readings. Once a stabilized value was obtained, the lead-wire resistance was recorded and the probe was lowered to the next depth. It took approximately 60 minutes to monitor the borings.

3. Data Reduction

The resistance values obtained in the field were corrected for lead-wire resistance by subtracting the measured lead-wire resistance from the total resistance. The resistance values were reduced to ground temperatures using the relationships in Equation C-1.

$$(1/T) = A + B\,(\ln R) + C\,(\ln R)^3 \tag{C-1}$$

Where: T = temperature degrees Kelvin

A, B, C = constants for the thermistors based on calibration curves

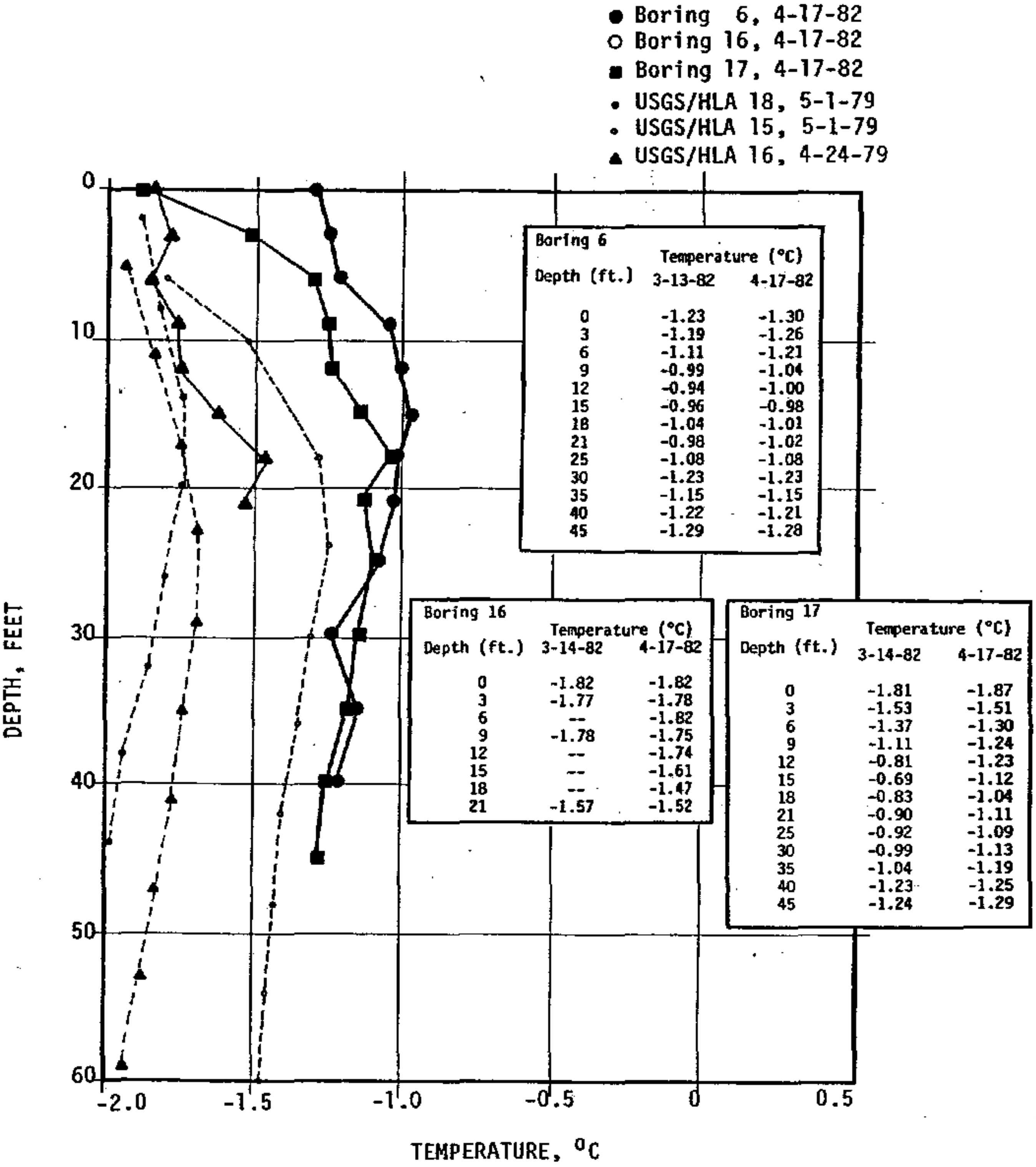
R = measured resistance in ohms

E. Findings

Plate C-1 shows the data obtained from the offshore Test Borings 6, 16, and 17. Furthermore, ground temperature data that were obtained in 1979 from HLA/USGS Test Borings 15, 16 and 18 are shown for purposes of comparison. The level of zero annual temperature change appears at a depth of 30 to 40 for the test borings.

Ground temperature data that were obtained from the onshore test borings are presented on Plate C-2. The data indicate that there is very little difference in onshore ground temperatures between the two borings. The level of zero temperature change appears at a depth of 30 to 50 feet in both test borings.

Barrier islands ground temperature data are shown on Plate C-3. Data obtained in 1980 from Drilling Pads F and D are also shown for comparison. The data for Test Borings 5 and 19 yield well-defined curves that appear to converge to a line of zero temperature change at a depth of 40 to 50 feet.



Boring 6

Depth (ft.)	Temperature (°C) 3-13-82	Temperature (°C) 4-17-82
0	-1.23	-1.30
3	-1.19	-1.26
6	-1.11	-1.21
9	-0.99	-1.04
12	-0.94	-1.00
15	-0.96	-0.98
18	-1.04	-1.01
21	-0.98	-1.02
25	-1.08	-1.08
30	-1.23	-1.23
35	-1.15	-1.15
40	-1.22	-1.21
45	-1.29	-1.28

Boring 16

Depth (ft.)	Temperature (°C) 3-14-82	Temperature (°C) 4-17-82
0	-1.82	-1.82
3	-1.77	-1.78
6	--	-1.82
9	-1.78	-1.75
12	--	-1.74
15	--	-1.61
18	--	-1.47
21	-1.57	-1.52

Boring 17

Depth (ft.)	Temperature (°C) 3-14-82	Temperature (°C) 4-17-82
0	-1.81	-1.87
3	-1.53	-1.51
6	-1.37	-1.30
9	-1.11	-1.24
12	-0.81	-1.23
15	-0.69	-1.12
18	-0.83	-1.04
21	-0.90	-1.11
25	-0.92	-1.09
30	-0.99	-1.13
35	-1.04	-1.19
40	-1.23	-1.25
45	-1.24	-1.29

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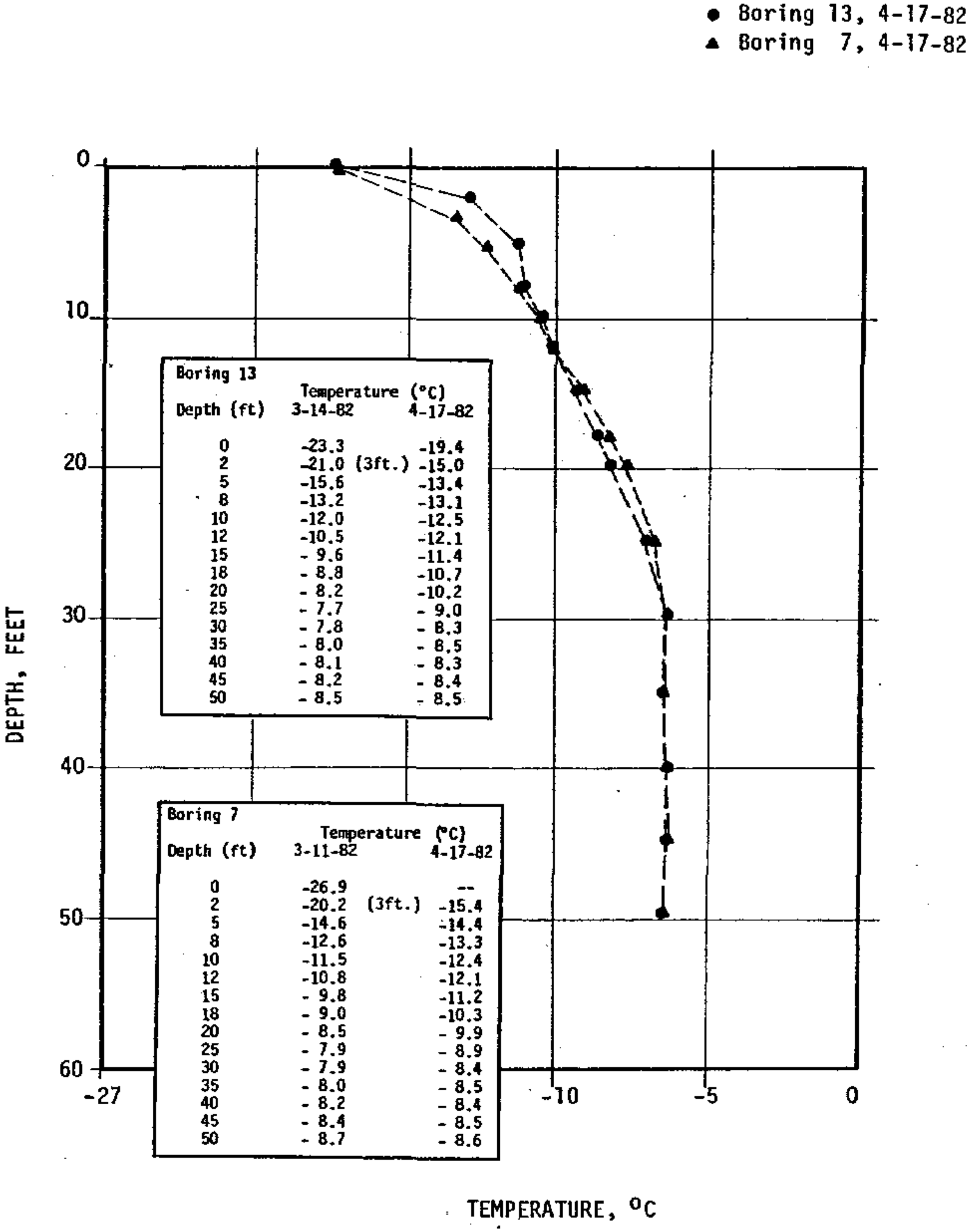
Ground Temperature vs Depth ,Offshore

Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
C-1

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08		4/82		



Boring 13

Depth (ft)	Temperature (°C) 3-14-82		4-17-82
0	-23.3		-19.4
2	-21.0	(3ft.)	-15.0
5	-15.6		-13.4
8	-13.2		-13.1
10	-12.0		-12.5
12	-10.5		-12.1
15	- 9.6		-11.4
18	- 8.8		-10.7
20	- 8.2		-10.2
25	- 7.7		- 9.0
30	- 7.8		- 8.3
35	- 8.0		- 8.5
40	- 8.1		- 8.3
45	- 8.2		- 8.4
50	- 8.5		- 8.5

Boring 7

Depth (ft)	Temperature (°C) 3-11-82		4-17-82
0	-26.9		--
2	-20.2	(3ft.)	-15.4
5	-14.6		-14.4
8	-12.6		-13.3
10	-11.5		-12.4
12	-10.8		-12.1
15	- 9.8		-11.2
18	- 9.0		-10.3
20	- 8.5		- 9.9
25	- 7.9		- 8.9
30	- 7.9		- 8.4
35	- 8.0		- 8.5
40	- 8.2		- 8.4
45	- 8.4		- 8.5
50	- 8.7		- 8.6

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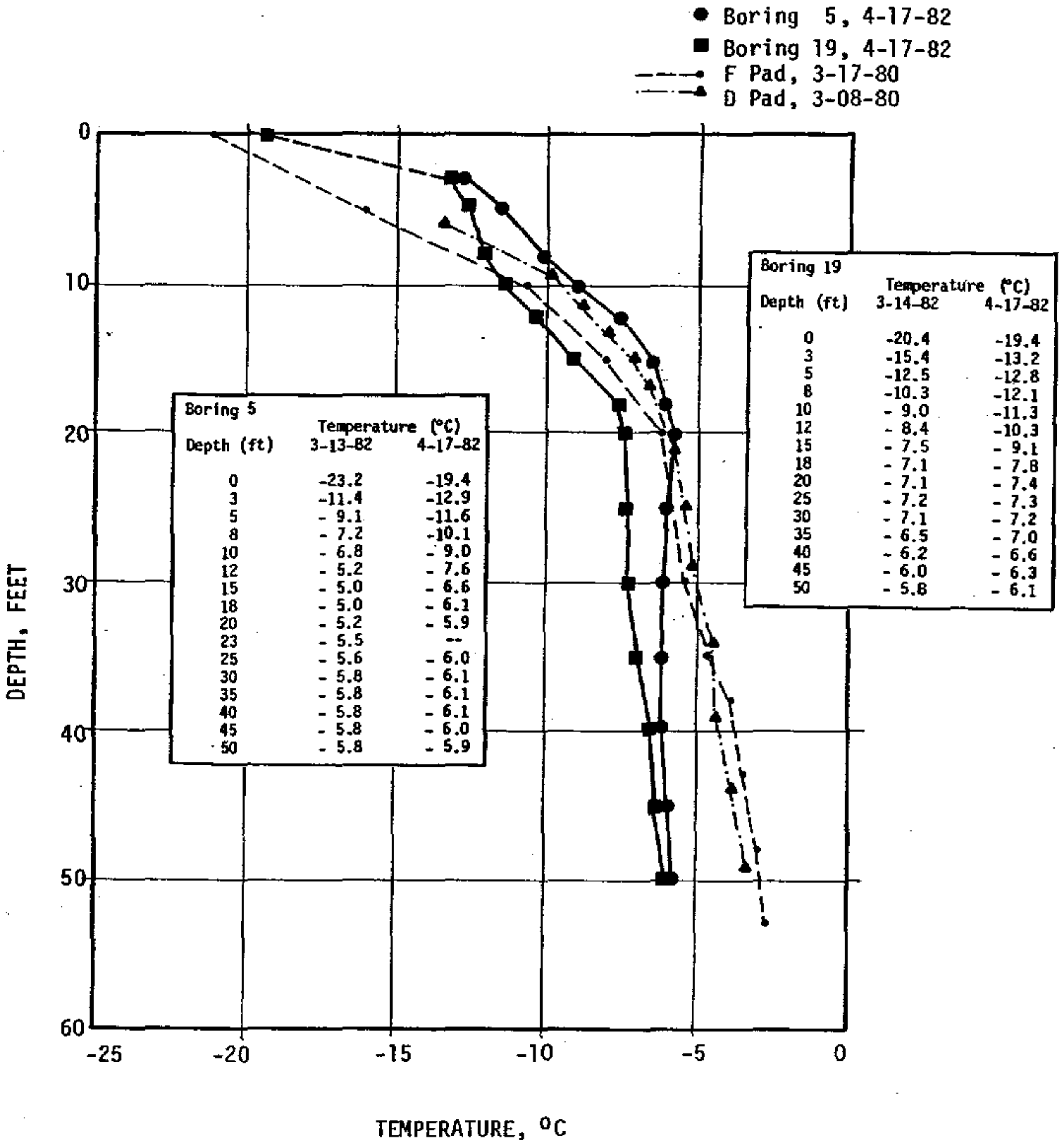
Ground Temperature vs Depth Onshore Borings

Pt. Thomson Development Project, Winter 1982
Geotechnical Study, EXXON Company, U.S.A.

PLATE
C-2

DRAWN
JOB NUMBER 9612,031.08
APPROVED
DATE 4/82
REVISED
DATE



Boring 5

Depth (ft)	Temperature (°C) 3-13-82	4-17-82
0	-23.2	-19.4
3	-11.4	-12.9
5	- 9.1	-11.6
8	- 7.2	-10.1
10	- 6.8	- 9.0
12	- 5.2	- 7.6
15	- 5.0	- 6.6
18	- 5.0	- 6.1
20	- 5.2	- 5.9
23	- 5.5	--
25	- 5.6	- 6.0
30	- 5.8	- 6.1
35	- 5.8	- 6.1
40	- 5.8	- 6.1
45	- 5.8	- 6.0
50	- 5.8	- 5.9

Boring 19

Depth (ft)	Temperature (°C) 3-14-82	4-17-82
0	-20.4	-19.4
3	-15.4	-13.2
5	-12.5	-12.8
8	-10.3	-12.1
10	- 9.0	-11.3
12	- 8.4	-10.3
15	- 7.5	- 9.1
18	- 7.1	- 7.8
20	- 7.1	- 7.4
25	- 7.2	- 7.3
30	- 7.1	- 7.2
35	- 6.5	- 7.0
40	- 6.2	- 6.6
45	- 6.0	- 6.3
50	- 5.8	- 6.1

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Ground Temperature vs Depth for Barrier Islands

Pt. Thomson Development Project, Winter 1982
Geotechnical Study, EXXON Company, U.S.A.

PLATE **C-3**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08		4/82		

The warmer temperatures recorded in Test Boring 5 are a direct result of the insulation provided by the thick layer of ice and snow at the boring. Below 20 to 30 feet, ground temperatures recorded at Drilling Pads F and D in 1980 were about 1^{0}C to 3.5^{o}C warmer than those observed during our investigation. This implies that subsea ground temperatures are getting colder due to the presence of the barrier islands.

APPENDIX D
LABORATORY TESTING

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS
(continued)

APPENDIX D
LABORATORY TESTING

A. General

A comprehensive laboratory testing program was conducted by Harding Lawson Associates to evaluate the properties of soil samples obtained from test borings drilled for the Point Thomson Development, Winter 1982 Geotechnical Study. Details of the field investigation program are given in Appendix B.

Soil index tests were performed to classify the sampled soils and to determine their in situ moisture contents, dry unit weights, grain size distributions, plasticity indexes, specific gravities and organic contents.

Soil strength parameters under static loading conditions were determined by unconsolidated-undrained triaxial shear tests (TXUU), consolidated-undrained triaxial shear tests (TXCU), consolidated-drained triaxial shear tests (TXCD), and direct shear tests (DS).

One-dimensional consolidation tests were used to analyze the soil stress history and deformation behavior of unfrozen samples, while thaw-strain tests were used to analyze the behavior of frozen samples.

The pore water chemistry and freezing point depression of selected samples were determined by conducting both chemistry and salinity tests. Thermal conductivity measurements were made on both frozen and thawed samples for use in performing heat transfer analyses.

The procedures employed in the laboratory testing program were generally in accordance with those suggested by the American Society for Testing and Materials (ASTM). The ASTM designations for the various tests are tabulated below:

Laboratory Test	ASTM Test Method
Visual Classification	D 2488-69
Laboratory Classification	D 2487-69
Moisture Content	D 2216-71
Liquid Limit	D 423-66
Plastic Limit	D 424-59
Particle Size Analysis	D 422-63
Specific Gravity	D 854-58
Triaxial Shear	D 2850-70
Direct Shear	D 3080-72
Consolidation	D 2435-70

Furthermore, several tests were conducted for which there are no suggested ASTM methods. These are as follows:

Laboratory Test
Sedimentation
Thaw Consolidation
Thermal Conductivity
Geochemical Analysis
Electrical Conductivity

All of the above test procedures are described in the following sections of this appendix. The laboratory testing program is summarized by test boring on Plates D-1 through D-23.

B. Sample Handling and Visual Classification

1. Sample Storage

Upon arrival at Anchorage International Airport, the soil samples were picked up and delivered to our Anchorage laboratory where they were stored until testing. Four types of samples were received: Shelby tube, brass liner, jar and grab.

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS[1]	ICE[2]	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond.[3]	F.P.D.[4]	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
1	0.0	OL	$V_{x,r}$				100.3																	
	1.3	ML	$V_{x,r}$				43.3				54													
	2.7	OL	$V_{x,r}$				301				15										X			
	3.7	ML	$V_{x,r}$				71.5				46													
	4.2	ML	$V_{x,r}$				92.6				47										X			
	8.5	SP	$V_{x,r}$				18.9																	
	10.5	SP	$V_{x,r}$				19.5				67													
	13.5	SP	$V_{x,r}$			4.6	18.1				75													
	18.5	SP-SM	V_x	22	70.2	7.8	13.5					2.71												
	23.5	SP-SM	V_x			11.3	13.0																	
	28.5	SM	V_x	18	68.4	13.6	12.1																	
	33.5	SM	V_x			13.8	10.6																	
	38.5	SM	V_x	17	69.7	13.3	10.4																	
	43.5	SM	V_x				9.7																	
	48.5	SM	V_x	24	63.3	12.7	8.6																	
2	0.1	SP					23.4				100		2.68							X				
	0.3	SP			97.7	2.3	22.8				102		2.69					X						
	0.9	SP					22.0							52.3	2.1									
	2.2	SM		11	75.5	13.5																		
	2.7	SP-SM												45.5	1.9							X		
	2.8	SP-SM				8.6																		
	3.0	SP-SM					23.0							49.7	2.0									
	3.4	SP					22.8				98		2.65					X						
	3.5	SP			96.1	3.9																		
	3.9	SP-SM				10.9																		
	8.4	ML					33.4							50.7	2.1									

1. USCS = Unified Soil Classification System
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3. Elec. Cond. = Electrical Conductivity in mmhos/cm
4. F.P.D. = Freezing Point Depression, °C
5. NP = Non-Plastic

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Laboratory Test Summary

Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
D-1

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS 1	ICE 2	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond. 3	F.P.D. 4	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
2	8.5	ML					26.3	NP	NP	NP	100		2.68							X				
	9.9	ML					31.2				90		2.72					X						
	10.5	ML					30.6							46.4	1.9									
	10.7	ML			15.2	84.8	29.0				94		2.73					X						
	11.3	ML					32.5				89		2.69					X						
	12.9	ML					38.6				80					X								
	14.1	ML					38.8				81		2.70							X				
	14.4	ML					28.7							40.8	1.6									
	14.5	ML					35.7				83					X								
	18.5	MH					51.8							29.9	1.2									
	18.6	MH					48.4				72													
	19.0	ML					46.2							35.0	1.4									
	19.2	ML					42.4				76													
	25.7	ML					55.5				65													
	26.5	ML			7.4	92.6	29.0				86													
	27.3	SM					23.4				99													
	30.0	SM					16.0							36.3	1.4									
	30.2	SM					15.0				98													
	35.0	ML					26.3				99													
	40.2	ML					21.2				106		2.74				X							
	40.7	ML					8.2							68.9	2.8									
	40.8	ML					21.1				107		2.72				X							
	41.6	ML					26.3				96		2.72				X							
	41.7	ML											2.72											
	41.9	ML											2.72											
	46.7	ML				97.3	32.5				89					X								
	51.2	ML					26.0				97					X								

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Laboratory Test Summary
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
D-2

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DAB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS[1]	ICE[2]	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond.[3]	F.P.D.[4]	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
2	60.5	SM		10	59.3	30.7	13.0							48.1	2.0									
	60.7	SM					14.8				120													
	66.5	GP				1.8	17.7							48.3	2.0									
	67.5	GP					9.1						2.69											
3	0.0	ML					37.9							44.3	1.8									
	1.5	SP		35	60.4	4.6	10.6						2.69	45.7	1.9									
	1.7	SP					18.8				117													
	3.5	SP					18.3							48.2	2.0									
	4.5	SP					2.2							57.2	2.3									
	6.0	SP				0.7	9.9						2.69	52.5	2.1									
	7.5	SP					8.7																	
	9.0	GP-GM		56	36.6	7.4	8.6							54.9	2.2									
	12.0	SP					6.5							51.9	2.1									
	15.0	SP		19	78.8	2.2	22.4							50.5	2.1									
	19.0	GP					8.6						2.69	51.6	2.1									
	25.0	GP					4.8																	
	30.0	GP-GM		50	44.3	5.7	5.8							50.8	2.1									
	30.2	GP-GM					5.3				118													
	50.0	GP-GM	N_{bn}				4.0							30.4	1.2									
4	0.0	ML					26.4				96													
	1.1	SM				21.4																		
	1.7	SP			98.0	2.0																		
	1.8	SP					22.7				101								X					
	2.8	SP					24.5							46.3	1.9									
	3.0	SM					27.1	--	--	NP	97		2.69							X				

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Laboratory Test Summary

Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
D-3

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS 1	ICE 2	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond. 3	F.P.D. 4	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
4	9.5	ML					43.8							44.4	1.8									
	9.6	ML					41.6				77													
	12.0	ML					41.0							43.8	1.8									
	12.4	ML					38.8				78												X	
	13.0	OL					36.3				80	15.9	2.67							X				
	13.3	OL					43.7	33	26	6	75		2.67				X							
	13.8	ML			9.9	90.1	47.5				72		2.67				X							
	14.4	ML					48.7	33	26	6	72		2.7							X				
	15.0	ML					45.5																	
	18.3	MH					70.8				57		2.68			X								
	18.8	CL					74.7				56		2.66				X			X				
	19.0	CL					68.4				58		2.66											
	19.5	CL					74.7	44	26	18														
	19.6	CL					71.1				57		2.66				X							
	20.2	ML					69.0							47.4	1.9									
	25.0	OL					25.9					12.0												
	25.5	SM					9.8							44.3	1.8									
	25.6	SP-SM					9.7				133													
	26.0	SM		7	52.8	40.2	12.9				120													
	30.0	ML				65.6	22.3																	
	31.0	ML					22.8				100													
	40.0	ML					24.4	27	22	5														
	40.2	ML					23.1				105													
	44.5	ML		1	24.1	74.9	22.5				107													
	49.5	SP					21.9							53.1	2.2									
	50.0	SP				2.8	13.7				121		2.69											

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Laboratory Test Summary
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
D-4

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JF	9612,031.08	DEB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS [1]	ICE [2]	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond. [3]	F.P.D. [4]	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
5	0.1	SP-SM	$V_{x,c}$	14	76.4	9.6	27.1						2.71	61.5	2.5									
	0.5	SP-SM	$V_{x,c}$				16.2							54.3	2.2									
	2.0	SP-SM	$V_{x,c}$				14.0							90.9	4.0							X		
	4.0	SP	$V_{x,c}$			3.5																		
	4.5	SM	$N_{f,bn}$				36.4							26.3	1.0									
	6.0	SM	$N_{f,bn}$				18.0				110													
	6.5	SM	$N_{f,bn}$			22.0	18.3							107.9	4.0									
	6.7	SM	$N_{f,bn}$				18.9				108													
	8.0	SM	$N_{f,bn}$				13.5				122			108.7	5.0							X		
	10.0	SP				1.1	6.9							21.2	0.8									
	10.1	SP					6.2				102													
	16.0	ML					33.0							83.7	3.4									
	16.1	ML					34.8				85													
	16.5	ML					52.0							17.6	0.7									
	16.7	ML					38.4				80													
	19.0	ML					35.5				61					X								
	19.2	CL					39.5				79												X	
	19.5	CL					36.6	31	21	10	87		2.72							X				
	20.3	CL					42.3							78.1	3.2									
	25.5	ML					52.4				66													
	31.1	ML	V_r				43.6							42.9	1.7									
	31.2	ML	V_r				46.3				72													
	45.5	CL	V_r		1.6	98.4	41.9							28.1	1.1									
	45.7	CL	V_r				33.6				86										X			
	46.0	CL	V_r		1.0	99.0	36.2				67										X			
	51.0	CL	V_r				27.0							37.9	1.5									
	51.2	CL	V_r				28.8				92													

1. USCS = Unified Soil Classification System
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Laboratory Test Summary
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
D-5

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DEB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
				Soil Gradation (%)				Atterberg Limits																
BORING NO.	DEPTH (ft)	USCS[1]	ICE[2]	Gravel +4	Sand -4 to +200	Fines -200	Moist. Cont. (%)	LL	PL	PI	Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond.[3]	F.P.D.[4]	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
6	0.1	SM			49.3	50.7	31.6							48.6	2.0									
	0.5	SM					22.5							47.3	1.9									
	1.0	SM					22.5							48.1	2.0									
	3.5	ML					29.2							47.3	1.9									
	3.6	ML					30.4				92		2.69							X				
	4.0	ML					34.7							52.1	2.1									
	4.1	ML				84.9	33.4				88		2.68				X							
	4.6	ML					32.3	NP	NP	NP	90		2.69				X							
	5.2	ML					21.3							48.4	2.0									
	5.3	SP-SM		22	68.5	9.5	14.1				121		2.69											
	6.5	SP-SM					18.7							50.1	2.0									
	6.7	ML				52.7	11.4				114													
	7.2	SP-SM					7.4							95.9	3.8									
	9.2	SM					11.4							49.4	2.0									
	9.3	SM					9.3				120													
	12.0	GM					19.1				111													
	12.5	ML					24.1							48.7	2.0									
	12.6	ML					22.5				87													
	13.5	ML											2.71											
	14.1	ML					25.1							34.1	1.3									
	14.3	ML			1.8	98.2																		
	14.7	ML					23.3				99		2.71	37.1	1.5		X							
	15.4	ML					26.2				100						X							
	16.5	ML					23.0				104		2.71											
	21.4	ML					26.4							47.7	1.9									
	21.5	ML					23.1	29	24	5														
	21.7	ML			4.2	95.8	23.1				107		2.73							X				

1. USCS = Unified Soil Classification System
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4. F.P.D. = Freezing Point Depression, °C
5. NP = Non-Plastic

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Laboratory Test Summary

Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DGB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
				Soil Gradation (%)				Atterberg Limits																
BORING NO.	DEPTH (ft)	USCS[1]	ICE[2]	Gravel +4	Sand -4 to +200	Fines -200	Moist. Cont. (%)	LL	PL	PI	Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond.[3]	F.P.D.[4]	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
6	22.1	ML					20.4				106													
	25.0	ML					25.5				101													
	30.0	ML					24.3				102													
	35.5	GP-GM		56	38.7	5.3	6.7						2.68	52.5	2.2									
	35.6	GP-GM					6.0				141													
	40.5	GP				2.8	3.4				123													
7	0.5	OL	$V_{x,r}$				108				34										X			
	1.0	OL	$V_{x,r}$				31.3				80	14.0	2.32											
	1.6	OL	$V_{x,r}$				138				29													
	2.0	OL	$V_{x,r}$				250				19										X			
	5.0	SP-SM	V_x				220				17													
	5.4	SP-SM	V_x				43.1				59													
	5.9	SP-SM	V_x				23.6				79													
	9.0	SM	V_x	8	70.3	21.7																		
	14.0	SP	$V_{x,r}$				245				18													
	15.0	SP	$V_{x,r}$				190				24													
	19.0	SP-SM	V_x				12.9																	
	24.8	ML	$V_{x,r}$				114				36													
	29.0	SM	V_x				7.3																	
	34.0	SP-SM	V_x			7.4	12.8																	
	39.0	SM	V_x	24	58.3	17.7	16.6																	
	44.0	SM	V_x			19.4	14.8																	
	49.0	SM	V_x	41	43.5	15.5	11.9																	
8	0.0	GM		44	26.7	29.3	23.8																	
	0.1	GM					31.8							49.6	2.0									

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Pt. Thomson Development Project
Winter 1982, Geotechnical Study
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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DEB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS 1	ICE 2	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond. 3	F.P.D. 4	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
8	3.0	SP		15	80.4	4.6	15.4						2.68	51.2	2.1									
	5.0	SP		40	56.4	3.6	9.5							55.9	2.3									
	7.0	SP					8.0							54.9	2.2									
	8.5	SP					9.2							60.2	2.5									
	8.7	SP					6.7				78													
	9.0	SP					15.3				120			72.5	3.0									
	10.2	ML					25.6							78.7	3.2									
	10.4	ML					24.1				100													
	12.2	ML					22.6				103												X	
	12.8	ML					26.0				99		2.73							X				
	13.0	ML					25.3							79.3	3.2									
	14.9	ML					28.8							52.4	2.1									
	15.0	ML					26.4				98					X								
	18.0	ML					23.3							63.1	2.6									
	24.0	SM		10	43.0	47.0	18.7																	
	25.0	SM				36.4	14.0				121													
	37.0	SP-SM		40	52.9	7.1	13.9																	
9	0.0	SM			63.5	36.5	23.7				113													
	0.1	SM					22.5							52.4	2.1									
	0.5	SM					22.1				105												X	
	4.4	SM												50.0	2.1							X		
	4.5	SM					24.7				101		2.71				X							
	5.0	SM					22.5							52.4	2.1									
	5.1	SM					22.7				103		2.70				X							
	5.6	ML					22.6							50.0	2.0									
	5.7	SM					32.1				90		2.72							X				

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Laboratory Test Summary
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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JF	9612,031.08	DGB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO	DEPTH (ft)	USCS 1	ICE 2	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond. 3	F.P.D. 4	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
9	6.6	ML					28.2							53.1	2.2									
	7.0	ML			40.6	59.4																		
	7.3	ML					28.2						2.75	39.8	1.6									
	7.4	ML					26.4				98		2.74				X							
	8.0	ML					34.2							51.8	2.1									
	8.1	ML					28.4				96		2.74				X							
	9.0	ML					27.4	NP	NP	NP	96		2.74				X							
	9.7	ML					35.0				86		2.71							X				
	9.9	ML					28.2							53.9	2.2									
	13.8	ML					37.0							50.7	2.1									
	14.4	ML					41.8				78					X								
	15.0	ML					40.7				77					X								
	19.3	MH					80.4				53		2.66							X				
	19.5	ML					51.3				68					X								
	20.0	ML					37.0							46.0	1.9									
	25.0	ML				67.4																		
	25.4	SM					33.2							42.5	1.7									
	25.5	SM					35.7				79													
	30.0	SM				38.8																		
	31.6	SM					30.2				90					X								
	36.0	SM				23.6																		
	36.3	SM					27.8				96													
	40.9	ML					32.8	35	27	8														
	41.1	ML					34.5							37.8	1.5									
	41.2	ML					32.8				91		2.73							X				
	41.4	CL			1.8	98.2	31.2				90					X								
	41.9	CL					27.6				96					X								

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DRAWN JOB NUMBER 9612,031.08 APPROVED DEB DATE 4/82 REVISED DATE

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS 1	ICE 2	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond. 3	F.P.D. 4	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
9	46.4	CL					29.3				93												X	
	50.5	ML					25.1				97													
	55.5	ML					16.5				112													
	60.0	GP					2.8				106													
	60.5	GP					6.2				96													
	61.0	GP		96.1	3.7	0.2																		
10	0.5	SP-SM	V_c		91.1	8.9																		
	1.0	SP-SM	V_c				23.3							10.5	0.4									
	2.5	SP-SM	V_c				111							23.9	0.9									
	3.0	SP-SM	V_c			10.2																		
	3.5	SP-SM	V_c				23.8							6.2	0.2									
	5.5	SP-SM	V_c				23.2							12.1	0.4									
	7.0	SP-SM	V_c				25.1							12.5	0.4									
	8.5	SP-SM	V_c		89.3	10.7																		
	9.5	SP-SM	V_c				26.9							27.2	1.1									
	12.0	SP-SM	N_f				23.5							109	4.1									
	14.5	SM					19.4				110			106	4.0									
	15.0	SM					23.2				101			90.9	3.9							X		
	16.5	SM					24.4				99													
	18.0	ML	V_r				28.1				85													
	20.5	ML	V_r				28.9				95													
	26.0	ML	$V_{x,r}$				42.7				77													
	31.0	ML	V_r				21.6	27	21	6	108										X			
	40.5	ML	V_r				19.6				107													
	46.0	ML	V_r				27.3				96													
	51.0	ML	V_r				22.7				104													

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JR	9612,031.08	DFB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS 1	ICE 2	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond. 3	F.P.D. 4	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
11	0.0	SP					12.2							44.8	1.8									
	4.0	GP		77	22.0	1.0																		
	10.0	GP		82	17.1	0.9	8.4							48.9	2.0									
	15.0	GP		51	45.5	3.5	8.1				109													
	17.0	GP				2.3																		
	19.5	GP					8.5							48.0	2.0									
	19.7	GP					8.3				114													
	22.0	GP		68	31.3	0.7							2.70											
	30.5	GP				0.5																		
	34.0	GP				1.1																		
	34.5	SP-SM				9.7																		
	40.0	SP					8.0				131		2.69											
	41.0	GP-GM		58	33.9	8.1	7.1							49.5	2.0									
	41.2	GP-GM					5.6				124													
	49.0	SP		41.3	54.8	3.9							2.68											
12	0.0	OL	$V_{x,r}$				406				11												X	
	0.5	OL	$V_{x,r}$				74.1							0.6	0.0									
	0.6	OL	$V_{x,r}$				27.6				78										X			
	1.0	Pt	--				100				37													
	1.5	Pt	--								5													
	3.3	ICE	--											0.3	0.0									
	6.2	SM	V_x				429				10													
	6.7	SM	V_x				74.7				45													
	9.0	SM	V_x	3	79.6	17.4	30.0							7.1	0.2									
	9.1	SM	V_x				19.2				93										X			
	9.5	SM	V_x				38.3				65													

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DKB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS[1]	ICE[2]	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond.[3]	F.P.D.[4]	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
12	14.4	GM	V_x	43	42.5	14.5	41.4				58													
	19.0	SP-SM	V_x			11.3	14.7							9.1	0.3									
	19.2	SP-SM	V_x				20.8																	
	24.0	SP-SM	V_x			9.3	10.4							11.2	0.4									
	24.2	SP-SM	V_x				14.4																	
	29.0	SP-SM	V_x				16.8							22.2	0.8									
	29.2	SP-SM	V_x				15.2				81													
	34.5	ML	V_x				46.9							31.3	1.2									
	34.7	ML	V_x				40.9				72													
	39.0	ML	V_x				25.8																	
	44.0	ML	V_x				17.0																	
	49.3	ML	V_x				27.2				79													
13	0.2	OL	$V_{x,r}$				60.1					15.9		1.6	0.0									
	0.3	OL	$V_{x,r}$				54.9				53										X			
	2.0	ML	$V_{x,r}$				153				24													
	3.0	SP-SM	V_x				21.0				82										X			
	3.8	GP-GM	V_x	49	43.8	7.2																		
	5.0	SP-SM	V_x				8.3							8.3	0.3									
	6.5	SM	V_x			16.1	24.3																	
	10.0	SP-SM	V_x	22	65.5	12.5	15.8							5.8	0.2									
	12.0	SM	V_x				20.0							7.2	0.2									
	17.5	ML	$V_{x,r}$				76.1	34	25	9	52										X			
	18.0	ML	$V_{x,r}$				154				29												X	
	22.3	ML	$V_{x,r}$				48.8							29.9	1.2									
	22.5	ML	$V_{x,r}$				58.6				59													
	27.0	SP-SM	V_x			11.5	6.9																	

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DEB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS 1	ICE 2	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond. 3	F.P.D. 4	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4to +200	Fines -200		LL	PL	PI														
13	32.0	SM	V_x	45	41.7	13.3	12.9							23.0	0.9									
	37.0	SM	V_x				11.0																	
	42.0	SM	V_x			12.6	9.8																	
	50.0	SP-SM	V_x	34	55.1	10.9	9.6							17.1	0.6									
14	0.0	SM					21.7				107			47.7	1.9									
	1.5	SM		1	71.9	27.1																		
	1.8	SM					21.6							46.1	1.9									
	2.4	ML					27.1				95		2.72				X							
	2.9	ML					26.7				96		2.71				X							
	6.1	ML					31.1							45.6	1.8									
	6.2	ML					33.1	32	26	6														
	6.3	ML					33.1				89		2.71							X				
	7.3	ML					31.1							44.9	1.8									
	7.9	ML					31.1				90													
	11.0	SM		11	61.1	27.9	25.2							50.4	2.1									
	11.2	SM					23.5				102													
	12.5	SP-SM					16.1							50.1	2.0									
	12.7	SP-SM					14.2				121													
	13.5	SP					6.2																	
	15.0	SP					9.5																	
	15.5	SP					15.1				119													
	16.7	CL					19.5	33	19	14														
	16.8	CL					19.5				112		2.75							X				
	17.0	CL					18.1				113					X								
	19.8	CL					20.4				110													

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS 1	ICE 2	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond. 3	F.P.D. 4	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
14	25.5	CL					22.9				103					X								
	31.1	ML					22.8				105												X	
	35.4	CL					25.1	40	26	14														
	36.0	ML					25.1				101					X								
	40.5	ML					25.1				101					X								
	45.0	GM		47	21.6	31.4	18.9																	
	50.0	GP		64	34.0	2.0	8.7																	
15	0.2	ML					32.8							51.4	2.1									
	1.9	ML					35.0							63.5	2.6									
	2.0	ML					36.0				83					X								
	2.7	ML					39.0							46.4	1.9									
	5.0	ML					43.2							49.4	2.0									
	5.2	ML					40.5	46	31	5	81		2.65							X				
	5.5	ML					47.8							50.3	2.1									
	7.5	SM			52.2	47.8																		
	7.7	SM					27.3				95													
	8.2	SM					26.0							64.5	2.6									
	8.4	MH				83.1	70.2				56						X							
	9.0	MH					81.1	--	--	NP	51		2.43			X								
	9.7	ML					64.9							64.3	2.6									
	10.7	ML					33.4							63.6	2.6									
	10.8	ML					32.2				86					X								
	11.5	SM					28.0							61.5	2.5									
	15.5	SM					18.2				114		2.73				X							
	16.0	SM					18.6				113		2.73				X							
	18.5	SM					15.2							50.8	2.1									

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08		4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
				Soil Gradation (%)				Atterberg Limits																
BORING NO.	DEPTH (ft)	USCS[1]	ICE[2]	Gravel +4	Sand -4 to +200	Fines -200	Moist. Cont. (%)	LL	PL	PI	Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond.[3]	F.P.D.[4]	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
15	18.7	SM					18.2				104													
	26.7	ML					18.4							72.0	3.0									
	26.8	ML					21.5				106		2.69							X				
	36.4	SC					16.8							51.8	2.1									
	36.8	CL					26.0				95					X								
	39.5	CL	$V_{x,r}$				30.3	28	21	7				26.2	1.0									
	39.6	CL	$V_{x,r}$				23.5				102										X			
	49.0	CL	$V_{x,r}$				19.2							28.1	1.1									
	49.1	CL	$V_{x,r}$				27.7				92										X			
	55.0	CL	$V_{x,r}$				54.4				68													
16	0.1	SP-SM		23	68.3	8.7																		
	0.8	SP-SM												40.8	1.7							X		
	1.1	SM				39.9	25.1							38.7	1.5									
	2.5	SM					31.9																	
	3.0	SM					32.9							18.0	0.7									
	3.1	SM	$V_{c,s}$				48.9				79										X			
	4.0	SM	$V_{c,s}$				25.2				97													
	5.0	ML	$V_{c,s}$			93.1	27.9							13.7	0.5									
	5.1	ML	$V_{c,s}$				42.6				73										X			
	5.5	SM	$V_{c,s}$				25.7																	
	6.0	SM	$V_{c,s}$				28.5				93													
	7.5	ML	$V_{c,s}$				21.6							26.1	1.0									
	8.0	ML	$V_{c,s}$				30.1				89													
	9.0	SM	$V_{c,s}$			39.1	29.5							7.8	0.3									
	9.1	SM	$V_{c,s}$				28.5				93										X			
	9.5	SM	$V_{c,s}$				29.6				91													

1. USCS = Unified Soil Classification System
2. Ice = U.S. Army Corps of Engineers Ice Classification System
3. Elec. Cond. = Electrical Conductivity in mmhos/cm
4. F.P.D. = Freezing Point Depression, °C
5. NP = Non-Plastic

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Laboratory Test Summary
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
SP	9612,031.08	DFB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS 1	ICE 2	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond. 3	F.P.D. 4	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
16	11.0	SM	$V_{c,s}$				27.7				91													
	11.5	SM	$V_{c,s}$				29.0							8.1	0.3									
	13.0	CL-ML	V_r				29.3							17.5	0.6									
	13.2	CL-ML	V_r				31.2	23	17	6														
	13.5	CL-ML	V_r				31.2	24	18	6	90													
	14.5	SM	V_r				30.7							7.0	0.2									
	15.0	ML	V_r			67.4	30.1				87													
	16.5	SM	V_c				33.8							9.3	0.3									
	17.5	SM	V_c		51.2	48.8	29.6				79													
	24.5	ML	V_r				33.1							11.0	0.4									
	24.6	ML	V_r				25.5				98										X			
17	0.2	SP					21.8				104													
	0.7	SP					19.9							46.8	1.9									
	0.8	SP					22.4				102													
	1.4	SP					19.6							45.2	1.8									
	3.4	CL-ML					32.6	25	21	5														
	3.5	CL-ML					32.6				90		2.71							X				
	3.8	CL-ML					29.7							49.0	2.0									
	4.9	ML					43.4							47.9	1.9									
	6.1	ML					33.1							36.9	1.5									
	6.2	ML		1	5.7	93.3	52.5				67					X								
	6.7	ML					40.5				77					X								
	7.3	SM					50.1							37.4	1.5									
	9.0	GM					25.7				89													
	9.4	GM		44	16.4	39.6	17.2							48.7	2.0									
	9.6	GM					17.8				108													

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Laboratory Test Summary
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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	JEB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS[1]	ICE[2]	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond.[3]	F.P.D.[4]	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
17	10.0	GM					19.4							50.2	2.0									
	11.5	GP				0.4	3.1																	
	13.3	GP					7.2				114													
	16.5	GP-GM					8.6																	
	18.5	ML					18.1																	
	25.7	ML					22.7							67.2	2.8									
	25.9	ML					21.4				106													
	30.4	ML					18.4				114					X								
	35.0	CL						43	26	17														
	35.3	CL					24.7				103		2.78				X							
	35.7	CL					23.9				103		2.78							X				
	36.3	ML					24.3				103		2.78				X							
	40.7	GP-GM		58	34.9	7.1	6.6																	
	49.8	GP-GM					9.8																	
	50.3	GP-GM					5.2				113													
18	0.3	OL	--				149				31												X	
	1.0	OL	--				55.2				55										X			
	18.5	GP-GM	V_x			5.7	20.4																	
	23.5	SP-SM	V_x	46	47.5	6.5	34.5						2.66											
	28.5	SP-SM	V_x				7.2																	
	33.5	SP-SM	V_x	43	47.3	9.7	1.2																	
	38.5	SP-SM	V_x			7.8	9.3																	
	43.5	SP-SM	V_x	32	57.0	11.0	13.7																	
	48.5	SP-SM	V_x			10.4	10.5																	
19	0.0	SP	N_{fbn}				2.8				115													

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Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DEB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS[1]	ICE[2]	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond.[3]	F.P.D.[4]	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
19	0.1	SP	N_f,bn	9	89.9	1.1																		
	1.0	SP	N_f,bn										2.73											
	2.2	SP	N_f,bn				2.2				113			8.33	0.4							X		
	4.0	SP	V_x	14	83	3.0	8.8																	
	4.8	SP	V_x				15.0							3.8	0.1									
	6.0	SP	V_x				22.5							9.0	0.3									
	8.0	SP	V_x				24.8							81.0	3.3									
	8.4	SP	V_x				28.3																	
	9.5	SP	V_x				20.2							45.7	1.9									
	11.0	SP-SM	V_x				21.3																	
	12.0	SP-SM	V_x			5.5	24.8							91.2	3.6									
	12.2	SP-SM	V_x				41.2				84													
	14.0	SP	N_f				25.9							93.2	3.7									
	14.2	SP	N_f				28.8																	
	14.5	SP	--				22.5				96													
	15.0	SP-SM	--				21.4							129	4.3									
	15.2	SP-SM	--				16.7				102													
	16.0	ML	V_r				30.4							130	4.3									
	16.2	ML	V_r				28.7				94													
	16.5	ML	V_r				26.8				97			110	4.1									
	24.5	ML	V_r				21.6				108										X			
	24.6	ML	V_r				36.2							73.8	3.0									
	24.7	ML	V_r				37.2	38	26	12														
	29.0	ML	V_r				48.9							62.2	2.6									

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Laboratory Test Summary

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Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	JEB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS[1]	ICE[2]	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond.[3]	F.P.D.[4]	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
19	29.2	ML	V_r				54.8				65													
	34.5	ML	V_r				51.1				69													
	44.0	ML	V_r				12.1																	
	49.5	ML	V_r				21.9							60.5	2.5									
	49.7	ML	V_r				21.0				105													
20	0.0	ML					336				25													
	0.1	ML		4	5.3	90.7																		
	0.2	ML					53.8							46.2	1.9									
	2.5	SM					42.9							44.8	1.8									
	4.0	GP					6.6							55.6	2.3									
	6.5	GP-GM		49	44.3	6.7	6.5							48.0	1.9									
	6.7	GP-GM					5.1				139													
	8.0	GP					8.0							50.9	2.1									
	10.0	GP					4.8							52.4	2.1									
	11.5	GP		75	24.1	0.9	3.2																	
	16.5	GP					7.8																	
	40.0	SP-SM		41	52.9	6.1	7.9						2.69											
21	0.0	SP-SM					23.4				106													
	0.1	SP-SM				6.4	22.9							49.1	2.0									
	0.5	SP-SM			92.1	7.9	21.3				102		2.70						X					
	1.5	SP-SM					21.7							38.2	1.5									
	1.7	SP-SM					22.1				102													
	2.0	SP-SM			91.0	9.0	20.8				105		2.72						X					
	2.5	SP-SM												46.50	2.0							X		
	3.1	CL					20.6							36.2	1.4									

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DLB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS[1]	ICE[2]	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond.[3]	F.P.D.[4]	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
21	3.2	CL					20.5	26	19	7														
	3.3	CL					20.1				111		2.76							X				
	4.1	ML					19.3				111		2.74				X							
	4.5	ML					19.6							39.1	1.6									
	4.7	ML			2.1	97.9	18.9				111		2.73				X							
	5.2	ML					20.5				108		2.74				X							
	5.8	ML					20.8							48.7	2.0									
	6.7	ML					21.5							37.4	1.5									
	7.0	ML					19.2				110					X								
	8.2	ML					16.8							52.9	2.2									
	9.0	SM					29.7				92													
	9.6	SM					31.2							61.2	2.5									
	10.6	SM					30.6							62.3	2.6									
	10.8	SM					29.2				93													
	12.9	ML					25.7							63.8	2.6									
	16.1	ML					27.3				97												X	
	16.8	SP-SM					30.2							70.7	2.9									
	18.0	ML					24.0				102		2.73				X							
	18.5	ML					26.6				97		2.74				X							
	19.0	ML					22.4							64.4	2.6									
	25.0	ML			5.6	94.4		22	21	1			2.73											
	25.9	ML					25.2							77.2	3.1									
	26.1	ML					25.9				99		2.76				X							
	26.8	ML					25.9				98		2.78				X							
	27.8	ML					27.0				100		2.81							X				

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Laboratory Test Summary
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

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DRAWN
JOB NUMBER 9612,031.08
APPROVED
DATE 4/82
REVISED
DATE

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS 1	ICE 2	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond. 3	F.P.D. 4	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
21	31.0	CL					24.4				101												X	
	31.5	CL					23.7				100					X								
	32.0	CL					23.0				101					X								
	32.5	CL					26.2							70.9	2.9									
	41.0	CL					24.1							38.3	1.5									
	41.2	CL					22.5				105													
	45.0	CL					18.7				108													
	55.2	CL-ML					44.2	26	20	6														
	55.5	CL					22.0				103													
	60.0	CL					22.6				104													
	62.0	SC		2	72.5	25.5	18.7							50.1	2.1									
22	0.7	SM					30.5																	
	1.0	SM					24.8							45.8	1.9									
	1.2	SM					25.1				81													
	2.2	SM			50.9	49.1								46.5	2.0							X		
	2.5	ML					24.5							49.4	2.0									
	2.7	ML					25.8				99		2.70	45.5	1.9		X					X		
	3.3	ML					27.4							46.7	1.9									
	3.5	ML			28.4	71.6	25.0	24	21	3														
	3.8	ML					30.7				90		2.69				X							
	4.5	ML					42.7																	
	5.0	ML					43.7							47.2	1.9									
	5.2	ML					41.4				78													
	7.5	CL					52.3	35	23	12				47.6	1.9									
	11.5	SP					9.2							49.7	2.0									
	12.0	SP-SM				10.3	15.9																	

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Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
X	9612,031.08	DEB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS[1]	ICE[2]	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond.[3]	F.P.D.[4]	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
22	13.0	SP		34	65.1	0.9	9.1							50.2	2.0									
	15.5	SP					8.3						2.68	55.4	2.3									
	20.0	SP		37	62.2	0.8	10.6						2.70											
	30.0	GP		54	44.5	1.5	0.9																	
	40.0	GP-GM				5.9	7.6						2.69											
	50.0	GP		63	35.4	1.6	11.3																	
23	0.0	ML	V_x				42.9				55										X			
	0.3	ML	V_x				29.5							3.6	0.1									
	0.5	ML	V_x				30.3				78												X	
	1.0	ML	V_x				23.2	21	13	8	107										X			
	6.3	ICE	--											0.3	0.0									
	8.3	ICE	--											0.3	0.0									
	10.3	SM	V_x				41.6							17.6	0.6									
	10.5	SM	V_x				47.4				63													
	10.8	ML	V_x		11.6	88.4	64.6				54										X			
	12.5	CL	V_r				43.9	33	22	11	70												X	
	14.0	CL	V_r				49.1				65													
	14.5	CL	V_r				30.8							36.5	1.5									
	14.7	CL	V_r				37.8				89													
	15.0	CL	V_r				56.7				62													
	19.0	CL	V_r				31.9				83										X			
	24.5	CL	V_r				24.6				93													
	29.0	SM	N_{be}		84.5	15.5	23.7							10.0	0.4									
	29.2	SM	N_{be}				22.8				58													
	34.0	CL	$V_{x,r}$				32.5				76													
	39.5	CL	$V_{x,r}$				27.7	27	20	7	89										X			

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EXXON Company, U.S.A.

PLATE
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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	TEB	4/82		

SAMPLE DESIGNATION		SOIL CLASS.		CLASSIFICATION TESTS												SECONDARY TESTS								
BORING NO.	DEPTH (ft)	USCS 1	ICE 2	Soil Gradation (%)			Moist. Cont. (%)	Atterberg Limits			Dry Density (pcf)	Org. Loss by Ignition (%)	Spec. Grav.	Elec. Cond. 3	F.P.D. 4	TXUU	TXCU	TXCD	D.S.	Consol.	Thaw Consol.	Chem.	Thermal Cond	Comments
				Gravel +4	Sand -4 to +200	Fines -200		LL	PL	PI														
23	44.4	CL	$V_{x,r}$				27.2				83													
	49.0	CL	$V_{x,r}$				29.3							35.5	1.4									
	49.2	CL	$V_{x,r}$				25.5				90													

1. USCS = Unified Soil Classification System
2. Ice = U.S. Army Corps of Engineers Ice Classification System
3. Elec. Cond. = Electrical Conductivity in mmhos/cm
4. F.P.D. = Freezing Point Depression, °C
5. NP = Non-Plastic

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Laboratory Test Summary

Pt. Thomson Development Project
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PLATE
D-23

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
X	9612,031.08	DEB	4/82		

Initially, all of the sample containers were visually inspected for signs of leakage or disturbance. The frozen samples were immediately placed in our cold room and stored at a temperature of approximately -8°C. The remaining specimens were stored as discussed below.

Shelby tubes were placed horizontally in a specially constructed rack to reduce sample disturbance during storage. Additionally, the Shelby tubes were turned 90 degrees every 24 hours to reduce the effects of water migration. Samples contained in brass liners were kept in an upright position on a storage shelf, as were jar samples. The grab samples were placed in moisture-proof plastic bags and stored in a single layer to prevent the bags from tearing or ripping.

Although care was taken to prevent moisture loss within the samples, desiccation is unavoidable. Therefore, we do not believe that samples stored longer than six months should be tested.

2. <u>Shelby Tube Sample Extraction, Visual Classification, and Preparation</u>

After a Shelby tube sample was extruded, an engineer and/or a technician inspected the specimen and logged it in accordance with the Unified Soil Classification System (USCS). These laboratory soil logs are presented as Plates D-24 through D-40. If the soil was bonded, the ice contained in the bonded soil sample was further classified in accordance with the U.S. Army Corps of Engineers' ice classification system. The information recorded on the laboratory soil logs includes comments on structural features and soil constituents, such as sea shells and organic materials. These logs provide more detailed information about the nature of the soils encountered in each boring than could be shown on the field test boring logs presented in Appendix B.

LOG OF SOIL SAMPLE

PROJECT PT THOMSON
FROZEN
JOB NO. 9612031.08
LOGGED BY D.G.
DATE 4/12/82
BORING NO. 1 DEPTH 0.0 TO 0.5

TEST RESULTS	DEPTH (ft)	VISUAL CLASSIFICATION
	0.0	Top SHELBY
		[illegible]
		[illegible]
		[illegible]

REMARKS SAMPLE THAWED [illegible]

LOG OF SOIL SAMPLE

PROJECT PT THOMSON
JOB NO. 9612031.08
LOGGED BY D.G.
DATE 4/12/82
BORING NO. 2 DEPTH 1.5 TO 4.2

TEST RESULTS	DEPTH (ft)	VISUAL CLASSIFICATION
	1.5	Top SHELBY
		SLOUGH
	2.0	GREY [illegible] SAND (SM)
		THERMAL [illegible]
		[illegible]
	3.5	[illegible]
		[illegible] (SP-SM)
		[illegible]
	4.0	[illegible]

REMARKS SHELBY WAS CUT IN THREE [illegible] SECTIONS TO [illegible] [illegible] THE THAWING

LOG OF SOIL SAMPLE

PROJECT PT THOMSON
JOB NO. 9612031.08
LOGGED BY D.G.
DATE 4/1/82
BORING NO. 2 DEPTH 0.0 TO 0.1

TEST RESULTS	DEPTH (ft)	VISUAL CLASSIFICATION
	0.0	Top SHELBY
		[illegible]
		[illegible] GREY SAND
		[illegible] (SP)
	1.0	MEDIUM TO FINE GRAIN. [illegible]

REMARKS

LOG OF SOIL SAMPLE

PROJECT
Pt. Thomson
JOB NO. 9612.033.08
LOGGED BY [illegible]
DATE 5-1-82
BORING NO. 2 DEPTH 9.5 TO 12.1

TEST RESULTS	DEPTH (ft)	VISUAL CLASSIFICATION
	9.5	Top SHELBY
		Grey Fine Sand [illegible]
[illegible]	10.5	
	11.0	Grey Silty Fine Sand (SM)
[illegible]	11.5	Blk Silty Fine Sand (SM)
	12.0 12.1	Grey Sandy Silt (ML)

REMARKS

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Laboratory Soil Logs

Pt. Thomson Development Project
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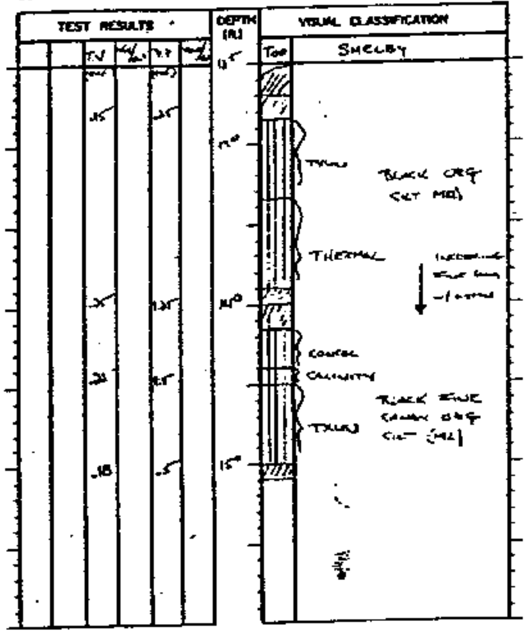
PLATE
D-24

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
[illegible]	9612,031.08	DAB	4/82		

LOG OF SOIL SAMPLE

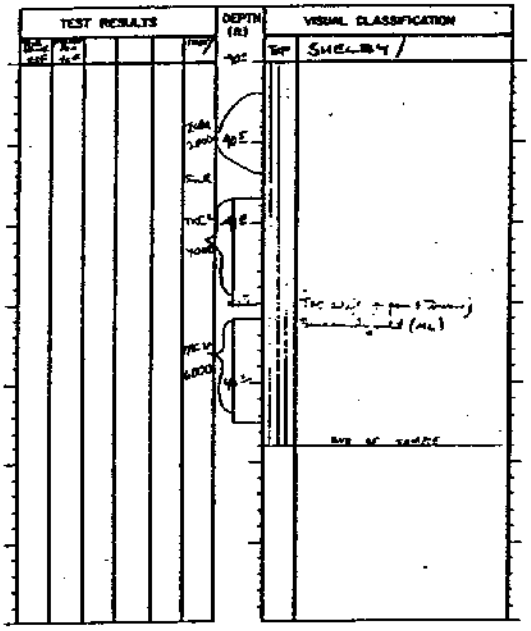
PROJECT Pt Thomson JOB NO. 9612031.08
LOGGED BY D.G.
DATE 3/25/82
BORING NO. 2 DEPTH 12^{5} TO 15^{5}



REMARKS

LOG OF SOIL SAMPLE

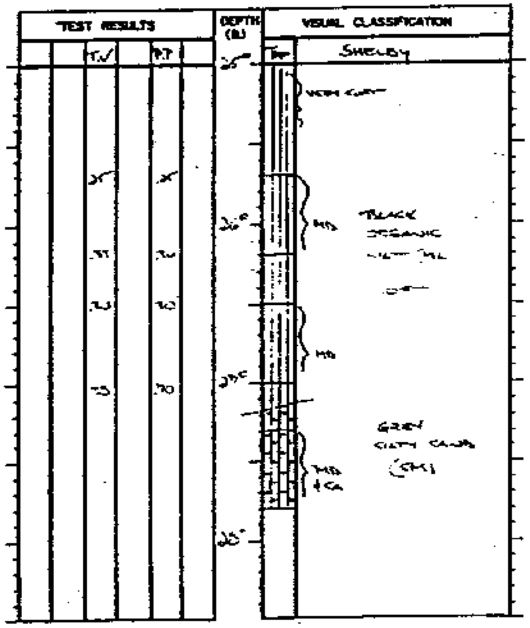
PROJECT Pt. Thomson JOB NO. 9612,053.08
LOGGED BY
DATE
BORING NO. 2 DEPTH 40^{8} TO 42^{1}



REMARKS

LOG OF SOIL SAMPLE

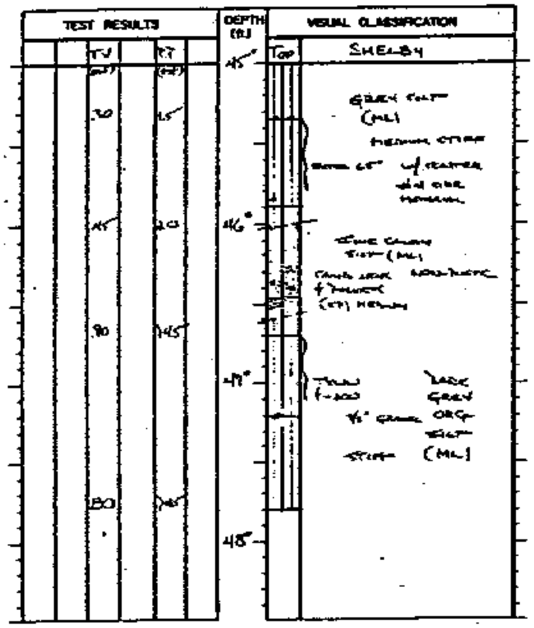
PROJECT Pt Thomson JOB NO. 9612031.08
LOGGED BY D.G.
DATE 4/6/82
BORING NO. 2 DEPTH 25^{5} TO 27^{8}



REMARKS

LOG OF SOIL SAMPLE

PROJECT Pt Thomson JOB NO. 9612031.08
LOGGED BY D.G.
DATE 4/1/82
BORING NO. 2 DEPTH 45^{0} TO 47^{8}



REMARKS

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PLATE
D-25

DRAWN
JOB NUMBER 9612,031.08
APPROVED DAB
DATE 4/82
REVISED
DATE

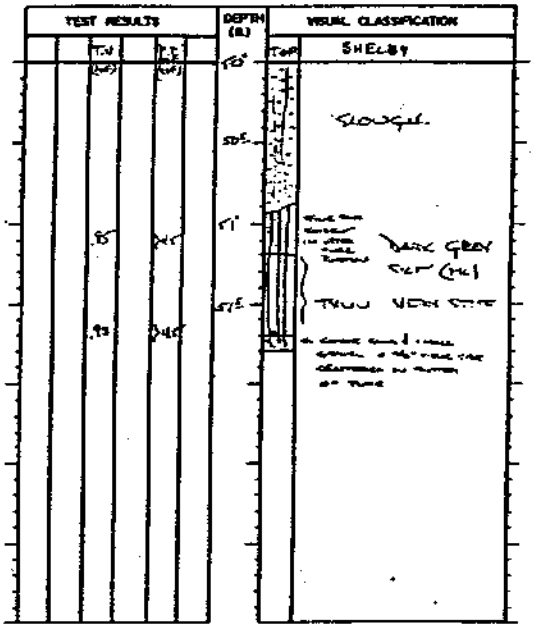
LOG OF SOIL SAMPLE

PROJECT PT THOMSON JOB NO. 9612,031.08

LOGGED BY D.G

DATE 4/11/82

BORING NO. 2 DEPTH 50' TO 51.5



SLOUGH.

DARK GREY SILT (ML)

THRU VERY STIFF

REMARKS

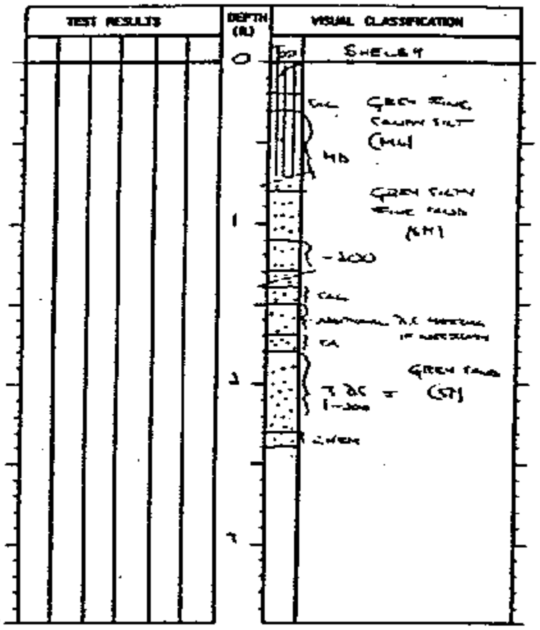
LOG OF SOIL SAMPLE

PROJECT PT THOMSON JOB NO. 9612,031.08

LOGGED BY D G

DATE 4/13/82

BORING NO. 4 DEPTH 0' TO 2.5



CAL GREEN FINE SANDY SILT (ML)

MD

GREEN SILTY FINE SAND (SM)

-200

CAL

SA

GREEN SAND (SP)

SIEVE

REMARKS

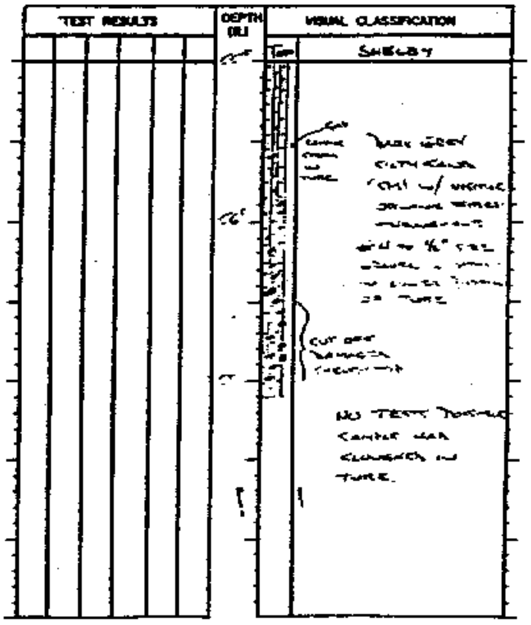
LOG OF SOIL SAMPLE

PROJECT PT THOMSON JOB NO. 9612,031.08

LOGGED BY D.G

DATE 4/6/82

BORING NO. 2 DEPTH 55' TO 57½



DARK GREY SILTY SAND (SM) w/

CUT OFF

NO TESTS POSSIBLE SAMPLE WAS CLOBBERED IN TUBE.

REMARKS

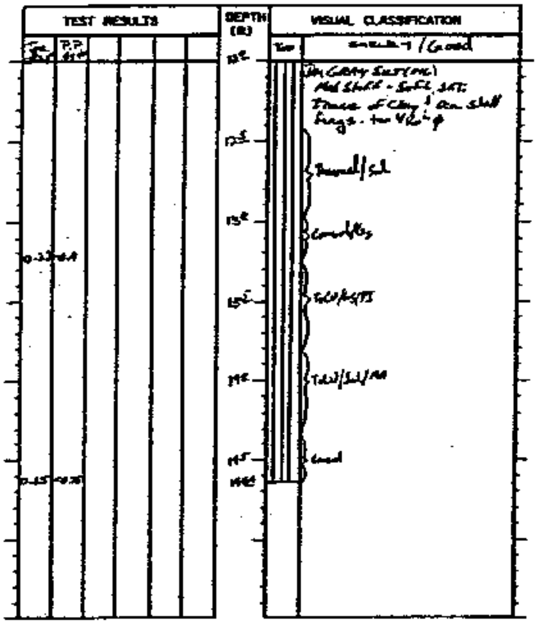
LOG OF SOIL SAMPLE

PROJECT Pt. Thomson JOB NO. 12,033.02

LOGGED BY HRM/DG

DATE 2/18/82

BORING NO. 4 DEPTH 12.0 TO 14.6



Dk Gray Silt (ML) Med Stiff - Soft, sat. Trace of Clay & occ. shell frags. to 1/2" φ

Trimmed/sl

Consolids

Tri/AtteTS

Tx/Sil/AA

Good

REMARKS Scan 3¾" @ Top. Flush @ Btm. 31½" long Top 0.4' Not Full tube. Some water loss out top of tube when uncapped

---

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Laboratory Soil Logs

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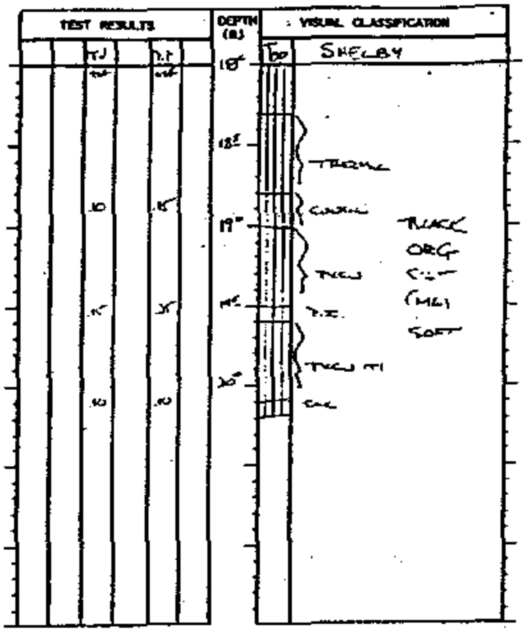
EXXON Company, U.S.A.

PLATE D-20

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DCB	4/82		

LOG OF SOIL SAMPLE

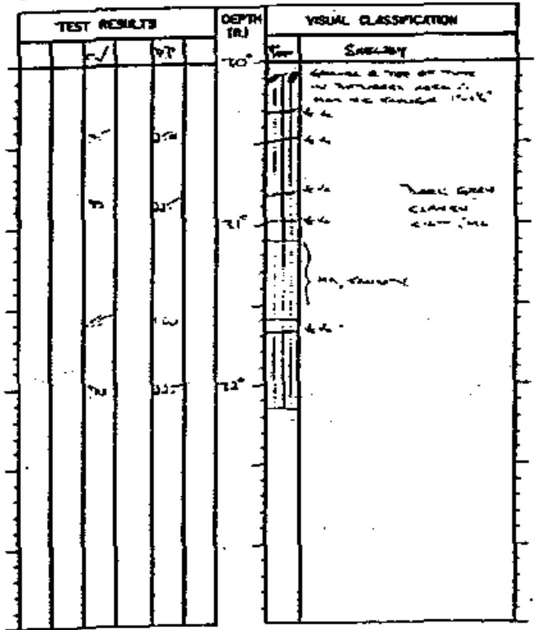
PROJECT Pt Thomson
JOB NO. [illegible]
LOGGED BY D.G.
DATE 7/26/82
BORING NO. 4 DEPTH 18' TO 20.5



REMARKS

LOG OF SOIL SAMPLE

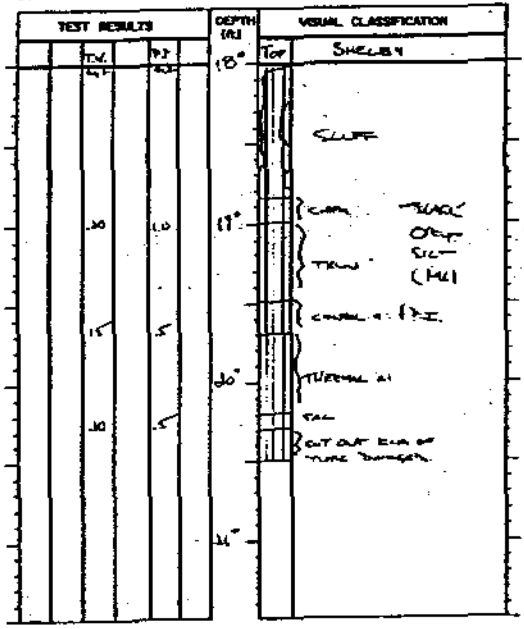
PROJECT Pt Thomson
Frozen Tube
JOB NO. [illegible]
LOGGED BY D.G.
DATE 4/17/82
BORING NO. 5 DEPTH 30.5 TO 32.5



REMARKS Torvane & Pocket Pen Reading Taken on Thawed Sample

LOG OF SOIL SAMPLE

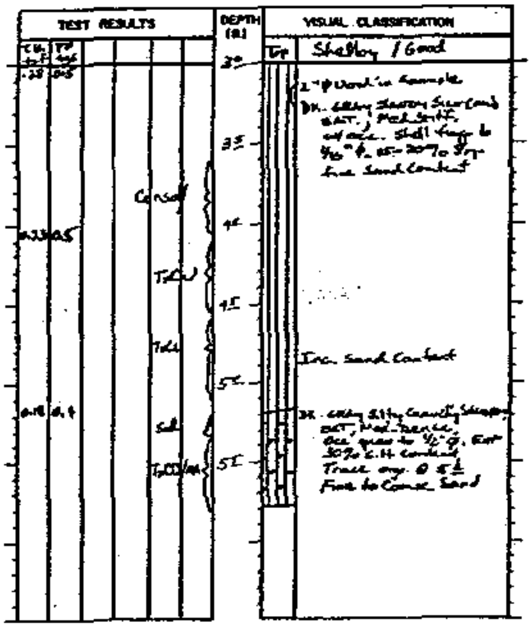
PROJECT Pt Thomson
JOB NO. [illegible]
LOGGED BY D.G.
DATE 7/26/82
BORING NO. 5 DEPTH 18' TO 20.5



REMARKS

LOG OF SOIL SAMPLE

PROJECT
Pt. Thomson
JOB NO. 9612.031.08
LOGGED BY DG/MEM
DATE 3/18/82
BORING NO. 6 DEPTH 32 TO 58



REMARKS Flush @ Btm -0.2' @ Top

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PLATE
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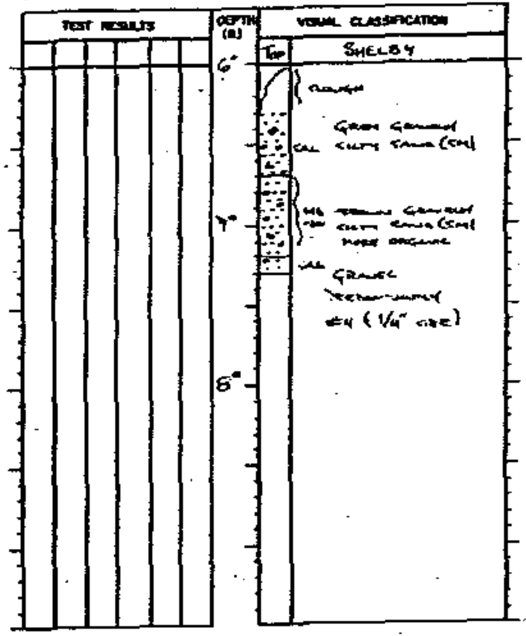
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DBB	4/82		

LOG OF SOIL SAMPLE

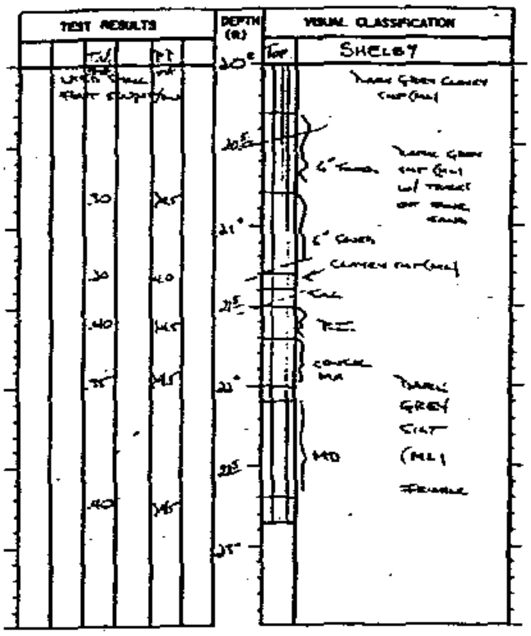
PROJECT Pt Thomson
JOB NO. [illegible]
LOGGED BY D.G.
DATE 4/[illegible]/82
BORING NO. 6 DEPTH 6^{0} TO 7^{4}



REMARKS

LOG OF SOIL SAMPLE

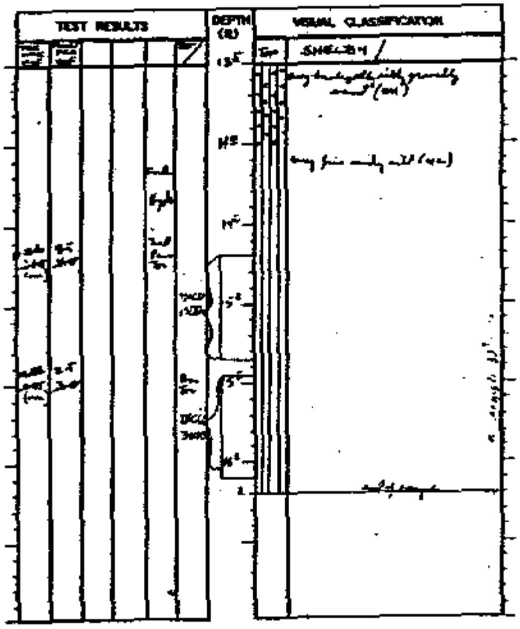
PROJECT Pt Thomson
JOB NO. [illegible]
LOGGED BY DG
DATE 4/[illegible]/82
BORING NO. 6 DEPTH 20^{0} TO 22^{8}



REMARKS

LOG OF SOIL SAMPLE

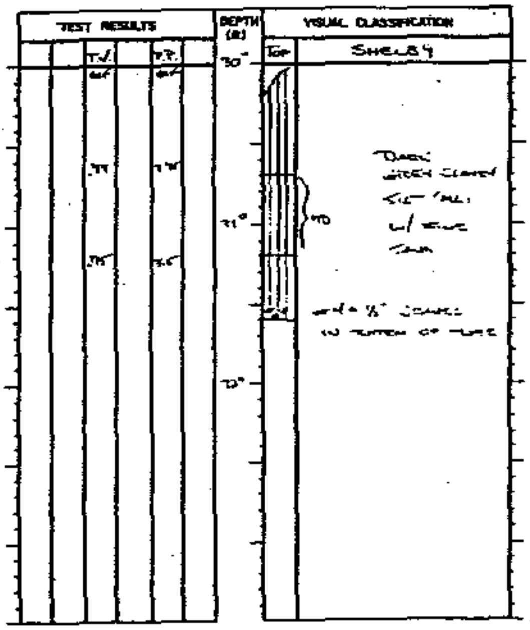
PROJECT Pt. Thomson
JOB NO. [illegible]
LOGGED BY
DATE
BORING NO. 6 DEPTH 13^{5} TO 16^{2}



REMARKS

LOG OF SOIL SAMPLE

PROJECT Pt. Thomson
JOB NO. [illegible]
LOGGED BY D.G.
DATE 4/4/82
BORING NO. 6 DEPTH 30^{0} TO 31^{6}



REMARKS

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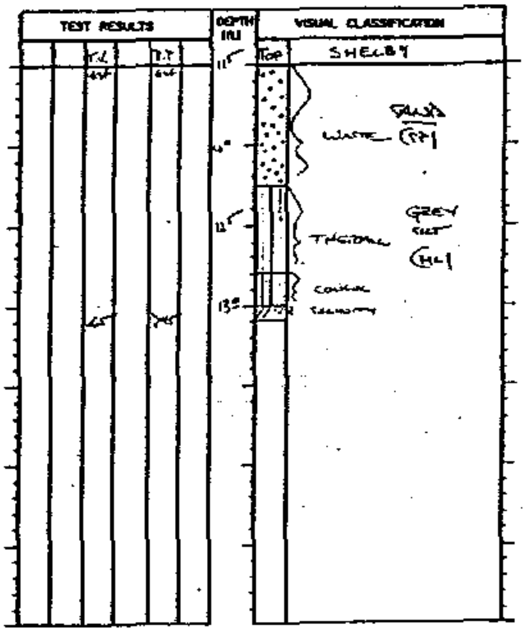
PLATE **D-28**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DEB	4/82		

LOG OF SOIL SAMPLE

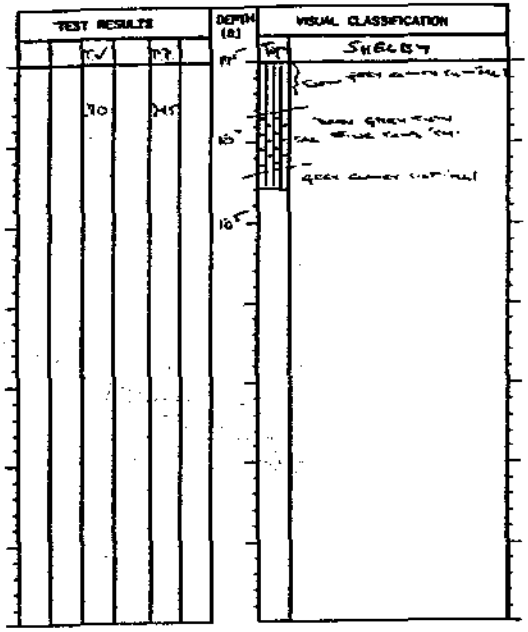
PROJECT PT THOMSON JOB NO. 96120308
LOGGED BY D.G.
DATE 3/15/82
BORING NO. 8 DEPTH 11.5 TO 13.4



REMARKS

LOG OF SOIL SAMPLE

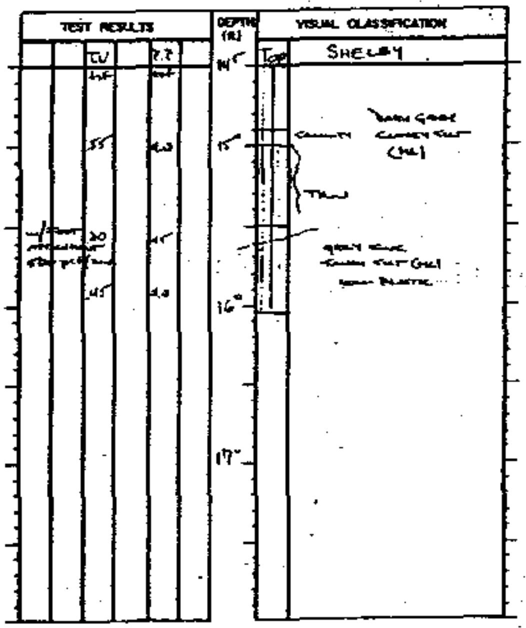
PROJECT PT THOMSON JOB NO. 96120308
LOGGED BY D.G.
DATE 4/7/82
BORING NO. 3 DEPTH 14.5 TO 16.3



REMARKS DIFFERS FROM BORING LOG ENTRY

LOG OF SOIL SAMPLE

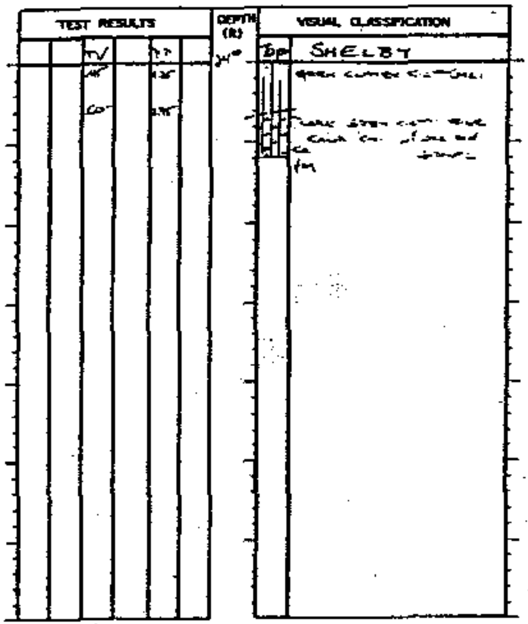
PROJECT PT THOMSON JOB NO. 96120308
LOGGED BY D.G.
DATE 4/1/82
BORING NO. 8 DEPTH 14.5 TO 16.2



REMARKS

LOG OF SOIL SAMPLE

PROJECT PT THOMSON JOB NO. 96120308
LOGGED BY D.G.
DATE 4/6/82
BORING NO. 8 DEPTH 24.0 TO 24.6



REMARKS DIFFERS FROM BORING LOG ENTRY

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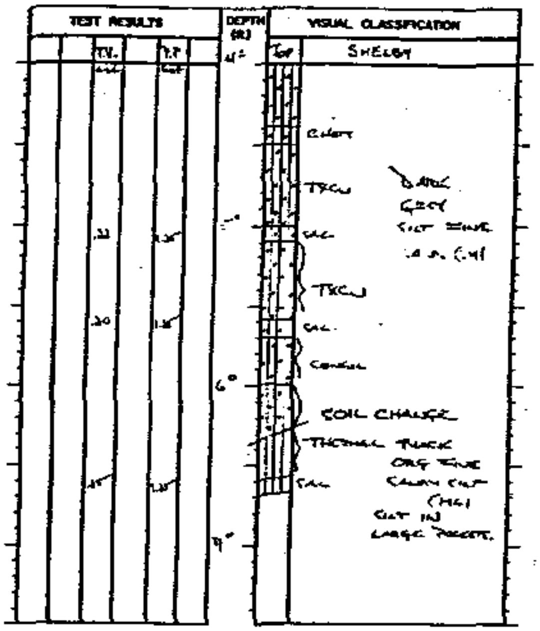
PLATE **D-29**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DEB	4/82		

LOG OF SOIL SAMPLE

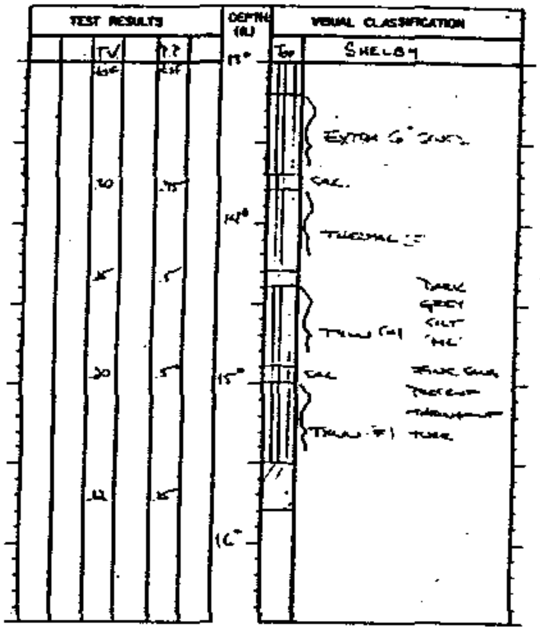
PROJECT Pt Thomson JOB NO. [illegible]
LOGGED BY D.G.
DATE [illegible]
BORING NO. 9 DEPTH 4^{0} TO 6^{5}



REMARKS

LOG OF SOIL SAMPLE

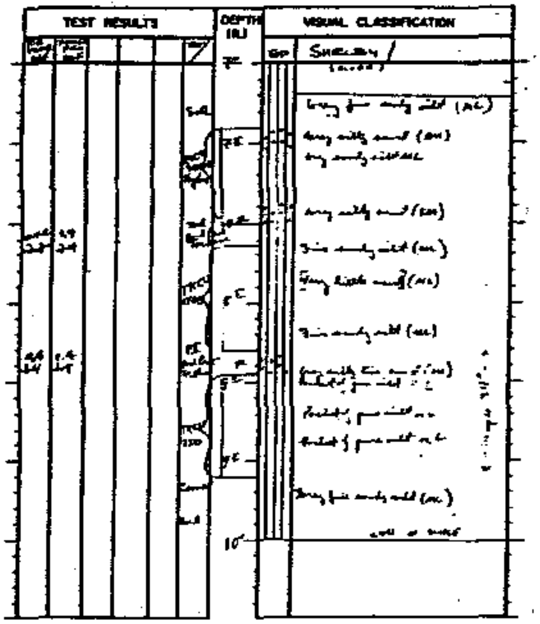
PROJECT Pt Thomson JOB NO. [illegible]
LOGGED BY D.G.
DATE [illegible]
BORING NO. 9 DEPTH 13^{0} TO 15^{5}



REMARKS

LOG OF SOIL SAMPLE

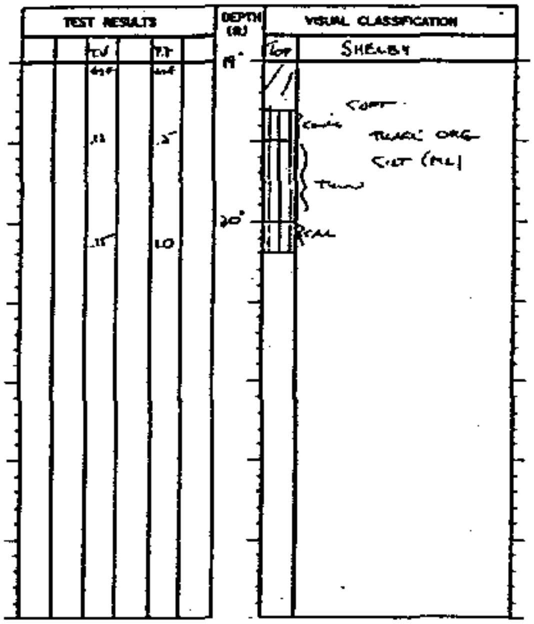
PROJECT Pt. Thomson JOB NO. 9612 033.08
LOGGED BY
DATE
BORING NO. 9 DEPTH 7^{5} TO



REMARKS

LOG OF SOIL SAMPLE

PROJECT Pt Thomson JOB NO. [illegible]
LOGGED BY D.G.
DATE [illegible]
BORING NO. 9 DEPTH 19^{5} TO 20^{4}



REMARKS

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Laboratory Soil Logs
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
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PLATE
D-30

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DMB	4/82		

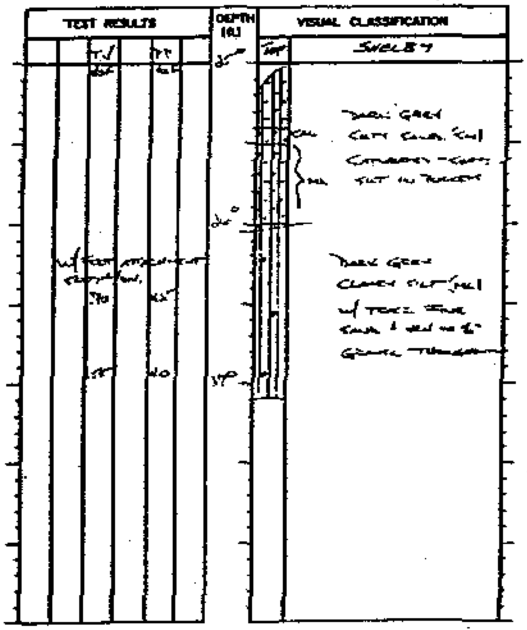
LOG OF SOIL SAMPLE

PROJECT Pt Thomson JOB NO. 9612,031.0

LOGGED BY D.G.

DATE 4/7/82

BORING NO. 9 DEPTH 25 TO 27'



REMARKS

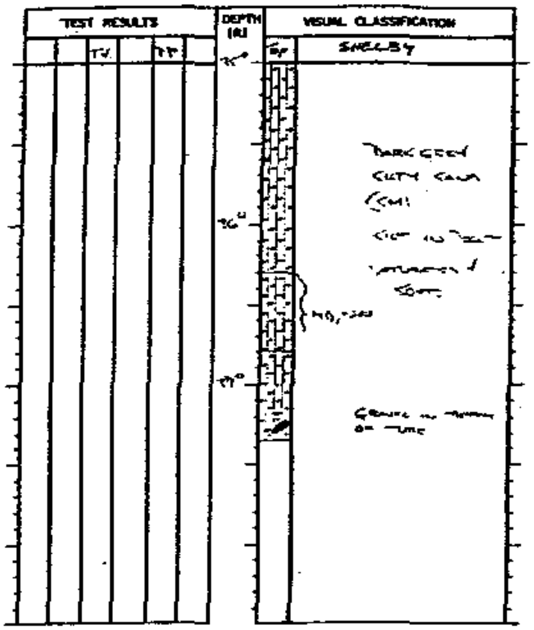
LOG OF SOIL SAMPLE

PROJECT Pt Thomson JOB NO. 9612,031.08

LOGGED BY D.G.

DATE 4/7/82

BORING NO. 9 DEPTH 35.5 TO 37.1



REMARKS Differs from Boring Log Entry

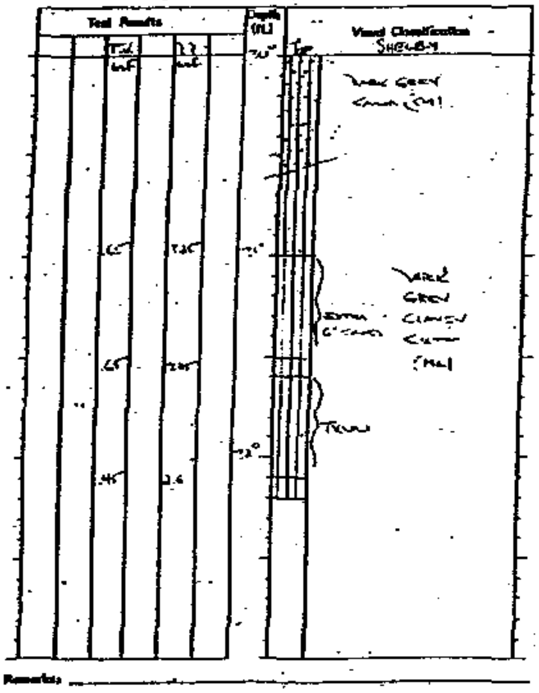
LOG OF SOIL SAMPLE

Project Pt Thomson Job No. 9612031

Logged By D.G.

Date 4/5/82

Boring No. 9 Depth 30 to 32



Remarks

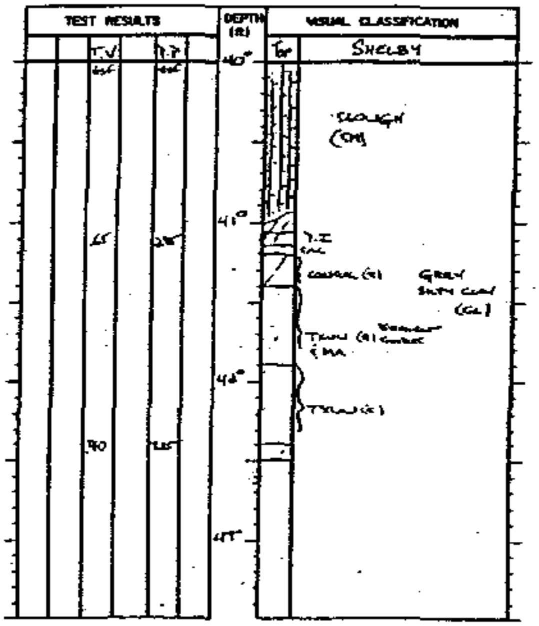
LOG OF SOIL SAMPLE

PROJECT Pt Thomson JOB NO. 96120308

LOGGED BY D.G.

DATE 3/5/82

BORING NO. 9 DEPTH 40.0 TO 41.5



REMARKS

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Laboratory Soil Logs

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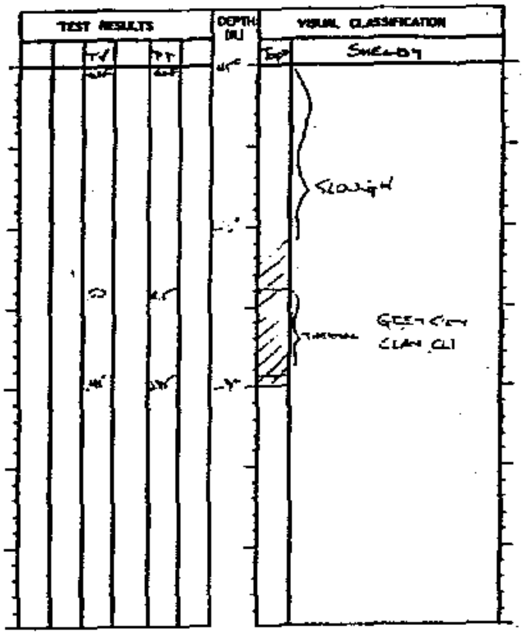
PLATE **D-31**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DEB	4/82		

LOG OF SOIL SAMPLE

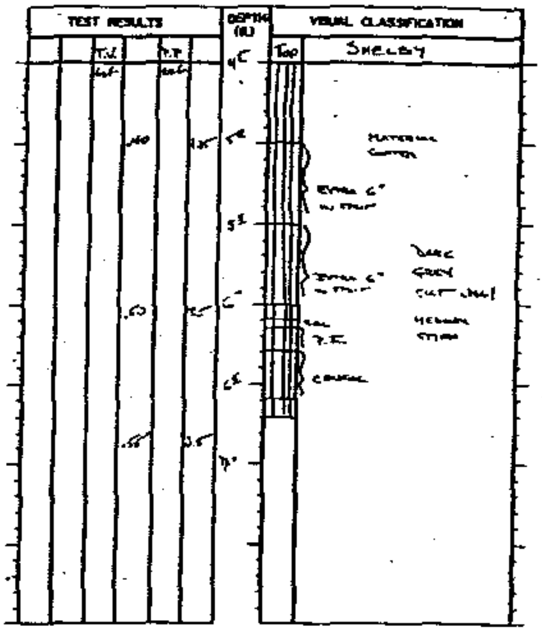
PROJECT PT THOMSON JOB NO. 9612031
LOGGED BY D.G.
DATE 3/17/82
BORING NO. 9 DEPTH 4.5 TO [illegible]



REMARKS

LOG OF SOIL SAMPLE

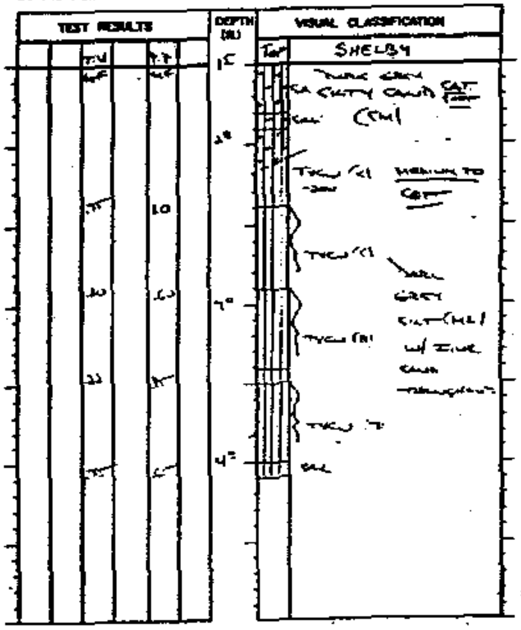
PROJECT PT THOMSON JOB NO. 9612031
LOGGED BY D.G.
DATE 3/21/82
BORING NO. 14 DEPTH 4.5 TO 6.7



REMARKS

LOG OF SOIL SAMPLE

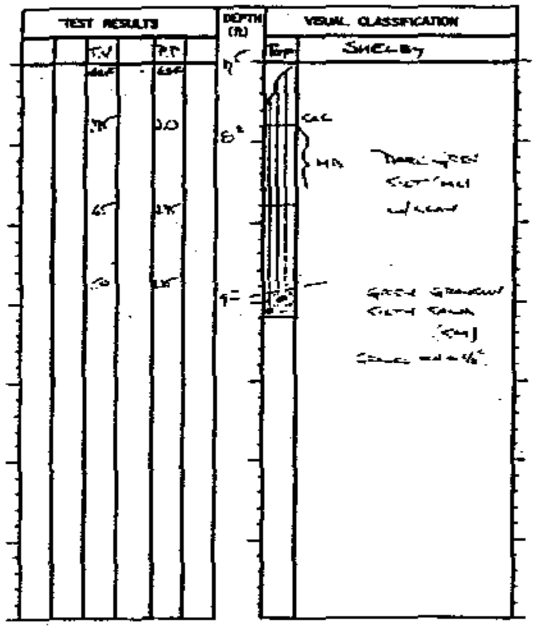
PROJECT PT THOMSON JOB NO. 9612031
LOGGED BY D.G.
DATE 3/20/82
BORING NO. 14 DEPTH 1.5 TO 4.2



REMARKS DIFFERS FROM BORING LOGS
SOIL CHANGE NOT AS DEEP AS
ANTICIPATED

LOG OF SOIL SAMPLE

PROJECT PT THOMSON JOB NO. 9612031
LOGGED BY D.G.
DATE 3/9/82
BORING NO. 14 DEPTH 7.5 TO 9.2



REMARKS

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Laboratory Soil Logs

Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
D-32

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DEB	4/82		

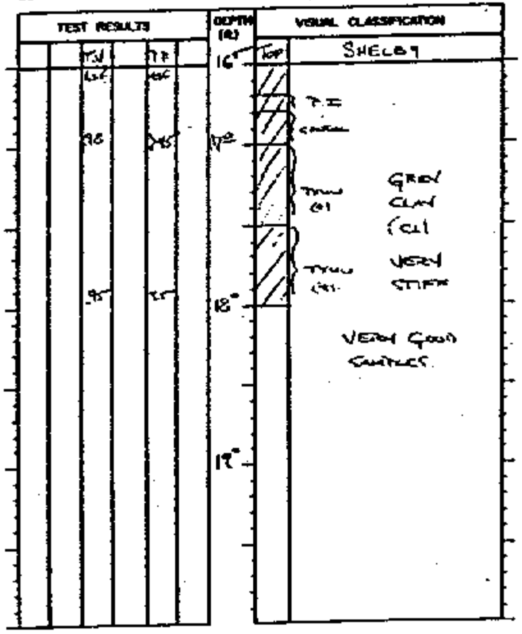
LOG OF SOIL SAMPLE

PROJECT PT THOMSON JOB NO. 9612031.08

LOGGED BY D.G.

DATE 3/31/82

BORING NO. 14 DEPTH 16.5 TO 18.0



REMARKS

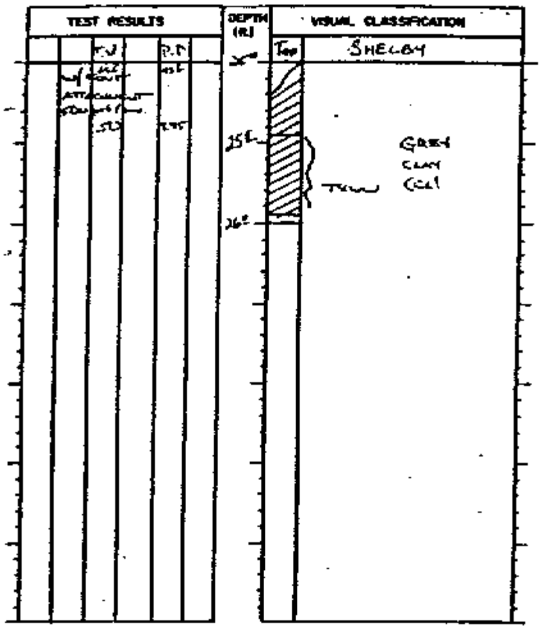
LOG OF SOIL SAMPLE

PROJECT PT THOMSON JOB NO. 9612031.08

LOGGED BY D.G.

DATE 4/1/82

BORING NO. 14 DEPTH 25.0 TO 26.0



REMARKS

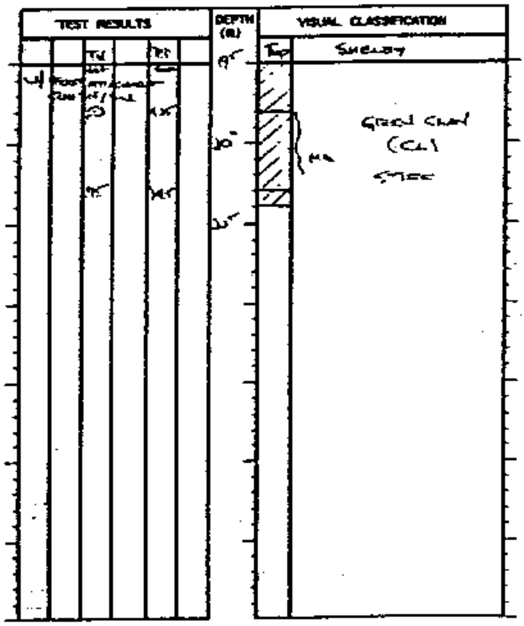
LOG OF SOIL SAMPLE

PROJECT PT THOMSON JOB NO. 9612031.08

LOGGED BY D.G.

DATE 4/1/82

BORING NO. 14 DEPTH 19.5 TO 20.5



REMARKS

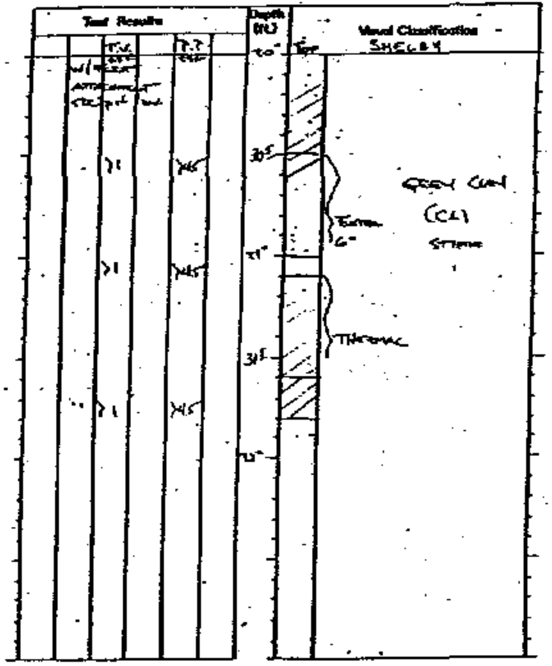
LOG OF SOIL SAMPLE

Project: PT THOMSON Job No. 9612031.08

Logged By D.G.

Date 4/5/82

Boring No. 14 Depth 30.0 to 31.5



Remarks:

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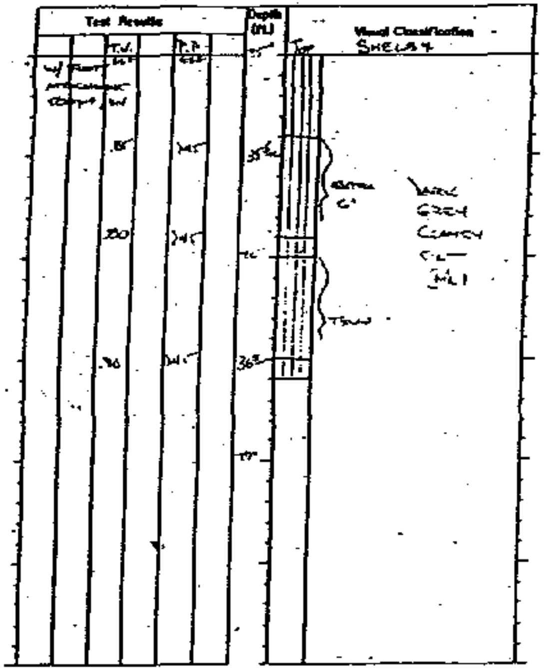
PLATE

D-33

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DEB	4/82		

LOG OF SOIL SAMPLE

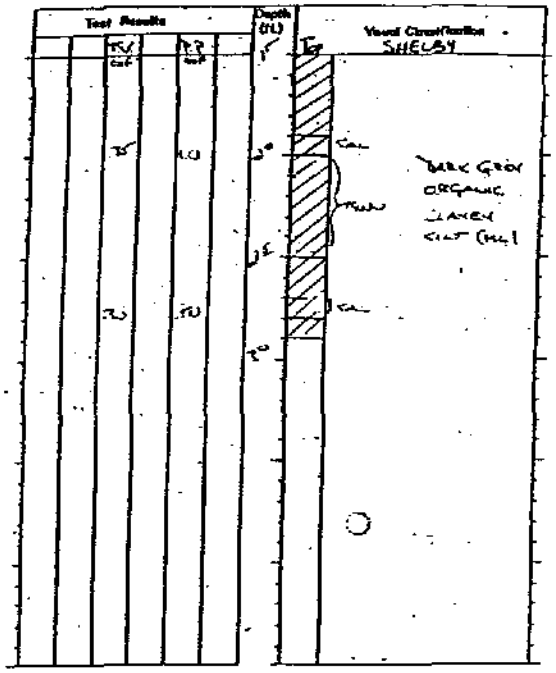
Project: PT. THOMSON
Job No. 9612031
Logged By D.G.
Date 4/7/82
Boring No. 14 Depth 35 to 36.5



Remarks:

LOG OF SOIL SAMPLE

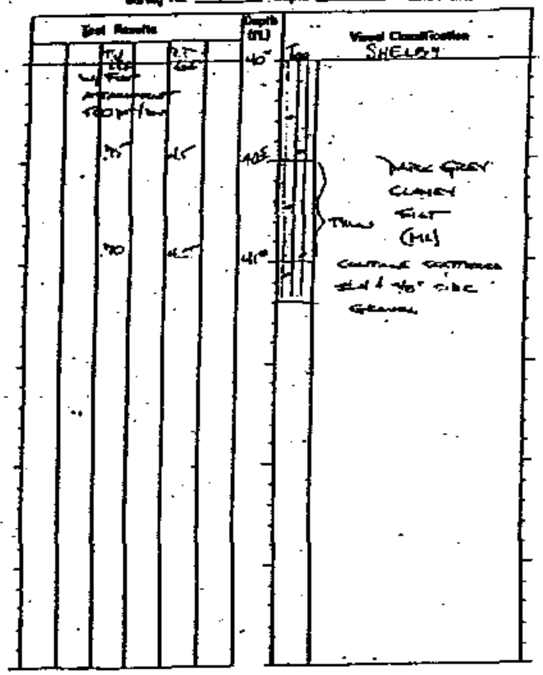
Project: PT. THOMSON
Job No. 9612031
Logged By D.G.
Date 4/9/82
Boring No. 15 Depth 15 to 17



Remarks:

LOG OF SOIL SAMPLE

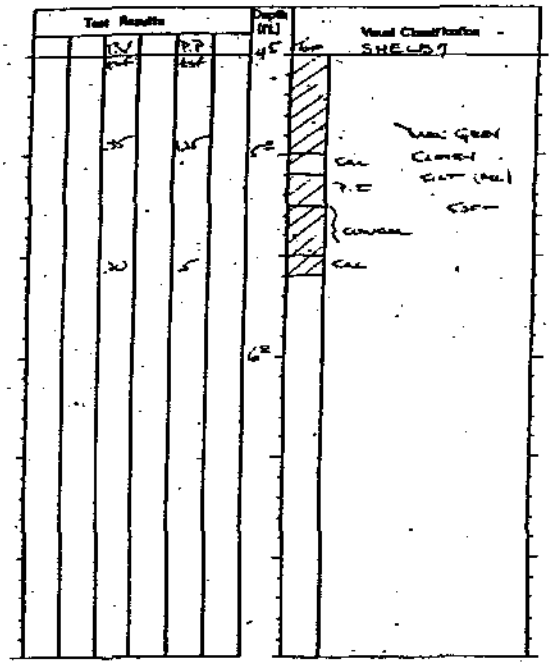
Project: PT. THOMSON
Job No. 9612031
Logged By D.G.
Date 4/6/82
Boring No. 14 Depth 40 to 41.5



Remarks:

LOG OF SOIL SAMPLE

Project: PT. THOMSON
Job No. 9612031
Logged By D.G.
Date 4/11/82
Boring No. 15 Depth 45 to 46



Remarks:

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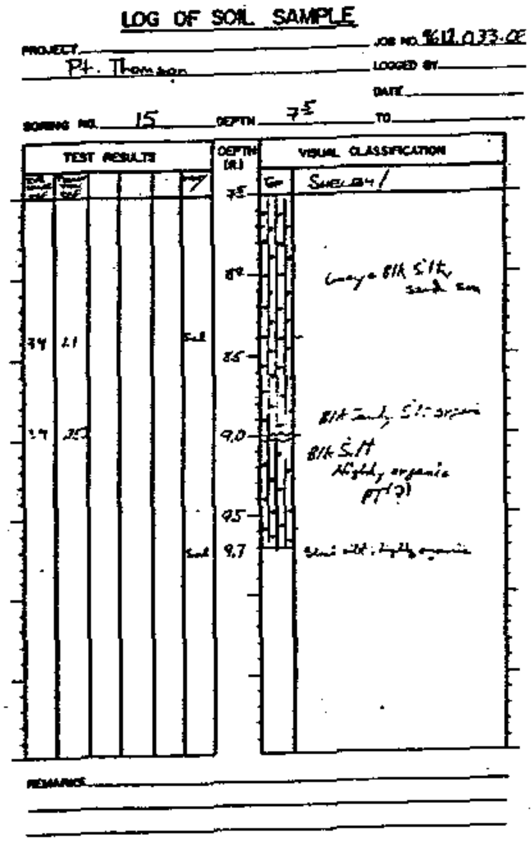
PLATE
D-34

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DGB	4/82		

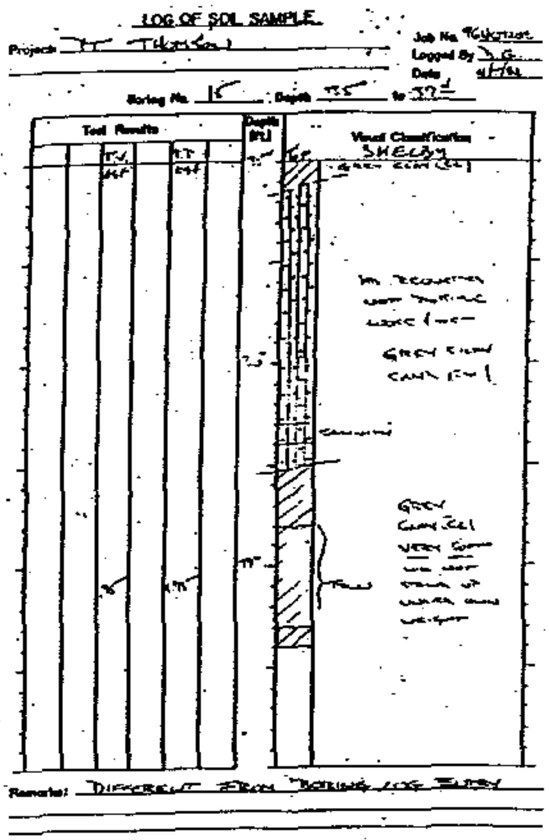


LOG OF SOIL SAMPLE

PROJECT Pt. Thomson
JOB NO. 9612.033.08
LOGGED BY
DATE
BORING NO. 15 DEPTH 7.5 TO

TEST RESULTS						DEPTH (ft.)	VISUAL CLASSIFICATION
						7.5	Shelby
						8.0	Grey-Blk Silt, sandy
34	21					8.5	
							Blk sandy Silt organic
39	25					9.0	Blk Silt Highly organic PT(?)
						9.5	
						9.7	[illegible] silt; highly organic

REMARKS

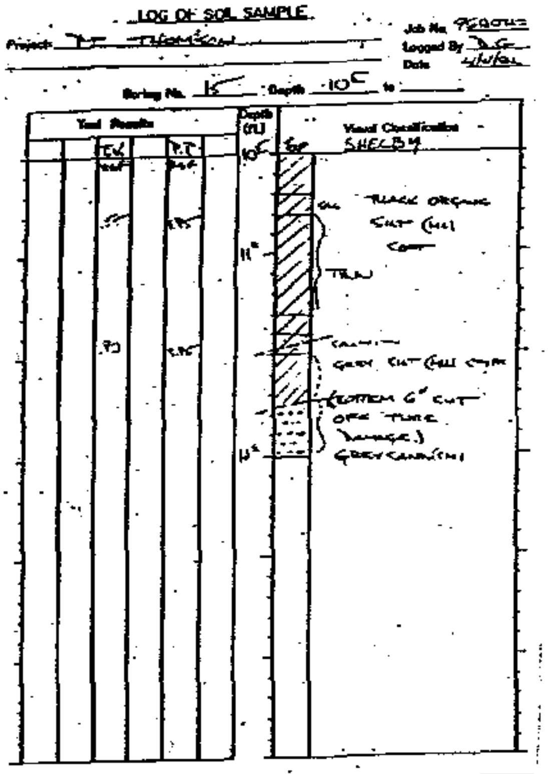


LOG OF SOIL SAMPLE

Project PT. THOMSON
Job No. 9612033
Logged By D.G.
Date 4/1/82
Boring No. 15 Depth 7.5 to 8.5

Test Results						Depth (ft.)	Visual Classification
		T.V.		P.T.		7.5	SHELBY
							[illegible]
							GREY SILTY SAND (SM)
						8.0	
							GREY CLAY (CL)
	.15						

Remarks: DIFFERENT FROM BORING LOG ENTRY

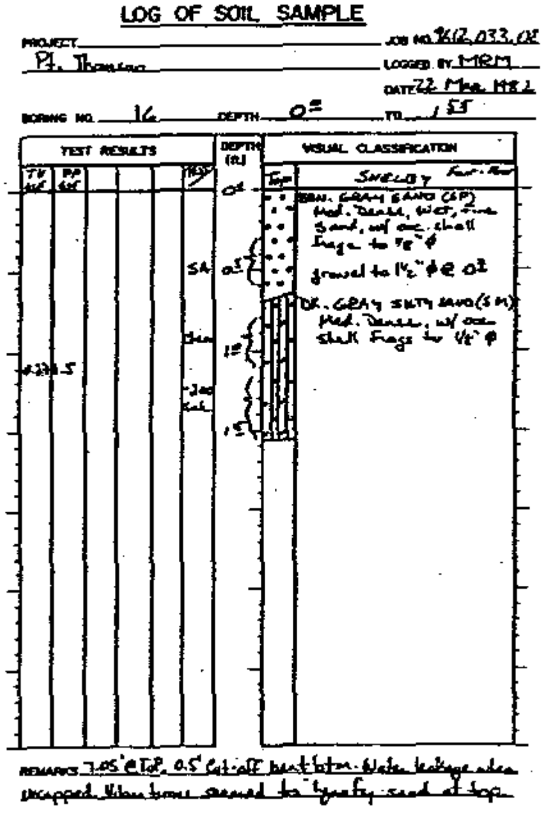


LOG OF SOIL SAMPLE

Project PT. THOMSON
Job No. 9612033
Logged By D.G.
Date 4/1/82
Boring No. 15 Depth 10.5 to

Test Results						Depth (ft.)	Visual Classification
		T.V.		P.T.		10.5	SHELBY
							BLACK ORGANIC SILT (ML) CONT
		.55		.75		11.0	
							[illegible]
		.75		1.75			GREY SILT (ML)
							(BOTTOM 6" CUT OFF TUBE DAMAGE) GREY SAND (SM)
						11.5	

Remarks:



LOG OF SOIL SAMPLE

PROJECT Pt. Thomson
JOB NO. 9612.033.08
LOGGED BY MRM
DATE 22 Mar. 1982
BORING NO. 16 DEPTH 0.0 TO 1.55

TEST RESULTS						DEPTH (ft.)	VISUAL CLASSIFICATION
TV	PP					0.0	Shelby
							BRN. GRAY SAND (SP) Med. Dense, wet, fine sand, w/ occ. shell frags to 1/8" φ
					SA	0.5	gravel to 1½" φ @ 0.2
							DK. GRAY SILTY SAND (SM) Med. Dense, w/ occ. shell frags to 1/8" φ
						1.0	
	5						
						1.5	

REMARKS 1.05' @ Top, 0.5' cut-off [illegible] btm. Water leakage when uncapped [illegible] seemed to [illegible] sand at top.

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PLATE
D-35

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DGB	4/82		

LOG OF SOIL SAMPLE

PROJECT Pt Thomson JOB NO. 9612031.05
LOGGED BY D.G.
DATE 4/6/82
BORING NO. 17 DEPTH 2.0 TO 2.5

TEST RESULTS						DEPTH (ft)	VISUAL CLASSIFICATION	
						0	Top	Shelby
							ML	Dark Green Silty fine Sand (SM)
							CAL	
						1.0	ML	Dark Grey trace organic Silt (ML) non Plastic
							CAL	
						2.5		Dark Green trace Silt (ML) [illegible]
								Bottom 6" of tube [illegible]

REMARKS

LOG OF SOIL SAMPLE

Project Pt Thomson Job No. 961203
Logged By D.G.
Date 4/82
Boring No. 17 Depth 6.5 to 7.2

Test Results						Depth (ft)	Visual Classification	
		TV tsf		PP tsf		6.0	Top	SHELBY
		.20		.5			Caving	
							Tube full	Dark Green trace organic Silt (ML)
						7.0	Tube	[illegible]
		.25		.15			Caving	[illegible]
						8.0		

Remarks:

LOG OF SOIL SAMPLE

PROJECT Pt Thomson JOB NO. 9612031.08
LOGGED BY D.G.
DATE 4/7/82
BORING NO. 17 DEPTH 3.5 TO 4.5

TEST RESULTS						DEPTH (ft)	VISUAL CLASSIFICATION	
		TV		PP		3.0	Top	SHELBY
								Soft [illegible]
								PP Control
		.35		1.25				[illegible]
						4.0	Tube full	Dark Green Silt (ML)
		.37		1.0			Tube full CAL	
						5.0		
						6.0		

REMARKS

LOG OF SOIL SAMPLE

PROJECT Pt Thomson JOB NO. 9612031.08
LOGGED BY D.G.
DATE 4/10/82
BORING NO. 17 DEPTH 9.0 TO 9.5

TEST RESULTS						DEPTH (ft)	VISUAL CLASSIFICATION	
		TV		PP		9.0	Top	Shelby
		.25		1.0				Dark Green [illegible] (ML)
								[illegible]
						9.5		[illegible]
								[illegible] Total Carrier

REMARKS

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PLATE
D-3b

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DEB	4/82		

LOG OF SOIL SAMPLE

Project PT THOMSON
Job No. [illegible]
Logged By D.G.
Date 4/7/82
Boring No. 17 Depth 30° to 31°

Test Results						Depth (ft)	Visual Classification
		T.V. KSF		T.T. KSF		30°	Top SHELBY

[illegible]

>10 >4.5

30.5

DARK GREY CLAYEY SILT (ML) STIFF

THAW

>10 >4.5

31°

w/ [illegible] [illegible]

[illegible] [illegible] [illegible]

CONTAINS [illegible] FINE GRAVEL

Remarks

LOG OF SOIL SAMPLE

PROJECT PT THOMSON
FROZEN
JOB NO. [illegible]
LOGGED BY D.G.
DATE 4/6/82
BORING NO. 18 DEPTH 0° TO 1²

TEST RESULTS						DEPTH (ft)	VISUAL CLASSIFICATION
						0°	Top Shelby

[illegible]

THERMAL [illegible]

1°

[illegible]

ICE [illegible]

1°

REMARKS

LOG OF SOIL SAMPLE

PROJECT Pt. Thomson
JOB NO. 9612.033.08
LOGGED BY [illegible]
DATE
BORING NO. 17 DEPTH 35° TO 37°

TEST RESULTS						DEPTH (ft)	VISUAL CLASSIFICATION
[illegible]	[illegible]				[illegible]	35°	Top SHELBY

Too Stiff For [illegible] Too Stiff

Dark Grey Layered Silt (ML) w/gravel

35.5

sample has 2 pockets of sluFF and Free water inside

36

CS

37°

Pocket [illegible] on end of Tube

REMARKS

LOG OF SOIL SAMPLE

PROJECT PT THOMSON
JOB NO. [illegible]
LOGGED BY D.G.
DATE 4/10/82
BORING NO. 20 DEPTH 0° TO .85

TEST RESULTS						DEPTH (ft)	VISUAL CLASSIFICATION
		T.V.		T.T.		0°	Top Shelby

[illegible]

REMARKS

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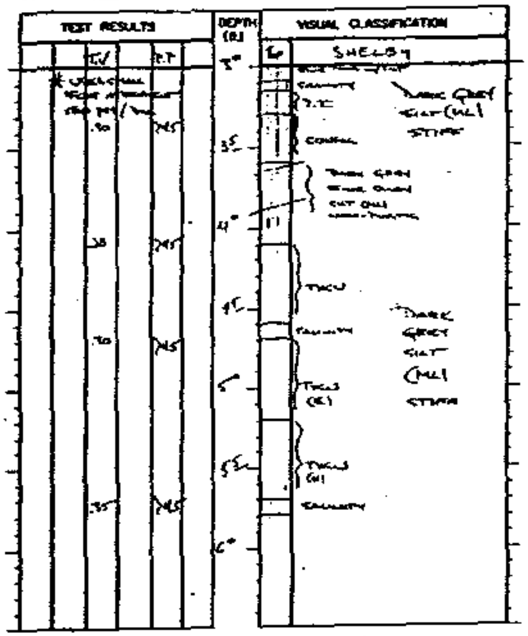
PLATE
D-37

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	HEB	4/82		

LOG OF SOIL SAMPLE

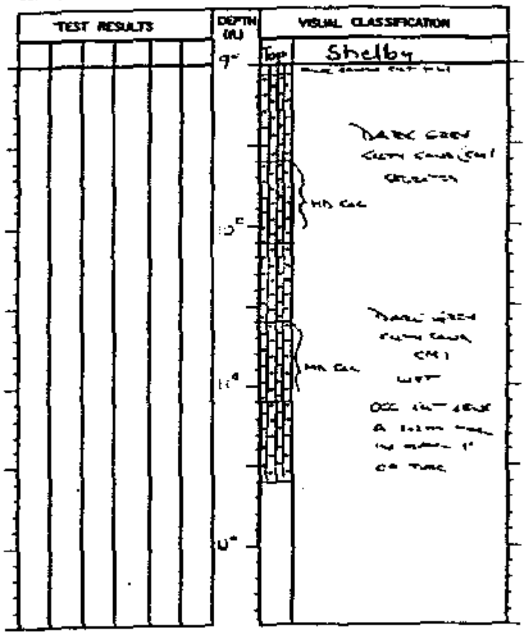
PROJECT PT THOMSON JOB NO. [illegible]
LOGGED BY [illegible]
DATE 4/1/83
BORING NO. 21 DEPTH 3" TO 5"



REMARKS

LOG OF SOIL SAMPLE

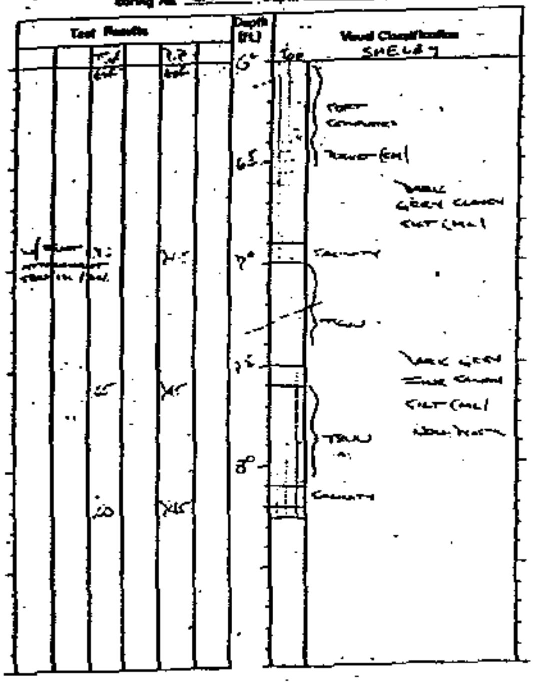
PROJECT PT THOMSON JOB NO. [illegible]
LOGGED BY [illegible]
DATE 4/10/82
BORING NO. 21 DEPTH 9° TO 11"



REMARKS

LOG OF SOIL SAMPLE

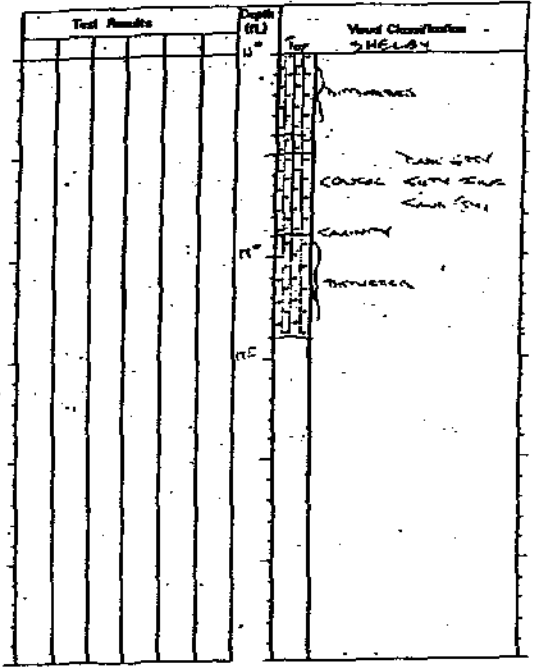
Project PT THOMSON Job No. [illegible]
Logged By [illegible]
Date [illegible]
Boring No. 21 Depth 6" to 8"



Remarks:

LOG OF SOIL SAMPLE

Project PT THOMSON Job No. [illegible]
Logged By [illegible]
Date [illegible]
Boring No. 21 Depth 12" to 13"



Remarks: [illegible]

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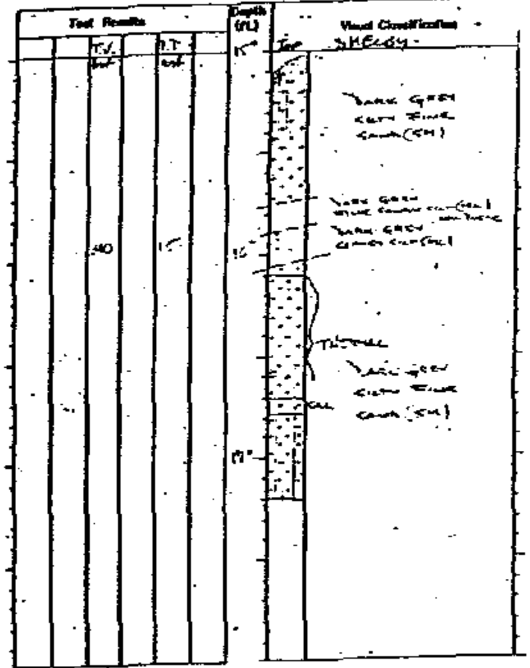
PLATE D-38

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DKB	4/82		

LOG OF SOIL SAMPLE

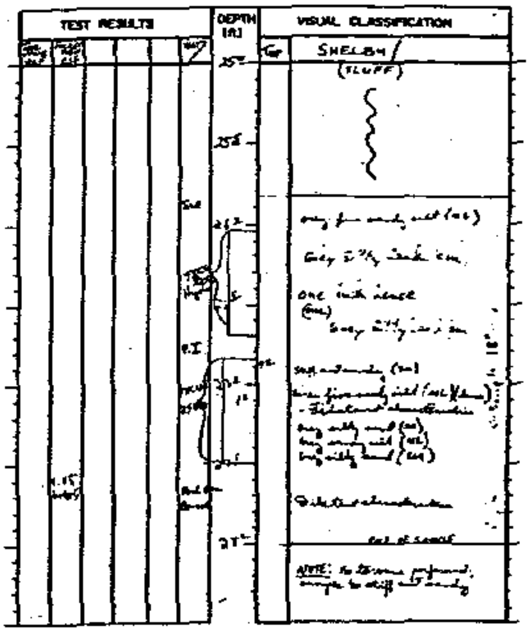
Project: Pt Thomson
Job No. 9612033
Logged By: I.G.
Date: 4/6/82
Boring No. 21 Depth 15 to 17½



Remarks: Differs from boring log entry

LOG OF SOIL SAMPLE

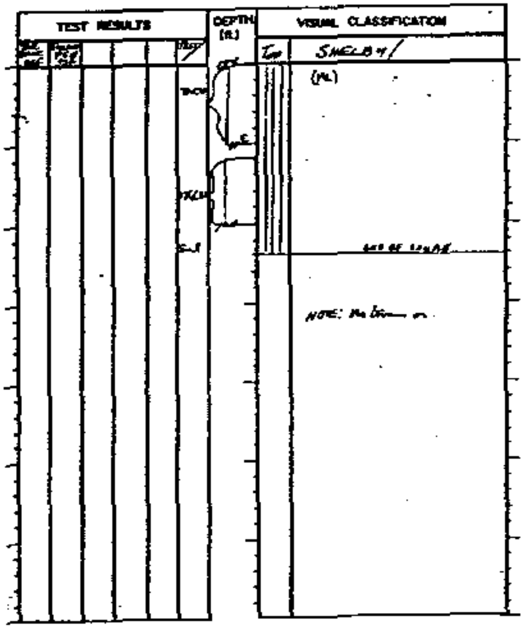
PROJECT Pt. Thomson
JOB NO. 9612,033.08
LOGGED BY
DATE
BORING NO. 21 DEPTH 25 TO



REMARKS

LOG OF SOIL SAMPLE

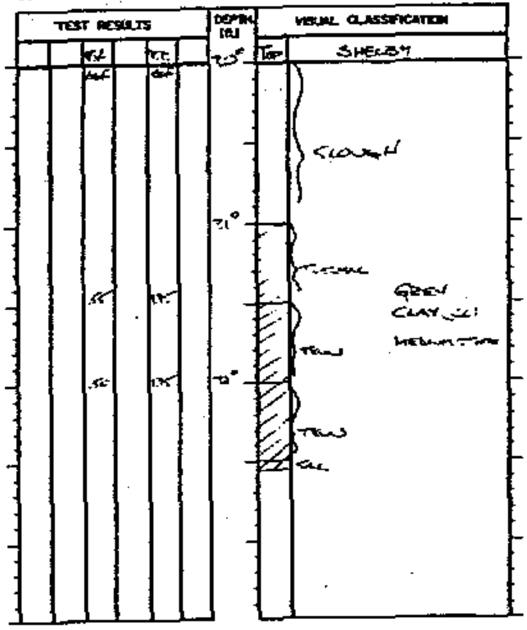
PROJECT Pt. Thomson
JOB NO. 9612,033.08
LOGGED BY
DATE
BORING NO. 21 DEPTH 18 TO 19½



REMARKS

LOG OF SOIL SAMPLE

PROJECT Pt THOMSON
JOB NO. 9612033
LOGGED BY I.G.
DATE 4/6/82
BORING NO. 21 DEPTH 30 TO 32



REMARKS

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PLATE
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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DB	4/82		

LOG OF SOIL SAMPLE

PROJECT Pt. THOMSON
JOB NO. [illegible]
LOGGED BY [illegible]
DATE 4/15/82
BORING NO. 21 DEPTH 40 TO 41.5

TEST RESULTS				DEPTH (ft)	VISUAL CLASSIFICATION	
	-V		P.P.		Top	Shelby
w/ Rout attachment				40		[illegible] Soft Sat. CL1
	.70		.45	41		[illegible]
						Green gray clay CL mottled [illegible] w/ black [illegible]
	.70		.45			
				42		

REMARKS

LOG OF SOIL SAMPLE

PROJECT Pt. Thomson
JOB NO. 9612,033.08
LOGGED BY MRM
DATE 3/22/82
BORING NO. 22 DEPTH 1.5 TO 4.35

TEST RESULTS						DEPTH (ft)	VISUAL CLASSIFICATION	
T.V. (tsf)	P.P. (tsf)				Test Spec		Top	Shelby / Good
0.1	0.6					1.5		Dk. gray SANDY SILT (ML) SAT, w/ occ. shell frags to 1/2" Φ,
					BAG			
						2.0		decreasing sand content & occ. pockets of black fib. organics to 1/2" Φ
					Sal			
						2.5		
					Chem			
0.25	0.50							
					T&U	3.0		trace of clay & occ. sandy pockets
					S/H	3.5		
					Consol			
0.45	0.4							
					T.C.U	4.0		inc. sand content
0.2	0.35							

REMARKS -0.5' @ Top. Pusher Btm

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PLATE
D-40

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DEB	4/82		

Torvane and pocket penetrometer readings were performed on all fine-grained soil samples; the values obtained are shown on the laboratory soil logs. However, because of the character of the soils encountered within the project area, these values should be used only to compare the relative consistencies of the soil samples.

Three types of samples were preserved for future use:

> Jar Samples. Samples to be saved for primary testing were stored in glass jars. These samples were generally 2 to 4 inches high. The tops of the jars were secured and sealed with electrical tape.
>
> Split Tubes. Some soil samples were preserved in split tubes. These tubes, constructed of brass, are 6 inches long and have an inside diameter of 2.87 inches. The tubes were split in half lengthwise and the soil sample was placed within the split tube. The ends and seams of the tubes were then covered with plastic caps and taped.
>
> Bag Samples. In some cases, there was excess material after all of the desired test specimens were removed. If this remaining material was not suitable for long-term storage in jars or split tubes, it was preserved in a sealed plastic bag and stored as discussed above.

Whenever possible, Shelby tube samples were not extruded until just prior to testing. This procedure kept moisture loss and disturbance of test specimens to a minimum and eliminated the need for sealing the temporary storage containers with wax.

C. Primary Testing of Offshore Materials

1. Moisture Content/Dry Density

Moisture content and dry density tests were performed to evaluate the natural water content and dry density of the soils encountered. These tests served as a basis for correlating the soil engineering characteristics determined from other laboratory tests. Generally, the wet density of a sample was determined by calculating its volume and weight. The specimen was then dried at 105°C, and the weight loss was used for determining the moisture content and dry density.

Moisture content and dry density was determined for all secondary test specimens. Additional moisture-density tests were performed as required to establish moisture and density profiles. The moisture contents and dry densities are reported on the test data sheets, laboratory test summaries and on the test boring logs in Appendix B.

The data indicate that the natural moisture contents of surficial fine-grained sediments generally vary between 15 to 35 percent. In the underlying gravels, the moisture contents are generally less than 15 percent. There appears to be no distinct variation in moisture content with depth at any of the test borings.

The boring logs summarize the variation in dry density with depth. Table IV-6 presents the range in dry density for different soil types.

2. Organic Content

The organic content of selected specimens was determined by the "Standard Method of Test for Organic Content of Soils" (State of Alaska, 1980), also known as the organic ignition test. The sample to be tested was oven-dried for 24 hours at a temperature of 105°C, and the dry weight was recorded. The sample was then weighed to the nearest 0.1 gram and placed in a tared crucible. Next, the crucible containing the sample was placed in a muffle furnace at a temperature of 950°C ±50°C until all organic matter was combusted. Combustion usually occurred within one to two hours. After cooling the sample to room temperature it was weighed and the percentage of organic material lost by ignition was calculated.

The organic contents are listed in the laboratory test summaries presented in this appendix and on the test boring logs in Appendix B. If the organic contents exceeded five percent by weight, the modifier "O" or term "organic" is used to describe the soil type.

Although deltaic and marine soils commonly contain high percentages of organic material (Kolb, 1967; Moore, 1977), the high compressibility, low shear strength, and high moisture content commonly associated with highly organic soil were not observed. The organic content of the samples that were tested ranged from 12 to 16 percent. Although these soils did exhibit a decreased density and an increased moisture content, when the behavior of the organic silts is compared with that of the non-organic silts, there was neither a noticeably reduced strength nor a significantly increased compressibility.

It has been reported in the literature that when the organic content of a soil is less than about 20 percent, the effect of the organic material is less important than that of minor mineralogical or structural differences (Franklin et al., 1973). The soils tested for this project commonly contained varying percentages of sands, silts, and clays. It appears that these mineralogical differences have a greater influence on the mechanical properties of the soil than do the percentages of organic materials.

3. Particle Size Analysis

Particle size is important because of its influence on the drainage, shear strength, and compaction characteristics of a soil. Furthermore, the distribution of particle sizes, i.e., gradation, will affect the in situ density of natural deposit of granular soils, in addition to being an indicator of frost susceptibility and stratigraphy. In general, coarse-grained soils drain more freely, have higher shear strengths, and are more readily compactible than fine-grained materials. Also, well graded, granular soil typically has a higher density and a higher shear strength than poorly graded, fine soil.

The quantitative distribution of particle sizes was determined for representative samples by performing sieve and hydrometer tests. Additional samples were also tested to determine only the percentage of material passing the No. 200 sieve size. Samples on which these tests were performed are indicated on the test boring logs in Appendix B. Those tested by mechanical analysis, including a hydrometer test, are marked "MA". The percentage of material passing the No. 4 and No. 200 sieve sizes is also listed on the logs. A summary of the particle size analysis tests is presented on Plates D-41 through D-47. Plate IV-15 presents a graphical summary of the test results.

SAMPLE DESIGNATION		PARTICLE SIZE ANALYSIS (% Passing)														
BORING NO.	DEPTH (ft)	USCS CLASS.	2"	1-1/2"	1"	3/4"	1/2"	No. 4	No. 10	No. 20	No. 30	No. 40	No. 100	No. 200	.02 mm	.005 mm
1	13.5	SP												4.6		
	18.5	SP-SM			100	96	96	78	58.4	47.4	44.0	39.1	15.7	7.8	5.0	0.9
	23.5	SP-SM												11.3		
	28.5	SM				100	97	82	61.4	47.1	42.1	36.1	18.4	13.6		
	33.5	SM												13.8		
	38.5	SM					100	83	56	43.9	39.5	33.7	17.3	13.3		
	48.5	SM				100	98	76	49	37.3	33.6	29.3	16.4	12.7		
2	0.3	SP						100	99.8	99.7	99.3	96.6	17.8	2.3	1.0	0.8
	2.2	SM				100	98	89	83.8	79.5	76.7	72.1	27.0	13.5		
	2.8	SP-SM												8.6		
	3.5	SP						100	99.9	98.5	94.9	79.3	9.0	3.9		
	3.9	SP-SM												10.9		
	10.7	ML									99.8	--	98.4	84.8	23.0	10.5
	26.5	ML							100	99.9	99.9	99.7	98.7	92.6		
	46.7	ML												97.3		
	60.5	SM				100	99	90	86.6	85.7	84.4	79.1	45.5	30.7		
	66.5	GP												1.8		
3	1.5	SP				100	96	65	43.3	33.8	30.5	25.8	9.9	4.6		
	6.0	SP												0.7		
	9.0	GP-GM		100	92	79	71	44	33.5	30.6	29.6	27.8	12.7	7.4		
	15.0	SP			100	95	92	81	76.6	75.4	74.2	63.4	4.4	2.2		
	30.0	GP-GM			100	90	78	50	32.6	24.5	21.9	18.7	8.4	5.7		

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PLATE
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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08		4/82		

SAMPLE DESIGNATION			PARTICLE SIZE ANALYSIS (% Passing)														
BORING NO.	DEPTH (ft)	USCS CLASS.	2"	1-1/2"	1"	3/4"	1/2"	No. 4	No. 10	No. 20	No. 30	No. 40	No. 100	No. 200	.02 mm	.005 mm
4	1.1	SM												21.4		
	1.7	SP						100	99.8	99.6	99.1	97.0	15.0	2.0		
	13.8	ML							99.8	99.8	99.8	99.6	98.2	90.1	49.8	21.8
	26.0	SM				100	98	93	89.8	88.1	87.0	85.3	58.1	40.2		
	30.0	ML												65.6		
	44.5	ML					100	99	99.3	98.9	98.4	97.5	81.3	74.9		
	50.0	SP												2.8		
5	0.1	SP-SM				100	93	86	82.5	80.4	78.5	75.2	17.0	9.6		
	4.0	SP												3.5		
	6.5	SM												22.0		
	10.0	SP												1.1		
	45.5	CL								100	99.8	99.8	99.6	98.4	67.2	28.4
	46.0	ML						100	99.8	99.8	99.8	99.8	99.6	99.0	58.6	25.2
6	0.1	SM							100	99.9	99.7	99.6	95.7	50.7		
	4.1	ML												84.9		
	5.3	SP-SM			100	98	92	78	71.0	67.6	66.1	63.7	33.8	9.5	5.2	2.3
	6.7	ML												52.7		
	14.3	ML									99.4	---	98.6	98.2	62.0	24.0
	21.7	ML							100	99.8	99.6	99.6	98.4	95.8	51.2	21.5
	35.5	GP-GM			100	91	74	44	31.4	24.2	21.4	17.4	7.7	5.3		
	40.5	GP												2.8		

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
X	9612,031.08	DEB	4/82		

SAMPLE DESIGNATION			PARTICLE SIZE ANALYSIS (% Passing)														
BORING NO.	DEPTH (ft)	USCS CLASS.	2"	1-1/2"	1"	3/4"	1/2"	No. 4	No. 10	No. 20	No. 30	No. 40	No. 100	No. 200	.02 mm	.005 mm
7	9.0	SM					100	92	83.8	78.5	75.9	69.3	36.7	21.7		
	34.0	SP-SM												7.4		
	39.0	SM				100	99	76	57.1	44.0	40.1	35.2	22.2	17.7		
	44.0	SM												19.4		
	49.0	SM			100	97	89	59	41.3	33.9	31.5	28.6	19.6	15.5		
8	0.1	GM	100	78	78	73	65	56	51.1	49.4	48.6	46.4	35.0	29.3		
	3.0	SP		100	97	97	96	85	77.1	68.6	63.1	50.4	11.5	4.6		
	5.0	SP		100	90	80	---	60	29.8	29.0	28.7	27.6	12.1	3.6		
	24.0	SM			100	92	92	90	89.3	88.3	87.9	87.4	84.0	47.0		
	25.0	SM												36.4		
	37.0	SP-SM			100	97	88	60	48.4	43.5	40.8	36.0	14.5	7.1		
9	0.0	SM						100	99.9	99.8	99.8	99.8	81.0	36.5		
	7.0	ML									99.5	---	93.2	59.4	22.0	9.0
	25.0	ML												67.4		
	30.0	SM												38.8		
	36.0	SM												23.6		
	41.4	CL							100	99.8	99.8	99.6	99.4	98.2	71.2	37.8
	61.0	GP			72.2	59.9	34.1	3.9	1.3	1.2	0.9	0.9	0.4	0.2		
10	0.5	SP-SM							100	99.9	99.5	96.3	12.4	8.9		
	3.0	SP-SM												10.2		
	8.5	SP-SM					100	99.9	99.9	99.5	98.8	93.0	15.2	10.7		

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DRAWN: J | JOB NUMBER: 9612,031.08 | APPROVED: DEB | DATE: 4/82 | REVISED: | DATE:

SAMPLE DESIGNATION			PARTICLE SIZE ANALYSIS (% Passing)													
BORING NO.	DEPTH (ft)	USCS CLASS.	2"	1-1/2"	1"	3/4"	1/2"	No. 4	No. 10	No. 20	No. 30	No. 40	No. 100	No. 200	.02 mm	.005 mm
11	4.0	GP		100	94	94	64	23	11.1	7.4	6.4	5.3	1.8	1.0		
	10.0	GP		100	96	89	57	18	11.3	8.6	7.5	5.9	1.7	0.9		
	15.0	GP				93	85	49	28.8	25.2	24.2	22.7	7.9	3.5		
	17.0	GP												2.3		
	22.0	GP						32	7.0	3.5	2.8	2.3	1.0	0.7		
	30.5	SP												0.5		
	34.0	GP												1.1		
	34.5	SP-SM												9.7		
	41.0	GP-GM		100	97	93	76	42	29.5	25.9	24.9	23.9	15.5	8.1		
	49.0	SP		100	94.8	90.6	82.5	58.7	50.1	44.7	41.1	31.7	7.2	3.9		
12	9.0	SM				100	99	97	96.2	95.9	95.5	92.1	48.5	17.4		
	14.4	GM			100	87	86	57	50.2	46.5	45.2	43.4	24.0	14.5		
	19.0	SP-SM												11.3		
	24.0	SP-SM												9.3		
13	3.8	GP-GM			100	91	80	51	36.5	30.1	27.9	23.7	9.7	7.2		
	6.5	SM												16.1		
	10.0	SM			100	97	95	78	62.6	53.4	50.3	45.2	18.0	12.5		
	27.0	SP-SM												11.5		
	32.0	SM		100	88	86	77	55	44.7	37.5	35.0	31.6	16.5	13.3		
	42.0	SM												12.6		
	50.0	SP-SM				100	97	66	44.5	35.4	32.4	28.5	14.5	10.9		

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JOB NUMBER 9612,031.08
APPROVED DPB
DATE 4/82
REVISED
DATE

SAMPLE DESIGNATION			PARTICLE SIZE ANALYSIS (% Passing)												
BORING NO.	DEPTH (ft)	USCS CLASS.	2"	1-1/2"	1"	3/4"	1/2"	No. 4	No. 10	No. 20	No. 30	No. 40	No. 100	No. 200	.02 mm	.005 mm
14	1.5	SM					100	99	98.9	98.9	98.8	98.7	72.0	27.1		
	11.0	SM				100	99	89	85.8	84.7	83.6	80.4	45.9	27.9		
	45.0	GM	100	75	75	75	69	53	50.8	49.8	49.5	48.9	44.1	31.4		
	50.0	GP				84	69	36	20.6	14.3	12.4	10.2	3.6	2.0		
15	7.5	SM									99.8	99.7	87.5	47.8	16.0	8.0
	8.4	MH												83.1		
16	0.1	SP-SM		90	84	82	80	77	76.1	74.3	70.7	56.4	22.6	8.7		
	1.1	SM												39.9		
	5.0	ML												93.1		
	9.0	SM												39.1		
	15.0	ML												67.4		
	17.5	SM										100	94.3	48.8		
17	6.2	ML					100	99	99.5	99.3	99.3	98.9	95.5	93.3	53.3	21.9
	9.4	GM				100	90	56	51.2	50.3	50.1	49.6	44.8	39.6		
	11.5	GP												0.4		
	40.7	GP-GM			100	93	82	42	24.3	18.1	16.3	14.5	10.1	7.1		

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JOB NUMBER 9612,031.08
APPROVED DRB
DATE 4/82
REVISED
DATE

SAMPLE DESIGNATION		PARTICLE SIZE ANALYSIS (% Passing)													
BORING NO.	DEPTH (ft)	USCS CLASS.	2"	1-1/2"	1"	3/4"	1/2"	No. 4	No. 10	No. 20	No. 30	No. 40	No. 100	No. 200	.02 mm	.005 mm
18	18.5	GP-GM												5.7		
	23.5	SP-SM			100	96	87	54	34.2	26.4	23.5	19.7	8.9	6.5		
	33.5	SP-SM		100	81	76	73	57	43.2	35.2	32.0	27.3	13.0	9.7		
	38.5	SP-SM												7.8		
	43.5	SP-SM				100	98	68	46.2	36.3	32.9	28.4	14.4	11.0		
	48.5	SP-SM												10.4		
19	0.1	SP				99	95	91	78.0	65.9	60.3	45.9	1.8	1.1		
	4.0	SP				100	99	86	72.4	63.9	59.0	43.3	4.0	3.0		
	12.0	SP-SM												5.5		
20	0.1	ML				100	98	96	96.0	95.9	95.7	95.4	93.1	90.7		
	6.5	GP-GM		100	90	84	79	51	34.7	27.1	24.5	20.9	10.8	6.7		
	11.5	GP			100	72	77	25	10.3	6.7	5.9	4.7	1.5	0.9		
	40.0	SP-SM				100	93	59	40.1	28.2	24.3	20.1	8.5	6.1		
21	0.1	SP-SM												6.4		
	0.5	SP-SM						100	99.4	98.9	98.3	96.4	48.9	7.9		
	2.0	SP-SM							100	99.9	99.7	99.1	60.5	9.0		
	4.7	ML									100	99.8	99.6	97.9	67.8	32.7
	25.0	ML									100	--	99.7	94.4	40.7	16.0
	62.0	SC					100	98	89.0	75.2	63.6	49.4	35.4	25.5	16.4	8.0

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
Y	9612,031.08	DRB	4/82		

SAMPLE DESIGNATION			PARTICLE SIZE ANALYSIS (% Passing)													
BORING NO.	DEPTH (ft)	USCS CLASS.	2"	1-1/2"	1"	3/4"	1/2"	No. 4	No. 10	No. 20	No. 30	No. 40	No. 100	No. 200	.02 mm	.005 mm
22	2.2	SM						100	99.5	99.1	98.9	97.9	93.5	49.1	21.6	9.7
	3.5	ML						100	99.9	99.9	99.9	99.5	97.3	71.6	31.2	13.3
	12.0	SP-SM												10.3		
	13.0	SP				100	98	66	12.3	5.2	3.9	2.9	1.4	0.9		
	20.0	SP				100	94	63	14.4	6.5	4.9	3.5	1.3	0.8		
	30.0	GP			100	97	87	46	25.5	14.4	11.4	8.5	2.7	1.5		
	40.0	GP-GM												5.9		
	50.0	GP				93	88	37	14.5	7.8	6.2	4.9	2.4	1.6		
23	10.8	ML						100	99.7	98.9	98.6	98.1	94.1	88.4		
	29.0	SM									100	99.9	--	15.5		

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JP	9612,031.08	DEB	4/82		

Plate IV-15 shows that the gravels (GP) are generally smaller than two inches in diameter, and that they have a mean grain size of about 1/4 inch. The gravels also contain a relatively high percentage of sand and a silt content varying between 5 and 30 percent but generally less than 5 percent. The sands encountered within the project area are fine to coarse grained and typically contain 5 to 50 percent silt. The silts encountered contain varying amounts of sand, ranging from less than 5 and up to 50 percent by weight. Finally, the clays generally contain substantial amounts of silt.

4. Liquid and Plastic Limits

The liquid and plastic limits, i.e., the moisture contents at which liquid and plastic behavior occur, were determined for selected fine-grained soil samples. These two parameters, along with the shrinkage limit, are known as the Atterberg limits. Atterberg limits are used to classify fine-grained soils by measuring differences in mechanical behavior and to aid in estimating the overconsolidation and compression indexes of the material. In classifying fine-grained soils, Atterberg limits are used instead of grain size distribution because it is possible to have two soils, such as clay and fine "rock flour", with similar grain size distributions, yet each exhibits a significantly different mechanical behavior.

Another term that is used to describe the behavior of fine-grained soils is "degree of plasticity". Leonards (1962) relates the plasticity index (liquid limit minus the plastic limit) to the degree of plasticity as follows:

Plasticity Index	Degree of Plasticity
05	non-plastic
5-15	moderately plastic
15-40	plastic
greater than 40	highly plastic

All of the data from these tests are plotted on Plate IV-16, and a numerical summary of the Atterberg limits is presented in the Laboratory Test Summary. Generally, the fine-grained soils in the project area range from non-plastic to moderately plastic. Both silts and clays were encountered, the silt being more plastic than the clay.

5. Specific Gravity

Specific gravity tests were performed to determine the specific gravity, G_s, of the soil constituents of all secondary tests. Additional tests were performed as required. The measured values are shown on the appropriate data sheets, and the results of the tests are summarized below:

Classification	Average
SAND (SP)	2.69
SILTY SAND (SM)	2.70
SILT (ML)	2.70
CLAY (CL)	2.75
GRAVEL (GP)	2.69

These values are within the range considered normal for these soil types.

6. Chemical Tests

Chemical testing of the pore fluids was performed by Chemical and Geological Laboratories of Alaska, Inc. in Anchorage. For these tests the pore water conductivity and total soluble salt concentration were measured using titration methods and the representative freezing point depression (FPD) was determined using standard seawater salt concentration - FPD relationships. The results of these tests are presented on Plate D-48.

Interpretation of the test results was not within the scope of our services. For a detailed discussion of interstitial water chemistry in the Prudhoe Bay region, the reader is referred to Page and Iskandar (1978) and Iskandar, Osterkamp, and Harrison (1978).

7. Electrical Conductivity Tests

The electrical conductivity of selected specimens was measured to determine the salinity of the interstitial fluids. With the salinity known, the freezing point depressions were calculated. The results of the electrical conductivity tests along with the results of tests performed by Chemical and Geological Laboratories of Alaska, Inc. are shown on Plates D-49 and D-54.

The general test procedure is as follows:

1. Approximately 100 grams of material is removed from a representative sample and weighed.
2. Approximately 100 grams of distilled water is added to the soil to create a solution. The solution is placed in a constant temperature bath that is maintained at 25°C.
3. A YSI Conductivity Bridge is inserted into the prepared solution, and the electrical conductivity is recorded.
4. The solution is weighed and oven-dried to determine the moisture content.

Boring No.	Depth (ft)	USCS	Bonded	Conductivity (mmhos/cm)	Freezing Point Depression (°C)	Interstitial Water Analysis (ppt)							Total Salts (ppt)
						Na	K	Ca	Mg	SO_4	CL	HCO_3	
2	2.7	SP-SM	No	45.45	1.90	10.460	0.365	0.420	0.950	1.700	18.310	0.730	32.935
5	2.0	SP-SM	Yes	90.90	3.95	23.080	0.560	0.900	2.240	2.465	41.820	1.030	72.095
5	8.0	SM	Yes	108.70	5.02	29.690	0.840	1.110	2.720	3.670	53.180	0.975	92.185
9	4.4	SM	No	50.00	2.10	11.72	0.380	0.300	0.985	1.200	20.440	0.870	35.895
10	15.0	SM	No	90.90	3.85	21.87	0.520	0.810	2.730	2.440	41.330	0.810	70.510
16	0.8	SP-SM	No	40.80	1.70	9.330	0.465	0.490	0.760	1.480	16.050	1.290	29.865
19	2.2	SP	Yes	8.33	0.35	0.920	0.515	0.810	0.465	1.090	0.670	5.550	10.020
21	2.5	SP-SM	No	46.50	1.95	10.680	0.350	0.455	0.970	1.660	18.740	0.790	33.645
22	2.2	SM	No	46.50	1.95	10.770	0.525	0.965	0.960	2.410	18.540	0.850	35.020
22	2.7	ML	No	45.45	1.90	10.950	0.470	0.295	0.730	1.330	18.430	0.960	33.165

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Chemical Analysis Summary

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JOB NUMBER 9612,031.08
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DATE 4/82
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DATE

Boring No.	Depth (ft)	USCS	Bonded	Moisture Content (%)	Electrical Conductivity (mmhos/cm)	FPD* (°C)
2	0.9	SP	No	22.0	52.32	2.13
2	2.7**	SP-SM	No	---	45.45	1.90
2	3.0	SP-SM	No	23.0	49.67	2.02
2	8.4	ML	No	33.4	50.67	2.06
2	10.5	ML	No	30.6	46.42	1.88
2	14.4	ML	No	28.7	40.75	1.64
2	18.5	MH	No	51.8	29.92	1.17
2	19.0	ML	No	46.2	35.01	1.39
2	30.0	SM	No	16.0	36.26	1.44
2	40.7	ML	No	8.2	68.91	2.83
2	60.5	SM	No	13.0	48.07	1.95
2	66.5	GP	No	17.7	48.26	1.97
3	0.0	ML	No	37.9	44.25	1.78
3	1.5	SP	No	10.6	45.70	1.85
3	3.5	SP	No	18.3	48.16	1.95
3	4.5	SP	No	2.2	57.23	2.34
3	6.0	SP	No	9.9	52.48	2.14
3	9.0	GP-GM	No	8.6	54.87	2.24
3	12.0	SP	No	6.5	51.93	2.12
3	15.0	SP	No	22.4	50.48	2.06
3	19.0	GP	No	8.6	51.56	2.10
3	30.0	GP-GM	No	5.8	50.76	2.07
3	50.0	GP-GM	Yes	4.0	30.42	1.19
4	2.8	ML	No	24.5	46.27	1.87
4	9.5	ML	No	43.8	44.44	1.79
4	12.0	ML	No	41.0	43.84	1.77
4	20.2	ML	No	69.0	47.42	1.93
4	25.5	SM	No	9.8	44.34	1.79
4	49.5	SP	No	21.9	53.10	2.18
5	0.1	SP-SM	Yes	27.1	61.47	2.52
5	0.5	SP-SM	Yes	16.2	54.32	2.22
5	2.0**	SP	Yes	14.0	90.90	3.95
5	4.5	SM	Yes	36.4	26.28	1.01
5	6.5	SM	Yes	18.3	107.94	4.04
5	8.0**	SM	Yes	13.5	108.70	5.02

* Calculated according to Page & Iskandar, 1978, other relationships are available.

** Chemical Analysis Data

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Electrical Conductivity Summary

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JF	9612,031.08	DGB	4/82		

Boring No.	Depth (ft)	USCS	Bonded	Moisture Content (%)	Electrical Conductivity (mmhos/cm)	FPD* (°C)
5	10.0	SP	No	6.9	21.15	0.79
5	16.0	ML	No	33.0	83.66	3.37
5	16.5	ML	No	52.0	17.60	0.65
5	20.3	CL	No	42.3	78.10	3.17
5	31.1	ML	Yes	43.6	42.89	1.73
5	45.5	CL	Yes	41.9	28.13	1.09
5	51.0	CL	Yes	27.0	37.85	1.52
6	0.1	SM	No	31.6	48.57	1.97
6	0.5	SM	No	22.5	47.32	1.92
6	1.0	SM	No	22.5	48.10	1.95
6	3.5	ML	No	29.2	47.27	1.91
6	4.1	ML	No	34.7	52.06	2.12
6	5.2	ML	No	21.3	48.36	1.96
6	6.5	SP-SM	No	18.7	50.08	2.04
6	7.2	SP-SM	No	7.4	95.87	3.75
6	9.2	SM	No	11.4	49.41	2.01
6	12.5	ML	No	24.1	48.69	1.98
6	14.1	ML	No	25.1	34.05	1.34
6	14.7	ML	No	23.3	37.09	1.47
6	21.4	ML	No	26.4	47.72	1.94
6	35.5	GP-GM	No	6.7	52.45	2.15
8	0.1	GM	No	31.8	49.61	2.02
8	3.0	SP	No	15.4	51.24	2.09
8	5.0	SP	No	9.5	55.94	2.29
8	7.0	SP	No	8.0	54.88	2.24
8	8.5	SP	No	9.2	60.17	2.47
8	9.0	SP	No	15.3	72.53	2.96
8	10.2	ML	No	25.6	78.68	3.19
8	13.0	ML	No	25.3	79.27	3.21
8	14.9	ML	No	28.8	52.37	2.14
8	18.0	ML	No	23.3	63.09	2.59
9	0.1	SM	No	19.7	48.46	1.97
9	4.4**	SM	No	---	50.00	2.10
9	5.0	SM	No	22.5	52.39	2.14
9	5.6	ML	No	22.6	50.01	2.03
9	6.6	ML	No	28.2	53.06	2.17
9	7.3	ML	No	28.2	39.77	1.59

* Calculated according to Page & Iskandar, 1978, other relationships are available.

** Chemical Analysis Data

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Electrical Conductivity Summary

Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
D-50

JOB NUMBER	APPROVED	DATE	REVISED	DATE
9612,031.08	DRB	4/82		

Boring No.	Depth (ft)	USCS	Bonded	Moisture Content (%)	Electrical Conductivity (mmhos/cm)	FPD* (°C)
17	7.3	SM	No	50.1	37.42	1.49
17	9.4	GM	No	17.2	48.65	1.98
17	10.0	GM	No	19.4	50.24	2.04
17	25.7	ML	No	22.7	67.22	2.76
19	2.2**	SP	Yes	---	8.33	0.35
19	4.8	SP	Yes	15.0	3.76	0.12
19	6.0	SP	Yes	22.5	9.01	0.31
19	8.0	SP	Yes	24.8	80.97	3.27
19	9.5	SP	Yes	20.2	45.72	1.85
19	12.0	SP-SM	Yes	24.8	91.24	3.62
19	14.0	SP-SM	Yes	25.9	93.16	3.67
19	15.0	SP-SM	Yes	21.4	129.04	4.30
19	16.0	ML	Yes	30.4	130.12	4.30
19	16.5	ML	Yes	26.8	110.15	4.09
19	24.5	ML	Yes	36.2	73.75	3.01
19	29.0	ML	Yes	48.9	62.21	2.56
19	49.5	ML	Yes	21.9	60.54	2.49
20	0.2	ML	No	53.8	46.17	1.87
20	2.5	SM	No	42.9	44.76	1.81
20	4.0	GP	No	6.6	55.63	2.27
20	6.5	GP-GM	No	6.5	47.95	1.94
20	8.0	GP	No	8.0	50.87	2.07
20	10.0	GP	No	4.8	52.37	2.14
21	0.1	SP-SM	No	22.9	49.09	1.99
21	1.5	SP-SM	No	21.7	38.30	1.52
21	2.5**	SP-SM	No	---	46.50	1.95
21	3.1	CL	No	20.6	36.24	1.43
21	4.5	ML	No	19.6	39.07	1.56
21	5.8	ML	No	20.8	48.67	1.98
21	6.7	ML	No	21.5	37.36	1.48
21	8.2	ML	No	16.8	52.89	2.16
21	9.6	SM	No	31.2	61.15	2.51
21	10.6	SM	No	30.6	62.26	2.55

Calculated according to Page & Iskandar, 1978, other relationships are available.

* Chemical Analysis Data

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Electrical Conductivity Summary

Pt. Thomson Development Project
Winter 1982, Geotechnical Study
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PLATE **D-53**

JOB NUMBER	APPROVED	DATE	REVISED	DATE
9612,031.08	DGB	4/82		

Boring No.	Depth (ft)	USCS	Bonded	Moisture Content (%)	Electrical Conductivity (mmhos/cm)	FPD* (°C)
21	12.9	ML	No	25.7	63.82	2.62
21	16.8	SP-SM	No	30.2	70.69	2.89
21	19.0	ML	No	22.4	64.36	2.64
21	25.9	ML	No	25.2	77.22	3.14
21	32.5	CL	No	26.2	70.94	2.91
21	41.0	CL	No	24.1	38.29	1.53
21	62.0	SC	No	18.7	50.07	2.05
22	1.0	SM	No	24.8	45.77	1.85
22	2.2**	ML	No	---	46.50	1.95
22	2.5	SM	No	24.5	49.41	2.01
22	2.7**	SM	No	25.8	45.45	1.90
22	3.3	ML	No	27.4	46.66	1.89
22	5.0	ML	No	43.7	47.19	1.91
22	7.5	CL	No	52.3	47.58	1.93
22	11.5	SP	No	9.2	49.66	2.02
22	13.0	SP	No	9.1	50.16	2.04
22	15.5	SP	No	8.3	55.37	2.27
23	0.3	ML	Yes	29.5	3.62	0.11
23	6.3	ICE	Yes	---	0.33	0.01
23	8.3	ICE	Yes	---	0.33	0.01
23	10.3	SM	Yes	41.6	17.60	0.64
23	14.5	CL	Yes	30.8	36.45	1.45
23	29.0	SM	Yes	23.7	10.02	0.35
23	49.0	CL	Yes	29.3	35.46	1.41

* Calculated according to Page & Iskandar, 1978, other relationships are available.

** Chemical Analysis Data

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Electrical Conductivity Summary
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

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JOB NUMBER 9612,031.08
APPROVED DEB
DATE 4/82
REVISED
DATE

The diluted electrical conductivity measurements were converted to a salinity value using the sea water-equivalent salinity content and the para-conductivity relationship that is presented in the Handbook of Chemistry and Physics (1976).

This diluted salinity value was then corrected to represent the salinity of the natural moisture content by applying Equation D-1 and the freezing point depression was calculated by applying the relationship presented in Equation D-2 (Page and Iskandar, 1978).(1) A discussion of the significance of salinity on the freezing point of soil is presented in Chapter IV.

$$C_1 V_1 = C_2 V_2 \qquad \text{(D-1)}$$

Where C_1 = Salinity concentration before dilution, ppt

V_1 = Volume before dilution, gm

C_2 = Salinity concentration after dilution, ppt

V_2 = Volume after dilution, gm

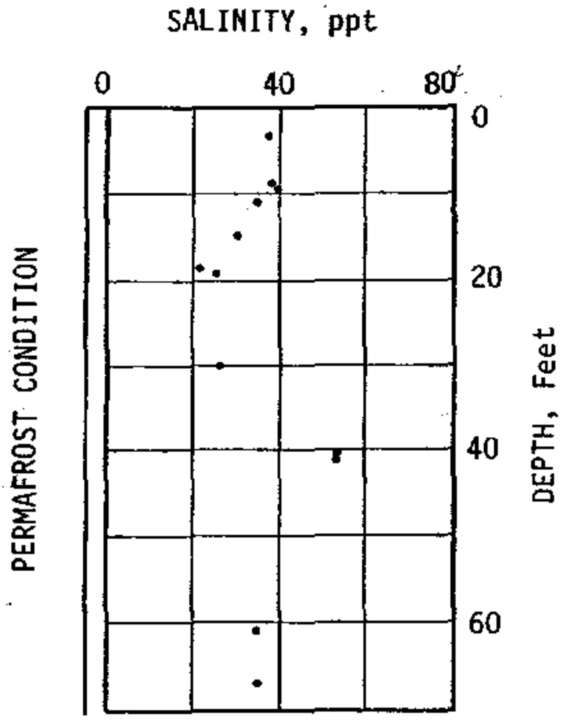
$$FPD = 0.00249-0.0533C_1 - 0.0000764C_1{}^2 + 0.00000187C_1{}^3 \qquad \text{(D-2)}$$

Where FPD = freezing point depression in degrees centigrade

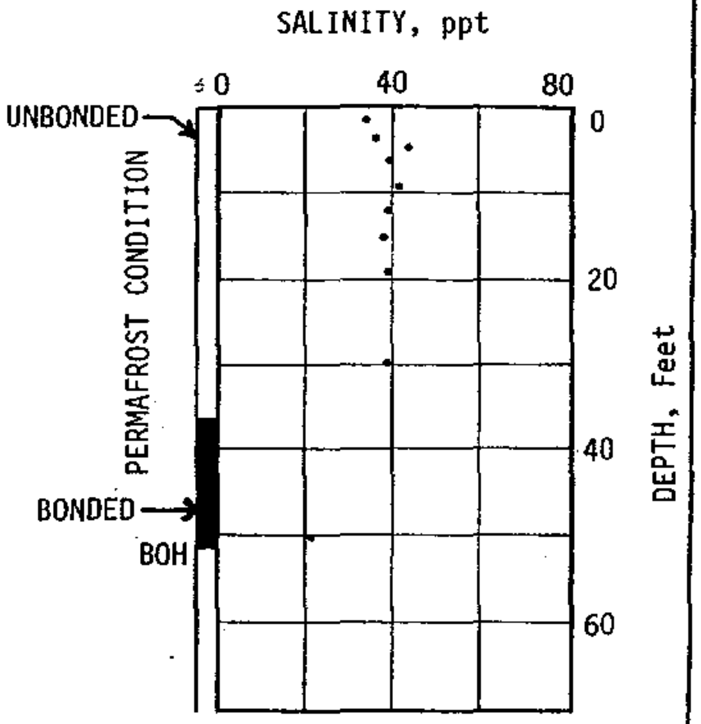
The calculated salinity values for each boring are presented on the Salinity Profile sheets, Plates D-55 through D-59. The calculated freezing point depression values are plotted with measured ground tempeatures on Plate IV-12.

---

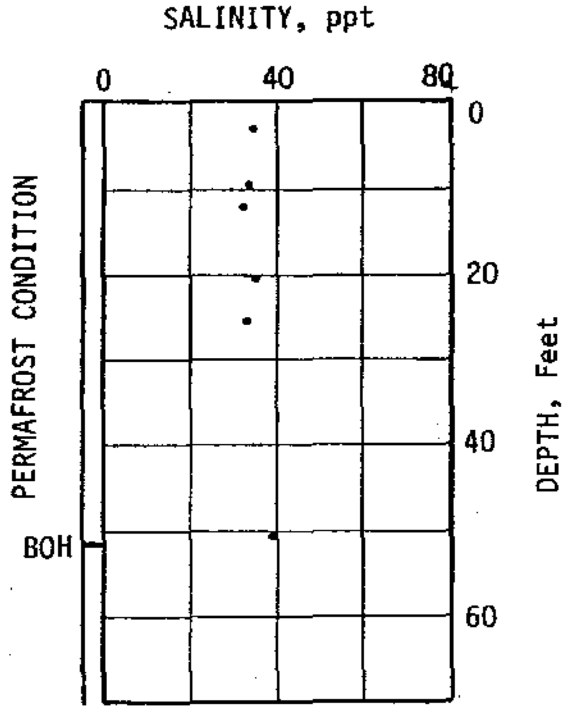
(1) Other relationships exist to compute the freezing point depression.



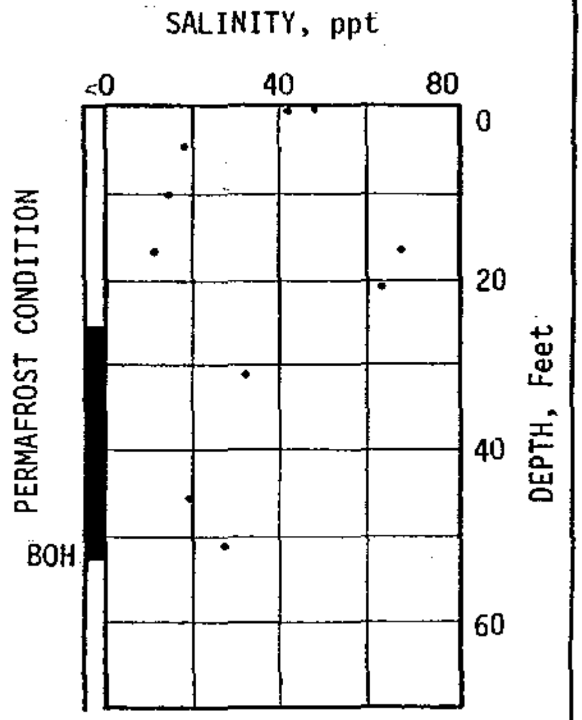
TEST BORING 2



TEST BORING 3



TEST BORING 4



TEST BORING 5

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Winter 1982, Geotechnical Study
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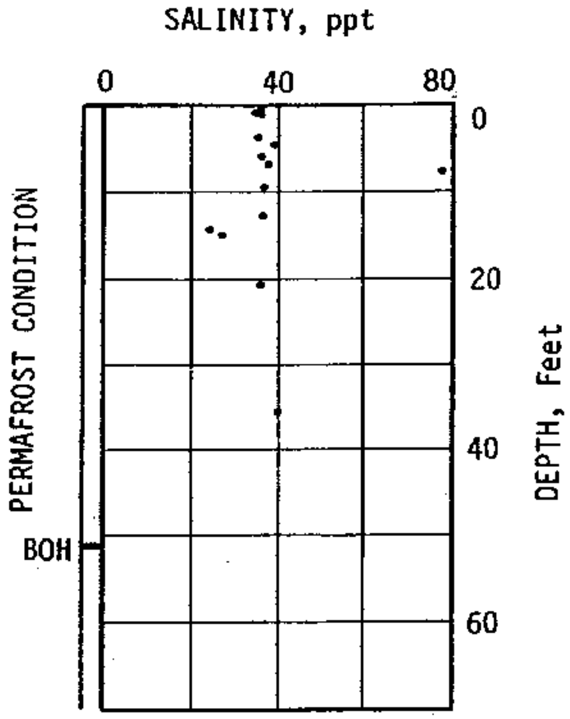
PLATE
D-55

DRAWN JP
JOB NUMBER 9612,031.08
APPROVED DGB
DATE 4/82
REVISED
DATE



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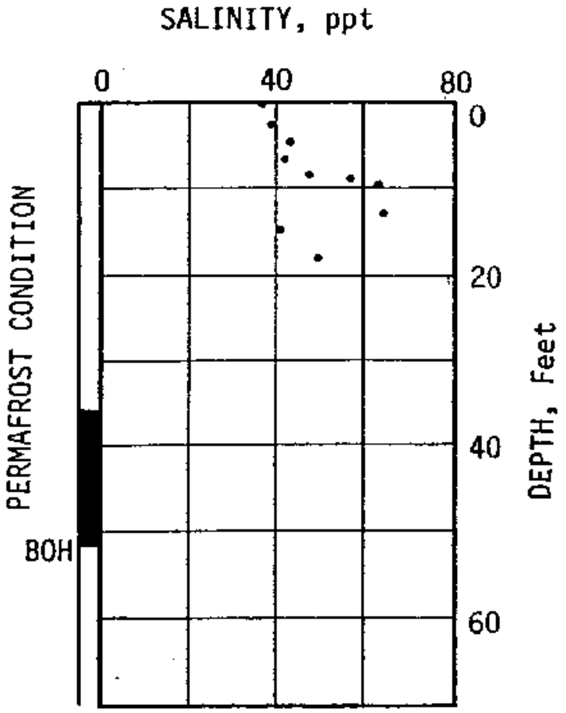

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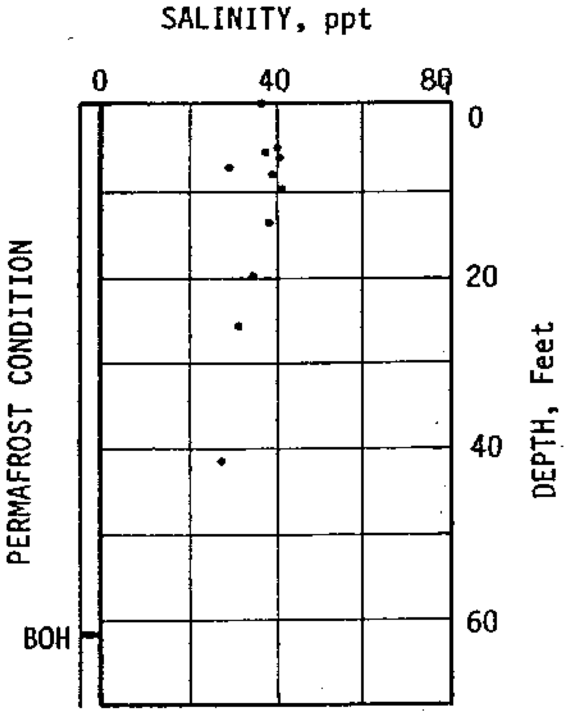
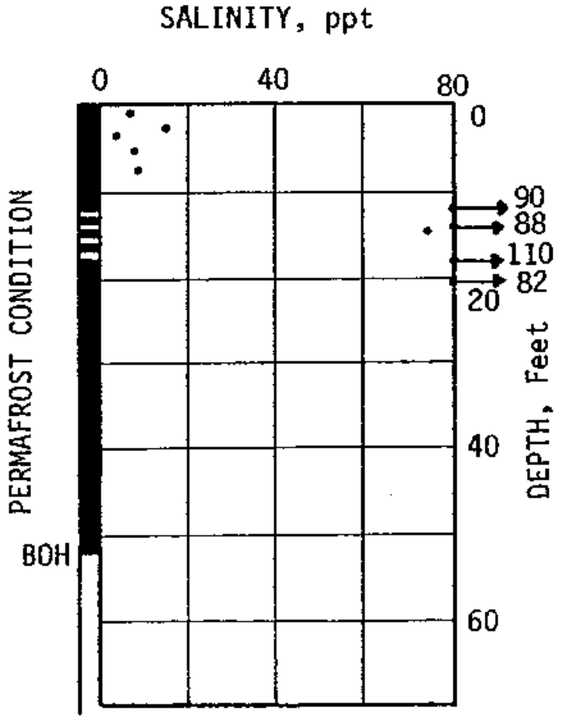


TEST BORING 9



TEST BORING 10

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PLATE
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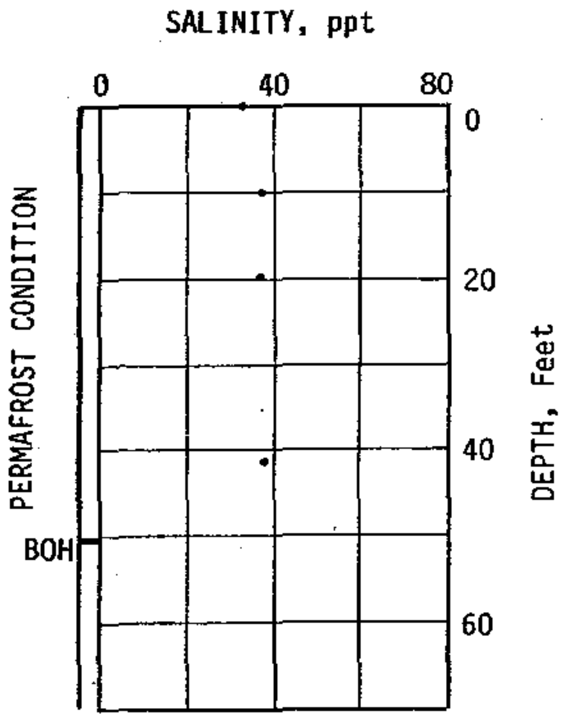
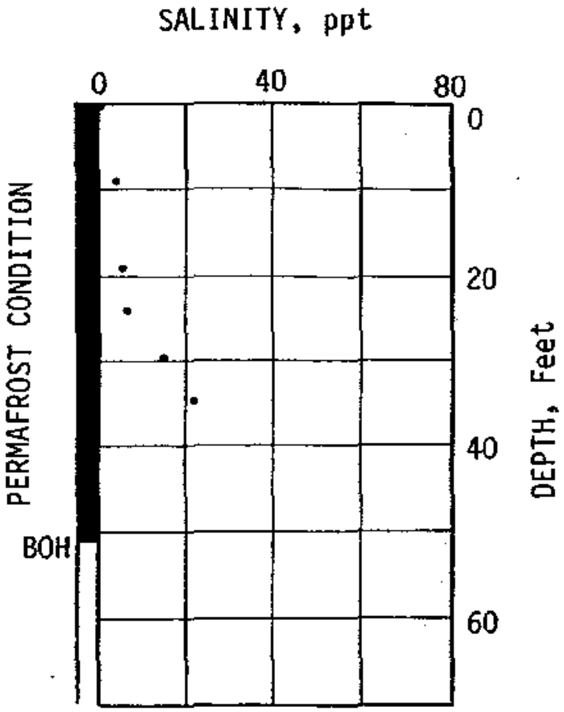
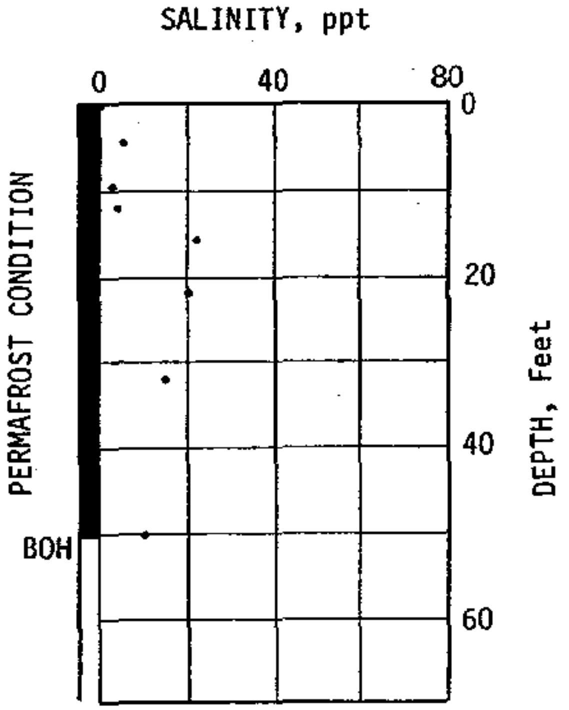
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		



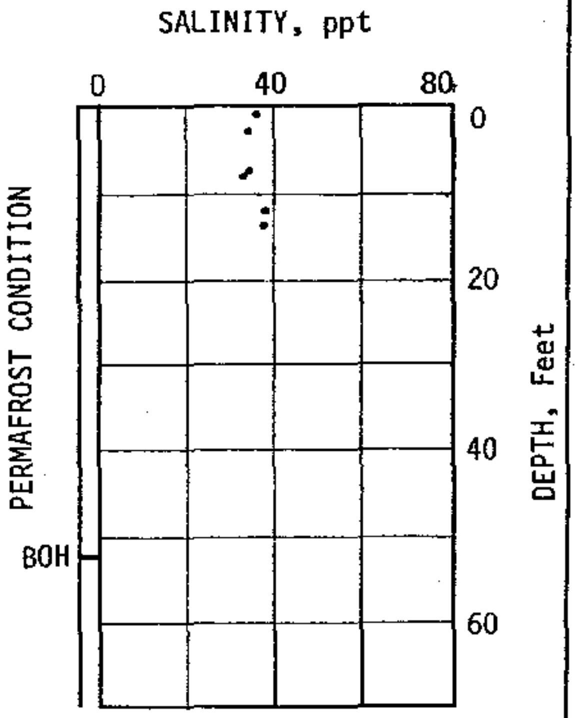
TEST BORING 11



TEST BORING 12



TEST BORING 13



TEST BORING 14

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Winter 1982, Geotechnical Study
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PLATE
D-57

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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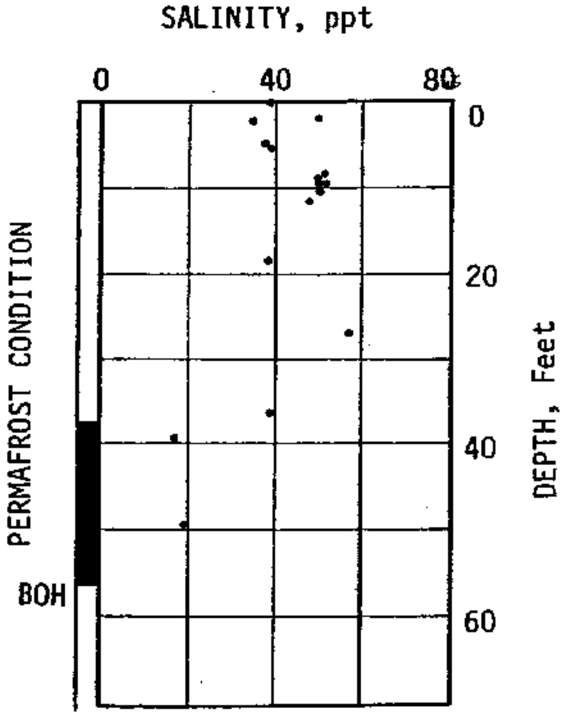

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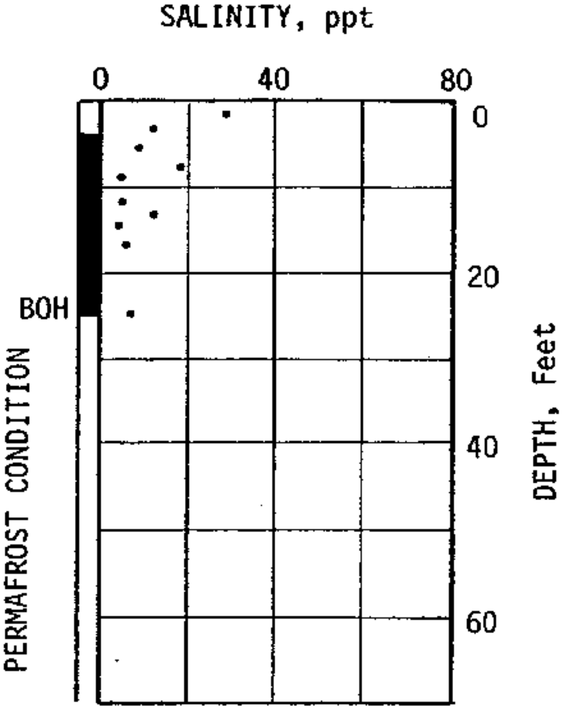

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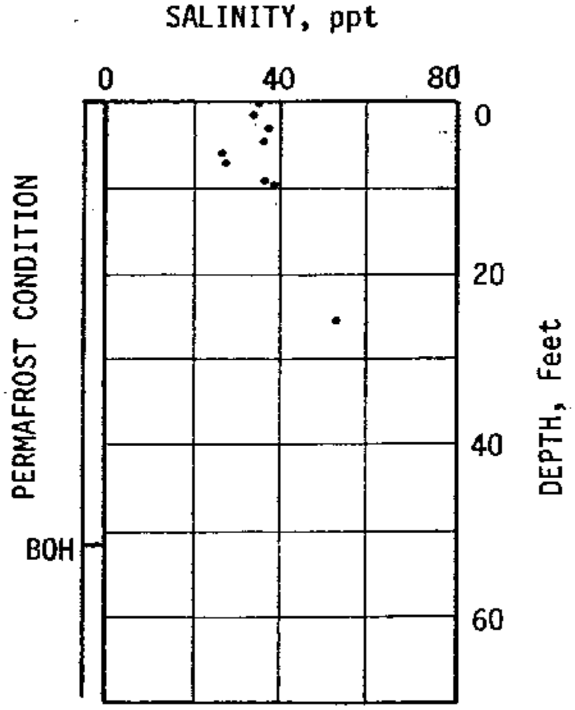
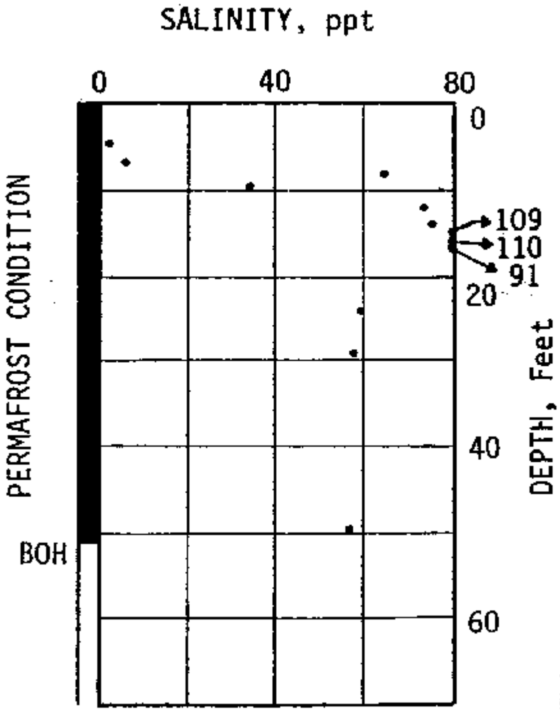


TEST BORING 17



TEST BORING 19

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Winter 1982, Geotechnical Study
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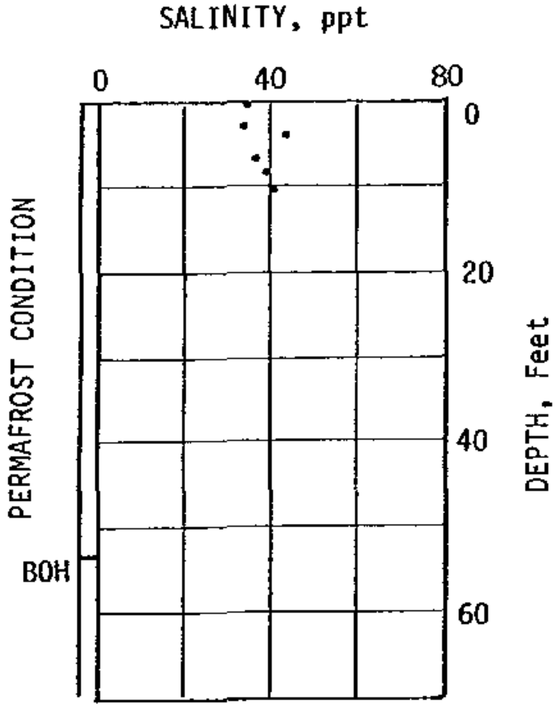
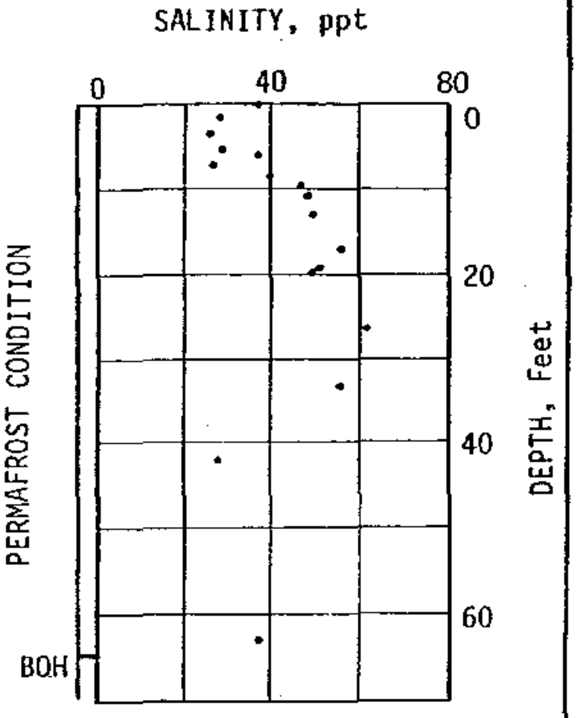
PLATE
D-58

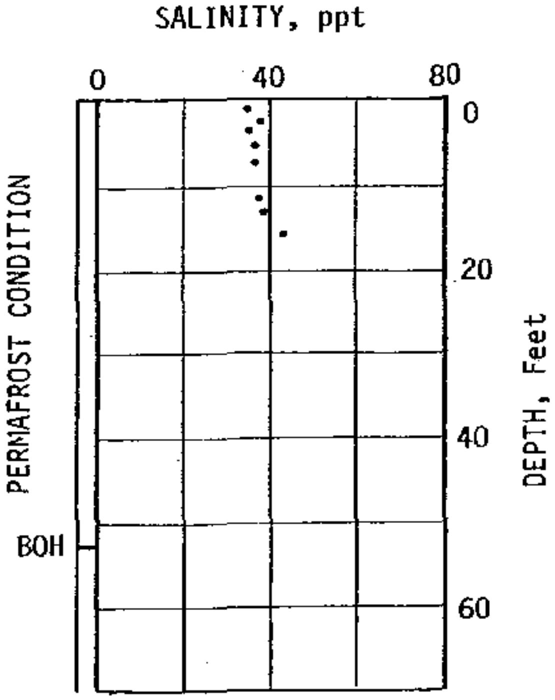
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		



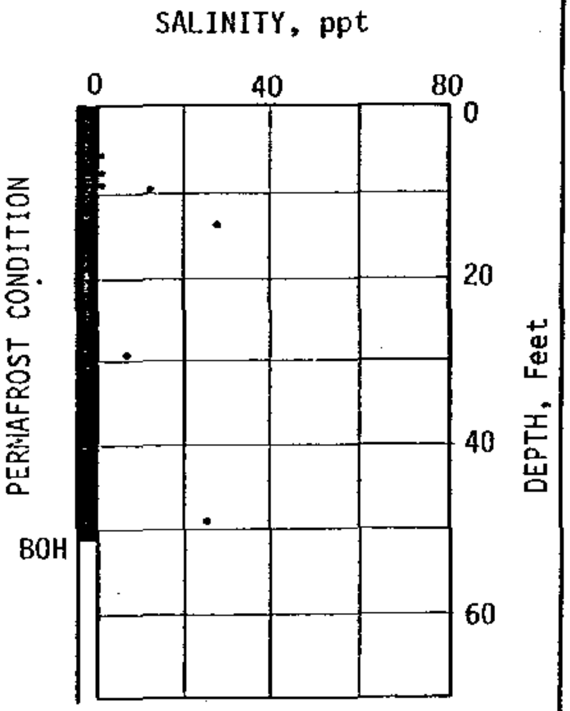
TEST BORING 20



TEST BORING 21



TEST BORING 22



TEST BORING 23

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Winter 1982, Geotechnical Study
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PLATE
D-59

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JF	9612,031.08	DGB	4/82		

D. Strength Testing

1. Triaxial Tests

Soil strength tests conducted under static loading conditions were performed on selected samples of unfrozen sand, silt, and clay to define the shear strength parameters used in engineering analyses. For a complete discussion of the triaxial test, the reader is referred to Bishop and Henkel (1978).

a. Unconsolidated-Undrained Triaxial Shear Tests

Unconsolidated-undrained triaxial shear (TXUU) tests were conducted on samples of clayey and organic silts. The maximum sample depth was approximately 51 feet below mudline. All samples were tested at their field moisture content and at a constant strain rate of about 1.5 percent per minute. Failure was defined as the peak deviator stress. The test results are summarized on Plate D-60, and the individual test results are presented on Plates D-61 through D-74.

Attempts were made to correlate the undrained shear strength (S_u) with depth and dry density, as well as the ratio of the undrained shear strength/overburden pressure (S_u/P_o) with depth. There are no significant correlations between S_u and S_u/P_o versus depth. However, a reasonable correlation was established between S_u and dry density as shown on Plate IV-17.

b. Consolidated-Undrained Triaxial Shear Tests

Consolidated-undrained triaxial shear (TXCU) tests with pore pressure measurements were conducted to provide information on the undrained shear strength (S_u), the effective angle of internal friction (ϕ'), the effective cohesion (C'), and the stress-strain behavior of selected samples.

Boring	Depth (ft)	USCS	Moisture Content (%)	Dry Density (pcf)	Cell Pressure (psf)	Shear Strength (psf)	Strain @ Peak Stress (%)
2	12.9	ML	38.6	80	3000	290	15.0
2	14.5	ML	35.7	83	1500	480	15.0
2	46.7	ML	32.5	89	5500	1600	6.0
2	51.2	ML	26.0	97	6500	2070	7.0
4	18.3	MH	70.8	57	4000	330	10.0
5	19.0	ML	35.5	61	1500	400	15.0
8	15.0	ML	26.4	98	1875	1320	15.0
9	14.4	ML	41.8	78	1500	620	11.0
9	15.0	ML	40.7	77	3000	560	15.0
9	19.5	ML	51.3	68	2000	360	11.0
9	31.6	SM	30.2	90	4000	1580	10.7
9	41.4	CL	31.2	90	2500	1630	9.0
9	41.9	CL	27.6	96	2500	2460	8.0
14	17.0	CL	18.1	113	2200	4730	7.0
14	25.5	CL	22.9	103	3200	2140	15.0
14	36.0	ML	25.1	101	4500	2380	6.1
14	40.5	ML	25.1	101	5000	2880	5.4
15	2.0	ML	36.0	83	500	790	8.7
15	9.0	MH	81.1	51	1000	800	6.0
15	10.8	ML	32.2	86	1300	710	15.0
15	36.8	CL	26.0	95	4600	520	15.5
17	6.2	ML	52.5	67	800	750	15.0
17	6.7	ML	40.5	77	900	1350	14.0
17	30.4	ML	18.4	114	3800	6450	4.7
21	7.0	ML	19.2	110	900	3820	10.8
21	31.5	CL	23.7	100	4000	1270	8.8
21	32.0	CL	23.0	101	4000	1090	15.2

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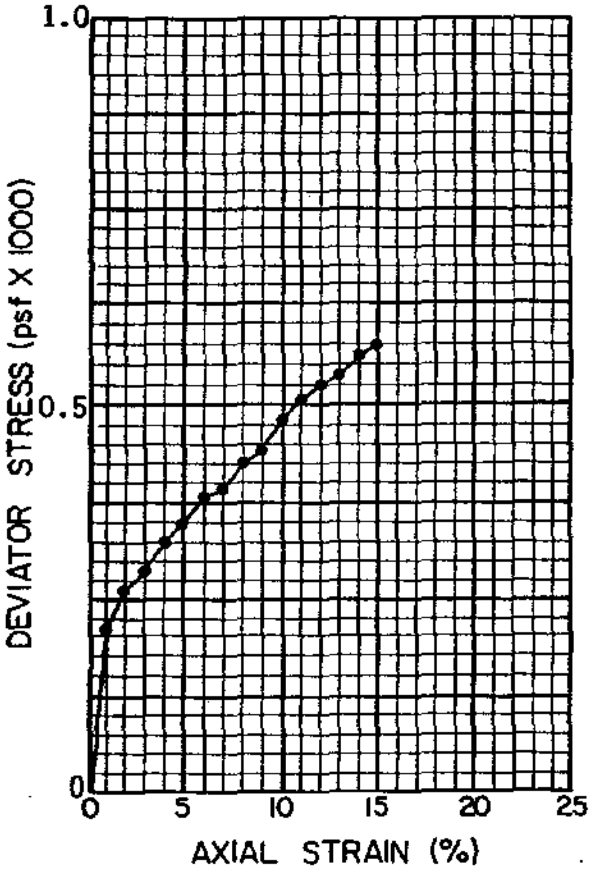
Unconsolidated-Undrained Triaxial Compression Test Report Summary
PT. Thomson Development Project, Winter 1982
Geotechnical Study, EXXON Company, U.S.A.

PLATE
D-60

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
Jp	9612,031.08	DCB	4/82		

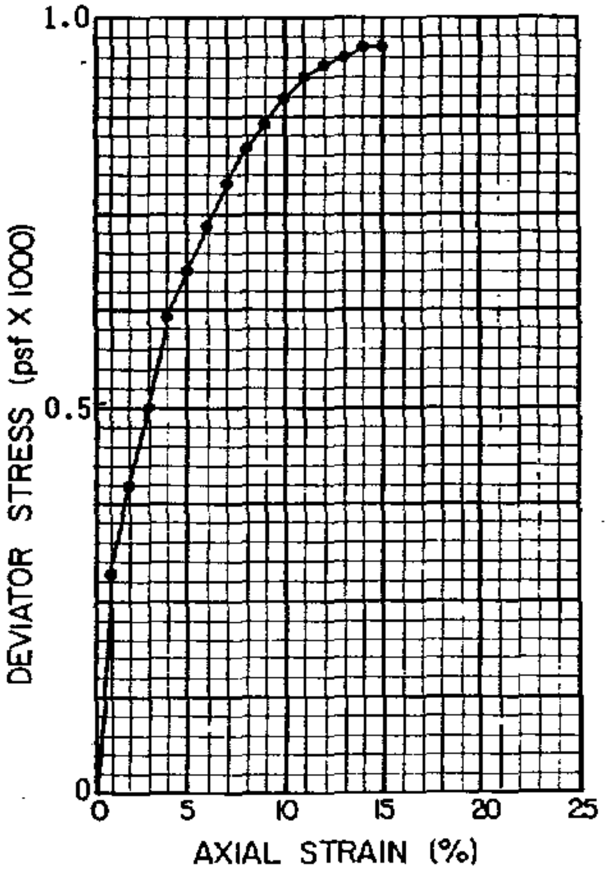


DIAMETER (in): 2.87
HEIGHT (in): 6.00

MOISTURE CONTENT (%): 38.6
DRY DENSITY (pcf): 80

CELL PRESSURE (psf): 3000
SHEAR STRENGTH (psf): 290

SAMPLE SOURCE: Boring 2 at 12.9'
CLASSIFICATION: SILT (ML)



DIAMETER (in): 2.87
HEIGHT (in): 6.00

MOISTURE CONTENT (%): 35.7
DRY DENSITY (pcf): 83

CELL PRESSURE (psf): 1500
SHEAR STRENGTH (psf): 480

SAMPLE SOURCE: Boring 2 at 14.5'
CLASSIFICATION: SANDY SILT (ML)

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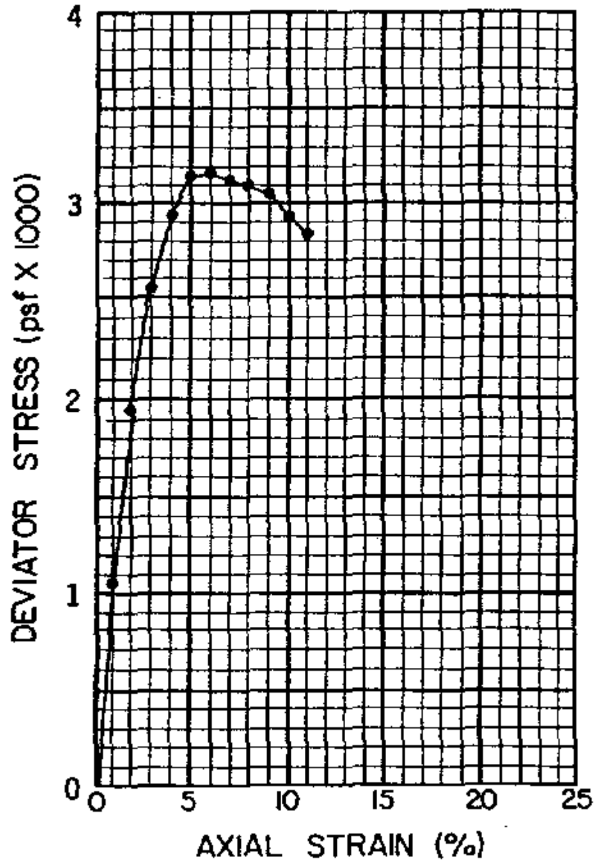
Unconsolidated-Undrained Triaxial Compression Test Report

Pt. Thomson Development Project, Winter 1982
Geotechnical Study, EXXON Company, U.S.A.

PLATE
D-61

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DGB	4/82		



DIAMETER (in): 2.87

HEIGHT (in): 6.00

MOISTURE CONTENT (%): 32.5

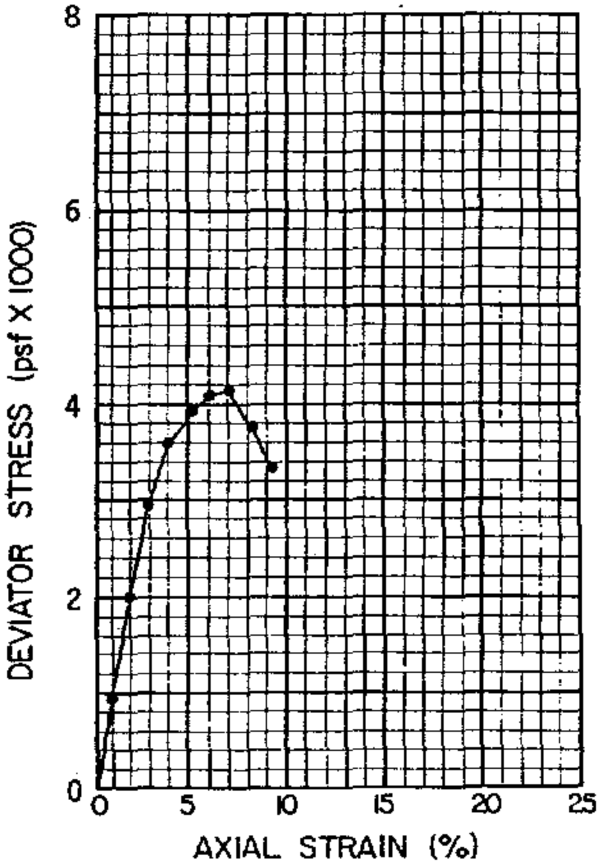
DRY DENSITY (pcf): 89

CELL PRESSURE (psf): 5500

SHEAR STRENGTH (psf): 1600

SAMPLE SOURCE: Boring 2 at 46.7'

CLASSIFICATION: SILT (ML)



DIAMETER (in): 2.87

HEIGHT (in): 5.9

MOISTURE CONTENT (%): 26.0

DRY DENSITY (pcf): 97

CELL PRESSURE (psf): 6500

SHEAR STRENGTH (psf): 2070

SAMPLE SOURCE: Boring 2 at 51.2'

CLASSIFICATION: SILT (ML)

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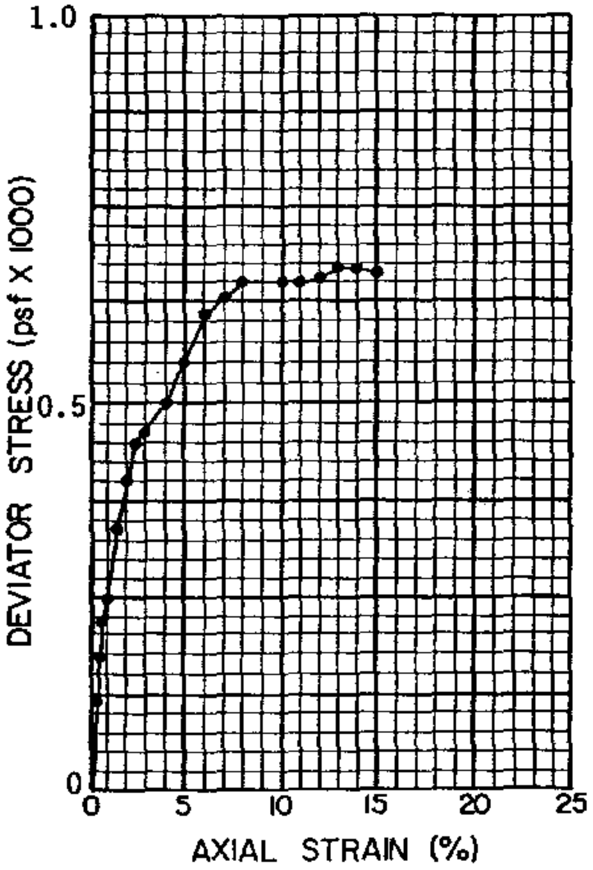
Unconsolidated-Undrained Triaxial Compression Test Report
Pt. Thomson Development Project, Winter 1982
Geotechnical Study, EXXON Company, U.S.A.

PLATE **D-62**

DRAWN JP
JOB NUMBER 9612,031.08
APPROVED DGB
DATE 4/82
REVISED
DATE

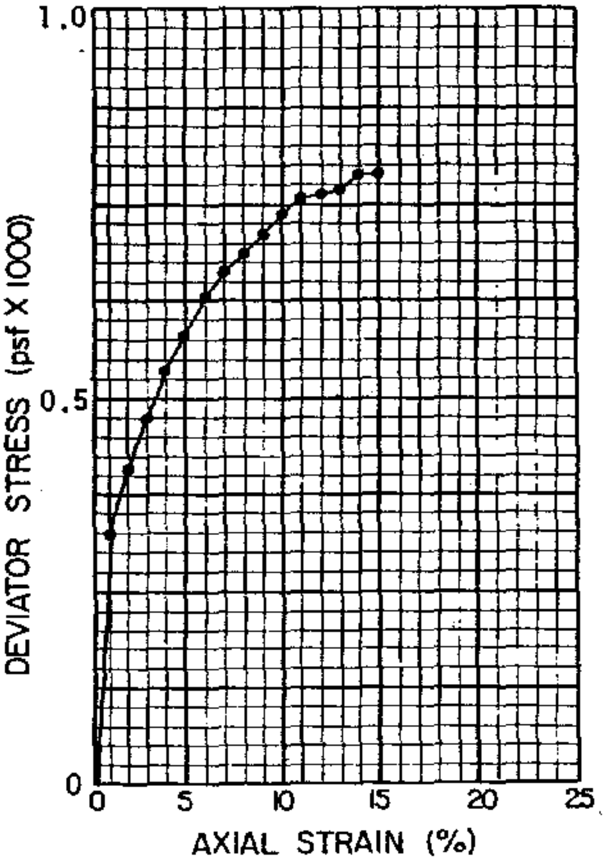


DIAMETER (in): 2.46
HEIGHT (in): 5.60

MOISTURE CONTENT (%): 70.8
DRY DENSITY (pcf): 57

CELL PRESSURE (psf): 4000
SHEAR STRENGTH (psf): 330

SAMPLE SOURCE: Boring 4 at 18.3'
CLASSIFICATION: SILT (MH)



DIAMETER (in): 2.43
HEIGHT (in): 5.90

MOISTURE CONTENT (%): 35.5
DRY DENSITY (pcf): 61

CELL PRESSURE (psf): 1500
SHEAR STRENGTH (psf): 400

SAMPLE SOURCE: Boring 5 at 19.0'
CLASSIFICATION: CLAYEY SILT (ML)

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PLATE
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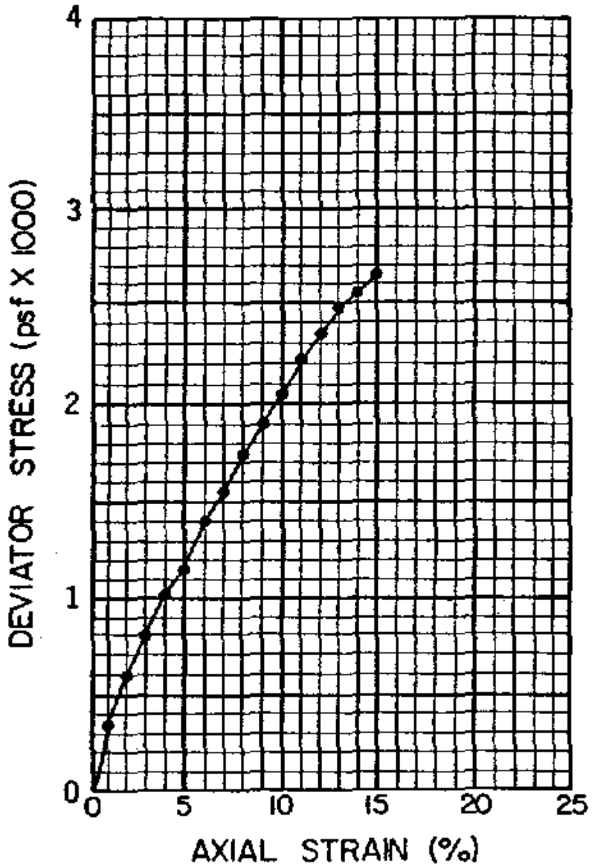
DRAWN JOB NUMBER 9612,031.08 APPROVED DGB DATE 4/82 REVISED DATE

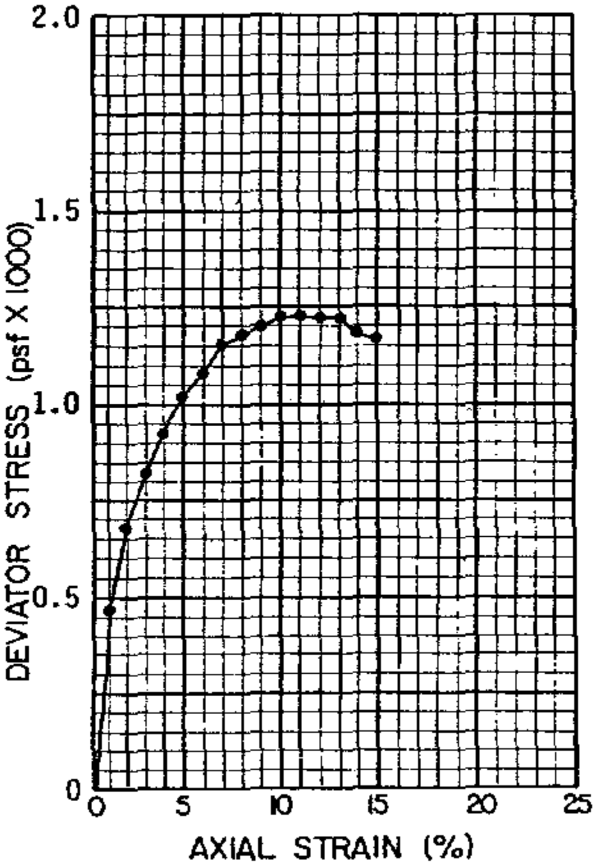


DIAMETER (in): 2.87
HEIGHT (in): 6.00

MOISTURE CONTENT (%): 26.4
DRY DENSITY (pcf): 98

CELL PRESSURE (psf): 1875
SHEAR STRENGTH (psf): 1320

SAMPLE SOURCE: Boring 8 at 15.0'
CLASSIFICATION: SILT (ML)



DIAMETER (in): 2.87
HEIGHT (in): 6.00

MOISTURE CONTENT (%): 41.8
DRY DENSITY (pcf): 78

CELL PRESSURE (psf): 1500
SHEAR STRENGTH (psf): 620

SAMPLE SOURCE: Boring 9 at 14.4'
CLASSIFICATION: SILT (ML)

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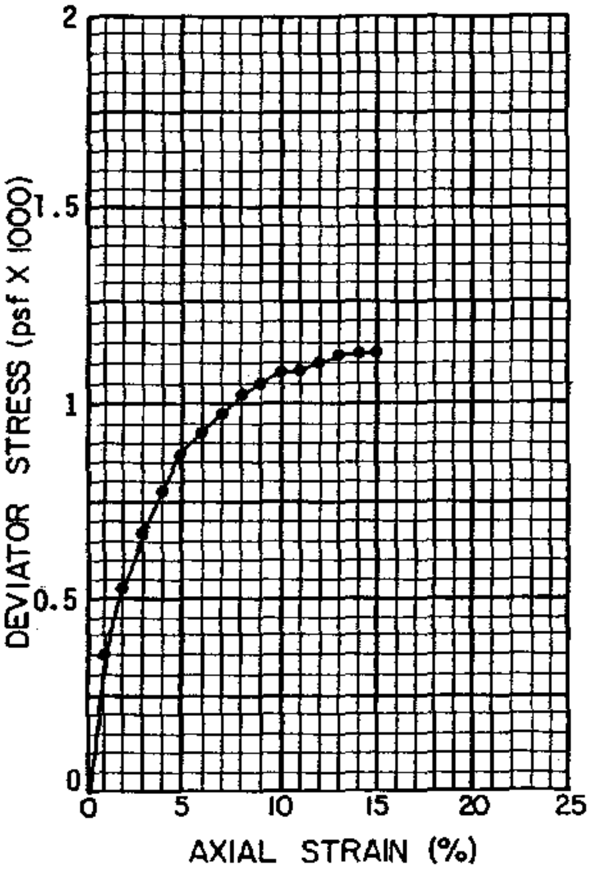
PLATE D-6

DRAWN JP
JOB NUMBER 9612,031.08
APPROVED DEB
DATE 4/82
REVISED
DATE

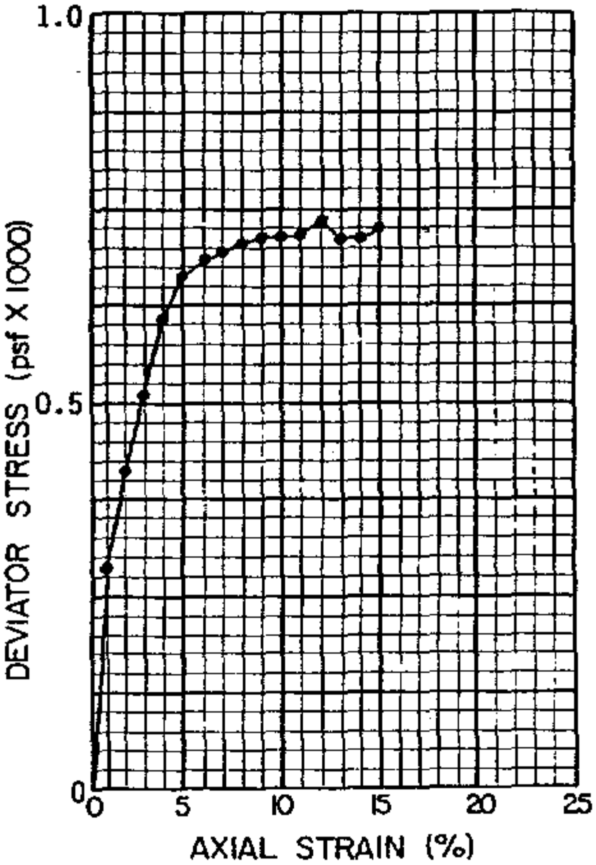


DIAMETER (in): 2.87
HEIGHT (in): 6.00

MOISTURE CONTENT (%): 40.7
DRY DENSITY (pcf): 77

CELL PRESSURE (psf): 3000
SHEAR STRENGTH (psf): 560

SAMPLE SOURCE: Boring 9 at 15.0'
CLASSIFICATION: SILT (ML)



DIAMETER (in): 2.87
HEIGHT (in): 5.75

MOISTURE CONTENT (%): 51.3
DRY DENSITY (pcf): 68

CELL PRESSURE (psf): 2000
SHEAR STRENGTH (psf): 360

SAMPLE SOURCE: Boring 9 at 19.5'
CLASSIFICATION: SILT (ML)

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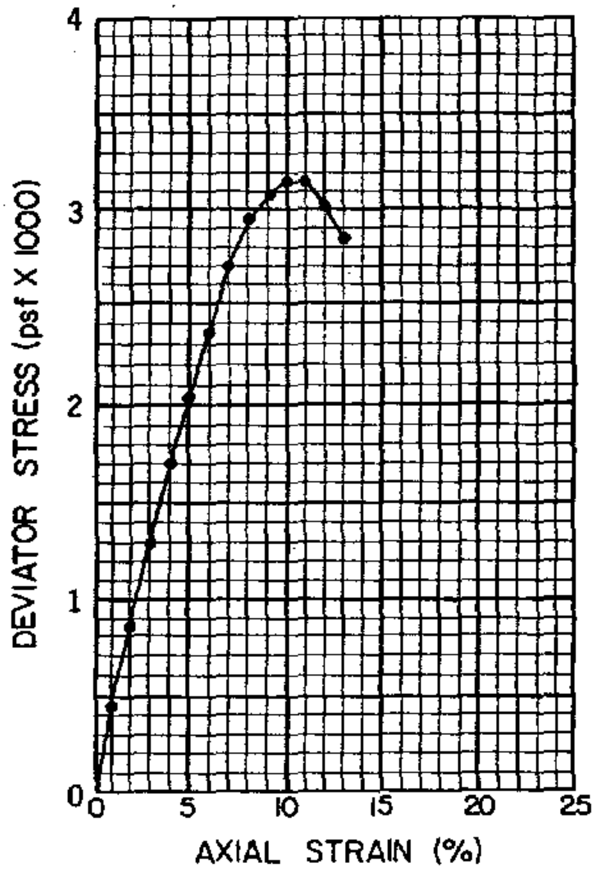
PLATE **D-65**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JY	9612,031.08	DEB	4/82		

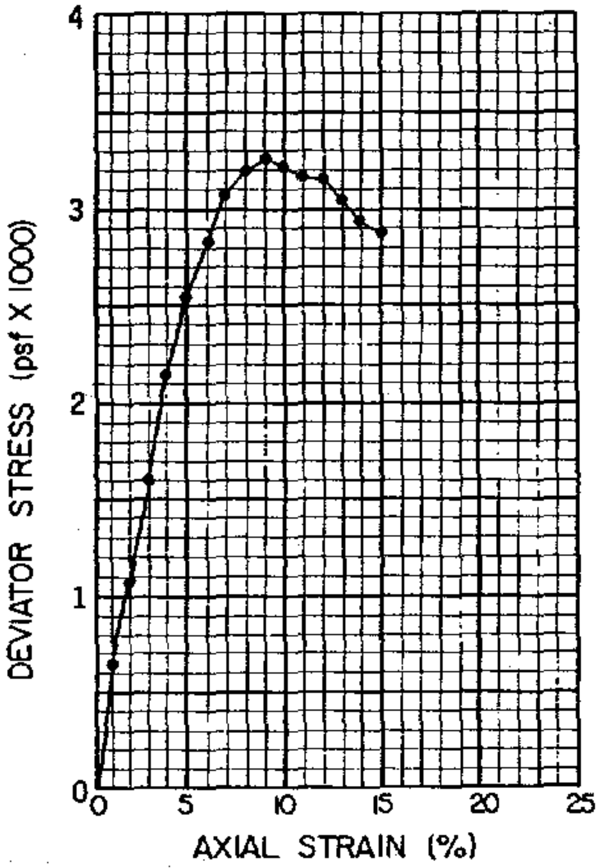


DIAMETER (in): 2.87
HEIGHT (in): 6.00

MOISTURE CONTENT (%): 30.2
DRY DENSITY (pcf): 90

CELL PRESSURE (psf): 4000
SHEAR STRENGTH (psf): 1580

SAMPLE SOURCE: Boring 9 at 31.6'
CLASSIFICATION: SILTY SAND (SM)



DIAMETER (in): 2.87
HEIGHT (in): 6.00

MOISTURE CONTENT (%): 31.2
DRY DENSITY (pcf): 90

CELL PRESSURE (psf): 2500
SHEAR STRENGTH (psf): 1630

SAMPLE SOURCE: Boring 9 at 41.4'
CLASSIFICATION: CLAY (CL)

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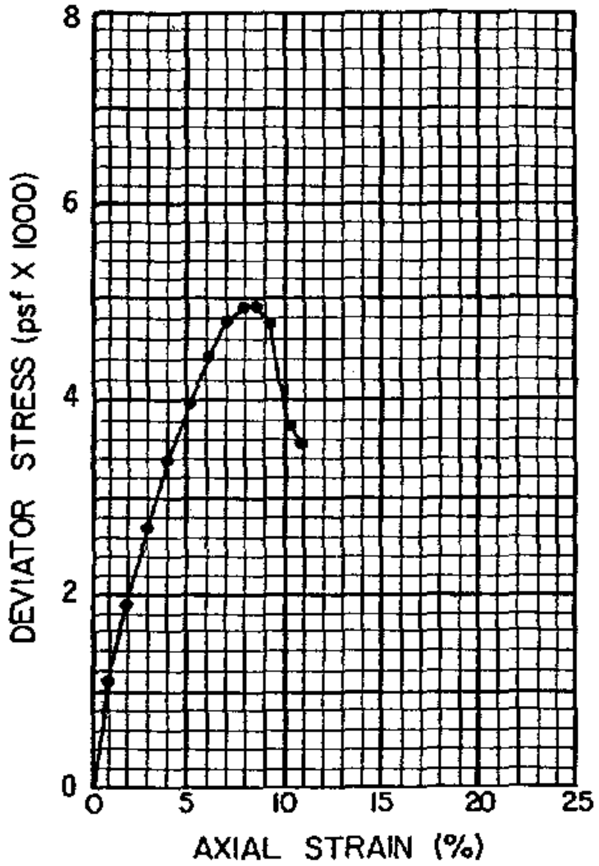
PLATE **D-66**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JF	9612,031.08	DGB	4/82		

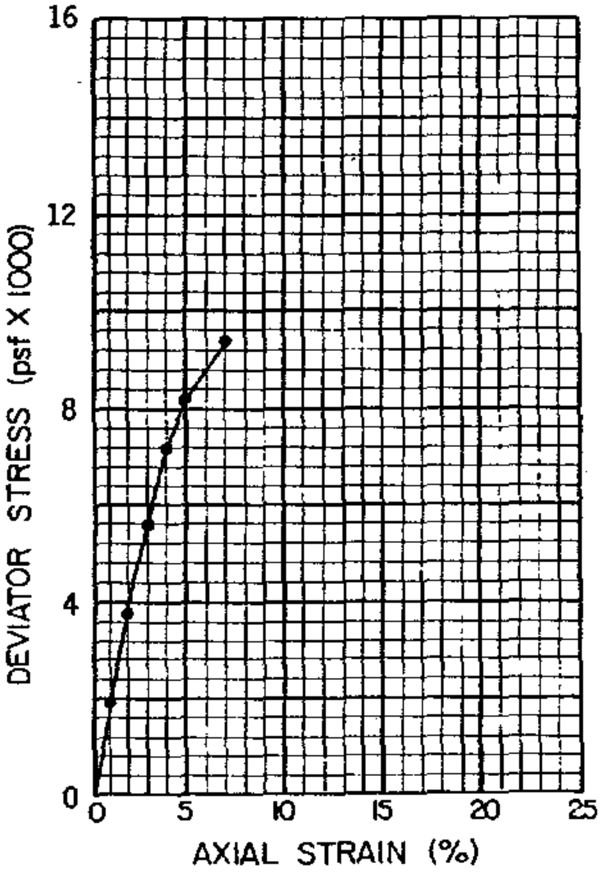


DIAMETER (in): 2.87
HEIGHT (in): 5.90

MOISTURE CONTENT (%): 27.6
DRY DENSITY (pcf): 96

CELL PRESSURE (psf): 2500
SHEAR STRENGTH (psf): 2460

SAMPLE SOURCE: Boring 9 at 41.9'
CLASSIFICATION: CLAY (CL)



DIAMETER (in): 2.87
HEIGHT (in): 6.00

MOISTURE CONTENT (%): 18.1
DRY DENSITY (pcf): 113

CELL PRESSURE (psf): 2200
SHEAR STRENGTH (psf): 4730

SAMPLE SOURCE: Boring 14 at 17.0'
CLASSIFICATION: CLAY (CL)

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PLATE
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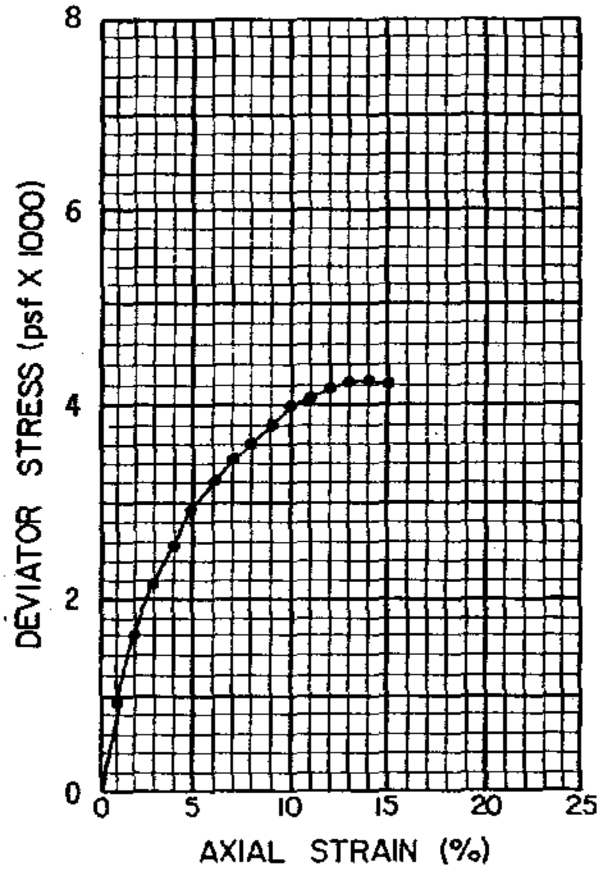
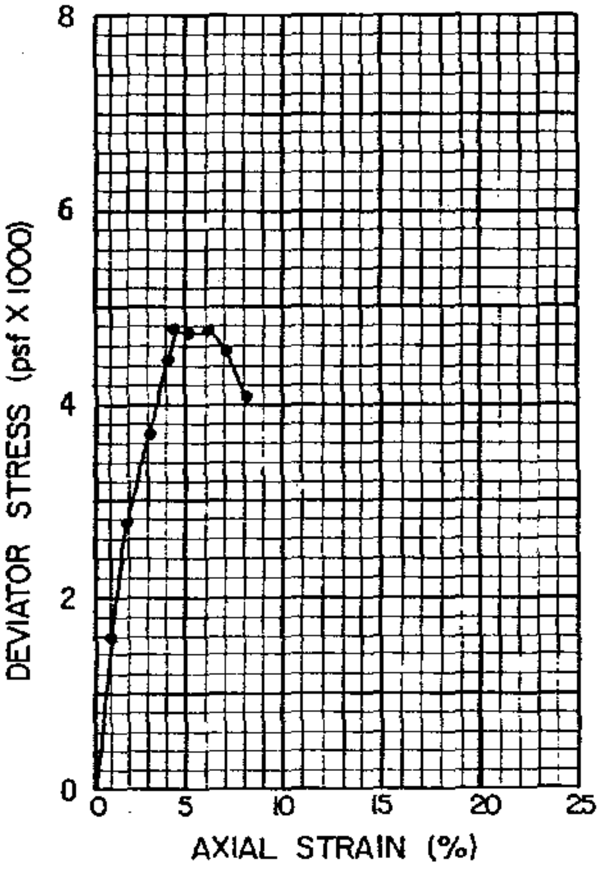
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JS	9612,031.08	DGB	4/82		



DIAMETER (in): 2.87
HEIGHT (in): 6.00
MOISTURE CONTENT (%): 22.9
DRY DENSITY (pcf): 103
CELL PRESSURE (psf): 3200
SHEAR STRENGTH (psf): 2140
SAMPLE SOURCE: Boring 14 at 25.5'
CLASSIFICATION: CLAY (CL)



DIAMETER (in): 2.87
HEIGHT (in): 5.90
MOISTURE CONTENT (%): 25.1
DRY DENSITY (pcf): 101
CELL PRESSURE (psf): 4500
SHEAR STRENGTH (psf): 2380
SAMPLE SOURCE: Boring 14 at 36.0'
CLASSIFICATION: CLAYEY SILT (ML)

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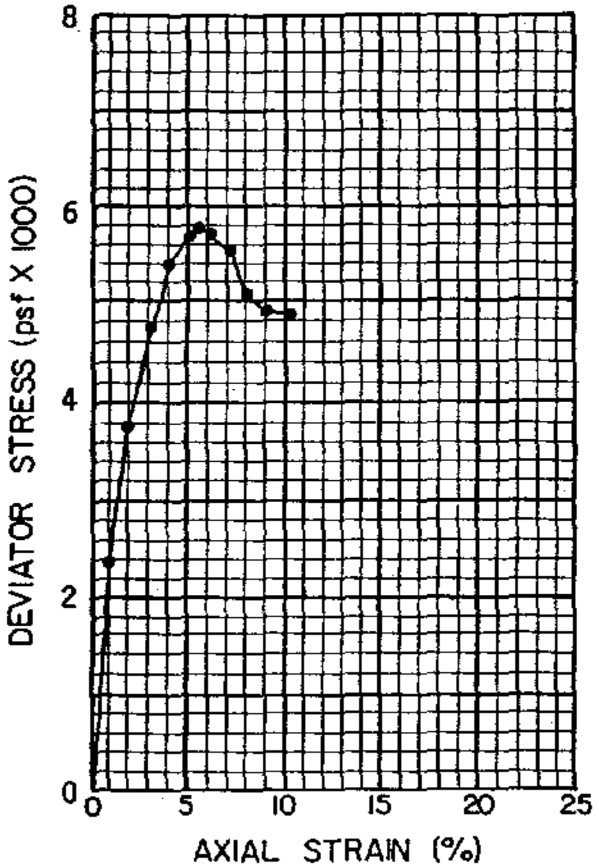
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		



DIAMETER (in): 2.87

HEIGHT (in): 5.90

MOISTURE CONTENT (%): 25.1

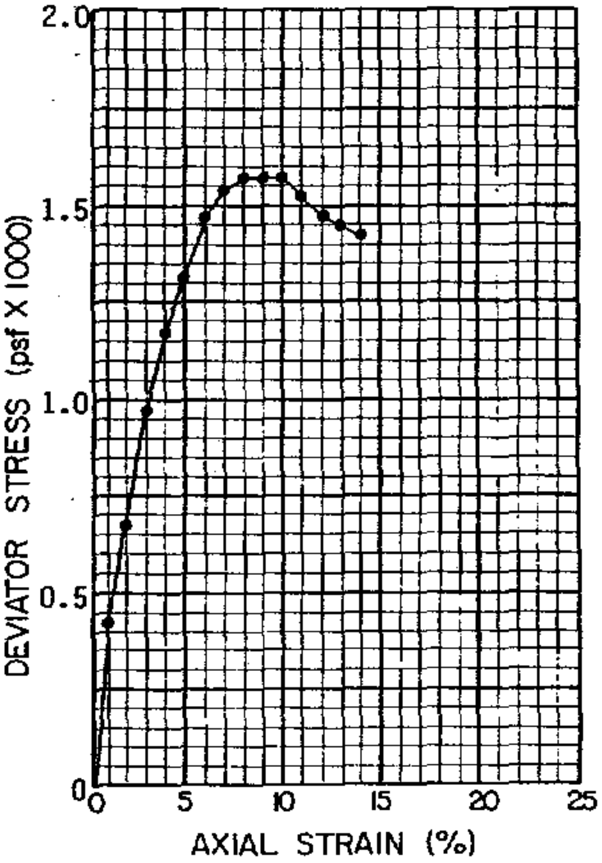
DRY DENSITY (pcf): 101

CELL PRESSURE (psf): 5000

SHEAR STRENGTH (psf): 2880

SAMPLE SOURCE: Boring 14 at 40.5'

CLASSIFICATION: CLAYEY SILT (ML)



DIAMETER (in): 2.87

HEIGHT (in): 5.75

MOISTURE CONTENT (%): 36.0

DRY DENSITY (pcf): 83

CELL PRESSURE (psf): 500

SHEAR STRENGTH (psf): 790

SAMPLE SOURCE: Boring 15 at 2.0'

CLASSIFICATION: CLAYEY SILT (ML)

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PLATE
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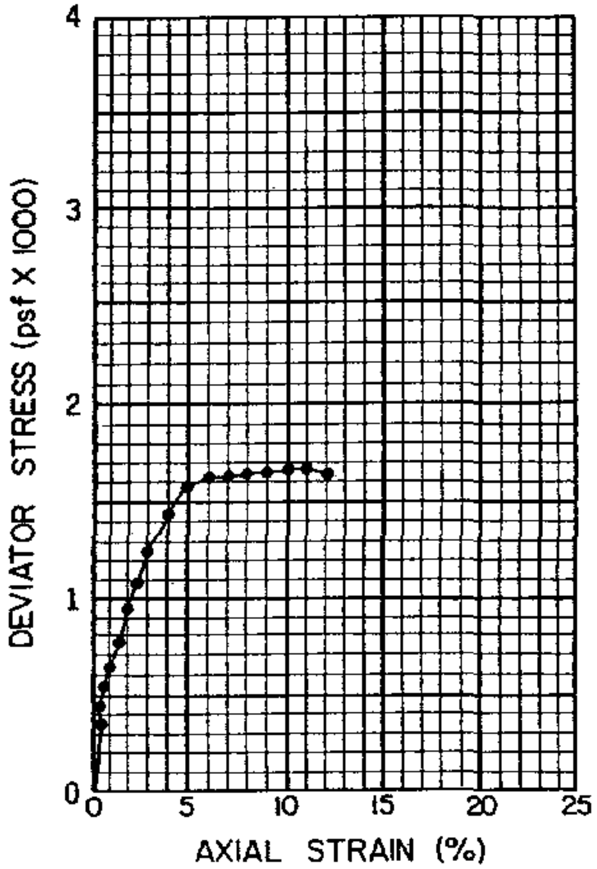
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JF	9612,031.08	DGB	4/82		



DIAMETER (in): 2.87

HEIGHT (in): 6.45

MOISTURE CONTENT (%): 81.1

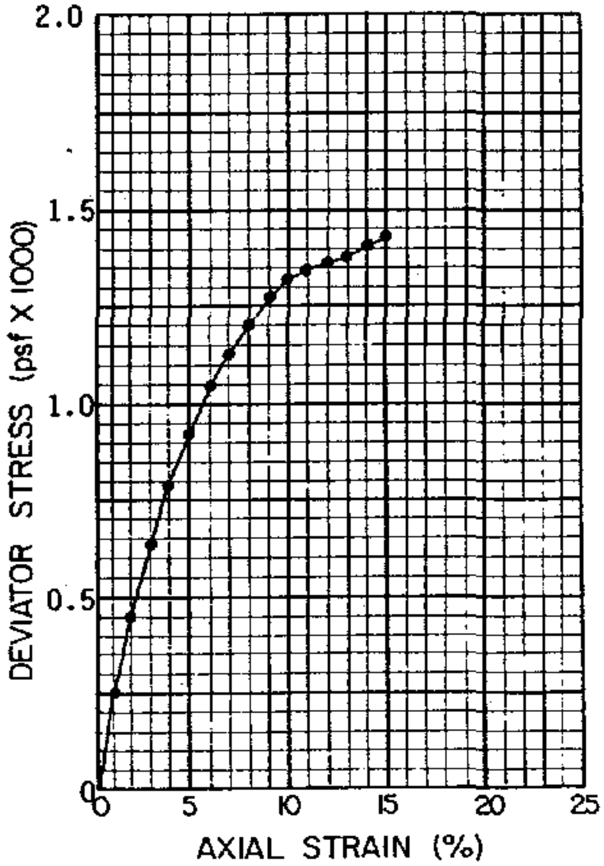
DRY DENSITY (pcf): 51

CELL PRESSURE (psf): 1000

SHEAR STRENGTH (psf): 800

SAMPLE SOURCE: Boring 15 at 9.0'

CLASSIFICATION: SILT (MH)



DIAMETER (in): 2.87

HEIGHT (in): 6.00

MOISTURE CONTENT (%): 32.2

DRY DENSITY (pcf): 86

CELL PRESSURE (psf): 1300

SHEAR STRENGTH (psf): 710

SAMPLE SOURCE: Boring 15 at 10.8'

CLASSIFICATION: SILT (ML)

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PLATE
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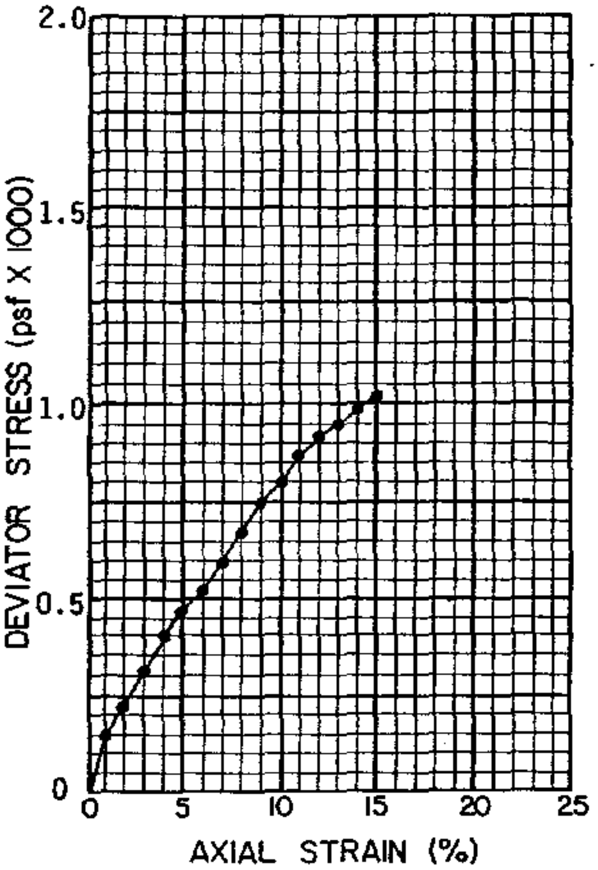
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DGB	4/82		



DIAMETER (in): 2.87

HEIGHT (in): 5.80

MOISTURE CONTENT (%): 26.0

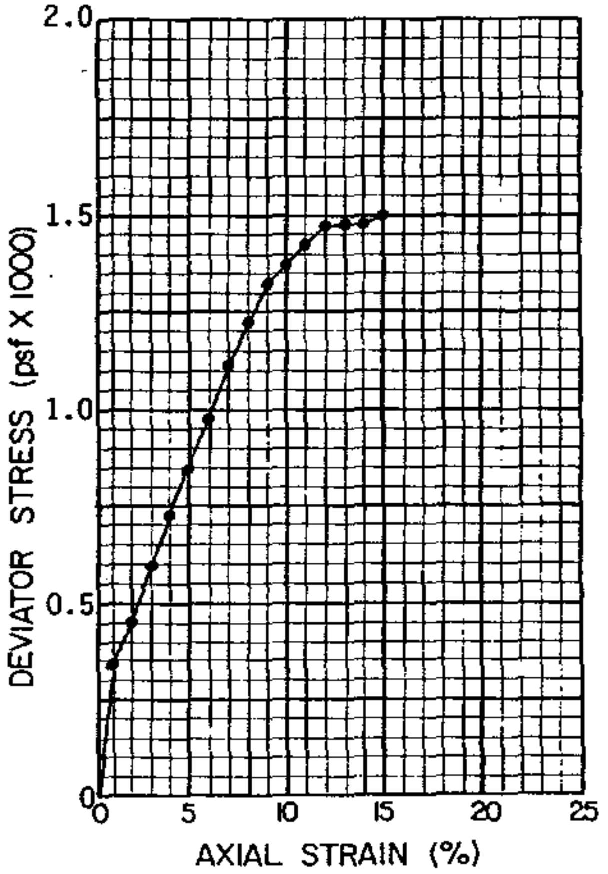
DRY DENSITY (pcf): 95

CELL PRESSURE (psf): 4600

SHEAR STRENGTH (psf): 520

SAMPLE SOURCE: Boring 15 at 36.8'

CLASSIFICATION: CLAY (CL)



DIAMETER (in): 2.87

HEIGHT (in): 6.00

MOISTURE CONTENT (%): 52.5

DRY DENSITY (pcf): 67

CELL PRESSURE (psf): 800

SHEAR STRENGTH (psf): 750

SAMPLE SOURCE: Boring 17 at 6.2'

CLASSIFICATION: CLAYEY SILT (ML)

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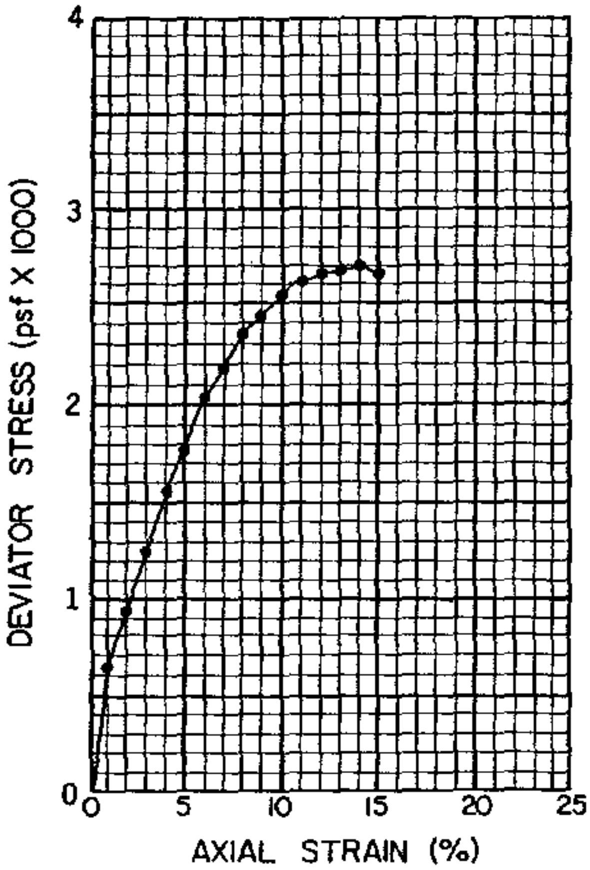
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
X	9612,031.08	DiB	4/82		

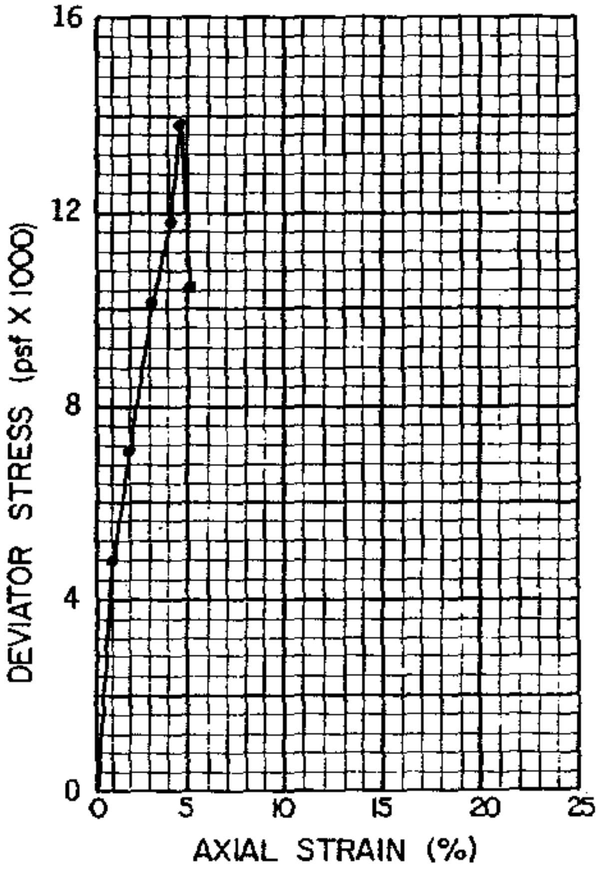


DIAMETER (in): 2.87
HEIGHT (in): 6.00

MOISTURE CONTENT (%): 40.5
DRY DENSITY (pcf): 77

CELL PRESSURE (psf): 900
SHEAR STRENGTH (psf): 1350

SAMPLE SOURCE: Boring 17 at 6.7'
CLASSIFICATION: CLAYEY SILT (ML)



DIAMETER (in): 2.43
HEIGHT (in): 5.90

MOISTURE CONTENT (%): 18.4
DRY DENSITY (pcf): 114

CELL PRESSURE (psf): 3800
SHEAR STRENGTH (psf): 6450

SAMPLE SOURCE: Boring 17 at 30.4'
CLASSIFICATION: CLAYEY SILT (ML)

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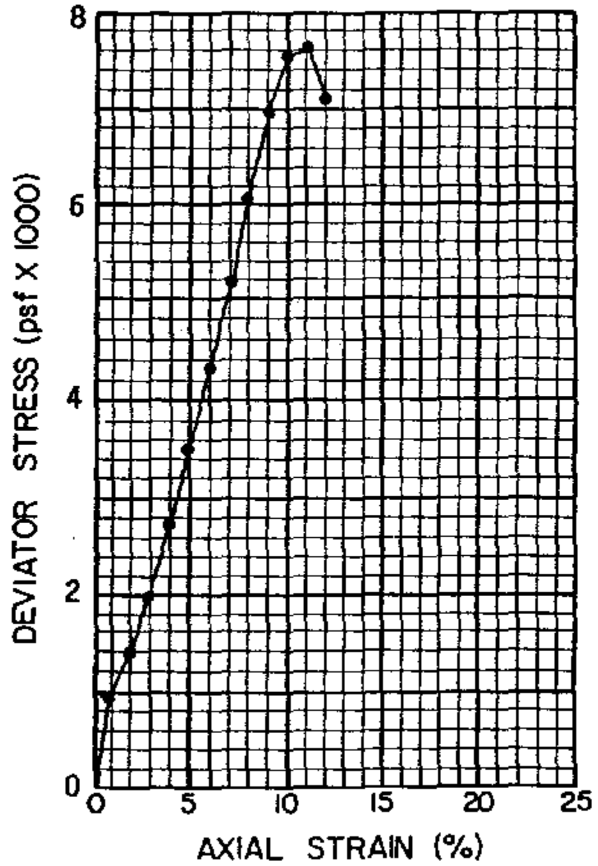
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82	-	



DIAMETER (in): 2.87

HEIGHT (in): 5.95

MOISTURE CONTENT (%): 19.2

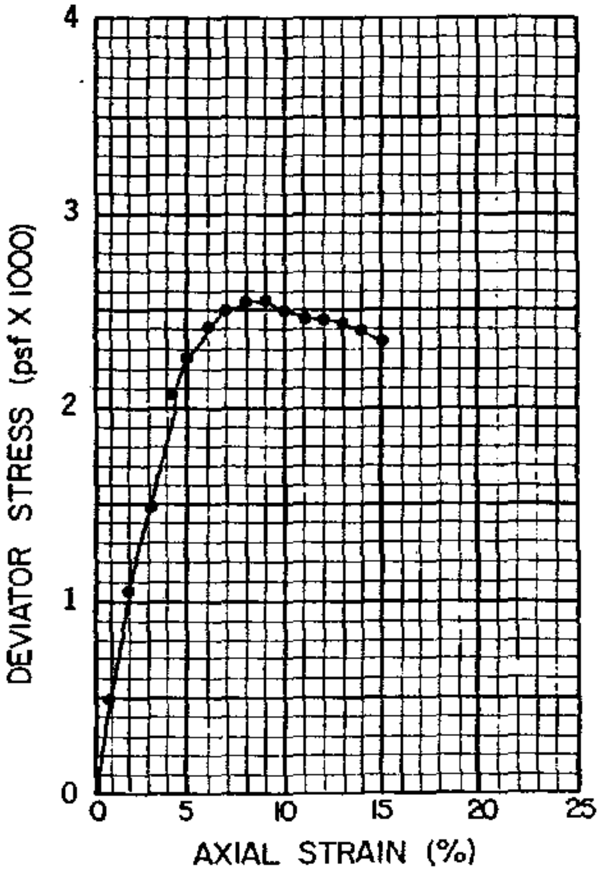
DRY DENSITY (pcf): 110

CELL PRESSURE (psf): 900

SHEAR STRENGTH (psf): 3820

SAMPLE SOURCE: Boring 21 at 7.0'

CLASSIFICATION: SANDY SILT (ML)



DIAMETER (in): 2.87

HEIGHT (in): 5.70

MOISTURE CONTENT (%): 23.7

DRY DENSITY (pcf): 100

CELL PRESSURE (psf): 4000

SHEAR STRENGTH (psf): 1270

SAMPLE SOURCE: Boring 21 at 31.5'

CLASSIFICATION: SILTY CLAY (CL)

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PLATE
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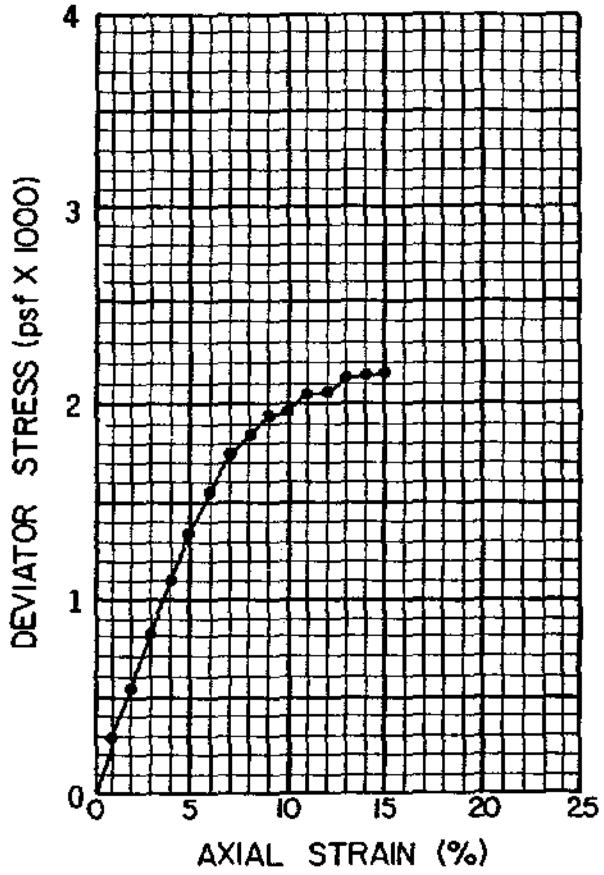
DRAWN JP
JOB NUMBER 9612,031.08
APPROVED JDB
DATE 4/82
REVISED
DATE



DIAMETER (in): 2.87

HEIGHT (in): 5.80

MOISTURE CONTENT (%): 23.0

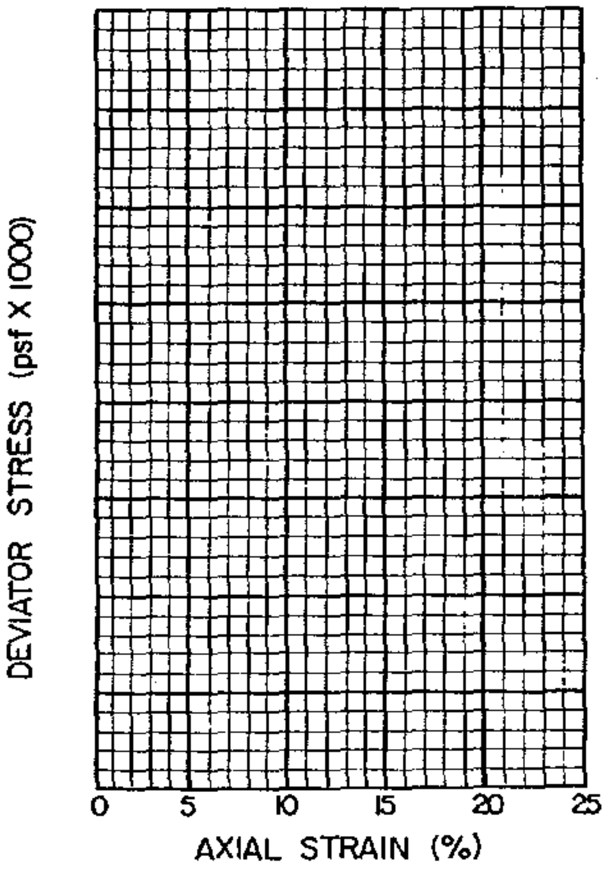
DRY DENSITY (pcf): 101

CELL PRESSURE (psf): 4000

SHEAR STRENGTH (psf): 1090

SAMPLE SOURCE: Boring 21 at 32.0'

CLASSIFICATION: SILTY CLAY (CL)



DIAMETER (in):

HEIGHT (in):

MOISTURE CONTENT (%):

DRY DENSITY (pcf):

CELL PRESSURE (psf):

SHEAR STRENGTH (psf):

SAMPLE SOURCE:

CLASSIFICATION:

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JT	9612,031.08	DWB	4/82		

The following procedure was used for these tests:

1) A 2.87-inch-diameter sample was trimmed to a height of approximately 6.00 inches and placed in a triaxial cell. A confining pressure of 2 psi was immediately applied to the sample to ensure sample integrity.

2) Back pressures, varying between 20 and 50 psi, were applied to achieve complete saturation. The "B parameter", which relates changes in pore water pressure to changes in confining pressure ($B = \Delta u / \Delta \sigma_c$) was calculated to check for sample saturation. If the sample was not saturated, a higher back pressure was employed.

3) The sample was consolidated under a selected confining pressure. During consolidation, the volume change of the sample was recorded and plotted against the logarithm of time. This plot was used to determine when primary consolidation had ended.

4) After completion of the consolidation phase, the drain valve was closed and an axial load was applied at a constant strain rate of approximately 0.1 percent per minute; the actual strain rate depended upon soil type. During loading, pore pressure readings were obtained with a Mercury manometer. The measurement of pore pressure allow direct correlation of TXCU results with TXCD results.

Results of the TXCU tests are summarized on Plate D-75. Both total and effective stresses and strains at failure are presented. Representative total and effective strengths are presented on Mohr's diagram, Plate D-76. The effective stress failure criterion is based on the effective principal stress ratios (σ_1'/σ_3'). If the material is non-dilatant, the maximum stress ratio, $(\sigma_1'/\sigma_3')_{max}$ is taken as the failure stress ratio (σ_1'/σ_3'). If the material is dilatant, the stress ratio at which the

Boring No.	Depth (ft)	USGS	Type of Test	Initial Moisture Content (%)	Initial Dry Density (pcf)	Consolidation Pressure (psf)	Stresses & Axial Strain at $(\sigma_1'/\sigma_3')_f$ (1)				Stress/Strain at $(\sigma_1-\sigma_3)_f$ (2)		Pore Pressure Coefficient at $(\sigma_1-\sigma_3)$ max
							σ_{1f}' (psf)	σ_{3f}' (psf)	$(\frac{\sigma_1'}{\sigma_3'})_f$	ϵ_1 (%)	$(\sigma_1-\sigma_3)_f$ (psf)	ϵ_1 (%)	A_f
2	0.3	SP	TxCD	22.8	102	1500	7310	1440	5.08	2.5	5870	2.5	---
2	3.4	SP	TxCD	22.8	98	3000	17060	3100	5.51	5.0	13950	5.0	---
2	9.9	ML	TxCD	31.2	90	1000	4990	990	5.04	9.0	4000	9.0	---
2	10.7	ML	TxCD	29.0	94	2000	9010	2270	3.96	9.0	6740	9.0	---
2	11.3	ML	TxCD	32.5	89	4000	15410	3930	3.92	12.0	11480	12.0	---
2	40.2	ML	TxCU	21.2	106	2000	11010	2240	4.92	5.0	8770	5.0	-0.03
2	40.8	ML	TxCU	21.1	107	4000	14130	2950	4.79	5.0	15040	8.0	-0.02
2	41.6	ML	TxCU	26.3	96	6000	14420	3960	3.64	8.1	>13050	15.0	0.05
4	13.3	OL	TxCU	43.7	75	3000	4390	950	4.62	9.0	> 3560	11.0	0.57
4	13.8	ML	TxCU	47.5	72	1500	2290	980	4.97	9.0	> 1930	12.0	0.48
4	19.0	CL	TxCU	68.4	58	1000	2190	350	6.33	8.0	1880	5.0	0.38
4	19.6	CL	TxCU	71.1	57	2000	2530	430	5.86	9.0	2100	9.0	0.73
6	4.1	ML	TxCU	33.4	88	3000	5080	1080	4.70	7.0	> 5360	15.0	0.26
6	4.6	ML	TxCU	32.3	90	750	2640	630	4.17	4.0	2550	6.0	-0.01
6	5.3	SP-SM	TxCU	14.1	121	750	3590	970	3.73	2.5	2630	2.5	-0.05
6	14.7	ML	TxCU	23.3	99	1500	7110	1570	4.53	4.0	5540	4.0	-0.16
6	15.4	ML	TxCU	26.2	100	3000	10140	2250	4.51	4.0	10310	6.0	-0.13
9	4.5	SM	TxCU	24.7	101	1600	5600	1270	4.42	2.5	5920	4.1	-0.03
9	5.1	SM	TxCU	22.7	103	3200	9570	2380	4.03	5.1	9280	9.0	0.00
9	7.4	ML	TxCU	26.4	98	3000	6880	1700	4.05	6.0	> 6610	16.0	0.10
9	8.1	ML	TxCU	28.4	96	1870	4940	1180	4.19	5.0	5460	15.2	-0.01
9	9.0	ML	TxCU	27.4	96	860	3330	760	4.38	3.0	2930	4.0	0.00
14	2.4	ML	TxCU	27.1	95	1000	2960	550	5.41	3.1	3990	8.0	-0.03
14	2.9	ML	TxCU	26.7	96	2000	5420	1240	4.37	5.0	> 5220	10.0	0.07
15	8.4	MH	TxCU	70.2	56	750	2300	460	5.01	6.0	1920	8.0	0.13
15	15.5	SM	TxCU	18.2	114	5000	24070	5170	4.66	6.0	18900	6.0	-0.01
15	16.0	SM	TxCU	18.6	113	2250	11010	2320	4.75	2.5	8690	2.5	-0.01
17	35.3	CL	TxCU	24.7	103	2000	6710	1540	4.36	3.2	7170	5.0	-0.04
17	36.3	ML	TxCU	24.3	103	4000	9370	2590	3.62	4.1	9010	10.0	-0.01
21	4.1	ML	TxCU	19.3	111	750	4120	910	4.54	1.1	3210	1.1	-0.10
21	4.7	ML	TxCU	18.9	111	1500	7210	1450	4.95	2.0	7080	2.5	-0.04
21	5.2	ML	TxCU	20.5	108	3000	7410	2130	3.48	2.5	6020	6.0	0.04
21	18.0	ML	TxCU	24.0	102	4000	13280	3680	3.61	10.1	10280	12.2	0.00
21	18.5	ML	TxCU	26.6	97	2000	5710	2040	2.80	7.0	3670	7.0	-0.01
21	26.1	ML	TxCU	25.9	99	5000	14570	3490	4.17	8.0	>14270	15.0	0.01
21	26.8	ML	TxCU	25.9	98	2500	10410	2330	4.47	6.0	9080	7.0	-0.02
22	2.7	ML	TxCU	25.8	99	750	1860	290	6.46	1.5	3480	7.3	-0.05
22	3.8	ML	TxCU	30.7	90	1500	3700	820	4.50	4.0	> 4180	10.0	0.05

NOTES:

(1) For TXCD tests, $(\sigma_1'/\sigma_3')f = (\sigma_1'/\sigma_3')max$;

For TXCU tests, $(\sigma_1'/\sigma_3')f = (\sigma_1'/\sigma_3')max$ or (σ_1'/σ_3') at which the pore pressure becomes negative, whichever is smaller.

(2) For TXCD tests, $(\sigma_1-\sigma_3)f = (\sigma_1-\sigma_3)max$. For TXCU tests, $(\sigma_1-\sigma_3) = (\sigma_1-\sigma_3)max$ or the deviator stress at which the pore pressure becomes negative, whichever is smaller.

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Consolidated-Undrained, Consolidated-Drained Triaxial Compression Test Report Summary

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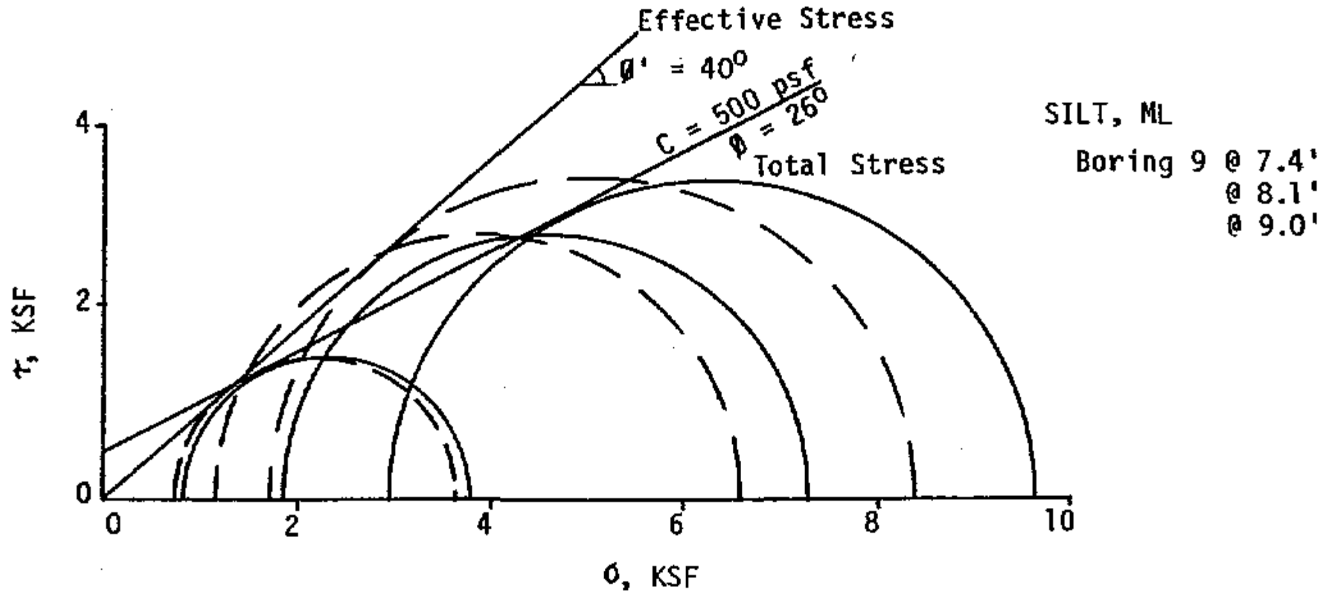
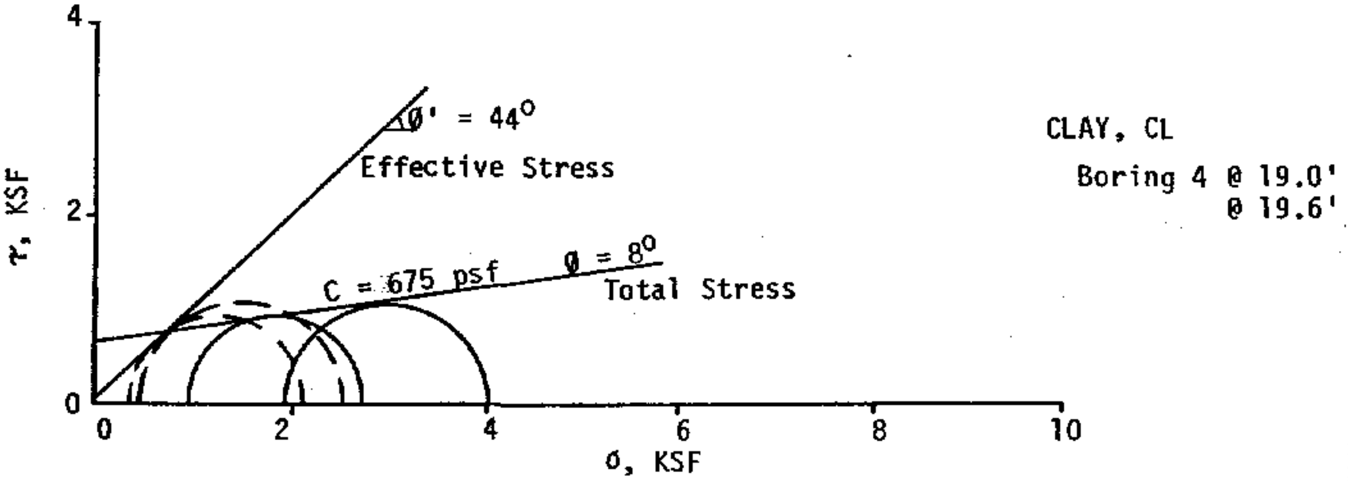
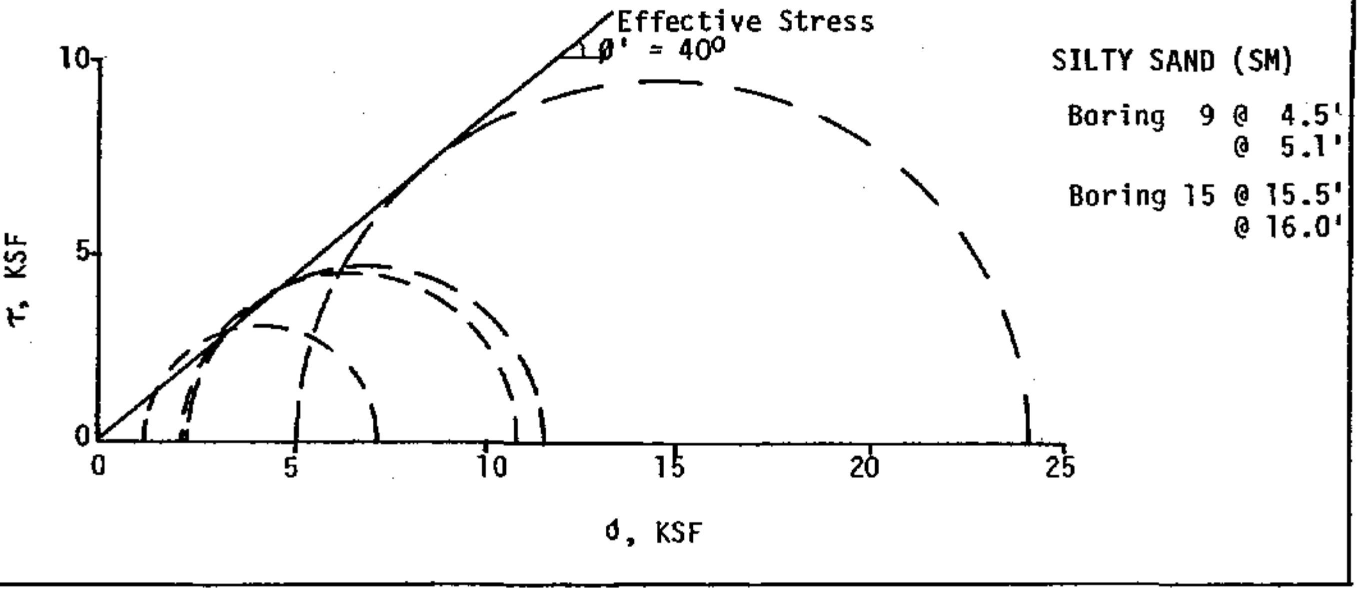
PLATE
D-75

DRAWN
JOB NUMBER 9612,031.08
APPROVED
DATE 4/82
REVISED
DATE







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Total and Effective Strengths

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PLATE
D-76

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DSB	4/82		

pore pressure becomes zero or $(\sigma_1'/\sigma_3')_{max}$ is taken as $(\sigma_1'/\sigma_3')_f$, whichever is smaller. The effective strengths for all tests are presented on a modified Mohr diagram as shown on Plate IV-19, which yields an effective friction angle of 40 degrees with no cohesion intercept.

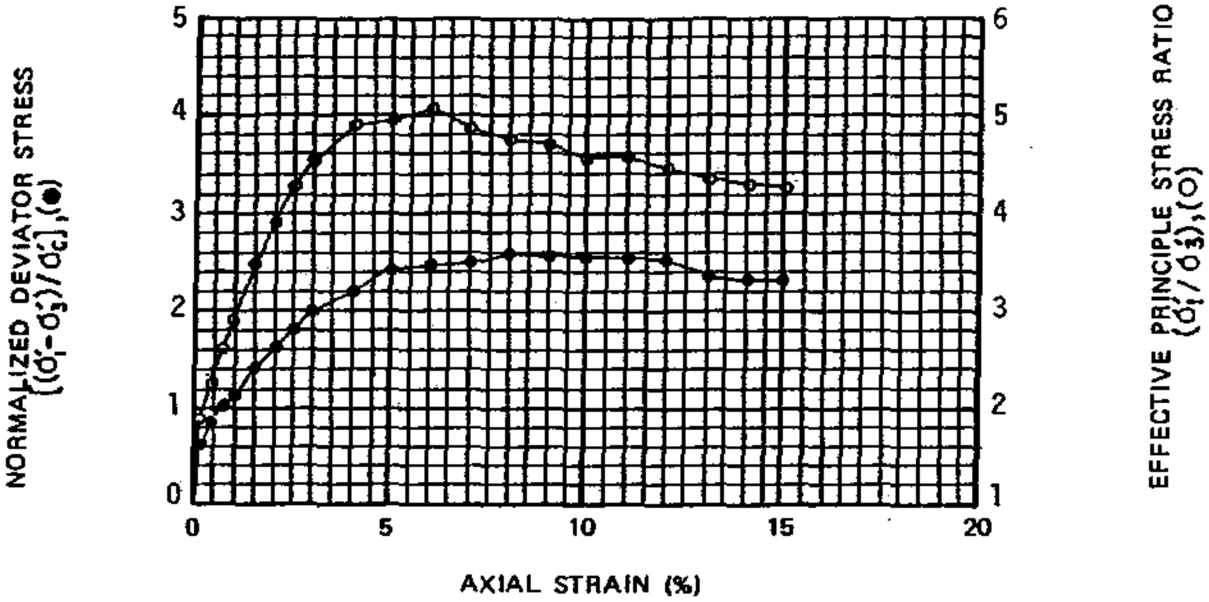
The deviator stress, $(\sigma_1-\sigma_3')$, is used as the total stress failure criterion. If the soil is non-dilatant, the maximum deviator stress $(\sigma_1'-\sigma_3)_{max}$ is taken as the failure stress, $(\sigma_1-\sigma_3)_f$. If the soil is dilatant, the $(\sigma_1-\sigma_3)$ at which the pore pressure becomes zero or the $(\sigma_1-\sigma_3)_{max}$ is taken as $(\sigma_1-\sigma_3)_f$, whichever is smaller. The pore pressure parameter, A_f is computed at $(\sigma_1-\sigma_3)_{max}$.

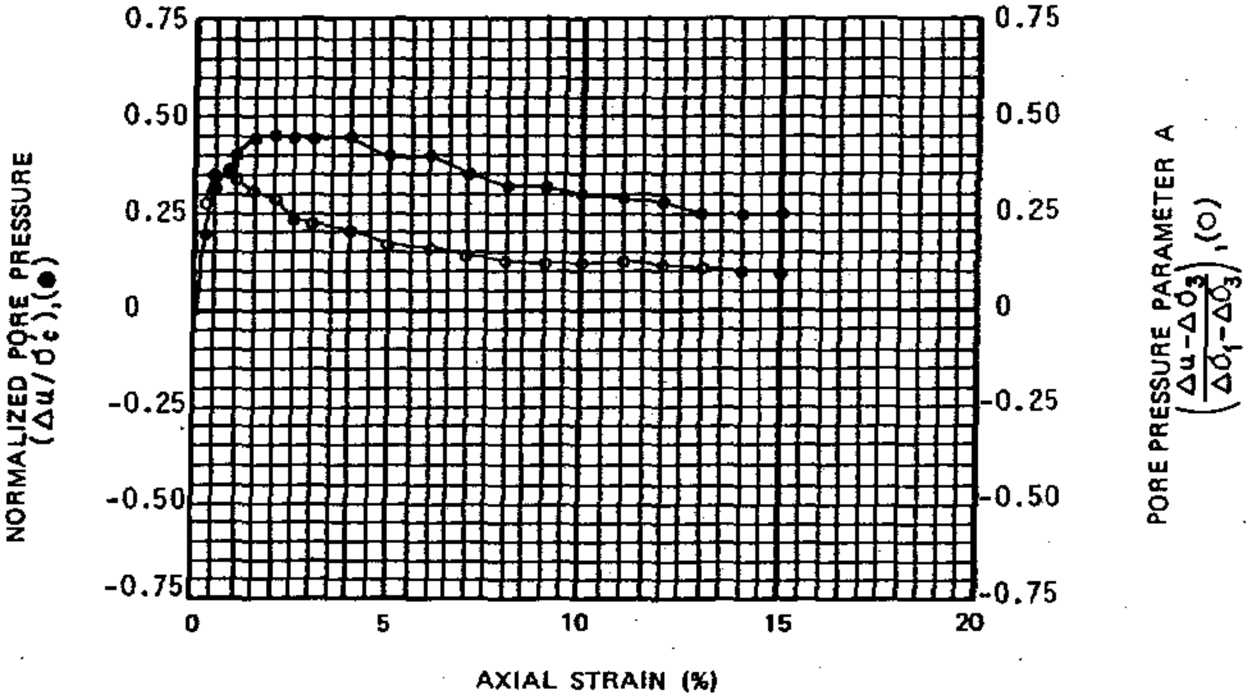
Several series of tests were made with two or more tested at different confining pressures. Results indicate that the rate of increase in undrained shear strength with the increase in consolidation pressure is approximately 0.5, regardless of material type and dry density as shown on Plate IV-18. The undrained shear stengths corresponding to the effective overburden pressures are plotted with TXUU data. The agreement between the TXCU and TXUU results is good as shown on Plate IV-17.

Results of each individual test are presented on Plates D-77 through D-110. The normalized deviator stress and pore pressure, as well as the effective stress ratios and pore pressure parameter A, are plotted versus the consolidation pressure.

c. Consolidated-Drained Triaxial Shear Tests

Consolidated-drained triaxial shear (TXCD) tests were conducted on samples of sandy silt (ML) and sand (SP). In these tests, the samples were saturated by seepage or back pressure, subjected to pressure, and allowed to





TYPE OF SPECIMEN	Undisturbed	BEFORE TEST			AFTER TEST	
DIAMETER(in.) 2.87	HEIGHT(in) 6.45	MOISTURE CONTENT	w_o	70.2 %	w_f	66.1 %
OVERBURDEN PRESS.,σ'_{vo}	460 psf	VOID RATIO	e_o	1.875	e_f	1.728
CONSOLIDATION PRESS.,) σ'_c	- psf	SATURATION	S_o	97	S_f	100 %
STRAIN RATE	- %/min	DRY DENSITY	γ_d	56	γ_d	60 pcf

LL --	PL --	PI --	G_s 2.60
LASSIFICATION		SOURCE Boring 2 at 8.4'	

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PLATE
D-77

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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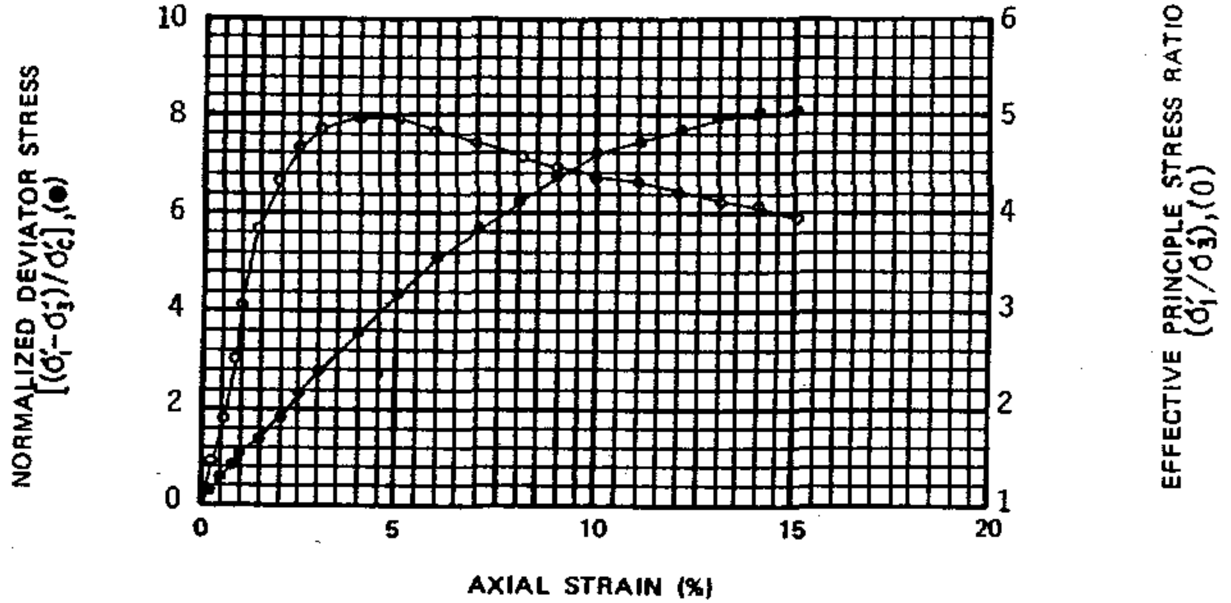

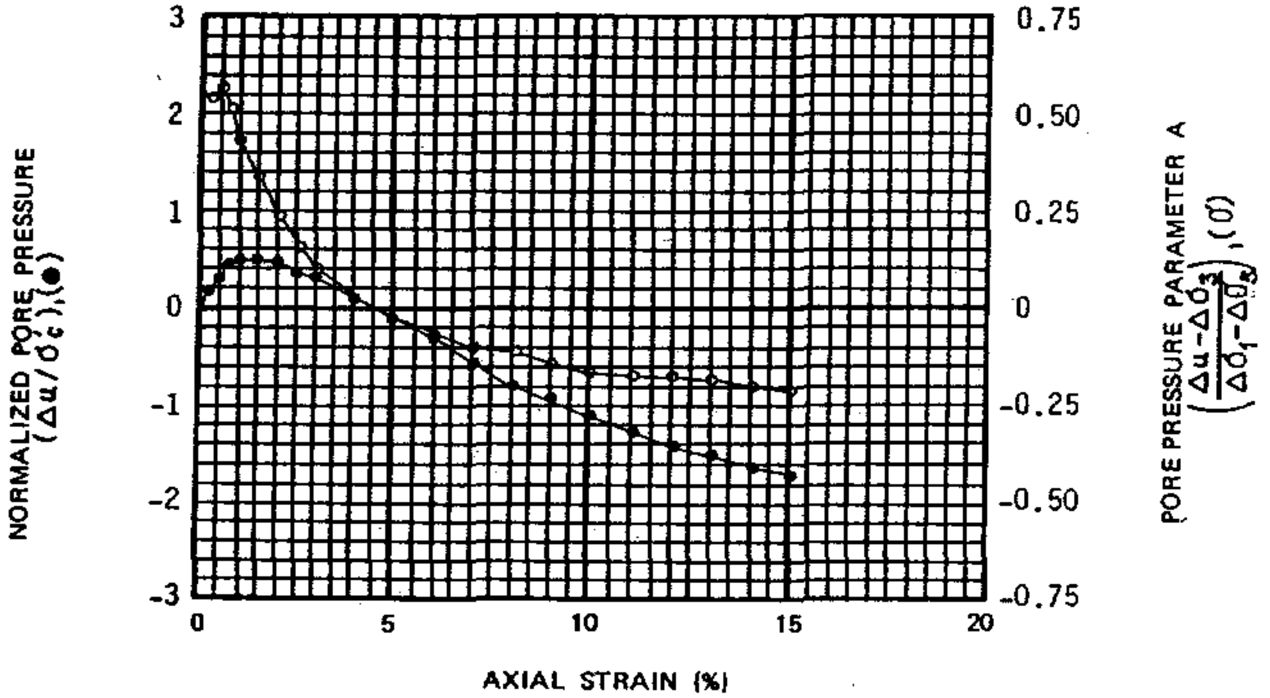

YPE OF SPECIMEN Undisturbed		BEFORE TEST			AFTER TEST	
IAMETER(in.) 2.87	HEIGHT(in) 6.45	MOISTURE CONTENT	w_o	21.2 %	w_f	20.0 %
VERBURDEN PRESS.,σ_{vo}' 2210 psf		VOID RATIO	e_o	0.616	e_f	0.546
ONSOLIDATION PRESS.,) σ_c' 2000 psf		SATURATION	S_o	94 %	S_f	100 %
TRAIN RATE -- %/min		DRY DENSITY	γ_d	106 pcf	γ_d	111 pcf
L --	PL --	PI --		G_s 2.74		
LASSIFICATION SANDY SILT (ML)		SOURCE Boring 2 at 40.2'				

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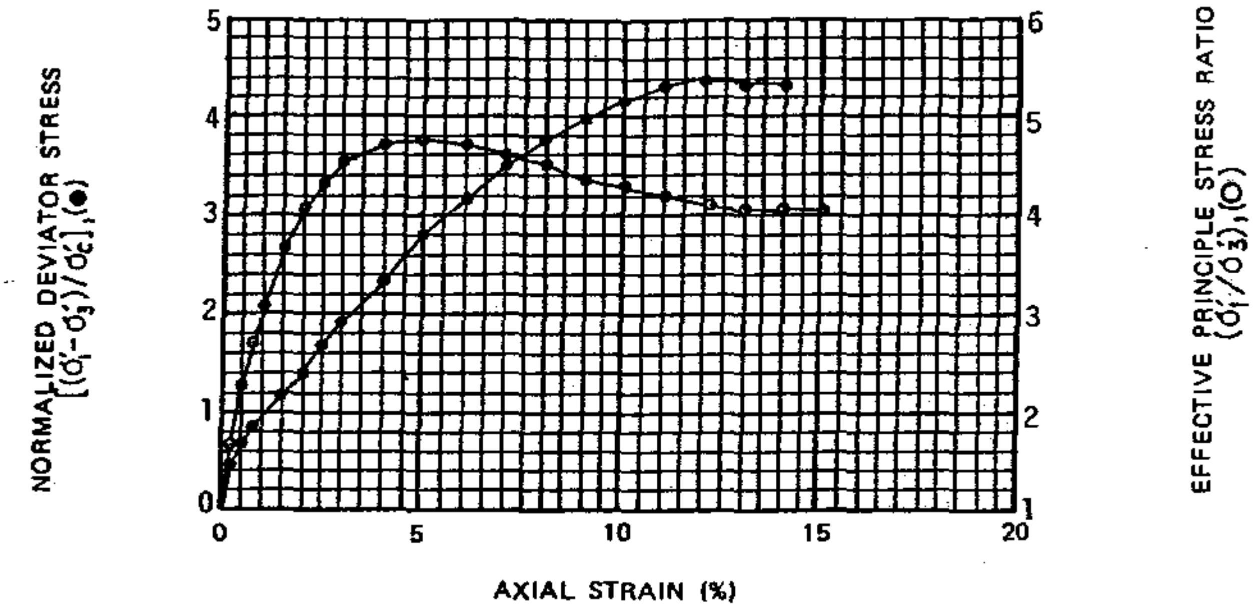
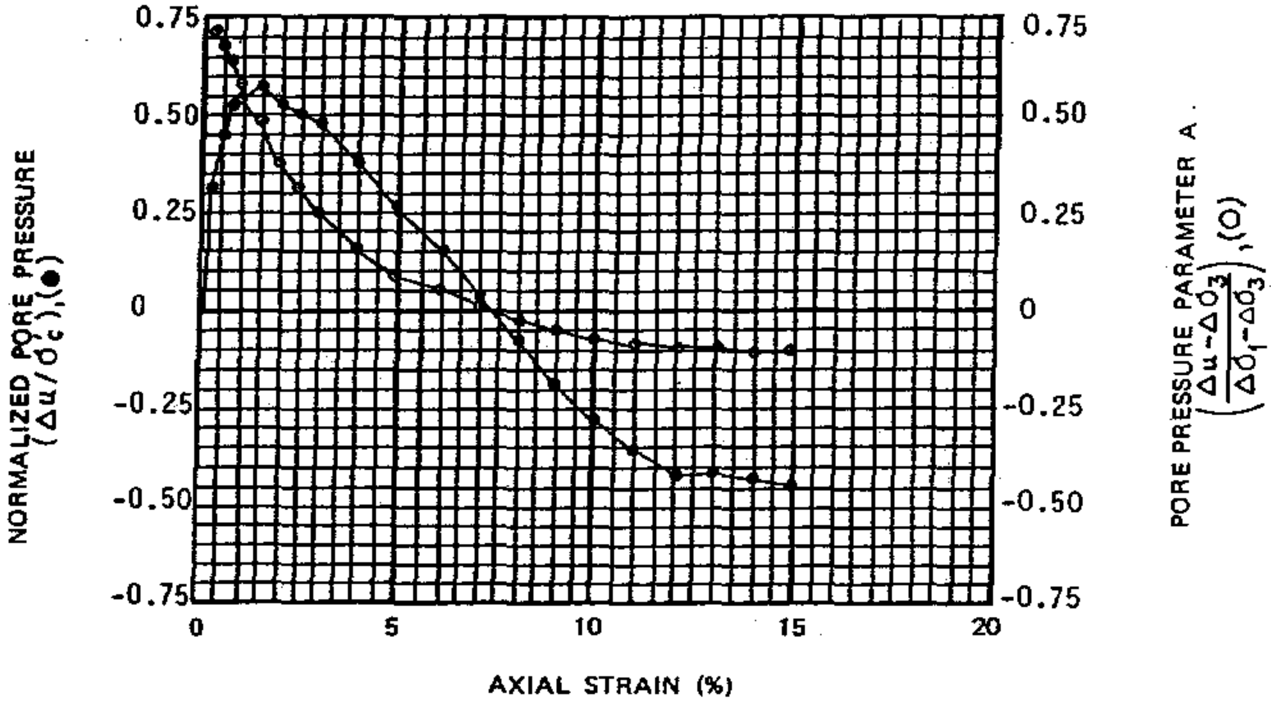
PLATE
D-78

RAWN | JOB NUMBER | APPROVED | DATE | REVISED | DATE





TYPE OF SPECIMEN Undisturbed		BEFORE TEST			AFTER TEST	
DIAMETER(in.) 2.87	HEIGHT(in) 6.44	MOISTURE CONTENT	w_o	21.1 %	w_f	19.0 %
OVERBURDEN PRESS.,σ_{vo}' 2240 psf		VOID RATIO	e_o	0.585	e_f	0.532
CONSOLIDATION PRESS.,) σ_c' 4000 psf		SATURATION	S_o	98 %	S_f	100 %
STRAIN RATE -- %/min		DRY DENSITY	γ_d	107 pcf	γ_d	111 pcf

LL --	PL --	PI --	G_s 2.72
CLASSIFICATION SANDY SILT (ML)		SOURCE Boring 2 at 40.8'	

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PLATE
D-79

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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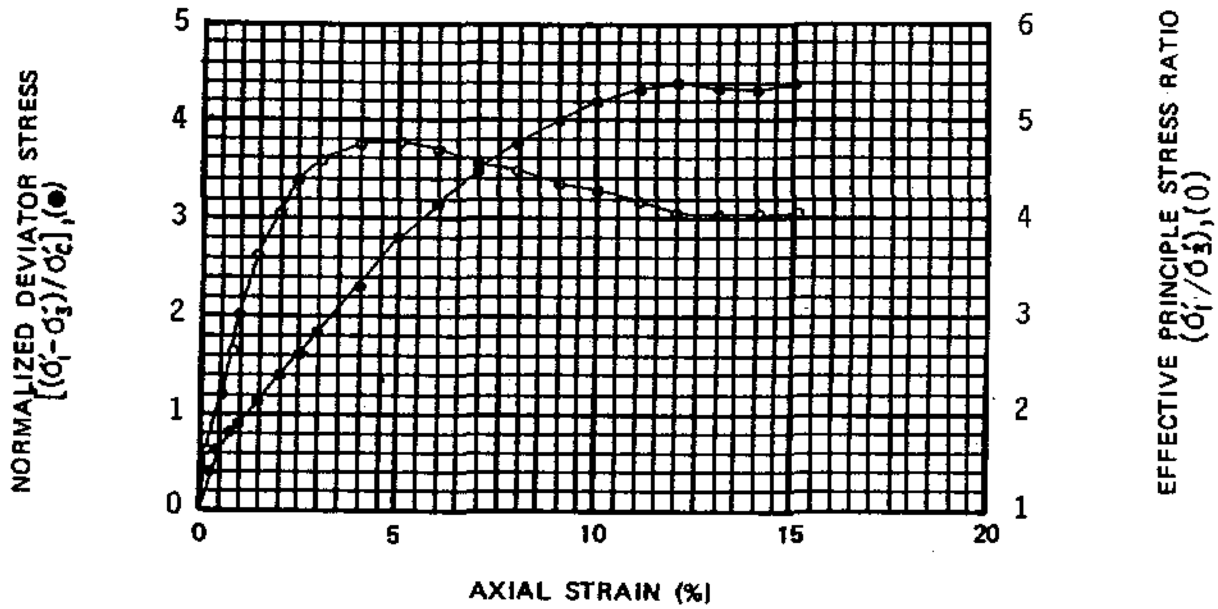

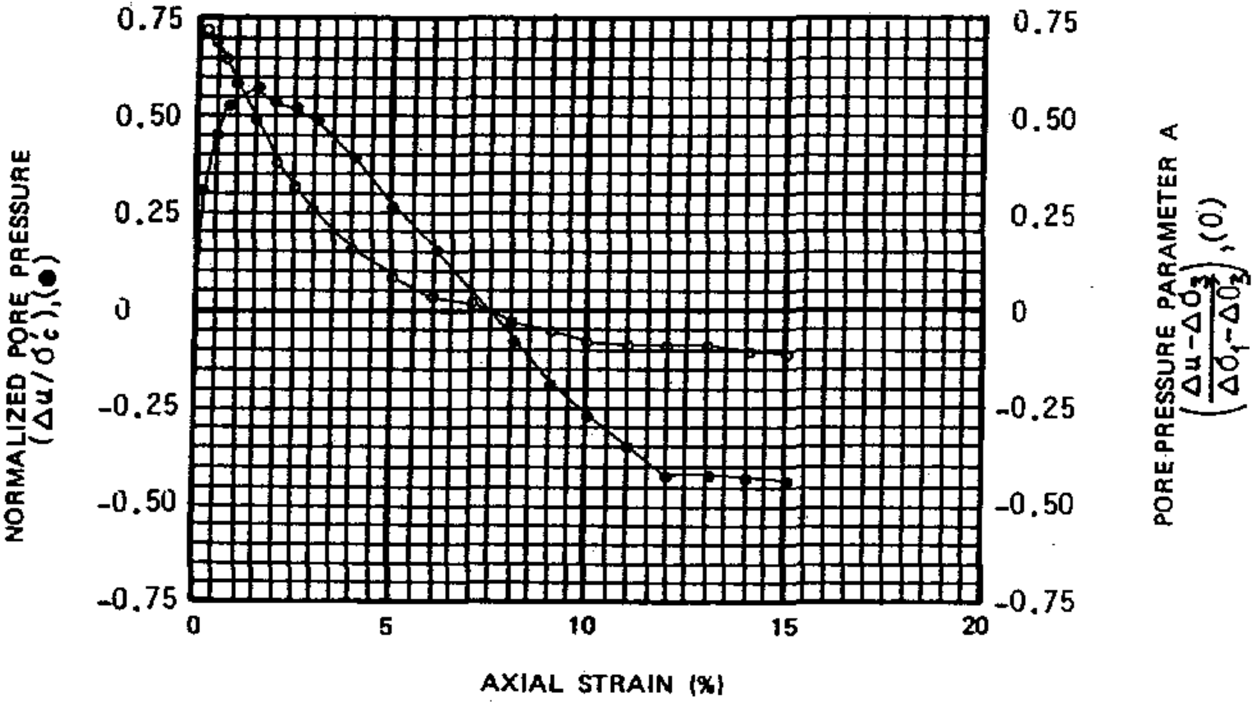

YPE OF SPECIMEN Undisturbed		BEFORE TEST			AFTER TEST	
IAMETER(in.) 2.87	HEIGHT(in) 6.45	MOISTURE CONTENT	w_o	26.3 %	w_f	19.0 %
VERBURDEN PRESS., σ'_{vo} 2300 psf		VOID RATIO	e_o	0.585	e_f	0.532
ONSOLIDATION PRESS.,) σ'_c 4000 psf		SATURATION	S_o	98 %	S_f	100 %
TRAIN RATE -- %/min		DRY DENSITY	γ_d	107 pcf	γ_d	111 pcf
L --	PL --	PI --		G_s 2.72		
LASSIFICATION SANDY SILT (ML)		SOURCE Boring 2 at 41.6'				

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PLATE
D-80

RAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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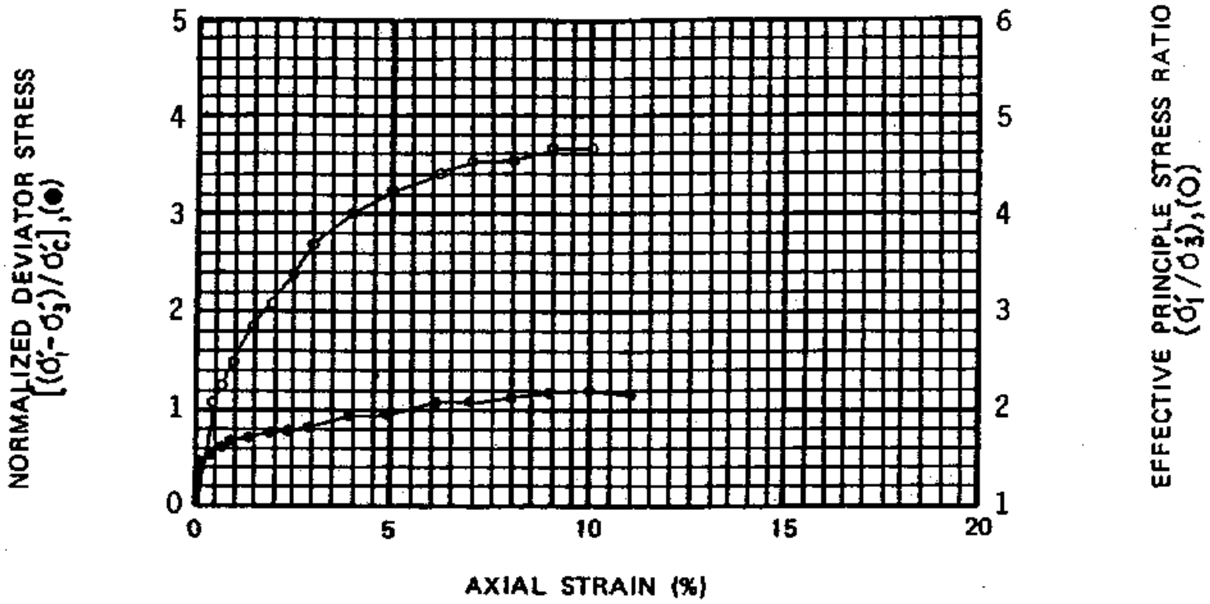

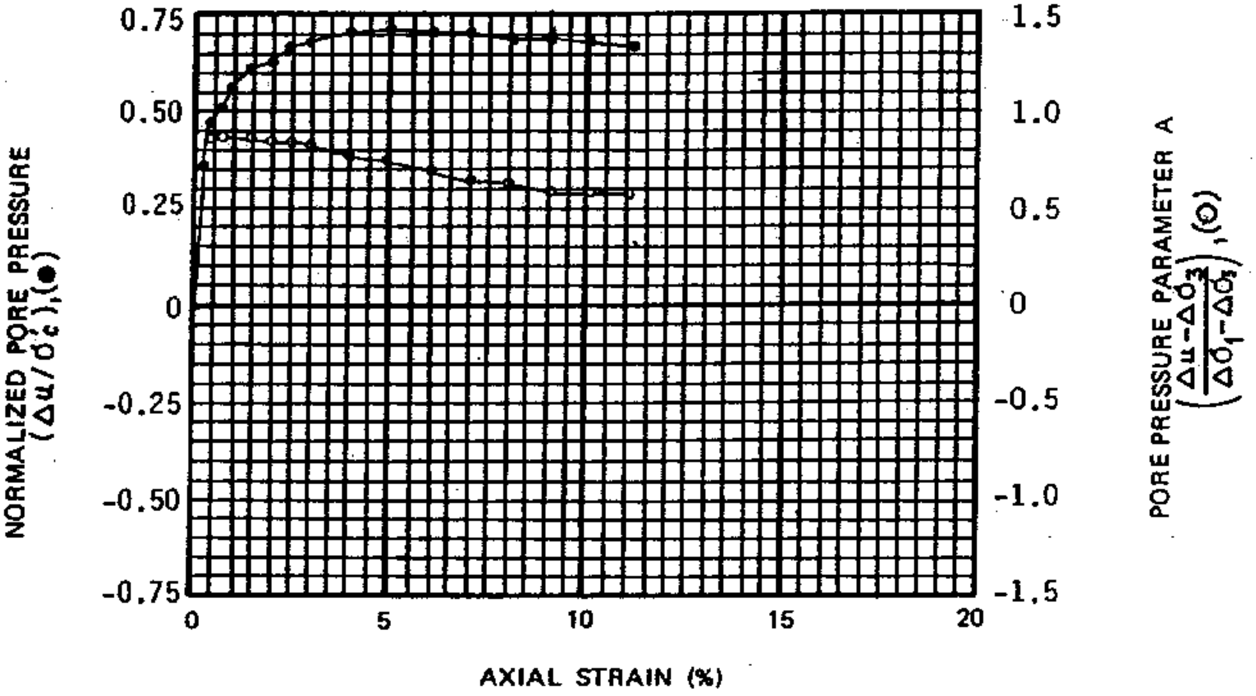

TYPE OF SPECIMEN	Undisturbed(trimmed)	BEFORE TEST			AFTER TEST	
DIAMETER(in.) 2.43	HEIGHT(in) 5.9	MOISTURE CONTENT	w_o	43.7 %	w_f	37.5 %
OVERBURDEN PRESS., σ'_{vo}	730 psf	VOID RATIO	e_o	1.235	e_f	1.003
CONSOLIDATION PRESS., σ'_c	1500 psf	SATURATION	S_o	95 %	S_f	100 %
STRAIN RATE	- - %/min	DRY DENSITY	γ_d	75 pcf	γ_d	83 pcf
LL 33	PL 26	PI 6		G_s 2.67		
LASSIFICATION ORGANIC SILT (OL)			SOURCE Boring 4 at 13.3'			

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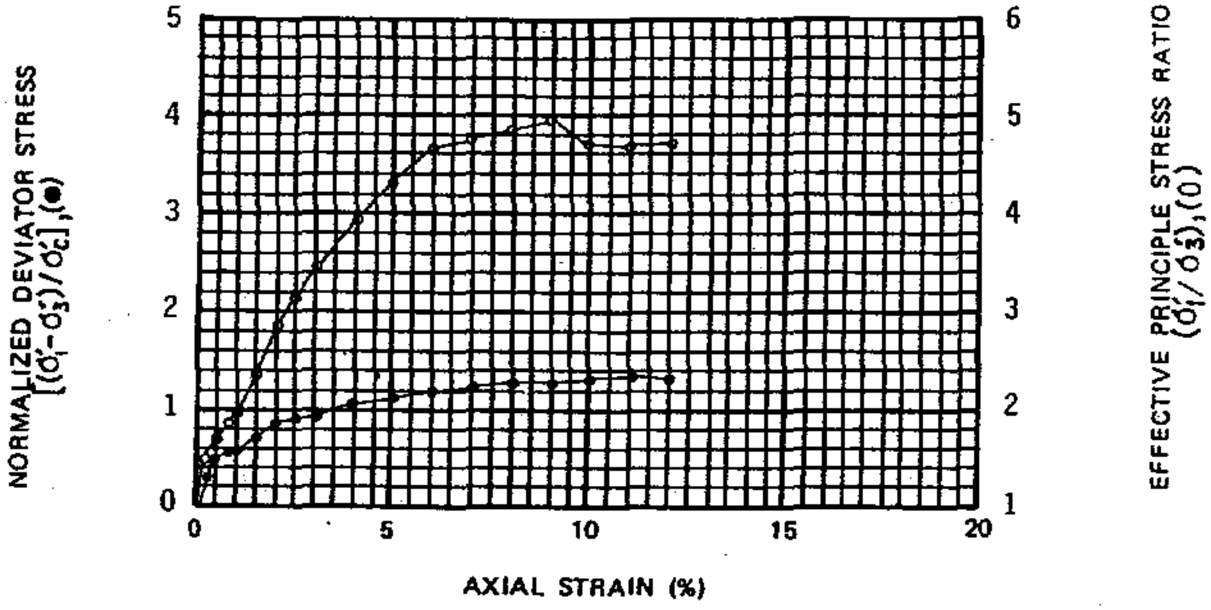
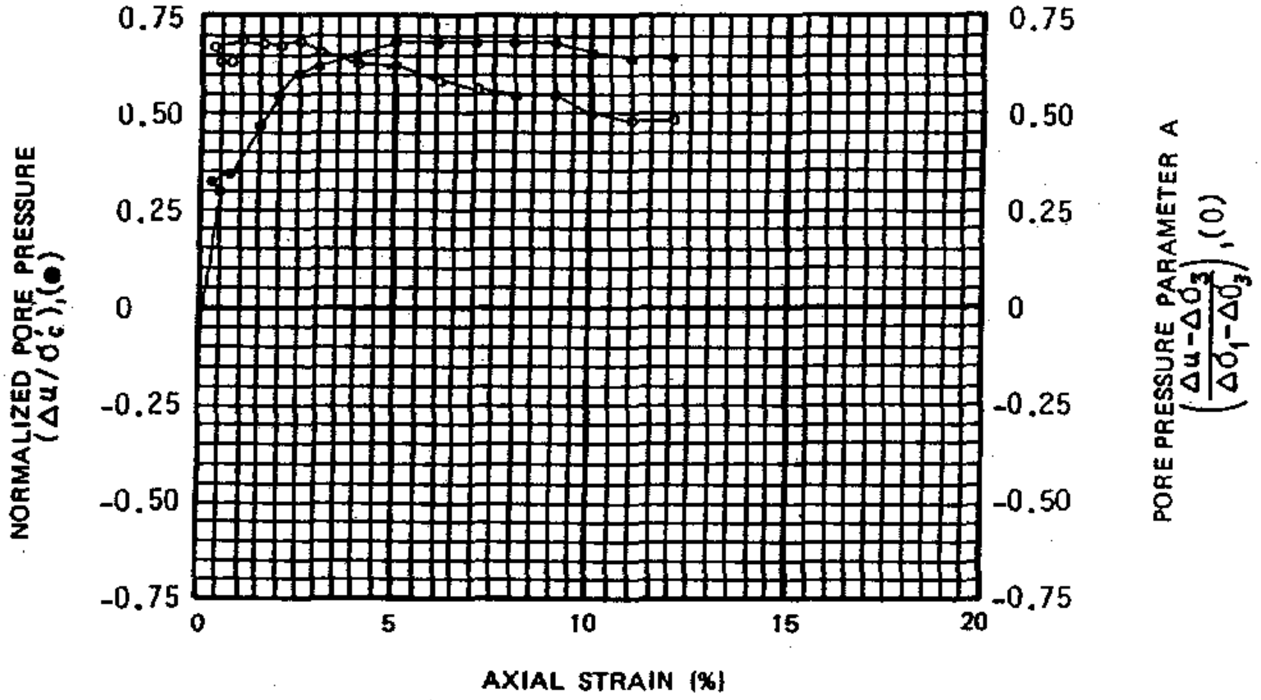
PLATE
D-81

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	0612,031.08	DEB	4/82		





YPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
IAMETER(in.) 2.43	HEIGHT(in) 5.90	MOISTURE CONTENT	w_o	47.5 %	w_f	40.9 %
VERBURDEN PRESS. σ_{vo}'	760 psf	VOID RATIO	e_o	1.311	e_f	1.089
ONSOLIDATION PRESS.) σ_c'	1500 psf	SATURATION	S_o	97 %	S_f	100 %
TRAIN RATE	-- %/min	DRY DENSITY	γ_d	72 pcf	γ_d	80 pcf
L 33	PL 26	PI 6		G_s 2.67		
LASSIFICATION SILT (ML)		SOURCE Boring 4 at 13.8'				

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PLATE
D-82

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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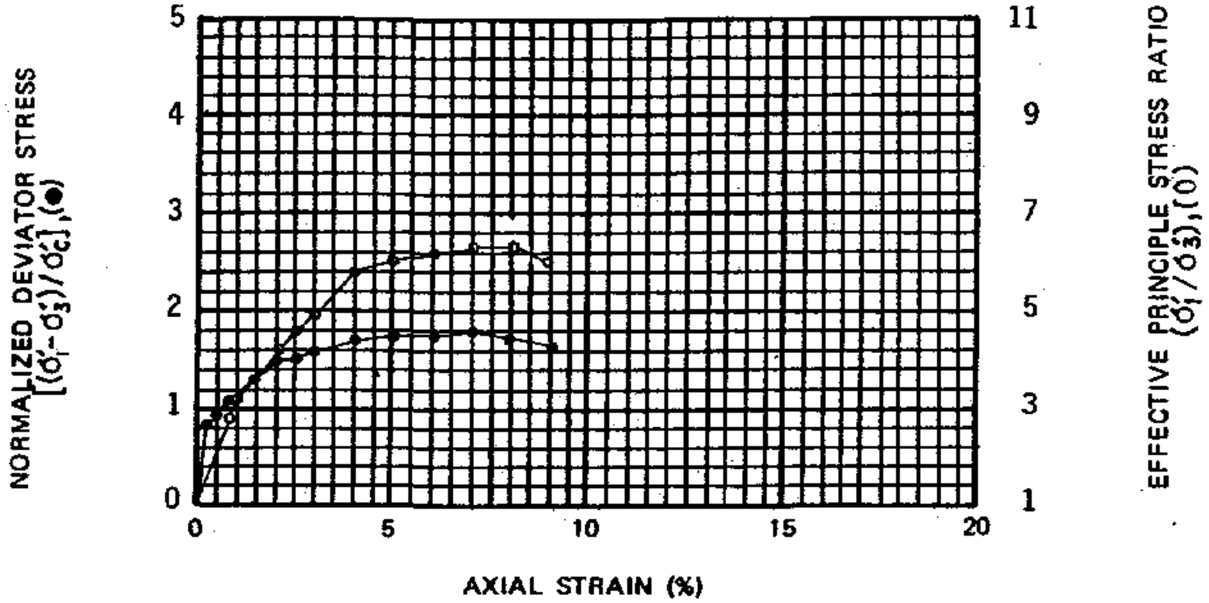

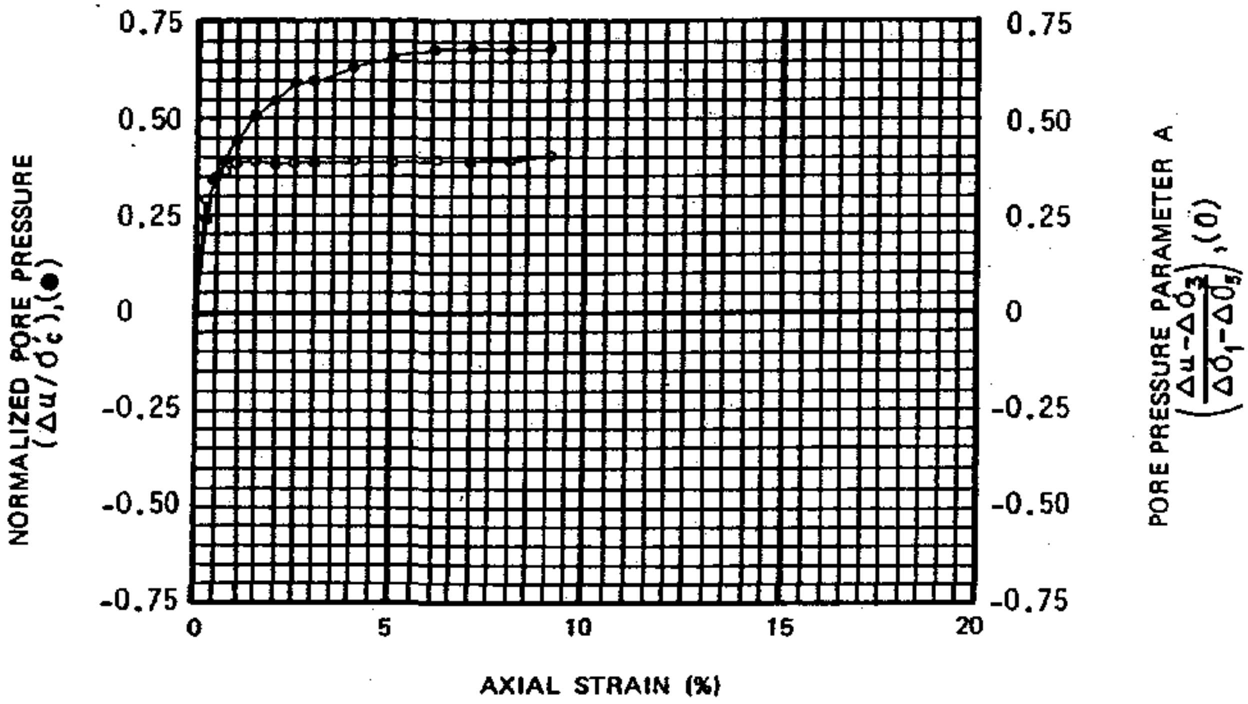

TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in.) 2.46	HEIGHT(in) 6.00	MOISTURE CONTENT	w_o	68.4 %	w_f	58.5 %
OVERBURDEN PRESS., σ'_{vo} 1050 psf		VOID RATIO	e_o	1.848	e_f	1.637
CONSOLIDATION PRESS., σ'_c 1000 psf		SATURATION	S_o	98 %	S_f	95 %
STRAIN RATE -- %/min		DRY DENSITY	γ_d	58 pcf	γ_d	63 pcf
LL 44	PL 26	PI 18			G_s	2.66
LASSIFICATION CLAY (CL)		SOURCE Boring 4 at 19.0'				

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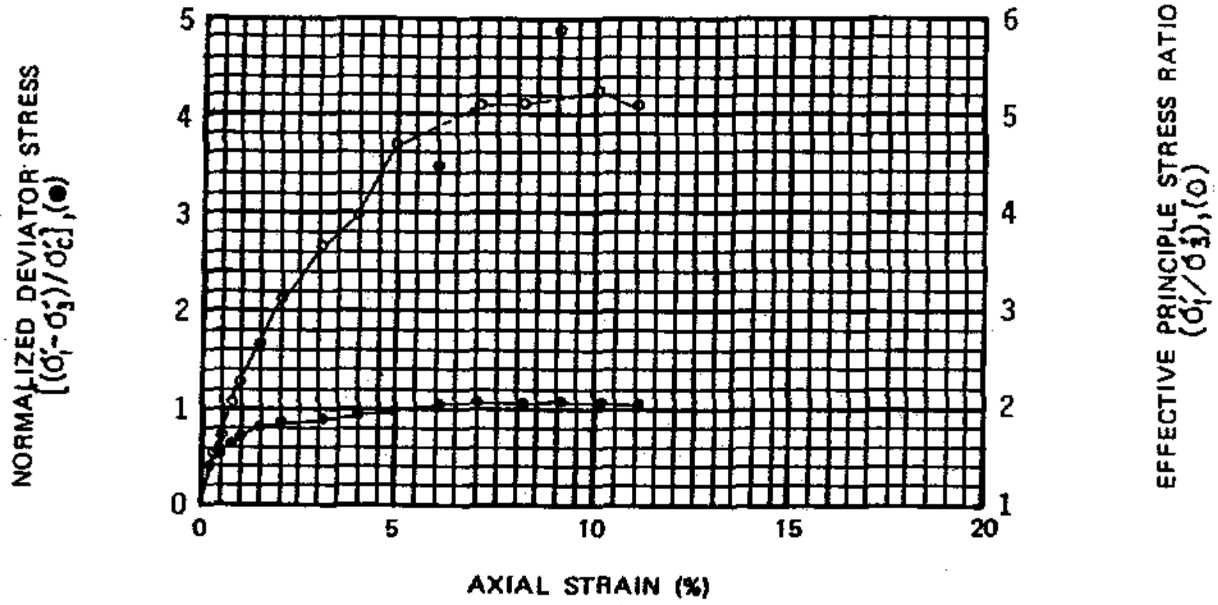
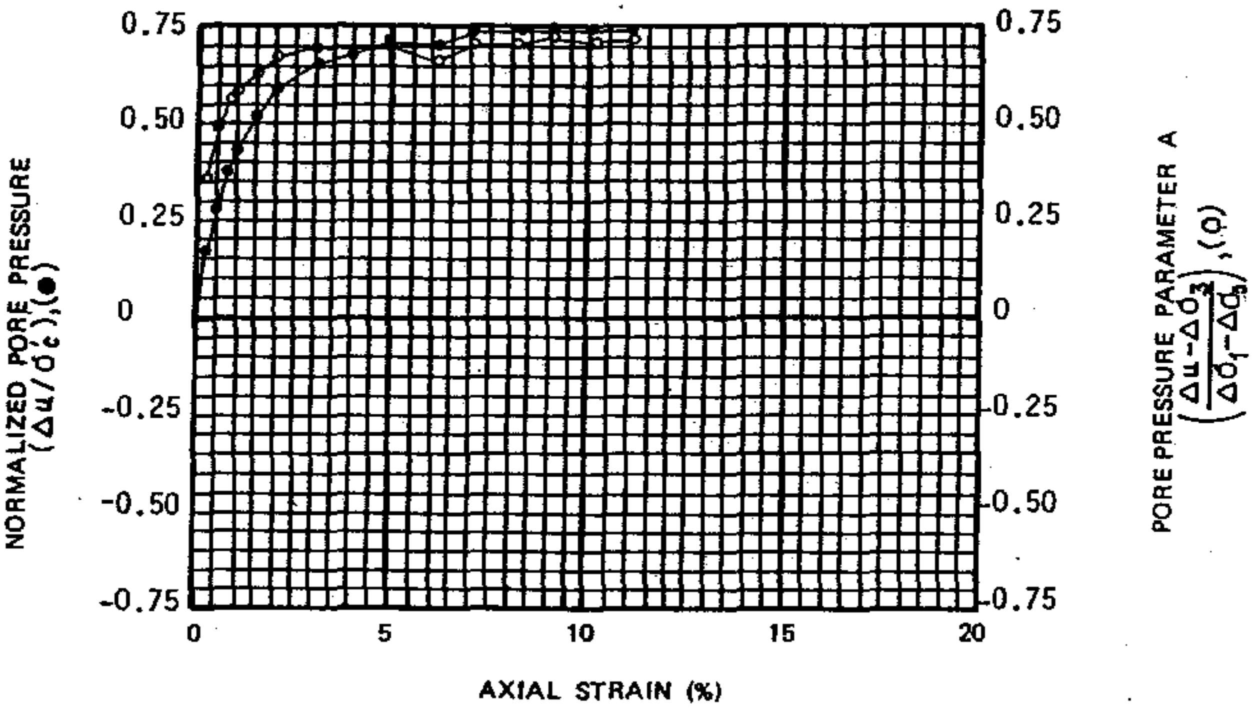
PLATE
D-83

DRAWN | JOB NUMBER 9612,031.08 | APPROVED DEB | DATE 4/82 | REVISED | DATE





YPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
IAMETER(in.) 2.46	HEIGHT(in) 6.05	MOISTURE CONTENT	w_o	71.1 %	w_f	57.1 %
VERBURDEN PRESS.,σ_{vo}' 1080 psf		VOID RATIO	e_o	1.933	e_f	1.519
ONSOLIDATION PRESS. σ_c' 2000 psf		SATURATION	S_o	98 %	S_f	100 %
TRAIN RATE -- %/min		DRY DENSITY	γ_d	57 pcf	γ_d	66 pcf
- 44	PL 26	PI 18			G_s 2.66	
LASSIFICATION CLAY (CL)		SOURCE Boring 4 at 19.6'				

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PLATE
D-84

RAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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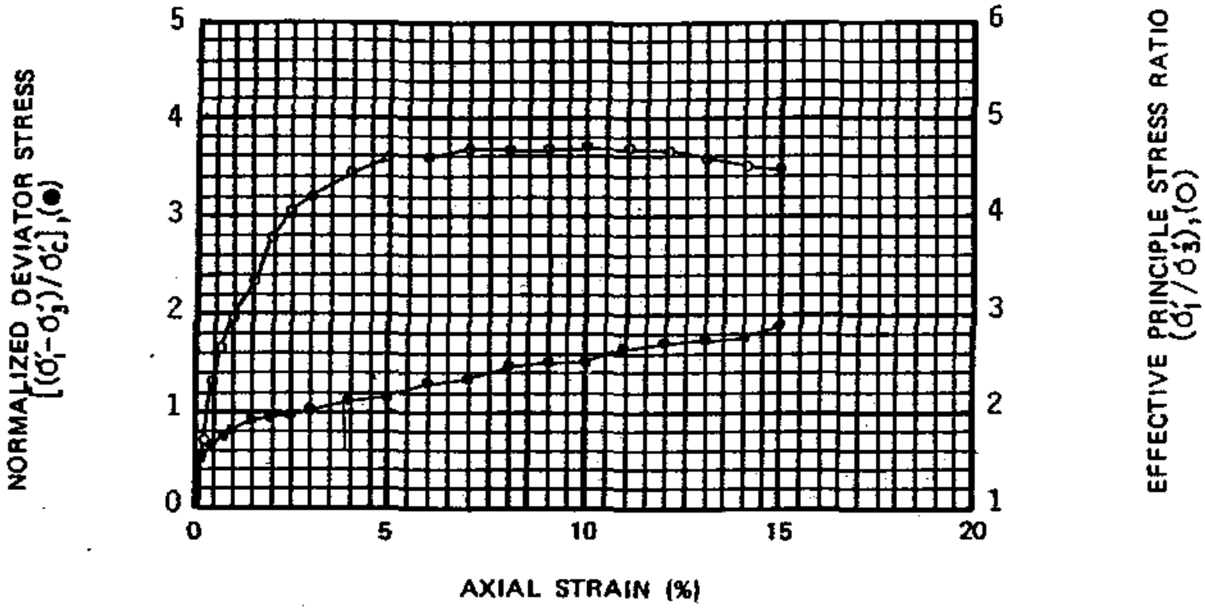

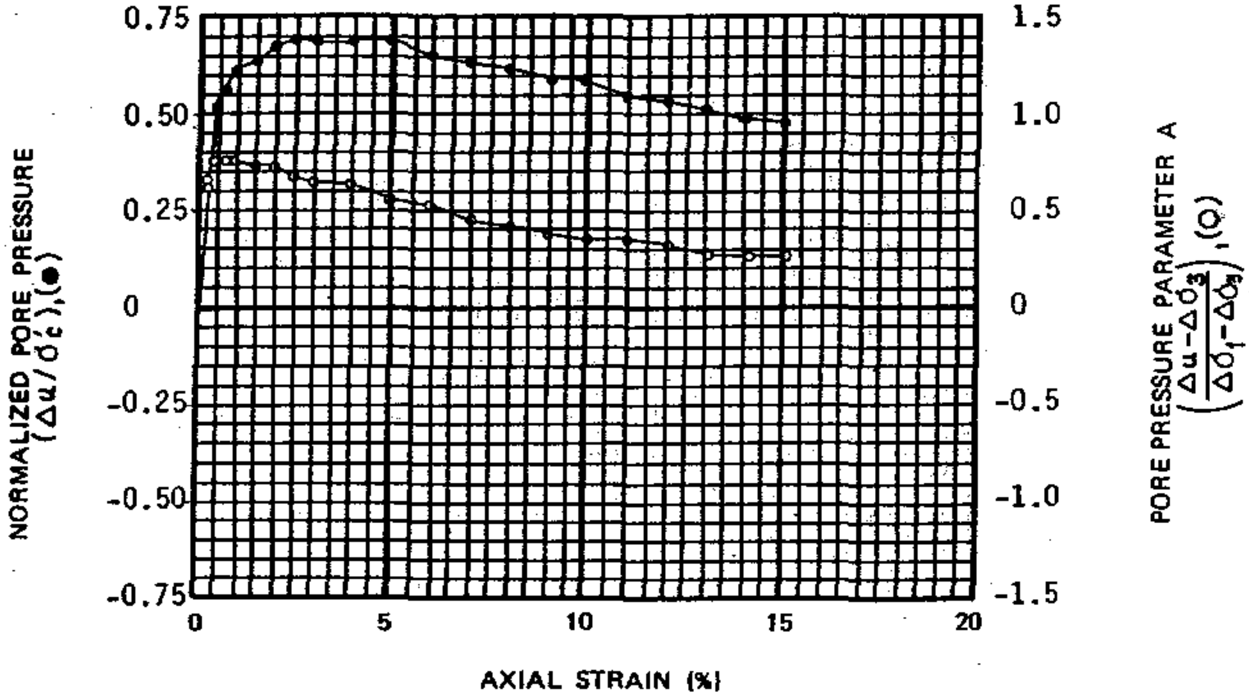

TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in.) 2.43	HEIGHT(in) 5.95	MOISTURE CONTENT	w_o	33.4 %	w_f	30.2 %
OVERBURDEN PRESS., σ_{vo}'	230 psf	VOID RATIO	e_o	0.893	e_f	0.831
CONSOLIDATION PRESS., σ_c'	3000 psf	SATURATION	S_o	100 %	S_f	100 %
STRAIN RATE	--- %/min	DRY DENSITY	γ_d	88 pcf	γ_d	92 pcf

LL ---	PL ---	PI ---	G_s 2.68

LASSIFICATION SANDY SILT (ML)	SOURCE Boring 6 at 4.1'

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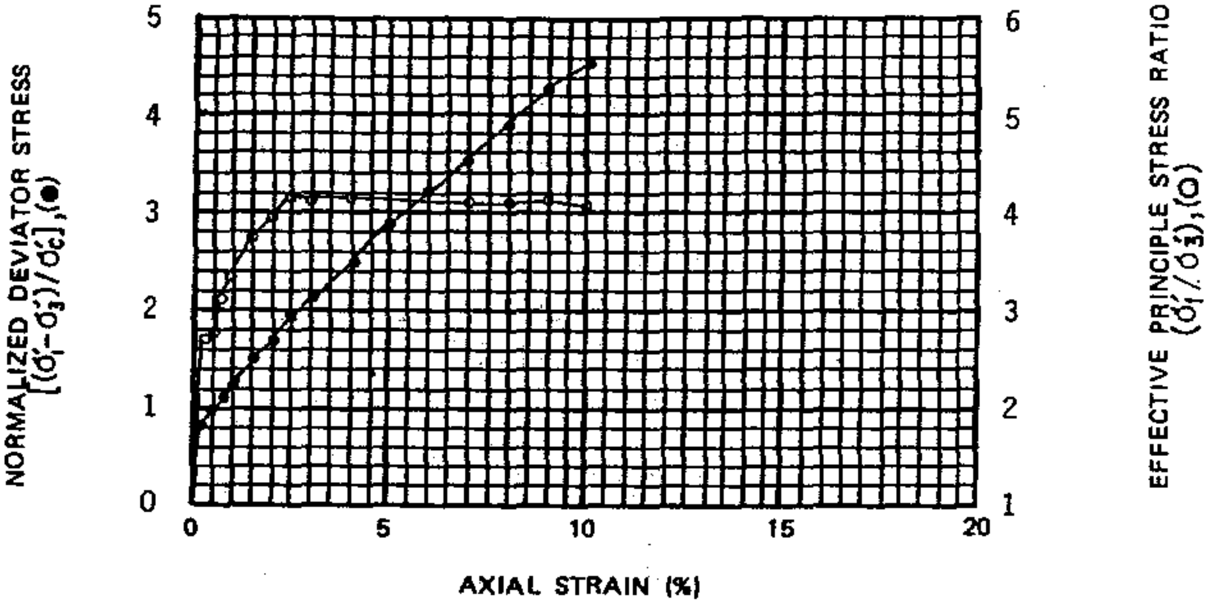
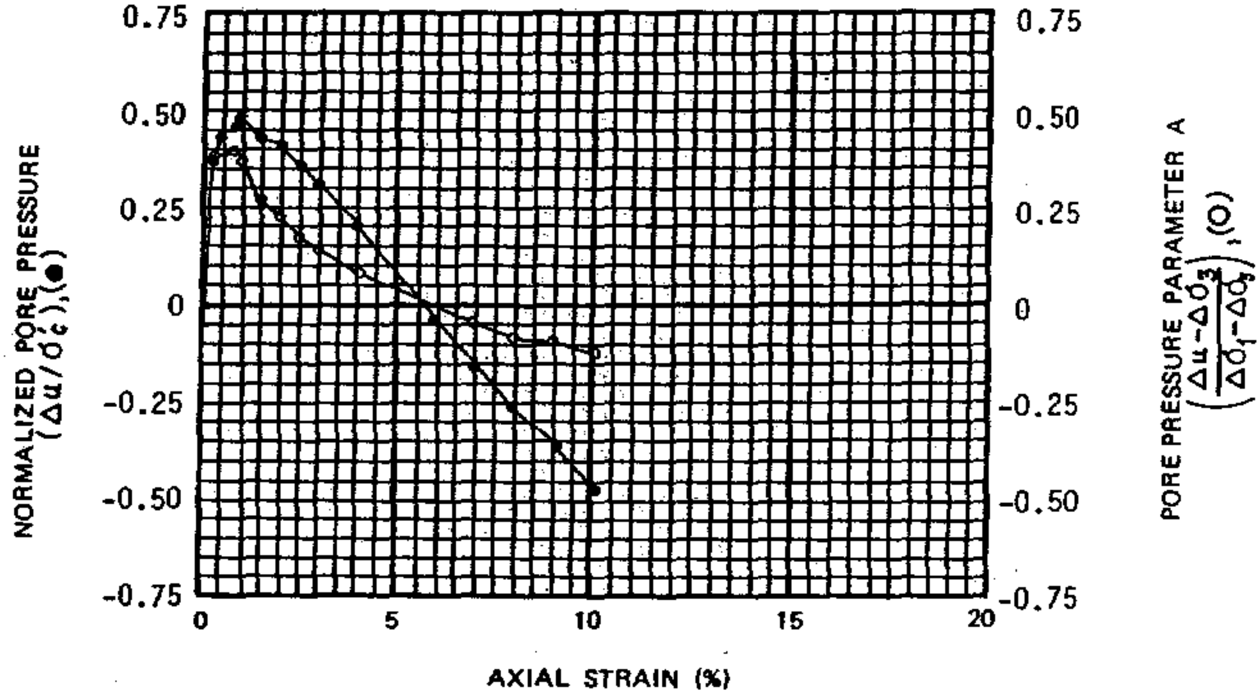
PLATE
D-85

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		





YPE OF SPECIMEN Undisturbed(trimmed)			BEFORE TEST			AFTER TEST	
IAMETER(in.) 2.43	HEIGHT(in) 5.80		MOISTURE CONTENT	w_o	32.3 %	w_f	30.6 %
VERBURDEN PRESS., σ_{vo}'	250	psf	VOID RATIO	e_o	0.873	e_f	0.828
ONSOLIDATION PRESS., σ_c'	750	psf	SATURATION	S_o	100 %	S_f	100 %
TRAIN RATE	--	%/min	DRY DENSITY	γ_d	90 pcf	γ_d	92 pcf
L NP	PL NP		PI NP		G_s 2.69		
LASSIFICATION SANDY SILT (ML)			SOURCE Boring 6 at 4.6'				

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PLATE
D-86

RAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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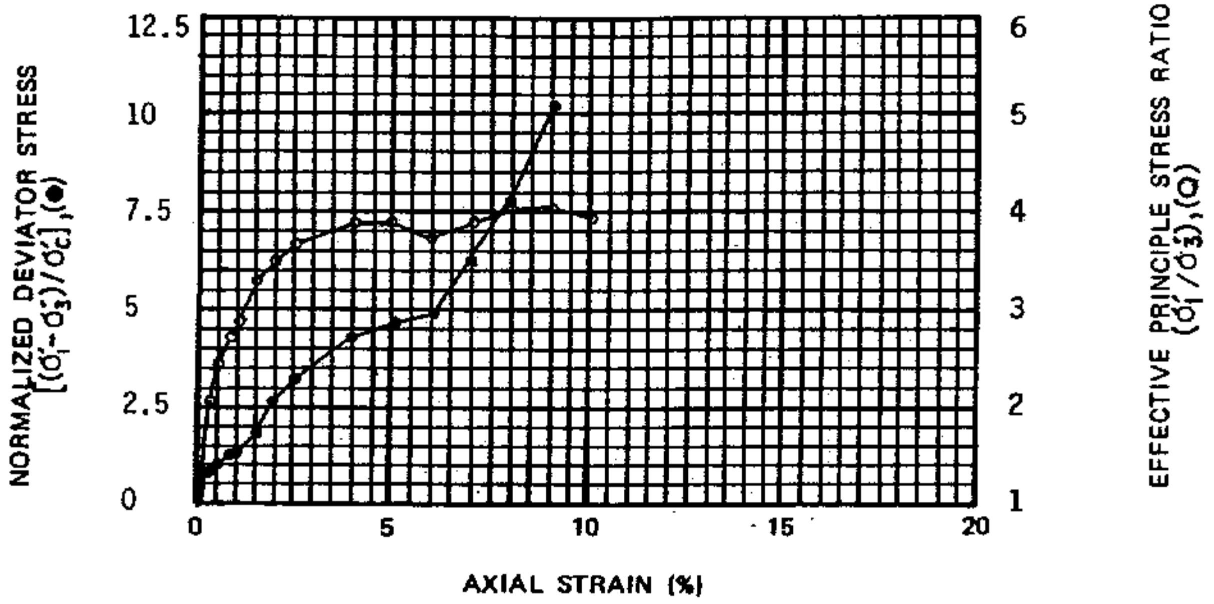

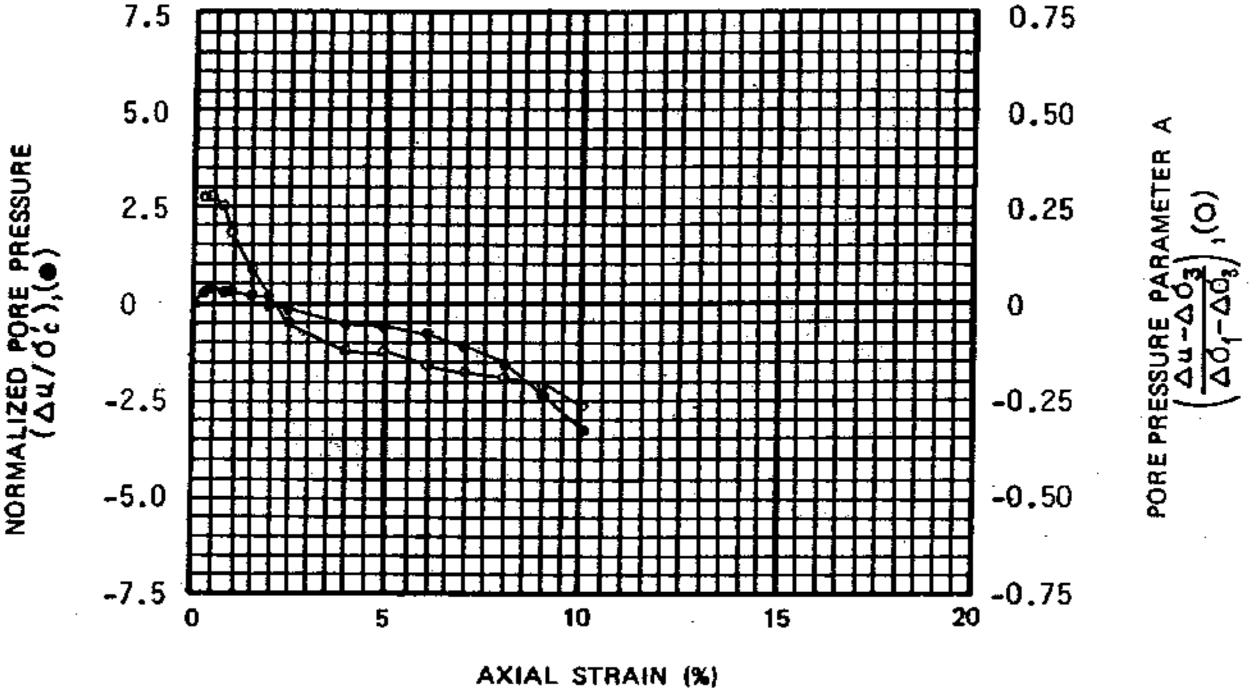

TYPE OF SPECIMEN Undisturbed		**BEFORE TEST**				**AFTER TEST**	
DIAMETER(in.) 2.87	**HEIGHT(in)** 5.9	**MOISTURE CONTENT**	w_o	14.1	%	w_f	13.6 %
OVERBURDEN PRESS. σ_{vo}' 300 psf		**VOID RATIO**	e_o	0.382		e_f	0.366
CONSOLIDATION PRESS., σ_c' 750 psf		**SATURATION**	S_o	99	%	S_f	100 %
STRAIN RATE -- %/min		**DRY DENSITY**	γ_d	121	pcf	γ_d	123 pcf
LL --	**PL** --	**PI** --		G_s 2.69			
LASSIFICATION GRAVELLY SAND (SP-SM)		**SOURCE** Boring 6 at 5.3'					

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PLATE
D-87

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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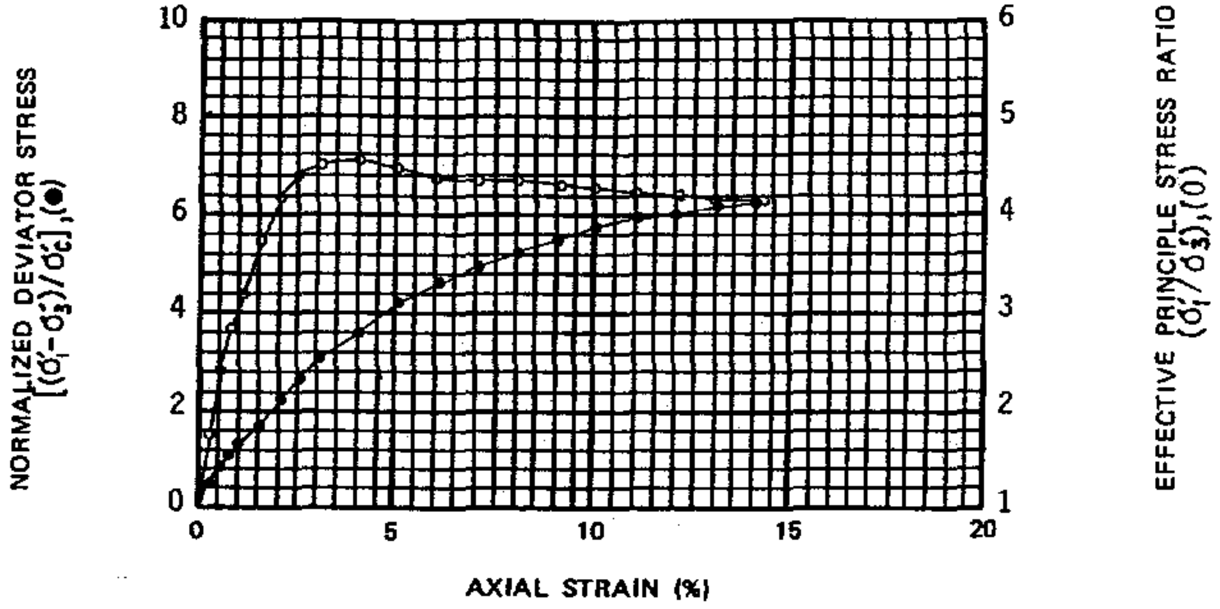

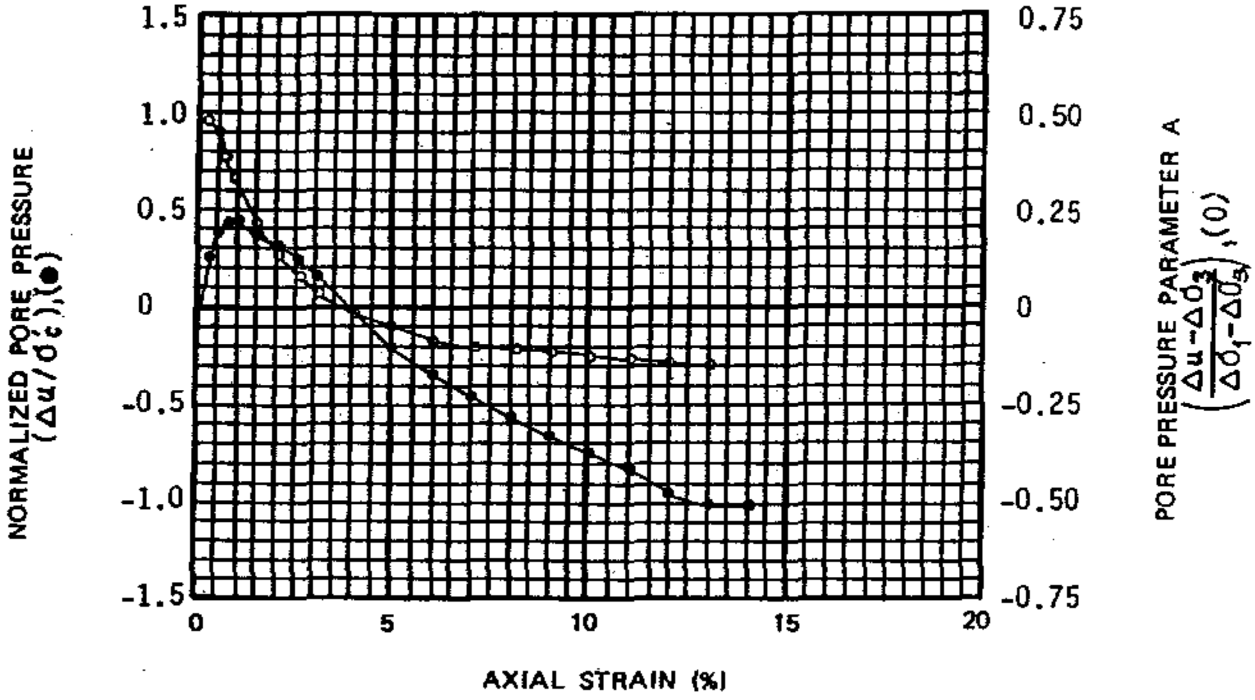

YPE OF SPECIMEN Undisturbed		BEFORE TEST			AFTER TEST	
IAMETER(in.) 2.87	HEIGHT(in) 6.44	MOISTURE CONTENT	w_o	23.3 %	w_f	21.7 %
VERBURDEN PRESS., σ_{vo}' 810 psf		VOID RATIO	e_o	0.714	e_f	0.673
ONSOLIDATION PRESS.,) σ_c' 1500 psf		SATURATION	S_o	99 %	S_f	100 %
TRAIN RATE -- %/min		DRY DENSITY	γ_d	99 pcf	γ_d	101 pcf
L --	PL --	PI --			G_s 2.71	
LASSIFICATION SANDY SILT (ML)		SOURCE Boring 6 at 14.7'				

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PLATE
D-88

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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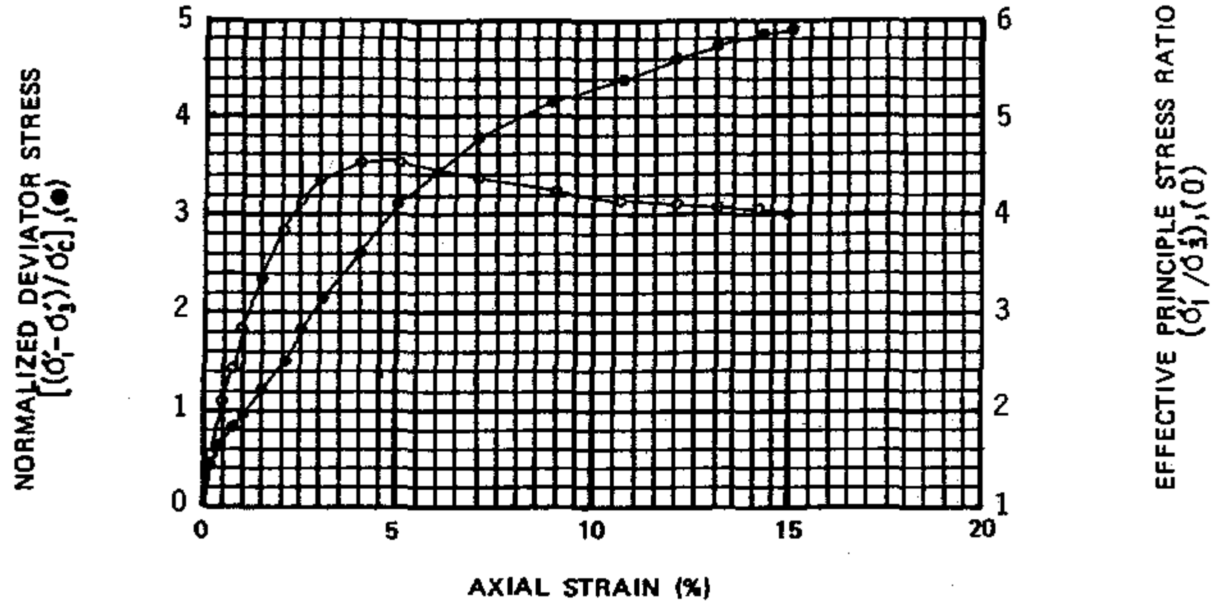

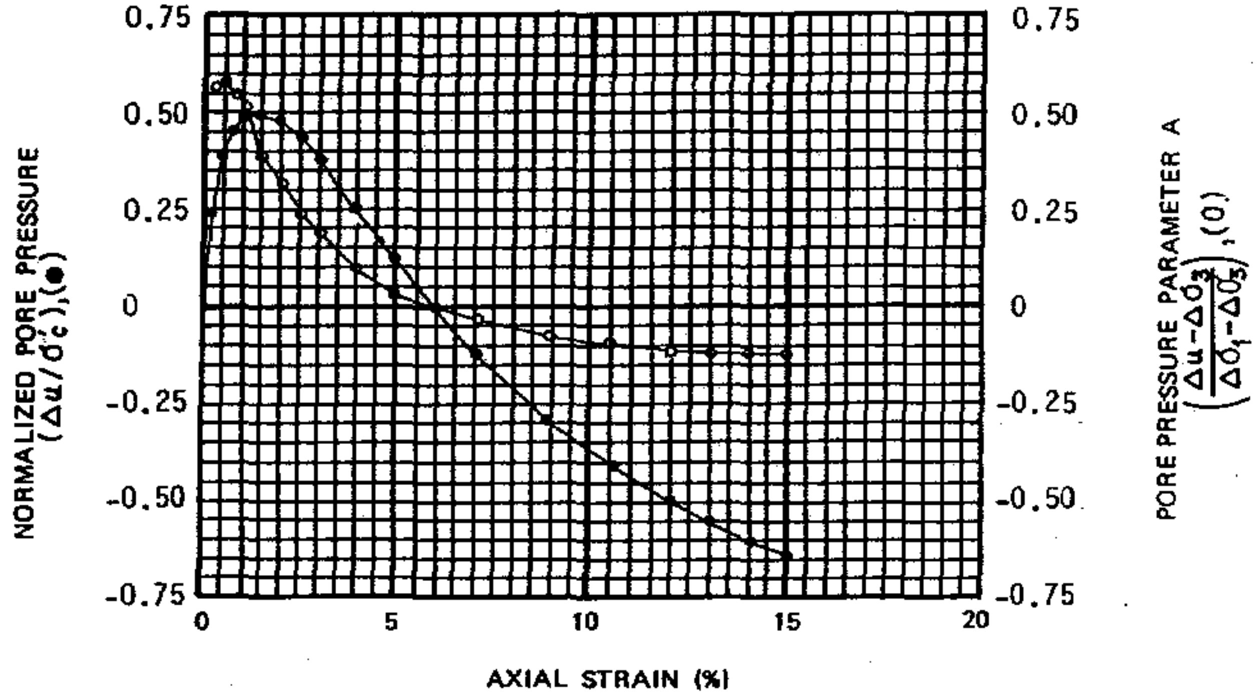

TYPE OF SPECIMEN Undisturbed		BEFORE TEST			AFTER TEST	
DIAMETER(in.) 2.87	HEIGHT(in) 6.45	MOISTURE CONTENT	w_o	26.2 %	w_f	24.2 %
OVERBURDEN PRESS., σ_{vo}'	850 psf	VOID RATIO	e_o	0.696	e_f	0.657
CONSOLIDATION PRESS.,) σ_c'	3000 psf	SATURATION	S_o	97 %	S_f	100 %
STRAIN RATE	-- %/min	DRY DENSITY	γ_d	100 pcf	γ_d	102 pcf

LL --	PL --	PI --	G_s 2.71
LASSIFICATION SANDY SILT (ML)		SOURCE Boring 6 at 15.4'	

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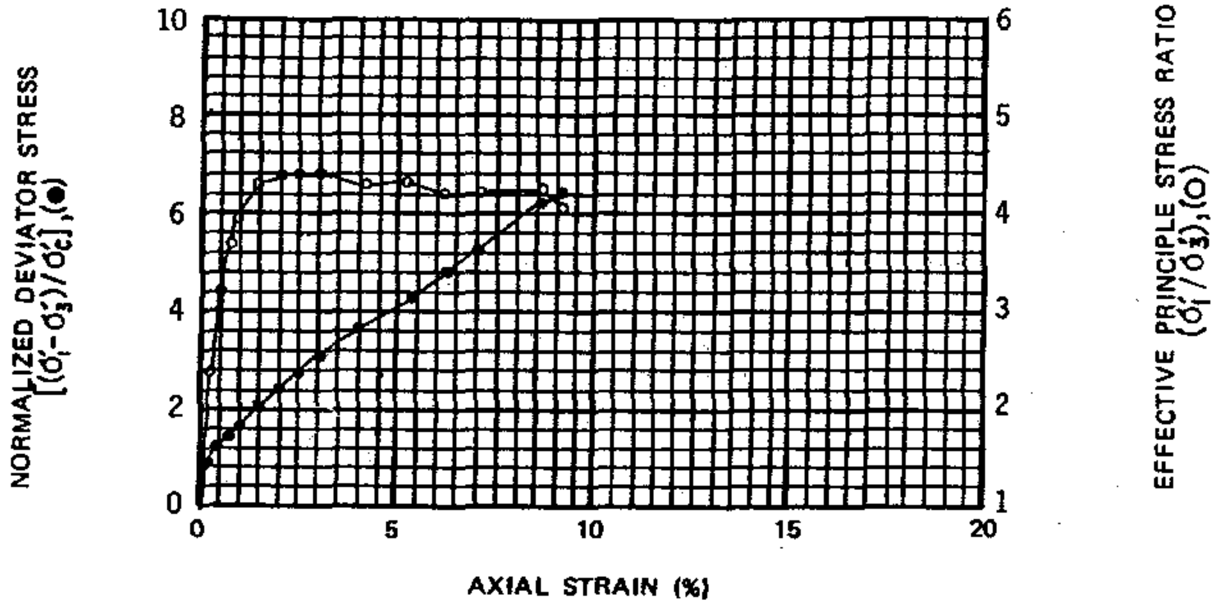
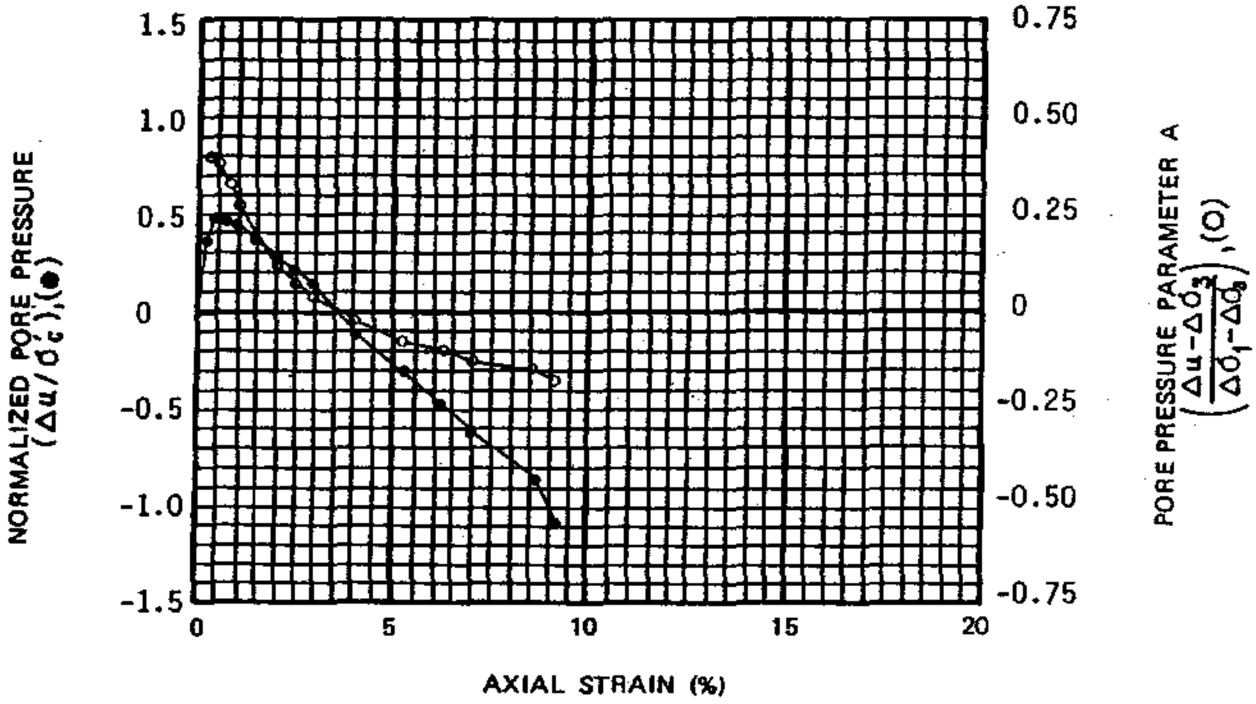
PLATE **D-89**

DRAWN Y | JOB NUMBER 9612.031.08 | APPROVED DGB | DATE 4/82 | REVISED | DATE





YPE OF SPECIMENUndisturbed(trimmed)		BEFORE TEST			AFTER TEST	
IAMETER(in.) 2.43	HEIGHT(in) 5.80	MOISTURE CONTENT	w_o	24.7 %	w_f	23.8 %
VERBURDEN PRESS.,σ'_{vo} 250 psf		VOID RATIO	e_o	0.667	e_f	0.647
ONSOLIDATION PRESS., σ'_c 1600 psf		SATURATION	S_o	100 %	S_f	100 %
TRAIN RATE --- %/min		DRY DENSITY	γ_d	101 pcf	γ_d	103 pcf
L ---	PL ---		PI ---		G_s 2.71	
LASSIFICATION SILTY SAND (SM)			SOURCE Boring 9 at 4.5'			

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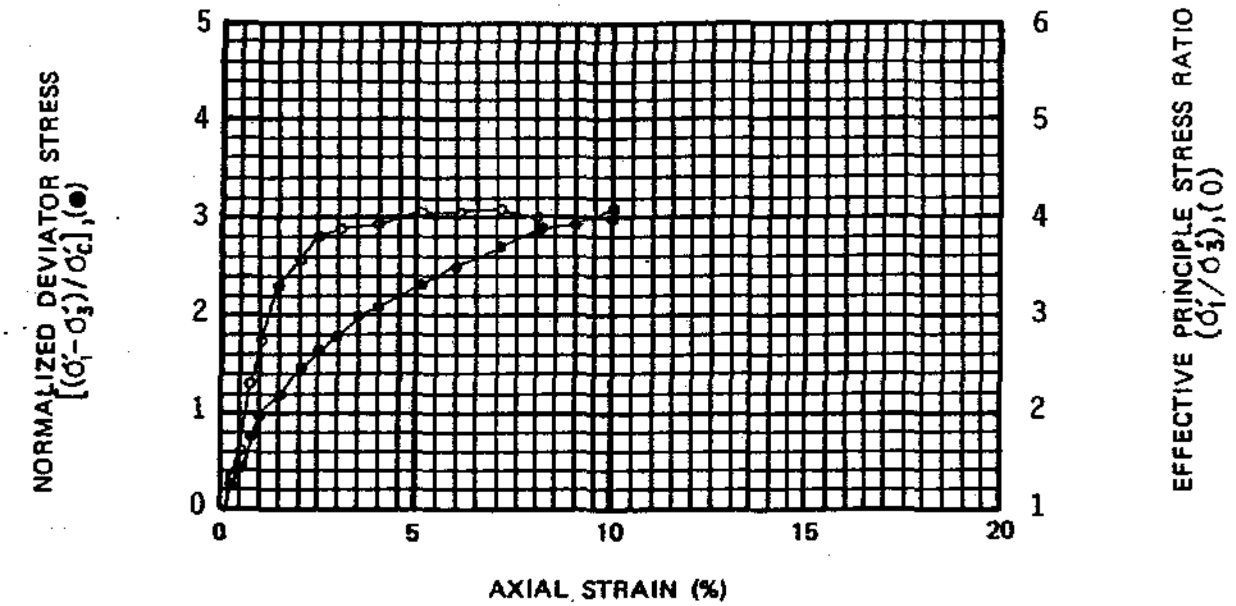
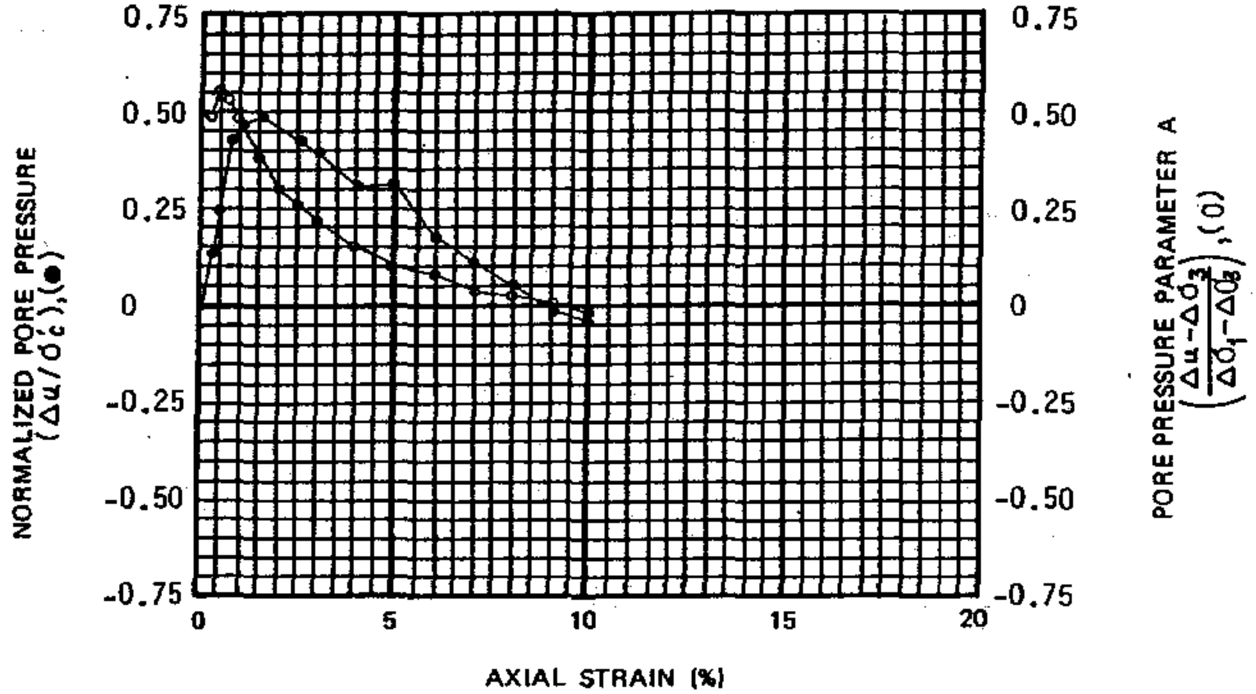
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612.031.08	DEB	4/82		





TYPE OF SPECIMEN	Undisturbed(trimmed)	BEFORE TEST			AFTER TEST	
DIAMETER(in.) 2.46	HEIGHT(in) 6.00	MOISTURE CONTENT	w_o	22.7 %	w_f	21.2 %
OVERBURDEN PRESS.,σ'_{vo}	280 psf	VOID RATIO	e_o	0.641	e_f	0.578
CONSOLIDATION PRESS.,) σ'_c	3200 psf	SATURATION	S_o	96 %	S_f	100 %
STRAIN RATE	-- %/min	DRY DENSITY	γ_d	103 pcf	γ_d	107 pcf

LL -- | PL -- | PI -- | G_s 2.70

LASSIFICATION SILTY SAND (SM) | SOURCE Boring 9 at 5.1'

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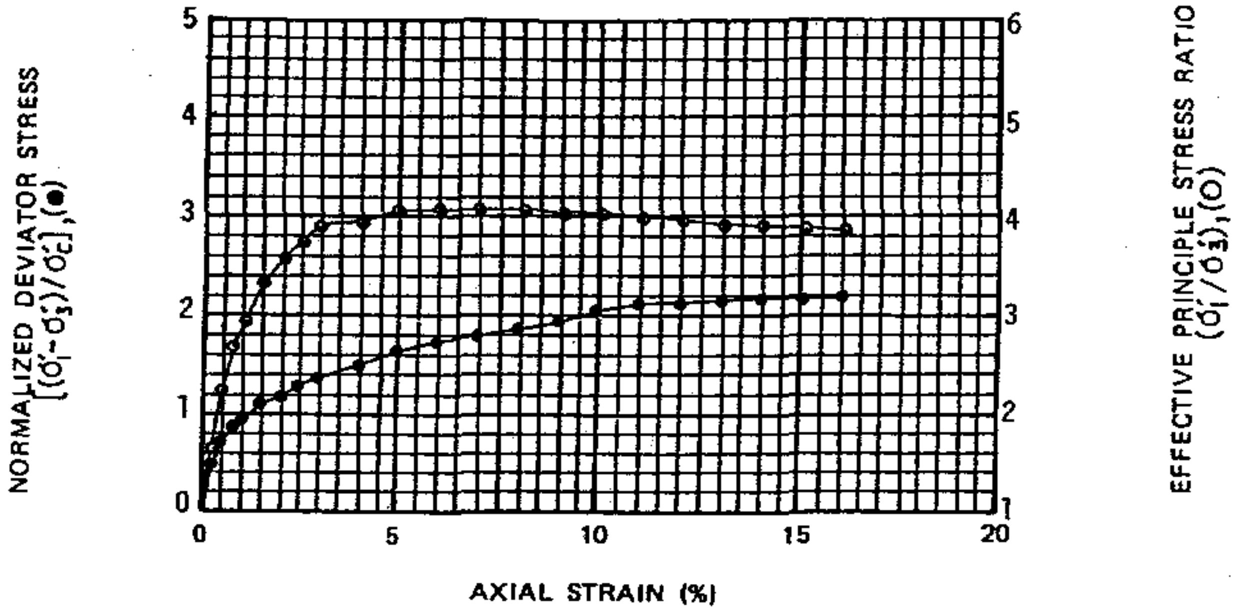
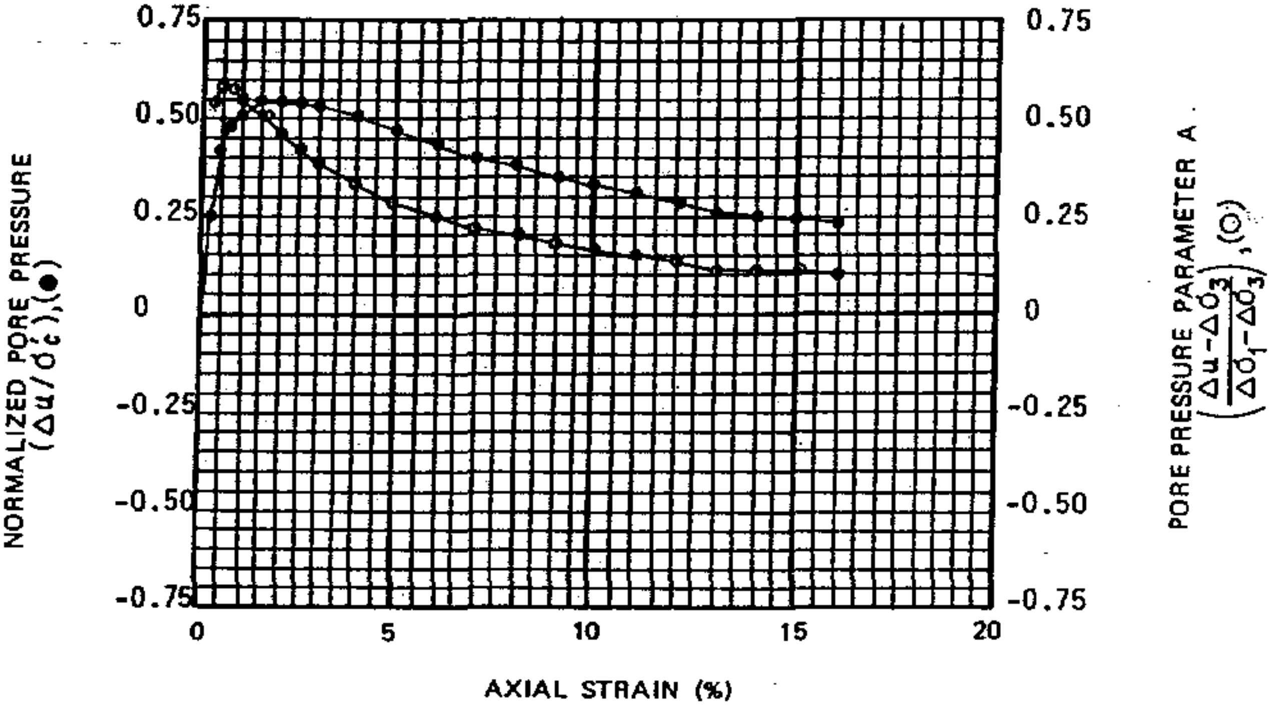
DRAWN | JOB NUMBER 9612,031.08 | APPROVED | DATE 4/82 | REVISED | DATE





YPE OF SPECIMEN Undisturbed		BEFORE TEST			AFTER TEST	
IAMETER(in.) 2.87	HEIGHT(in) 6.45	MOISTURE CONTENT	w_o	26.4 %	w_f	24.4 %
VERBURDEN PRESS., σ_{vo}'	410 psf	VOID RATIO	e_o	0.749	e_f	0.668
ONSOLIDATION PRESS.,) σ_c'	3000 psf	SATURATION	S_o	97 %	S_f	100 %
TRAIN RATE --	%/min	DRY DENSITY	γ_d	98 pcf	γ_d	103 pcf

L --

PL --

PI --

G_s 2.74

LASSIFICATION SANDY SILT (ML)

SOURCE Boring 9 at 7.4'

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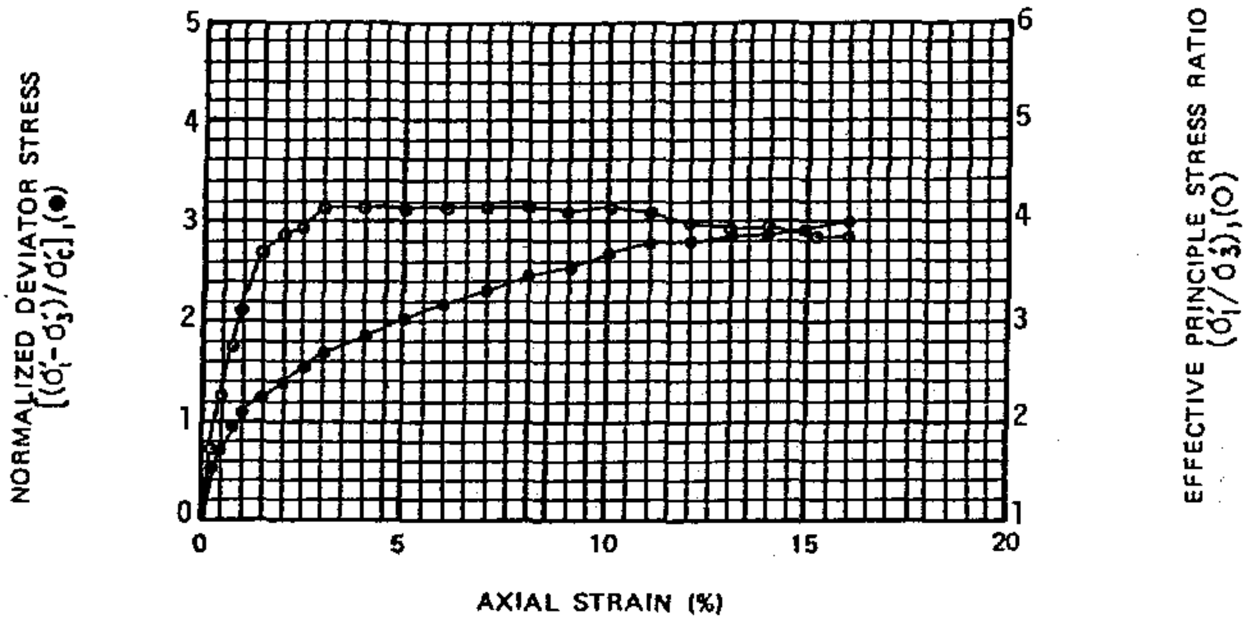
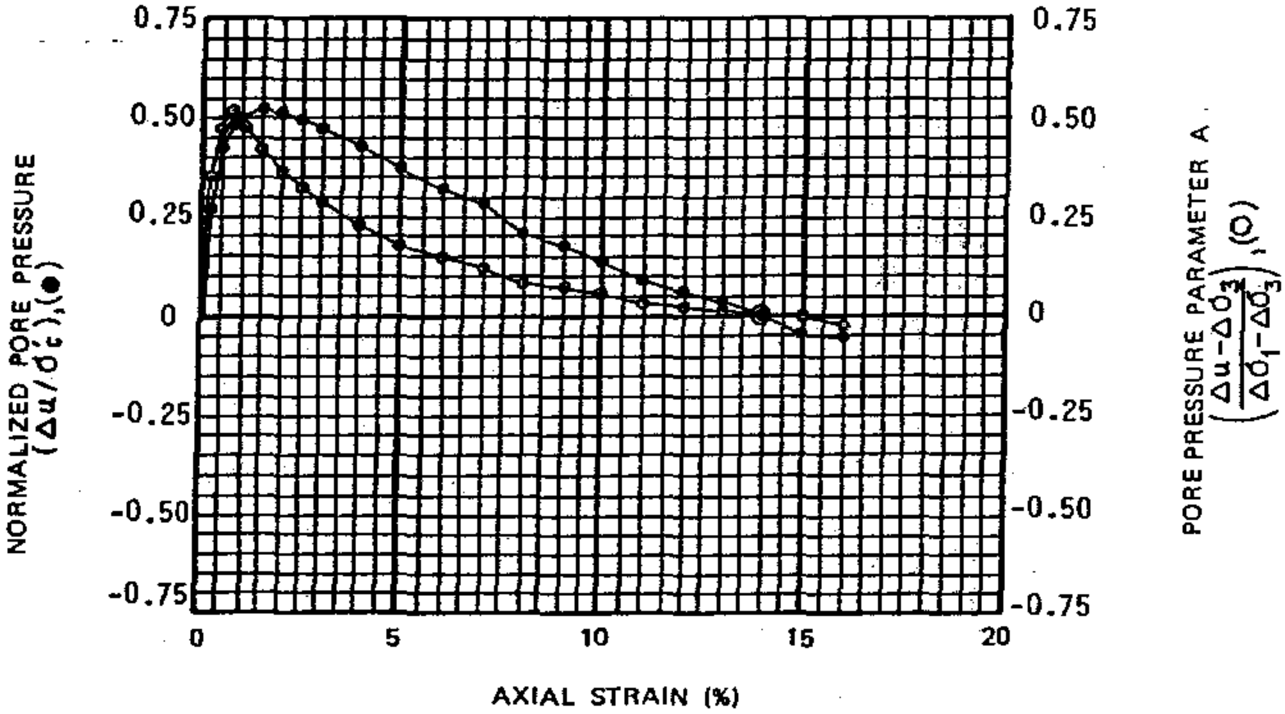
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612.031.08	DEB	4/82		





TYPE OF SPECIMEN Undisturbed		BEFORE TEST			AFTER TEST
DIAMETER(in.) 2.87	HEIGHT(in) 6.45	MOISTURE CONTENT	w_o	28.4%	w_f 27.4 %
OVERBURDEN PRESS., σ_{vo}'	450 psf	VOID RATIO	e_o	0.789	e_f 0.747
CONSOLIDATION PRESS., σ_c'	1870 psf	SATURATION	S_o	99%	S_f 100 %
STRAIN RATE --	%/min	DRY DENSITY	γ_d	96 pcf	γ_d 98 pcf
LL --	PL --	PI --		G_s 2.74	
CLASSIFICATION SANDY SILT (ML)			SOURCE Boring 9 at 8.1'		

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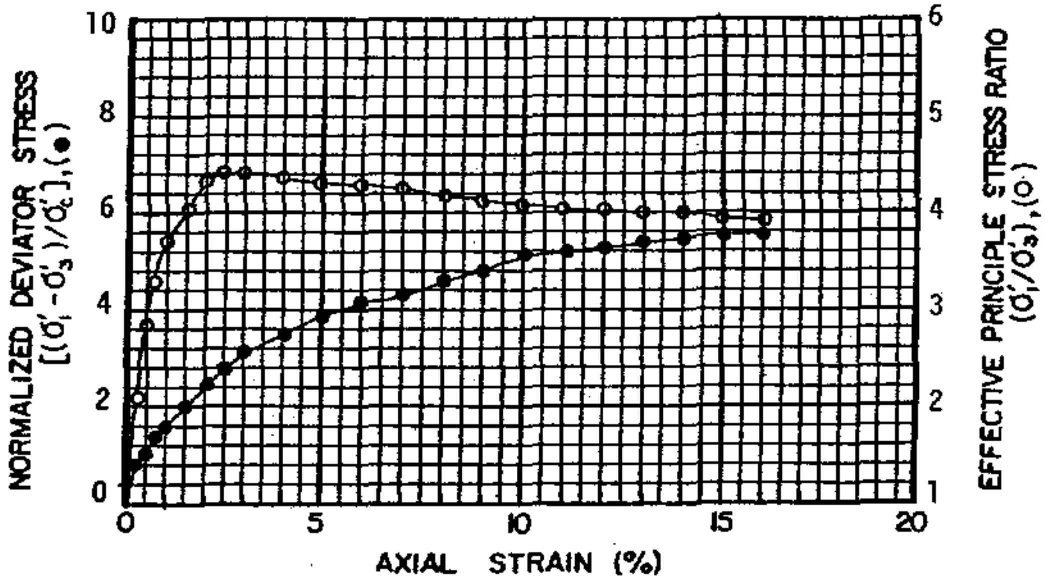
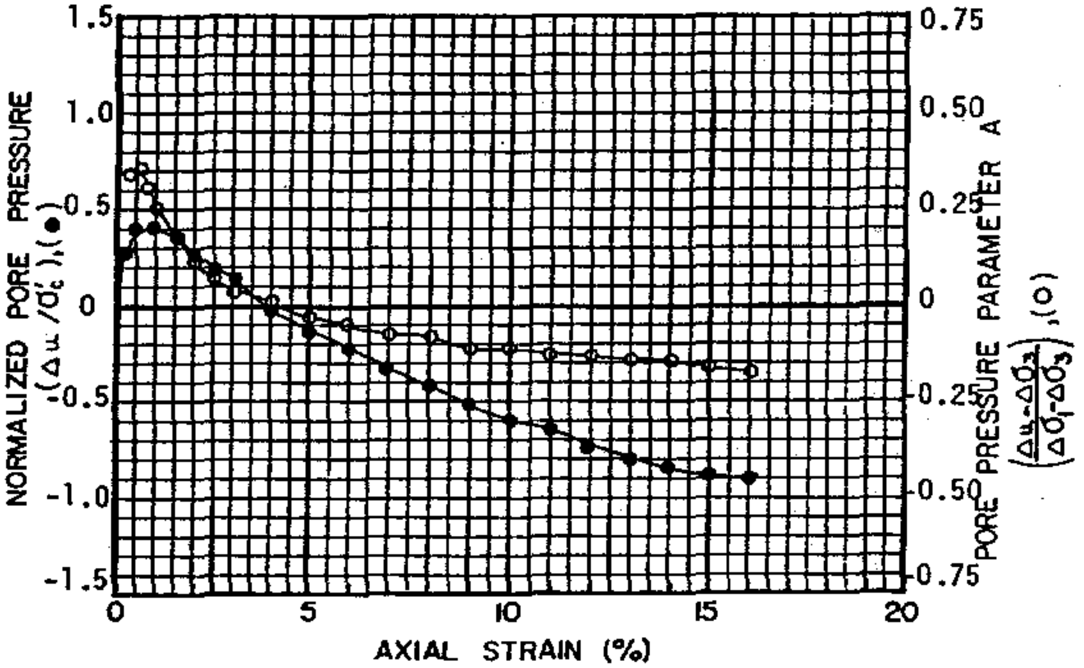
DRAWN | JOB NUMBER | APPROVED | DATE | REVISED | DATE





TYPE OF SPECIMEN Undisturbed				BEFORE TEST		AFTER TEST	
DIAMETER (in.) 2.87	HEIGHT (in.) 6.45	MOISTURE CONTENT	w_o	27.4 %	w_f	27.2 %
OVERBURDEN PRESS., σ_{vo}'	500 psf	VOID RATIO	e_o	0.781	e_f	0.743
CONSOLIDATION PRESS., σ_c'	860 psf	SATURATION	S_o	96 %	S_f	100 %
STRAIN RATE --	%/min	DRY DENSITY	γ_d	96 pcf	γ_d	98 pcf
LL NP	PL NP	PI NP	G_s 2.74			
CLASSIFICATION SANDY SILT (ML)		SOURCE Boring 9 at 9.0'				

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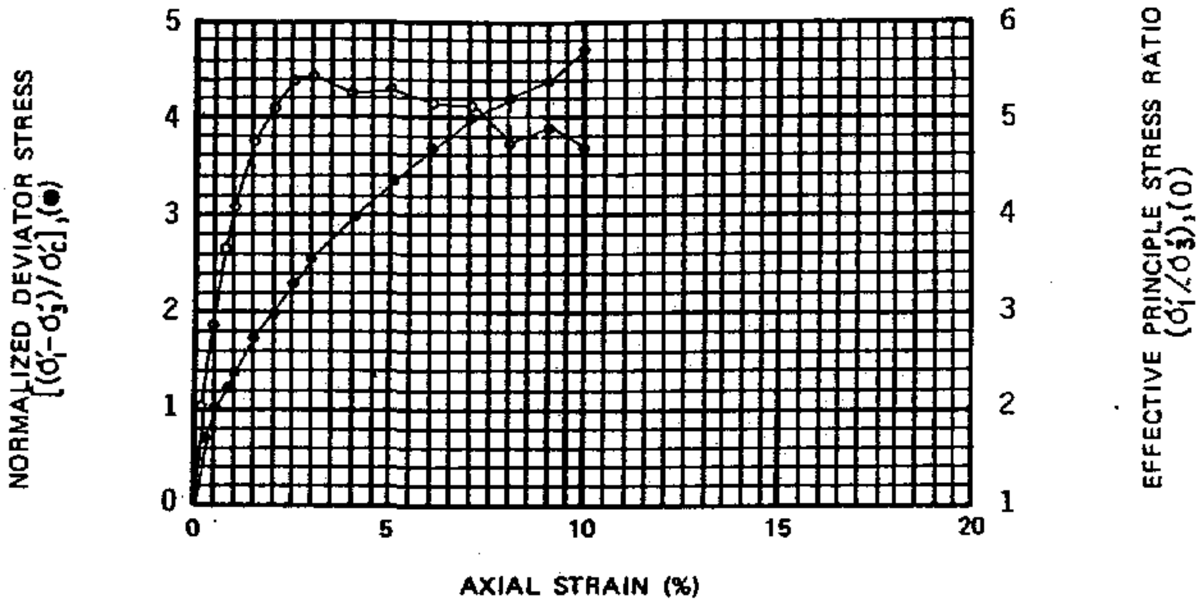
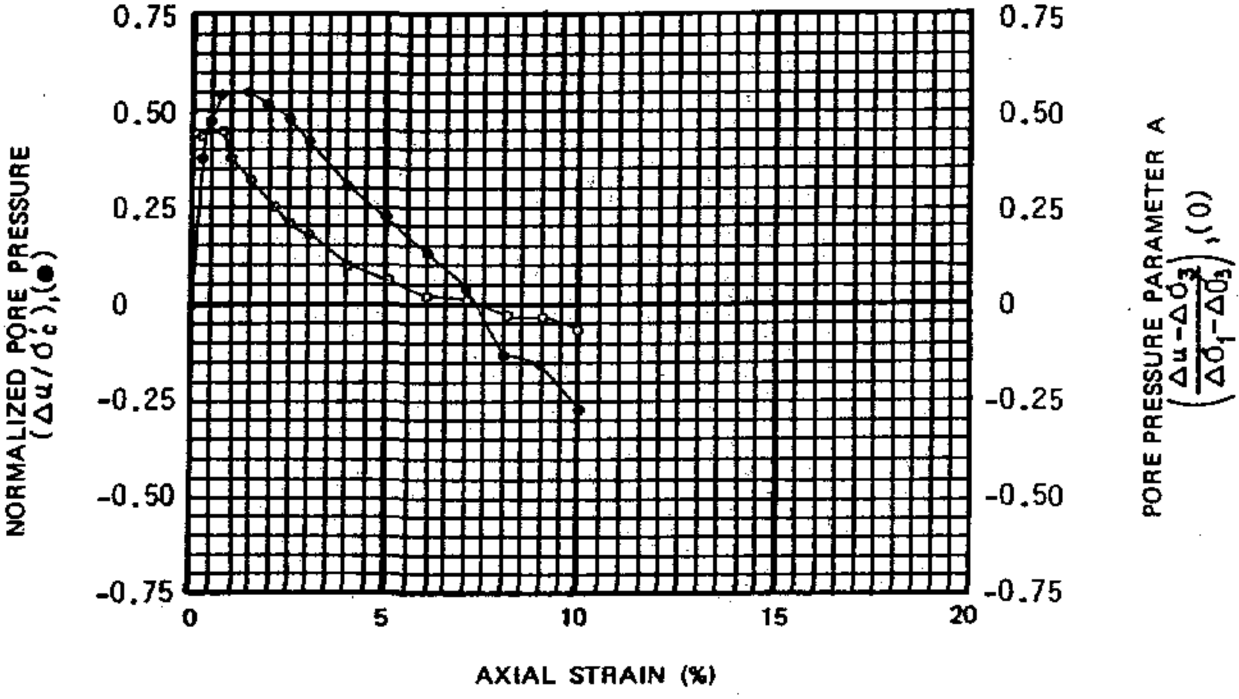
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DGB	4/82		





TYPE OF SPECIMEN	Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in.) 2.46	HEIGHT(in) 5.95		MOISTURE CONTENT	w_o	27.1 %	w_f	25.4 %
OVERBURDEN PRESS., σ_{vo}'	130	psf	VOID RATIO	e_o	0.782	e_f	0.692
CONSOLIDATION PRESS., σ_c'	1000	psf	SATURATION	S_o	94 %	S_f	100 %
STRAIN RATE	--	%/min	DRY DENSITY	γ_d	95 pcf	γ_d	100 pcf

LL --	PL --	PI --	G_s 2.72

CLASSIFICATION SANDY SILT (ML)

SOURCE Boring 14 at 2.4'

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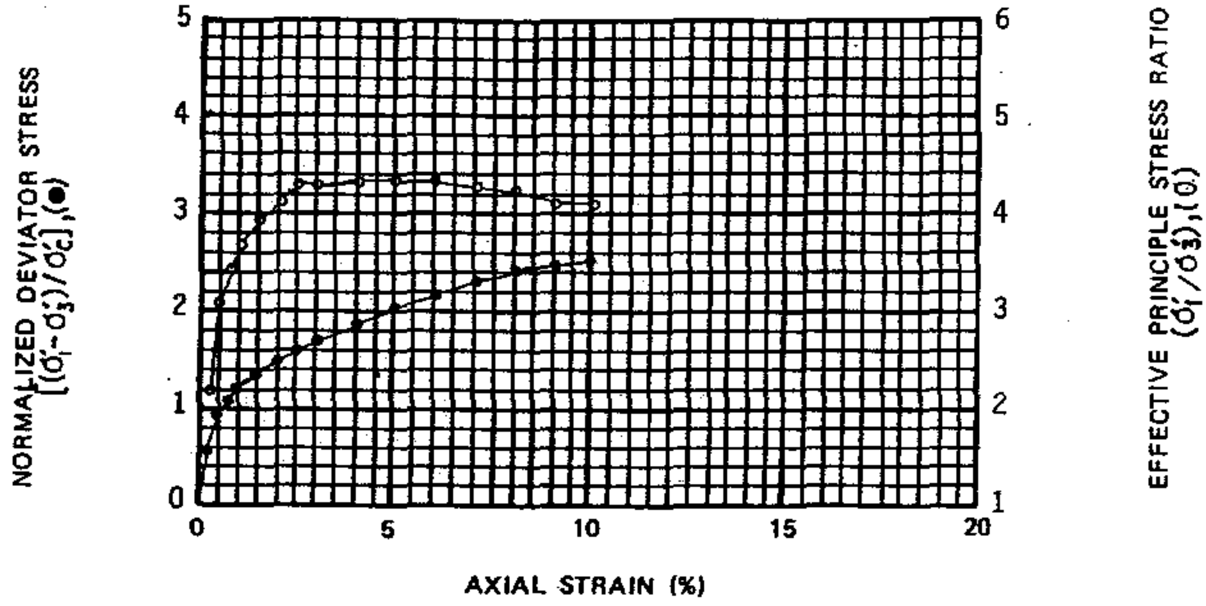
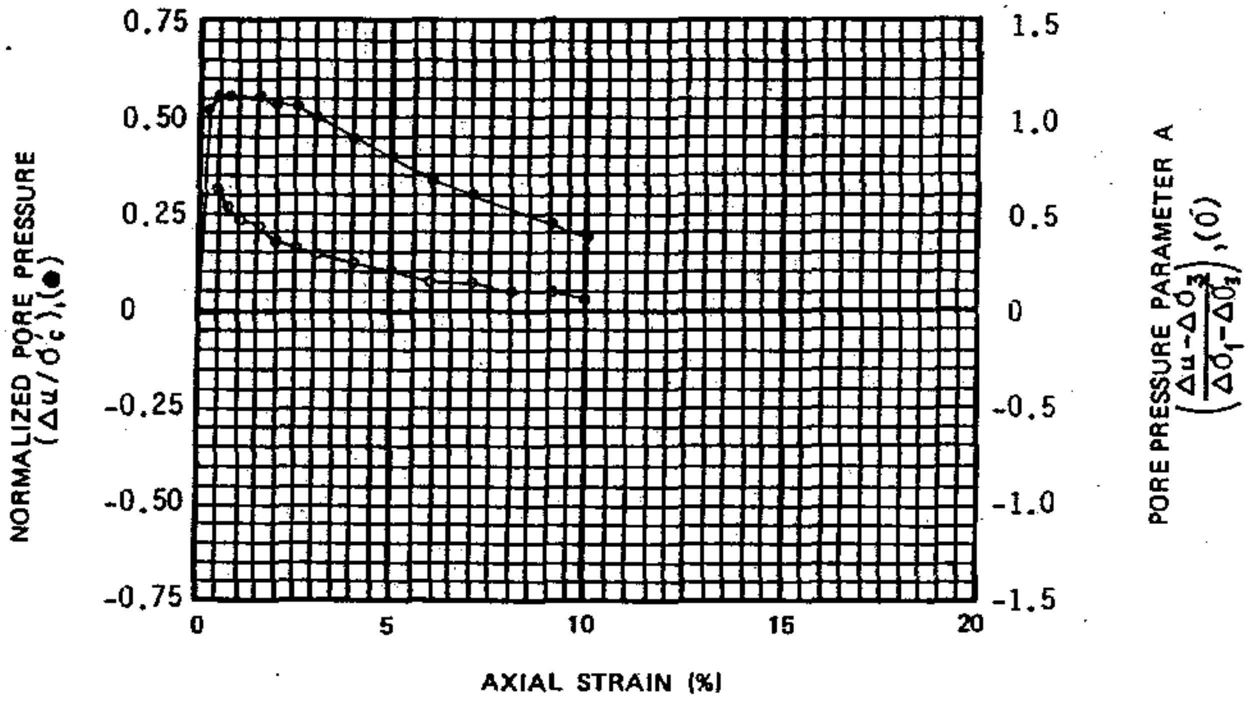
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		





TYPE OF SPECIMEN Undisturbed (trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in.) 2.46	HEIGHT(in) 6.00	MOISTURE CONTENT	w_o	26.7 %	w_f	23.8 %
OVERBURDEN PRESS., σ'_{vo} 160 psf		VOID RATIO	e_o	0.755	e_f	0.683
CONSOLIDATION PRESS.,) σ'_c 2000 psf		SATURATION	S_o	96 %	S_f	100 %
STRAIN RATE -- %/min		DRY DENSITY	γ_d	96 pcf	γ_d	101 pcf

LL --	PL --	PI --	G_s 2.71
CLASSIFICATION SANDY SILT (ML)		SOURCE Boring 14 at 2.9'	

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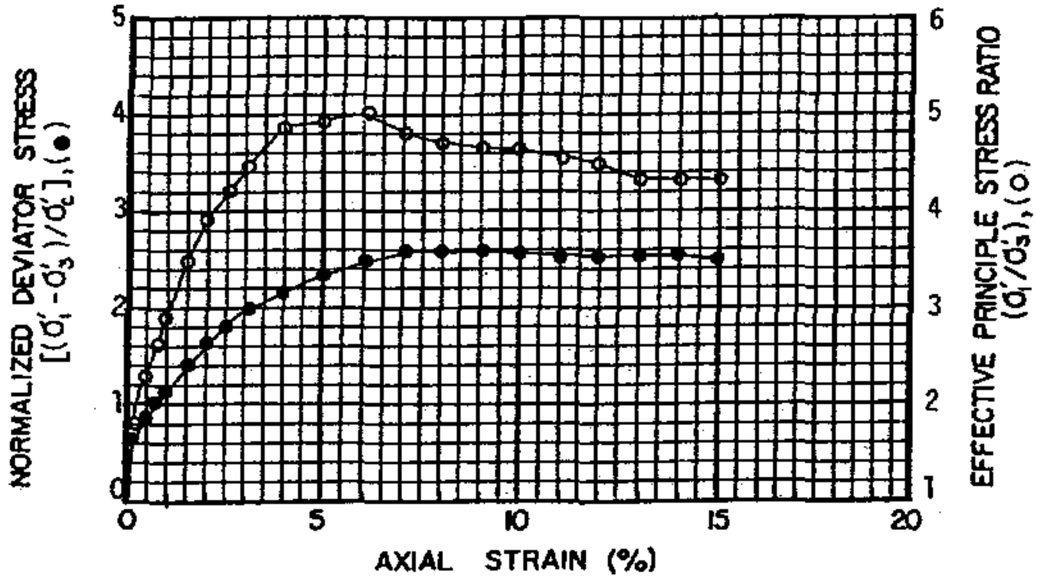
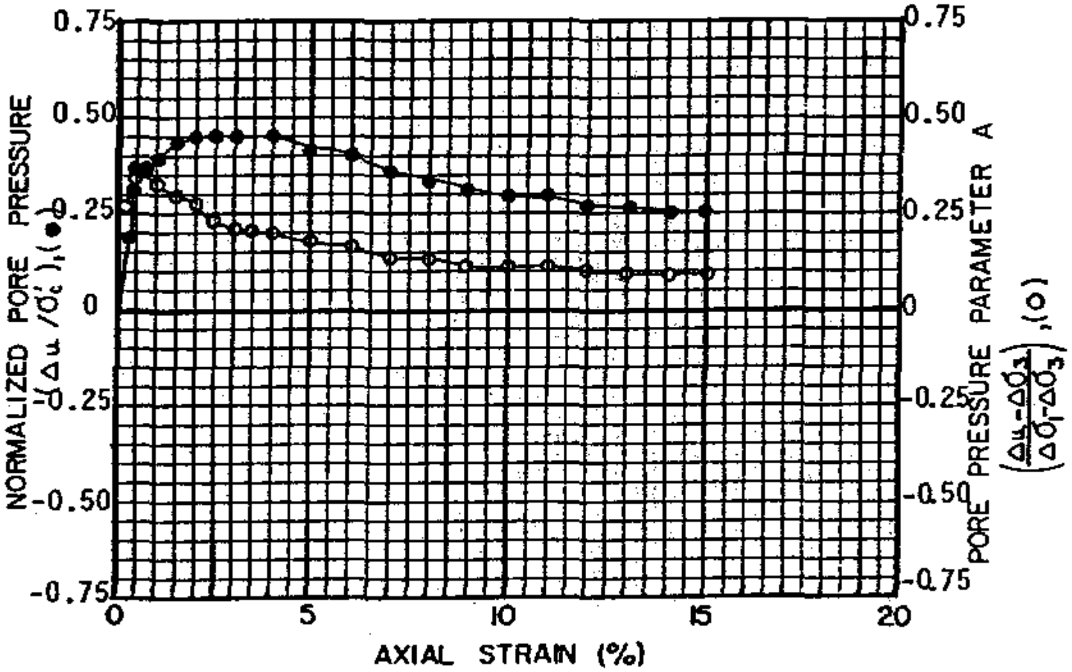
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		





TYPE OF SPECIMEN Undisturbed			BEFORE TEST		AFTER TEST	
DIAMETER (in.) 2.87	HEIGHT (in.) 6.45	MOISTURE CONTENT	w_o	70.2%	w_f	66.1 %
OVERBURDEN PRESS., σ_{vo}' 460 psf		VOID RATIO	e_o	1.875	e_f	1.728
CONSOLIDATION PRESS., σ_c' 750 psf		SATURATION	S_o	97 %	S_f	100 %
STRAIN RATE -- %/min		DRY DENSITY	γ_d	56 pcf	γ_d	60 pcf
LL --	PL --	PI --		G_s 2.60		
CLASSIFICATION SILT (MH)		SOURCE Boring 15 at 8.4'				

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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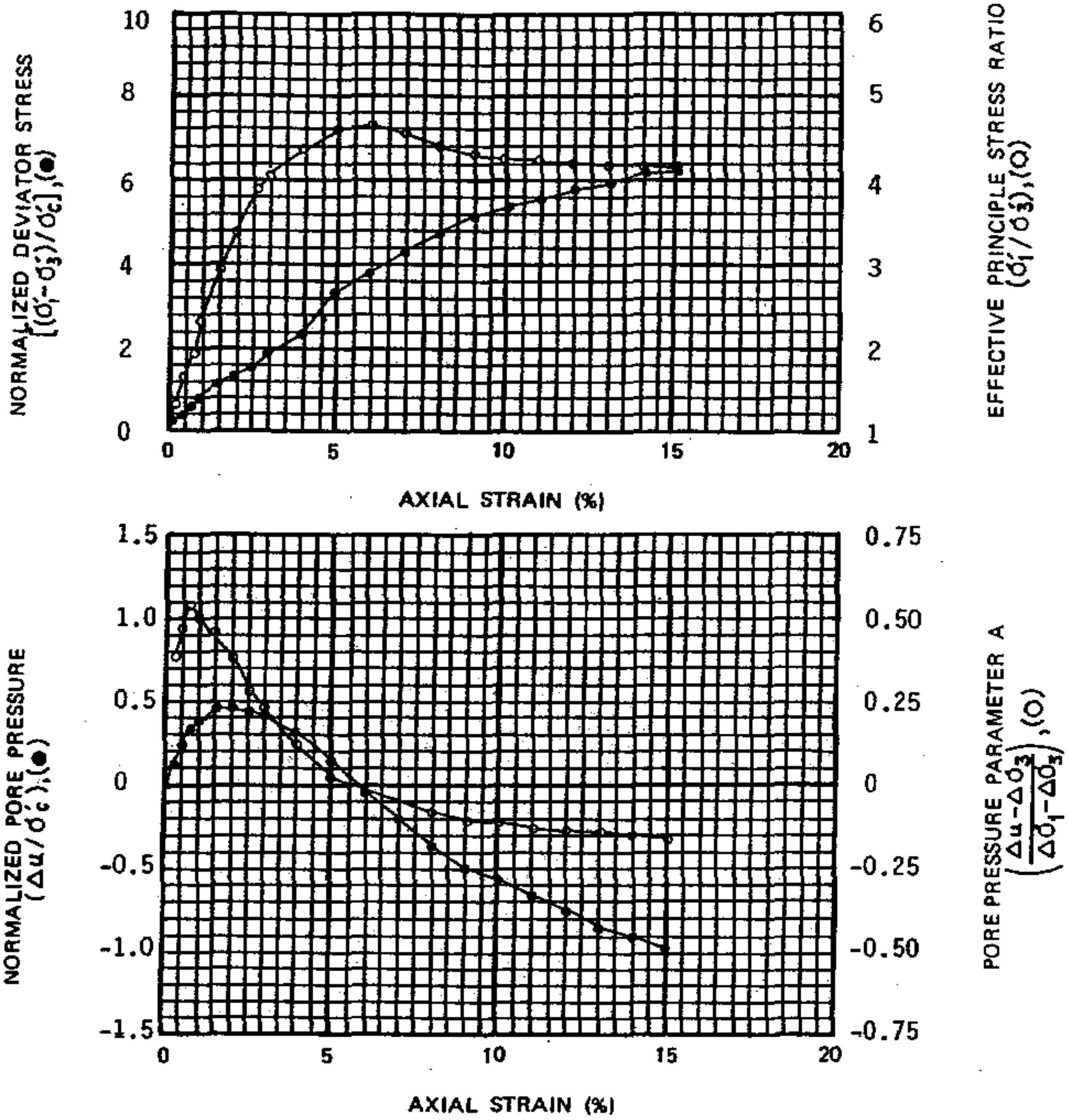

TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in.) 2.43	HEIGHT(in) 5.15	MOISTURE CONTENT	w_o	18.2 %	w_f	16.6 %
OVERBURDEN PRESS., σ'_{vo} 850 psf		VOID RATIO	e_o	0.500	e_f	0.443
CONSOLIDATION PRESS., σ'_c 5000 psf		SATURATION	S_o	100 %	S_f	100 %
STRAIN RATE -- %/min		DRY DENSITY	γ_d	114 pcf	γ_d	118 pcf
LL --	PL --		PI --		G_s 2.73	
CLASSIFICATION SILTY SAND (SM)			SOURCE Boring 15 at 15.5'			

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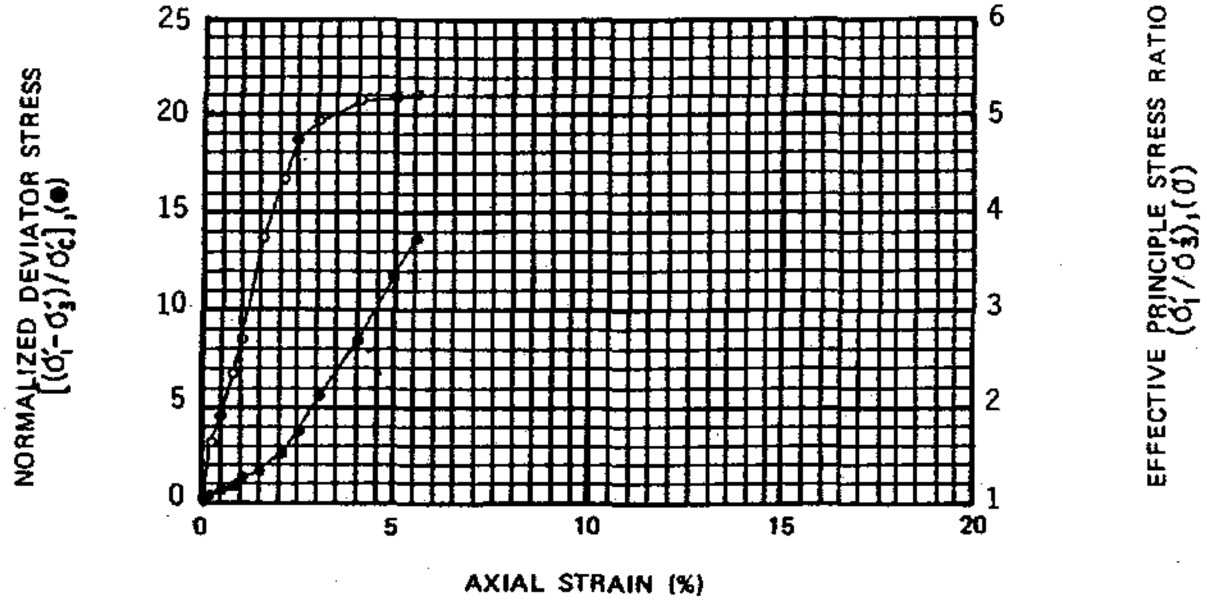
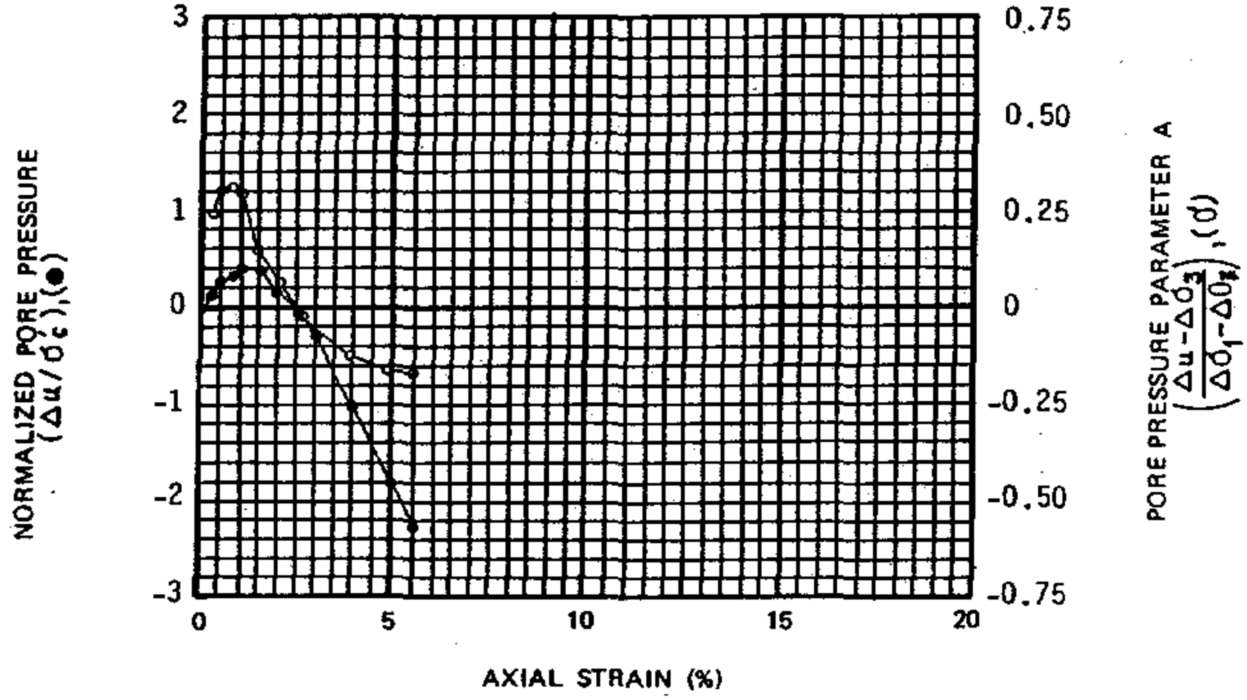
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		





TYPE OF SPECIMEN Undisturbed (trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in.) 2.46	HEIGHT(in) 5.10	MOISTURE CONTENT	w_o	18.6 %	w_f	16.8 %
OVERBURDEN PRESS., σ_{vo}' 880 psf		VOID RATIO	e_o	0.514	e_f	0.462
CONSOLIDATION PRESS., σ_c' 2250 psf		SATURATION	S_o	99 %	S_f	100 %
STRAIN RATE -- %/min		DRY DENSITY	γ_d	113 pcf	γ_d	117 pcf
LL --	PL --	PI --		G_s 2.73		
CLASSIFICATION SILTY SAND (SM)		SOURCE Boring 15 at 16.0'				

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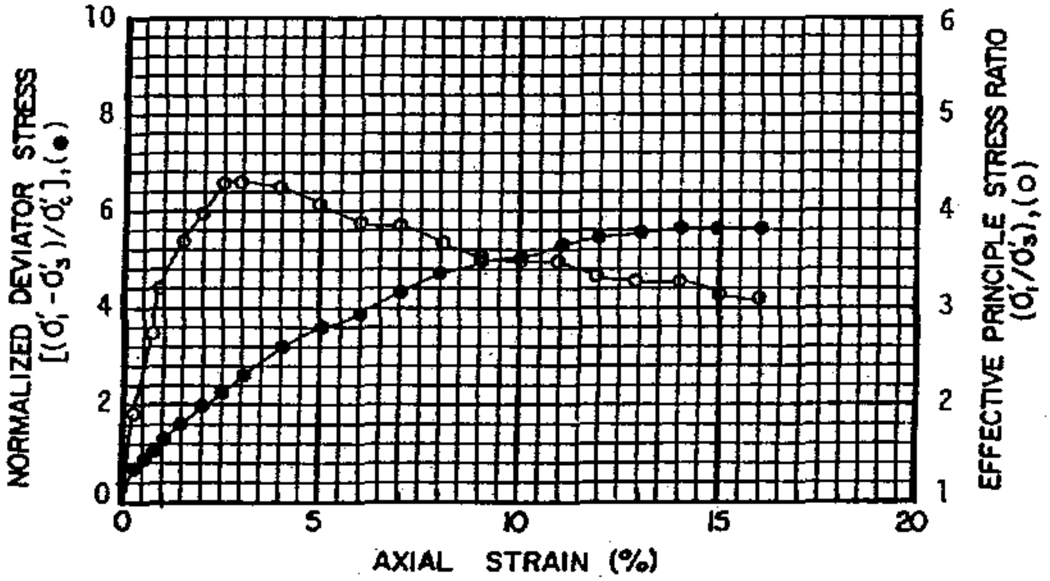
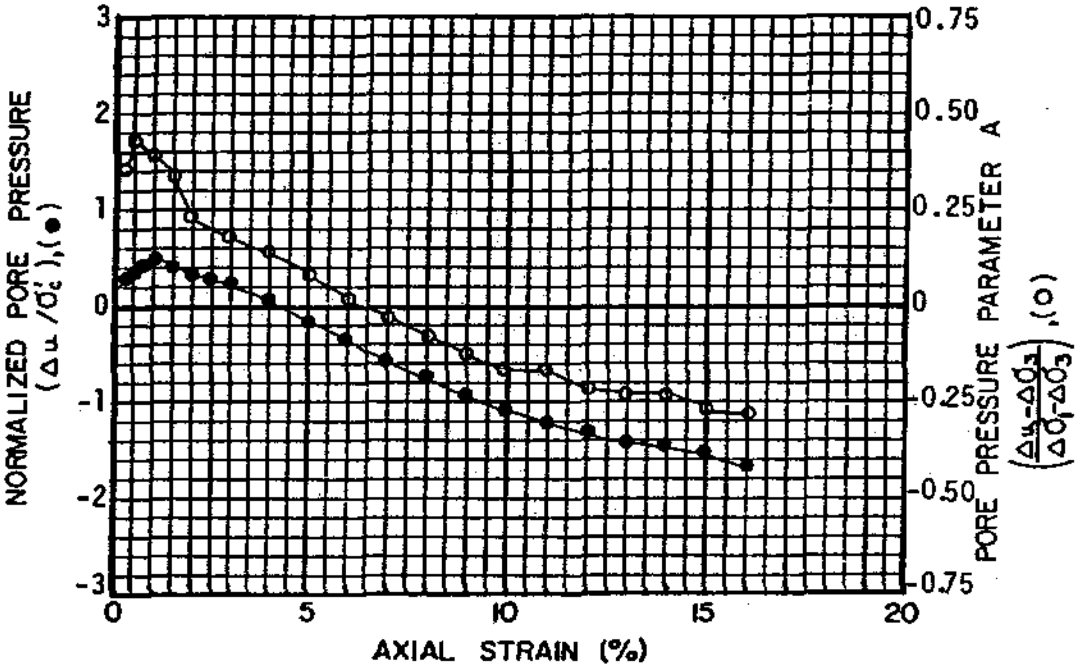
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		





TYPE OF SPECIMEN	Undisturbed			BEFORE TEST		AFTER TEST
DIAMETER (in.) 2.87	HEIGHT (in.) 6.45	MOISTURE CONTENT	w_o	24.7 %	w_f	24.1 %
OVERBURDEN PRESS., σ'_{vo}	1940 psf	VOID RATIO	e_o	0.690	e_f	0.670
CONSOLIDATION PRESS., σ'_c	2000 psf	SATURATION	S_o	99 %	S_f	100 %
STRAIN RATE	-- %/min	DRY DENSITY	γ_d	103 pcf	γ_d	104 pcf

LL 43	PL 16	PI 17	G_s 2.78

CLASSIFICATION SILTY CLAY (CL)	SOURCE Boring 17 at 35.3'

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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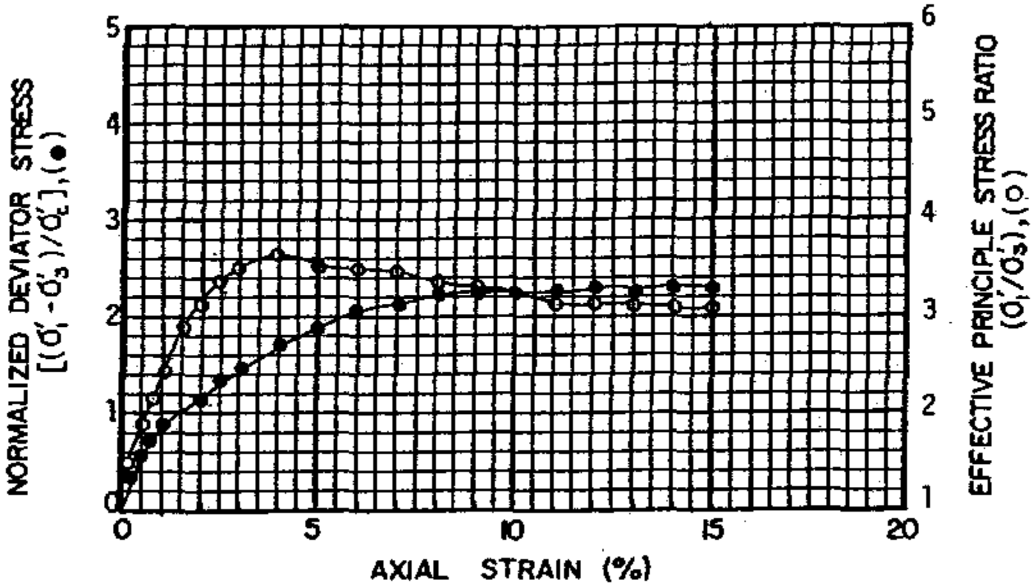

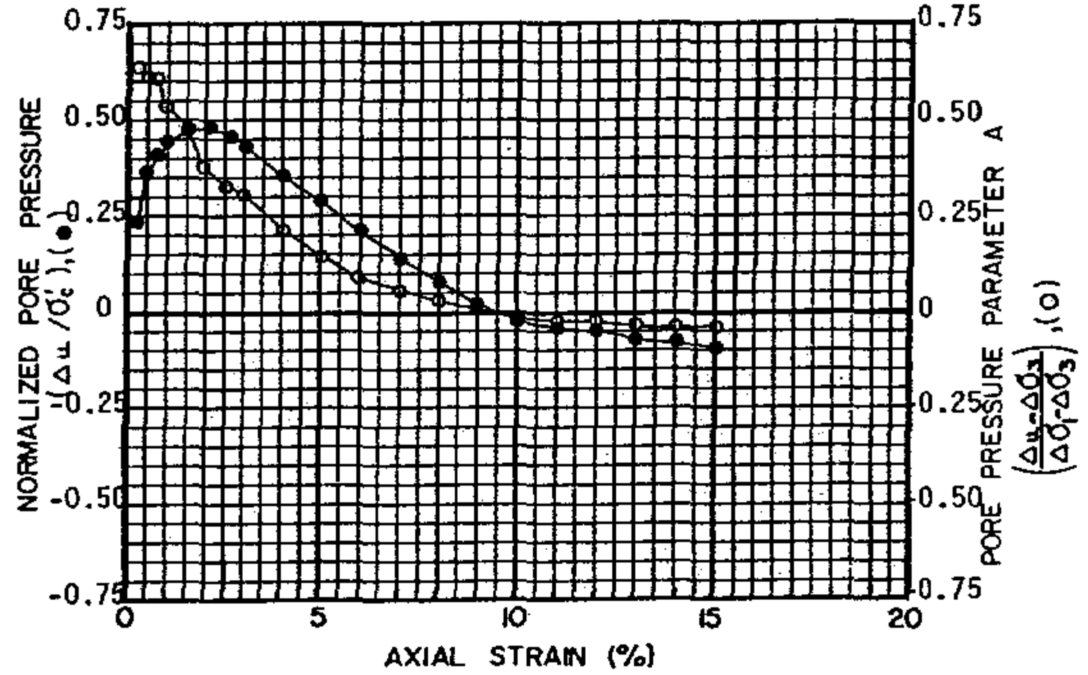

TYPE OF SPECIMEN Undisturbed				BEFORE TEST		AFTER TEST
DIAMETER (in.) 2.87	HEIGHT (in.) 6.45	MOISTURE CONTENT	w_o	24.3 %	w_f	24.1 %
OVERBURDEN PRESS., σ'_{vo}	2000 psf	VOID RATIO	e_o	0.677	e_f	0.670
CONSOLIDATION PRESS., σ'_c	4000 psf	SATURATION	S_o	99 %	S_f	100 %
STRAIN RATE --	%/min	DRY DENSITY	γ_d	103 pcf	γ_d	104 pcf
LL 43	PL 26	PI 17		G_s 2.78		
CLASSIFICATION CLAYEY SILT (ML)			SOURCE Boring 17 at 36.3'			

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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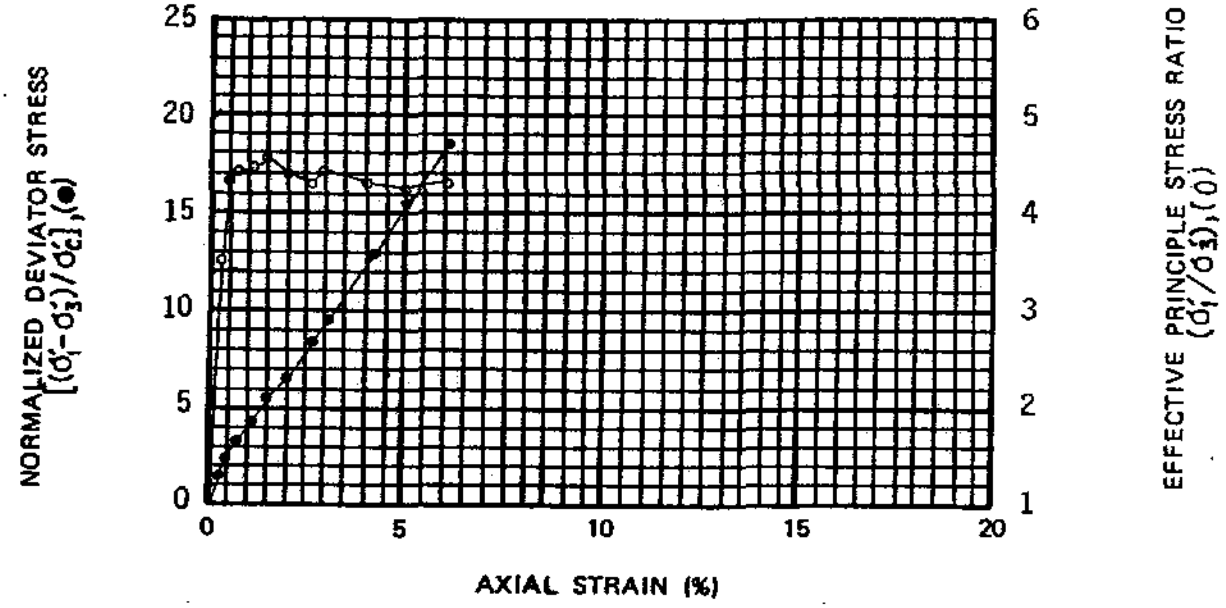

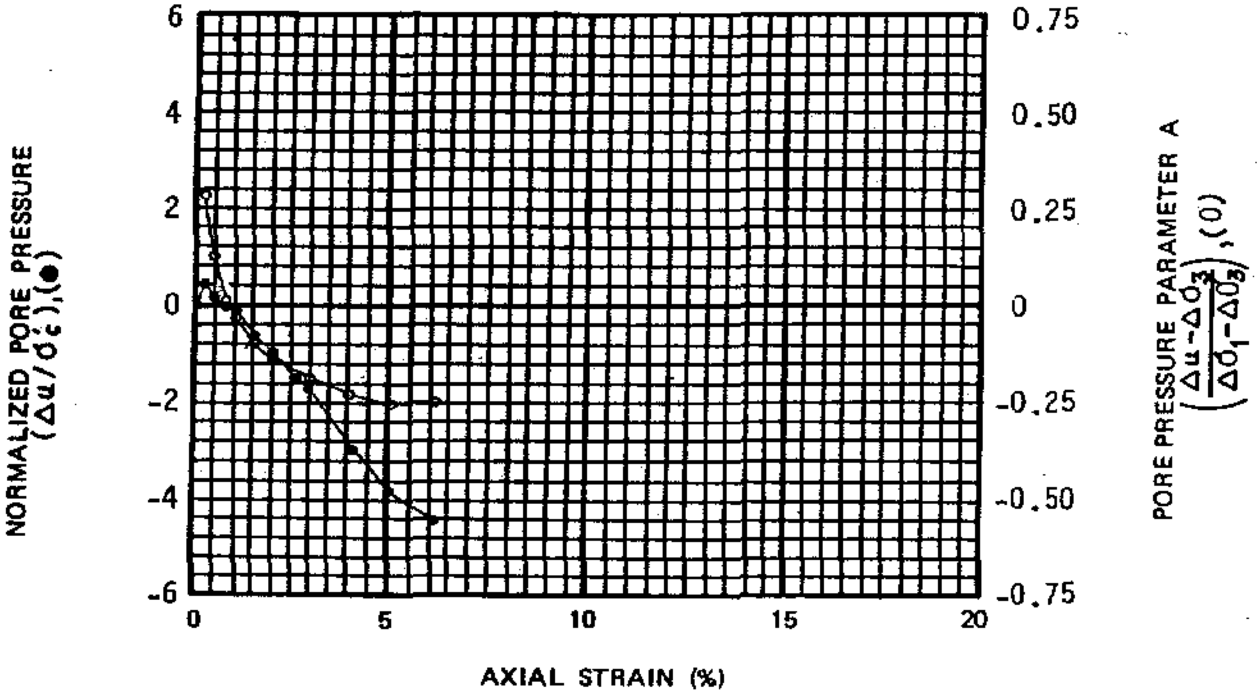

TYPE OF SPECIMEN Undisturbed (trimmed)		**BEFORE TEST**				**AFTER TEST**	
DIAMETER(in.) 2.46	**HEIGHT(in)** 6.00	**MOISTURE CONTENT**	w_o	19.3 %		w_f	18.6 %
OVERBURDEN PRESS., σ_{vo}' 230 psf		**VOID RATIO**	e_o	0.535		e_f	0.505
CONSOLIDATION PRESS., σ_c' 750 psf		**SATURATION**	S_o	99 %		S_f	100 %
STRAIN RATE -- %/min		**DRY DENSITY**	γ_d	111 pcf		γ_d	114 pcf
LL --	**PL** --		**PI** --		**G_s** 2.74		
CLASSIFICATION SANDY SILT (ML)			**SOURCE** Boring 21 at 4.1'				

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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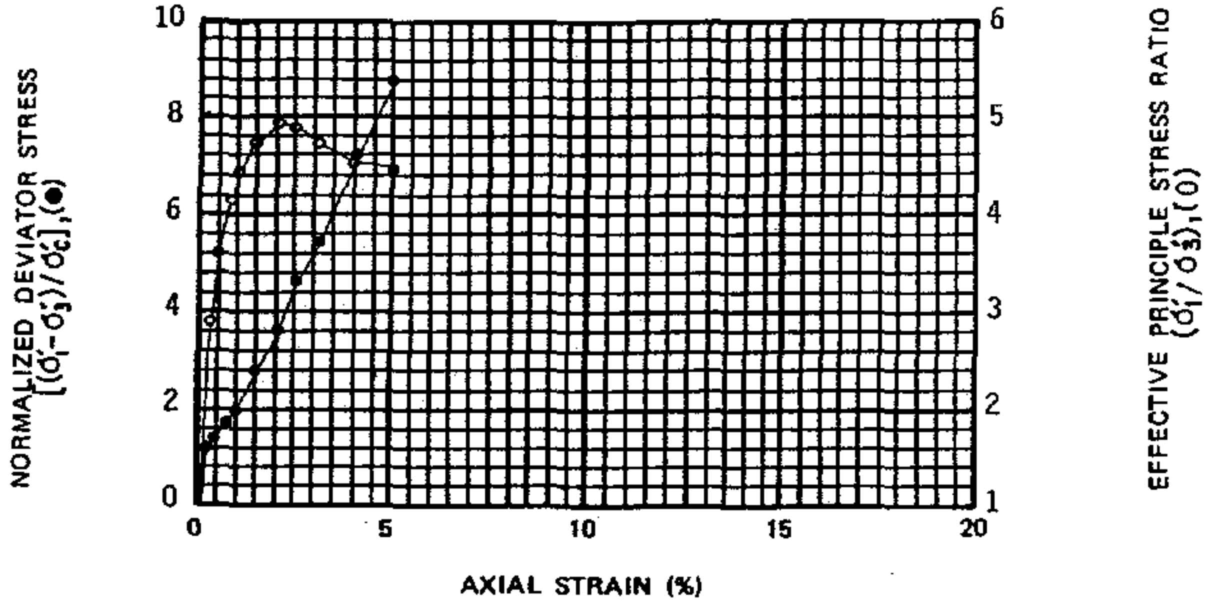

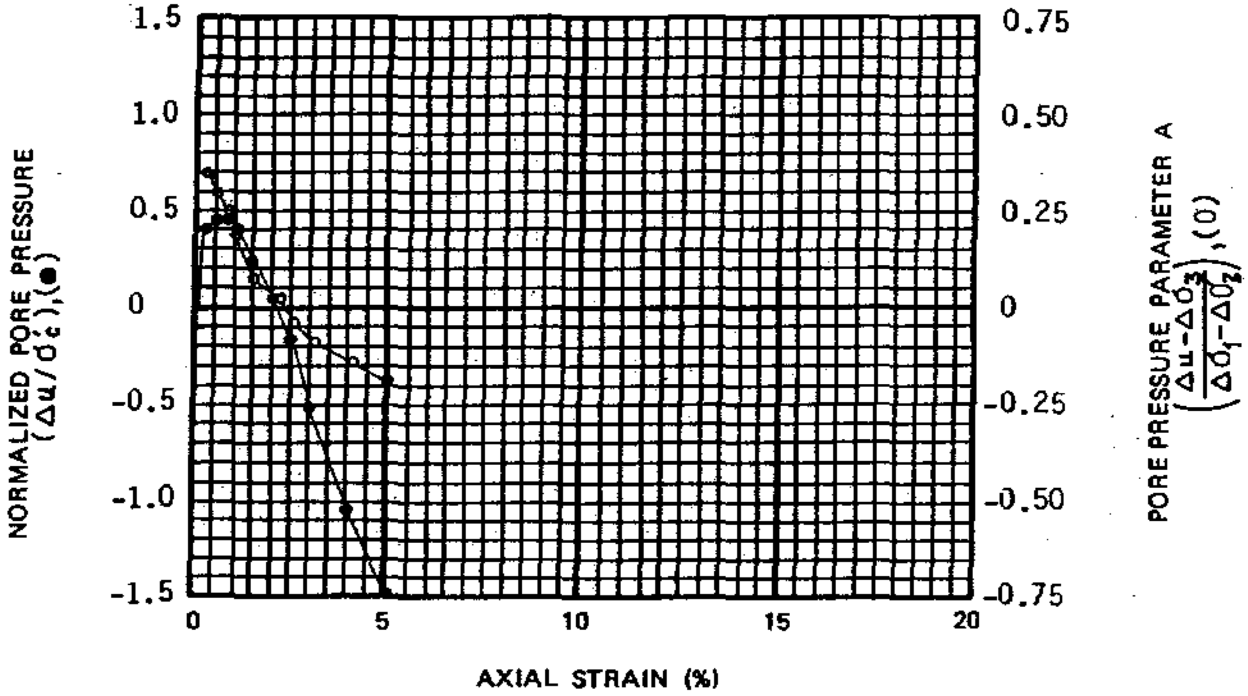

TYPE OF SPECIMEN	Undisturbed (trimmed)	BEFORE TEST			AFTER TEST	
DIAMETER(in.) 2.46	HEIGHT(in) 5.65	MOISTURE CONTENT	w_o	18.9 %	w_f	18.2 %
OVERBURDEN PRESS., σ_{vo}'	260 psf	VOID RATIO	e_o	0.535	e_f	0.497
CONSOLIDATION PRESS., σ_c'	1500 psf	SATURATION	S_o	96 %	S_f	100 %
STRAIN RATE	-- %/min	DRY DENSITY	γ_d	111 pcf	γ_d	114 pcf

LL --	PL --	PI --	G_s 2.73
CLASSIFICATION SANDY SILT (ML)		SOURCE Boring 21 at 4.7'	

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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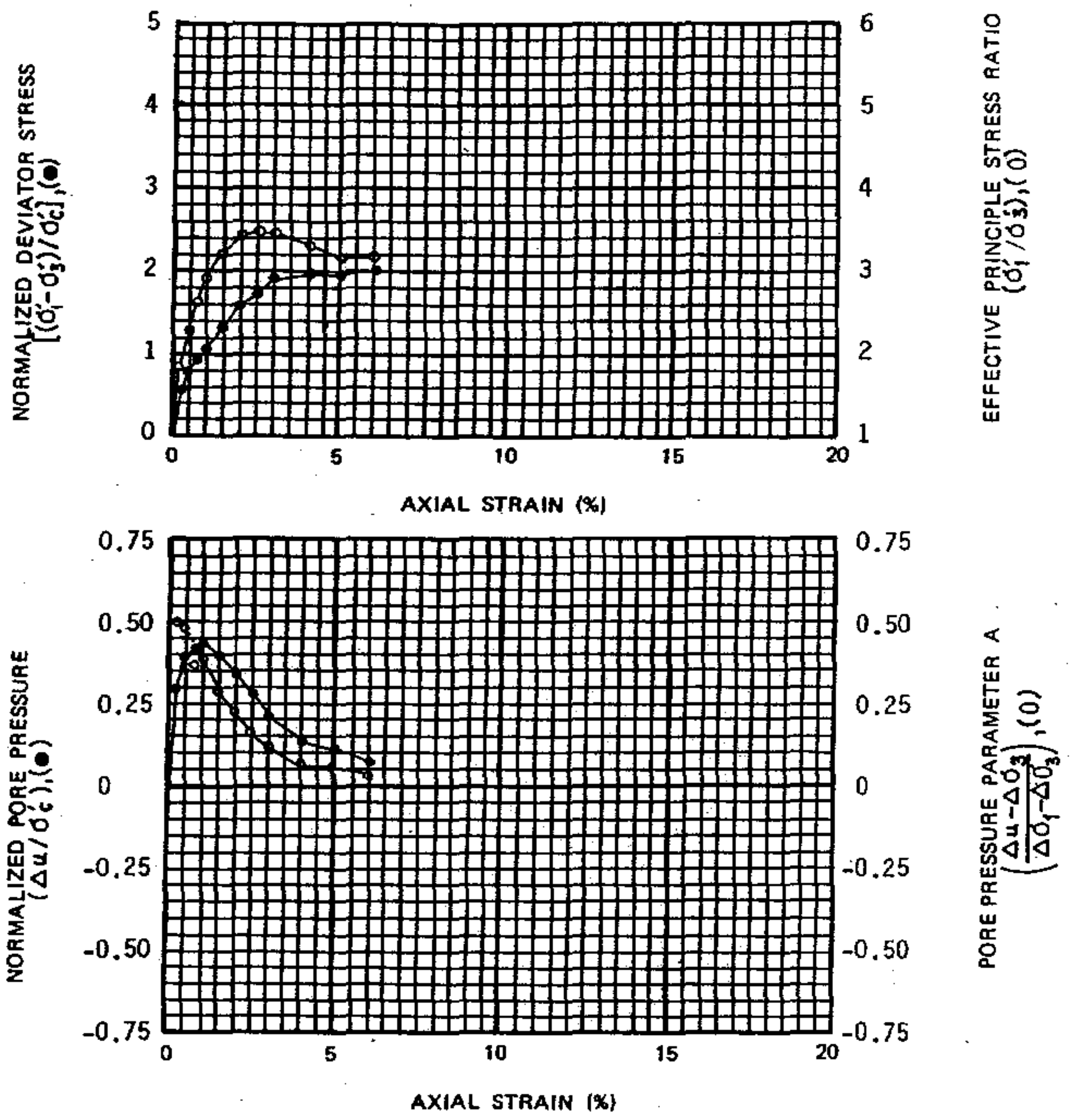

TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST		AFTER TEST	
DIAMETER(in.) 2.46	HEIGHT(in) 5.75	MOISTURE CONTENT	w_o 20.5 %	w_f	19.3 %
OVERBURDEN PRESS.,σ_{vo}' 290 psf		VOID RATIO	e_o 0.582	e_f	0.532
CONSOLIDATION PRESS.,) σ_c' 3000 psf		SATURATION	S_o 96 %	S_f	100 %
STRAIN RATE -- %/min		DRY DENSITY	γ_d 108 pcf	γ_d	112 pcf

LL --	PL --	PI --	G_s 2.74
CLASSIFICATION SANDY SILT (ML)		SOURCE Boring 21 at 5.2'	

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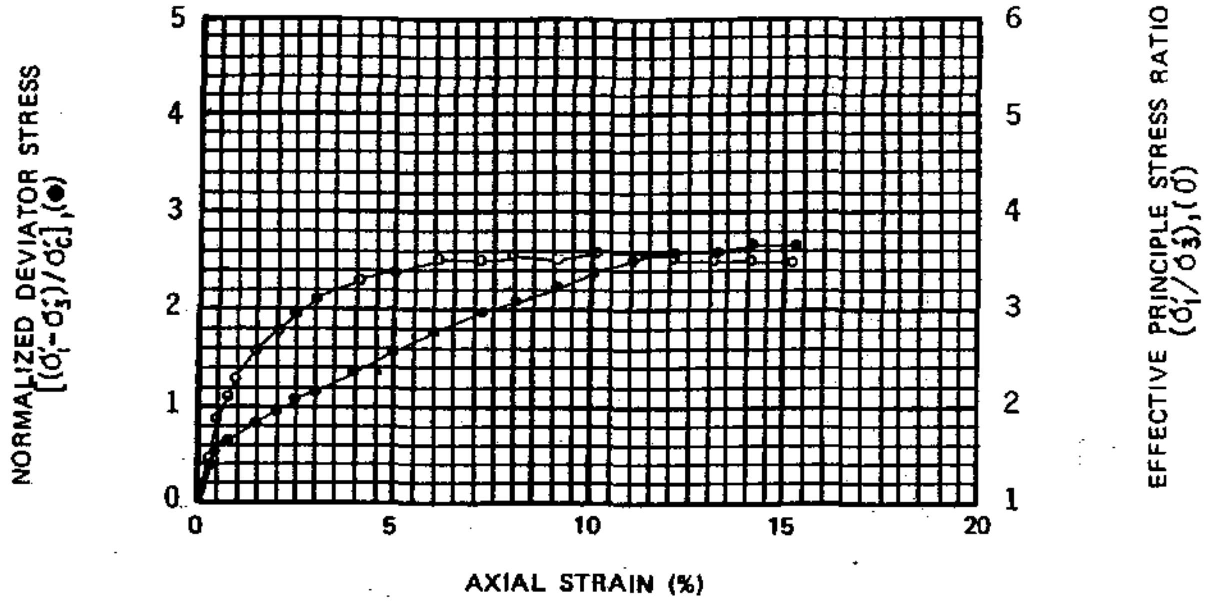
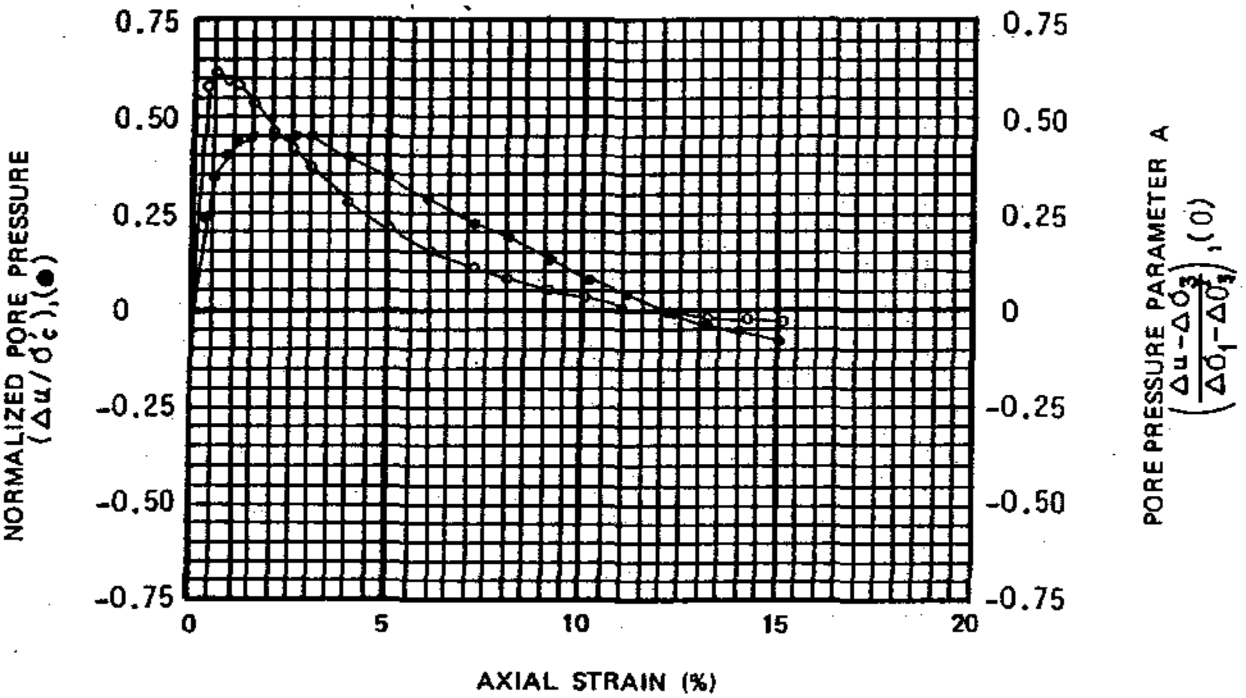
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612.031.08	DGB	4/82		





TYPE OF SPECIMEN Undisturbed		BEFORE TEST			AFTER TEST		
DIAMETER(in.) 2.87	HEIGHT(in) 6.25	MOISTURE CONTENT	w_o	24.0 %	w_f	22.1 %	
OVERBURDEN PRESS.,σ'_{vo} 990 psf		VOID RATIO	e_o	0.665	e_f	0.597	
CONSOLIDATION PRESS.,) σ'_c 4000 psf		SATURATION	S_o	98 %	S_f	100 %	
STRAIN RATE -- %/min		DRY DENSITY	γ_d	102 pcf	γ_d	107 pcf	
LL --	PL --		PI --		G_s 2.73		
CLASSIFICATION SANDY SILT (ML)			SOURCE Boring 21 at 18.0'				

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PLATE
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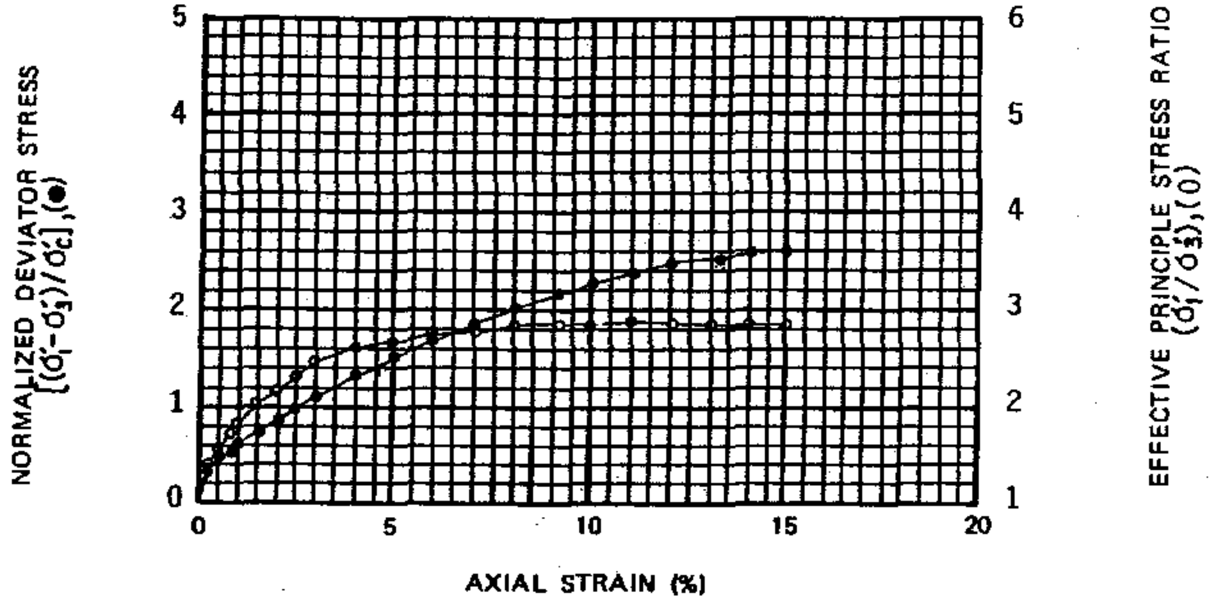
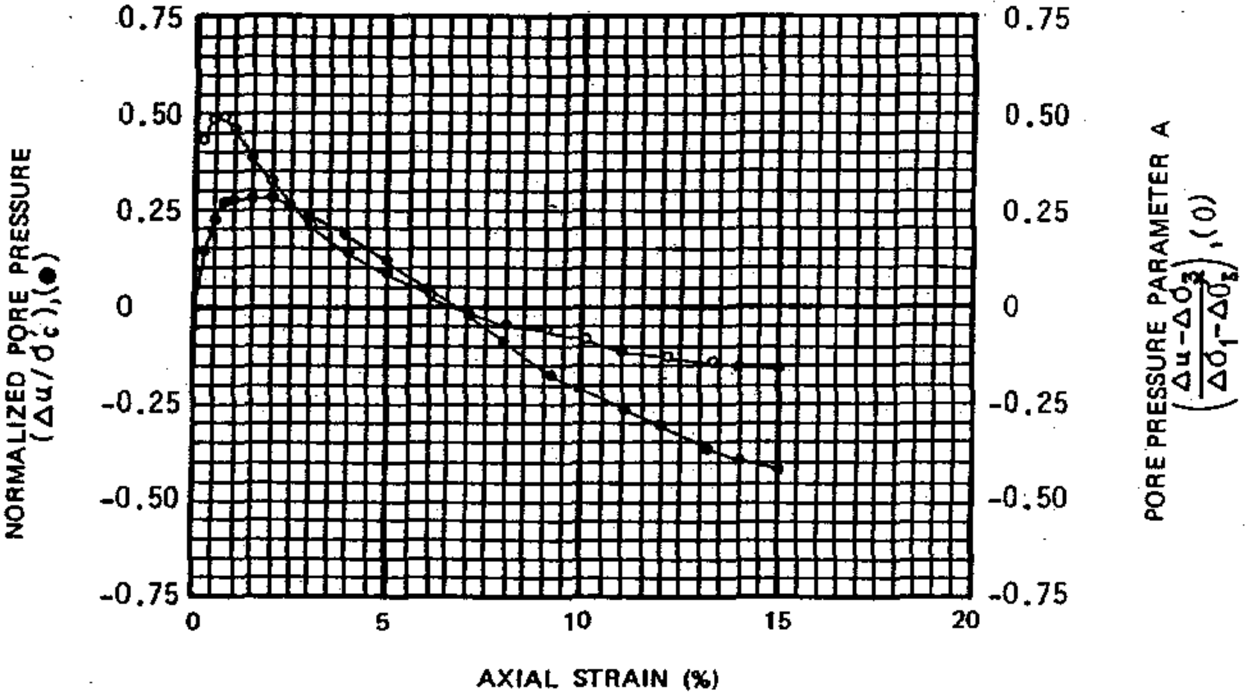
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612.031.08	DEB	4/82		





TYPE OF SPECIMEN Undisturbed		BEFORE TEST			AFTER TEST	
DIAMETER(in.) 2.87	HEIGHT(in) 6.45	MOISTURE CONTENT	w_o	26.6 %	w_f	24.3 %
OVERBURDEN PRESS., σ_{vo}' 1020 psf		VOID RATIO	e_o	0.763	e_f	0.665
CONSOLIDATION PRESS., σ_c' 2000 psf		SATURATION	S_o	96 %	S_f	100 %
STRAIN RATE -- %/min		DRY DENSITY	γ_d	97 pcf	γ_d	103 pcf

LL -- | PL -- | PI -- | G_s 2.74

CLASSIFICATION SANDY SILT (ML) | SOURCE Boring 21 at 18.5'

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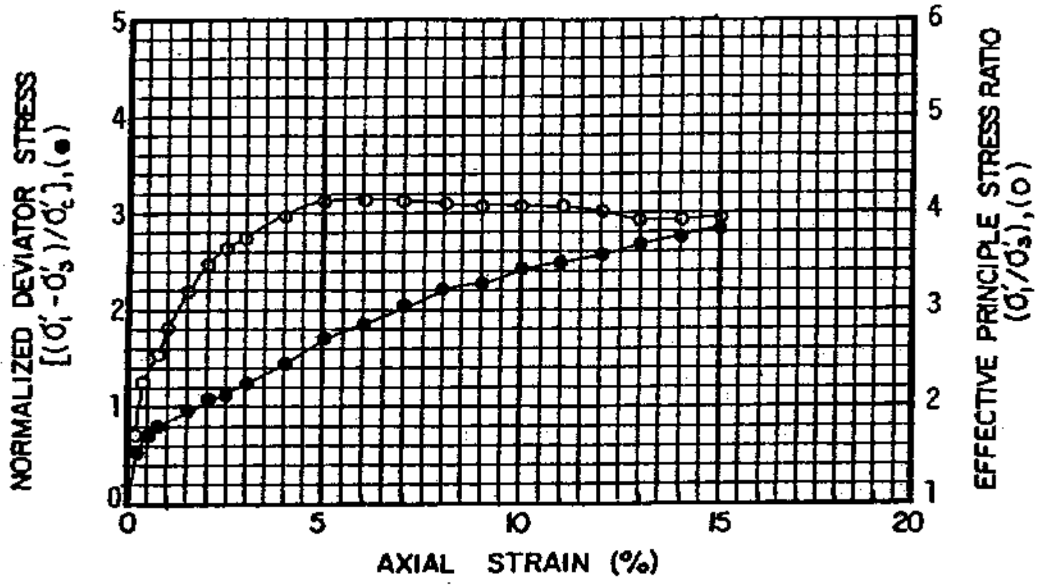
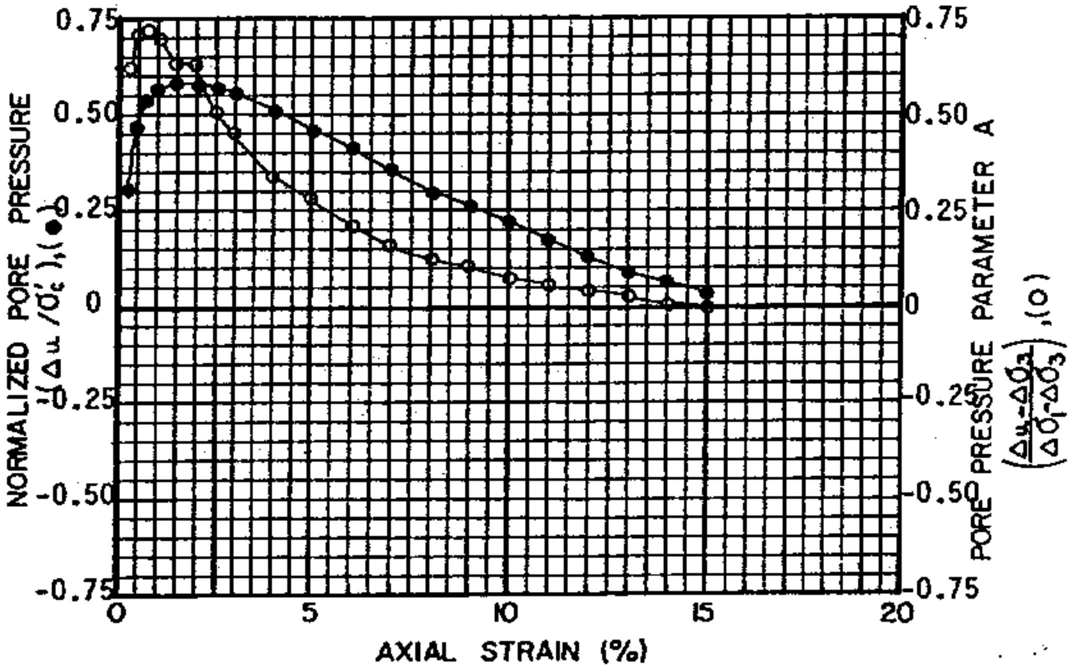
DRAWN VP | JOB NUMBER 9612 031 08 | APPROVED | DATE 4/82 | REVISED | DATE





TYPE OF SPECIMEN Undisturbed			BEFORE TEST		AFTER TEST
DIAMETER (in.) 2.87	HEIGHT (in.) 6.45	MOISTURE CONTENT	w_o 25.9 %	w_f	22.5 %
OVERBURDEN PRESS., σ_{vo}'	1440 psf	VOID RATIO	e_o 0.749	e_f	0.647
CONSOLIDATION PRESS., σ_c'	5000 psf	SATURATION	S_o 95 %	S_f	100 %
STRAIN RATE --	%/min	DRY DENSITY	γ_d 99 pcf	γ_d	105 pcf
LL --	PL. --	PI --	G_s 2.76		
CLASSIFICATION SANDY SILT (ML)		SOURCE Boring 21 at 26.1'			

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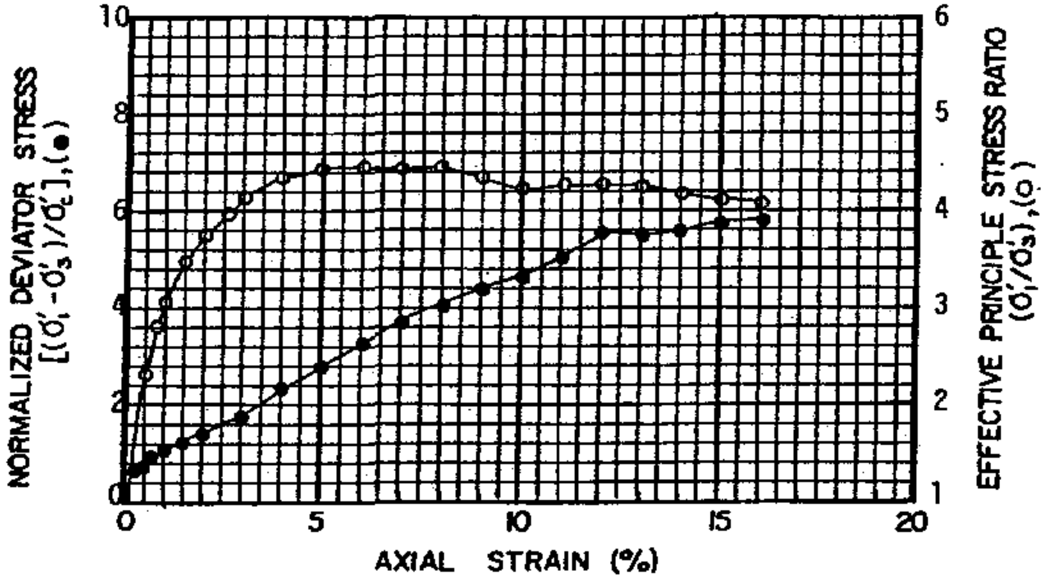
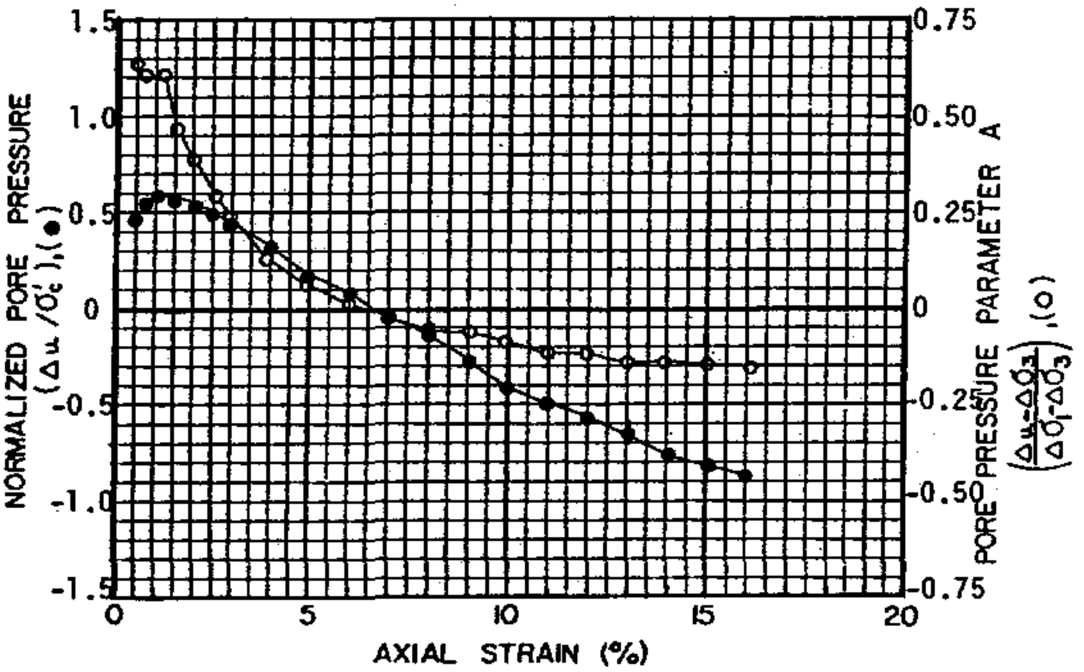
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
Y	9612,031.08	DGB	4/82		





TYPE OF SPECIMEN	Undisturbed		BEFORE TEST		AFTER TEST	
DIAMETER (in.) 2.87	HEIGHT (in.) 6.45	MOISTURE CONTENT	w_o	25.9 %	w_f	23.3 %
OVERBURDEN PRESS., σ'_{vo}	1470 psf	VOID RATIO	e_o	0.763	e_f	0.660
CONSOLIDATION PRESS., σ'_c	2500 psf	SATURATION	S_o	94 %	S_f	100 %
STRAIN RATE --	%/min	DRY DENSITY	γ_d	98 pcf	γ_d	104 pcf
LL --	PL --	PI --		G_s 2.78		
CLASSIFICATION	SANDY SILT (ML)	SOURCE Boring 21 at 26.8'				

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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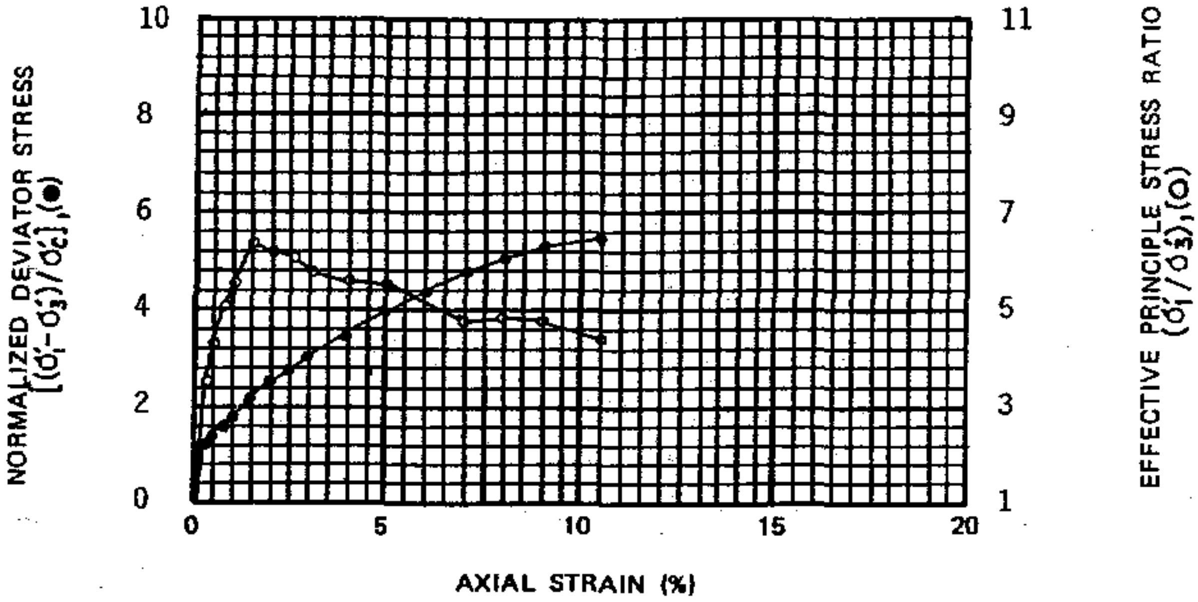

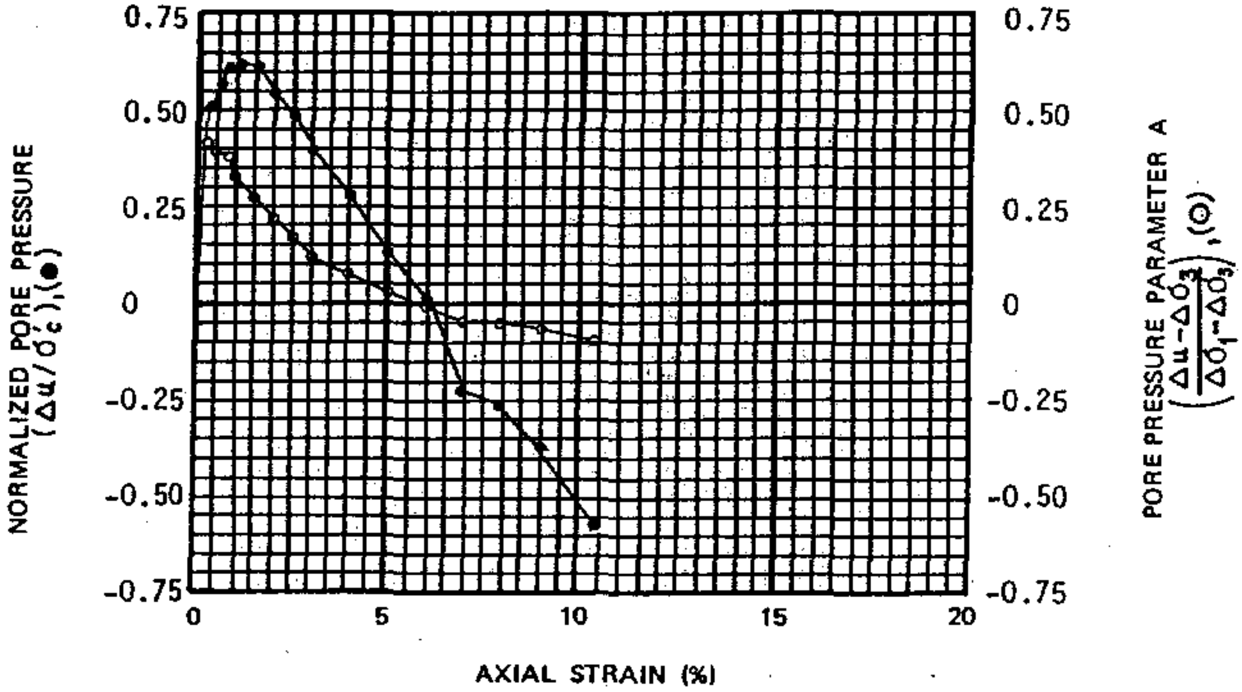

TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in.) 2.43	HEIGHT(in) 5.70	MOISTURE CONTENT	w_o	25.8 %	w_f	24.1 %
OVERBURDEN PRESS., σ_{vo}'	150 psf	VOID RATIO	e_o	0.695	e_f	0.660
CONSOLIDATION PRESS., σ_c'	750 psf	SATURATION	S_o	100 %	S_f	99 %
STRAIN RATE	--- %/min	DRY DENSITY	γ_d	99 pcf	γ_d	101 pcf
LL ---	PL ---		PI ---		G_s 2.70	
CLASSIFICATION SANDY SILT (ML)			SOURCE Boring 22 at 2.7'			

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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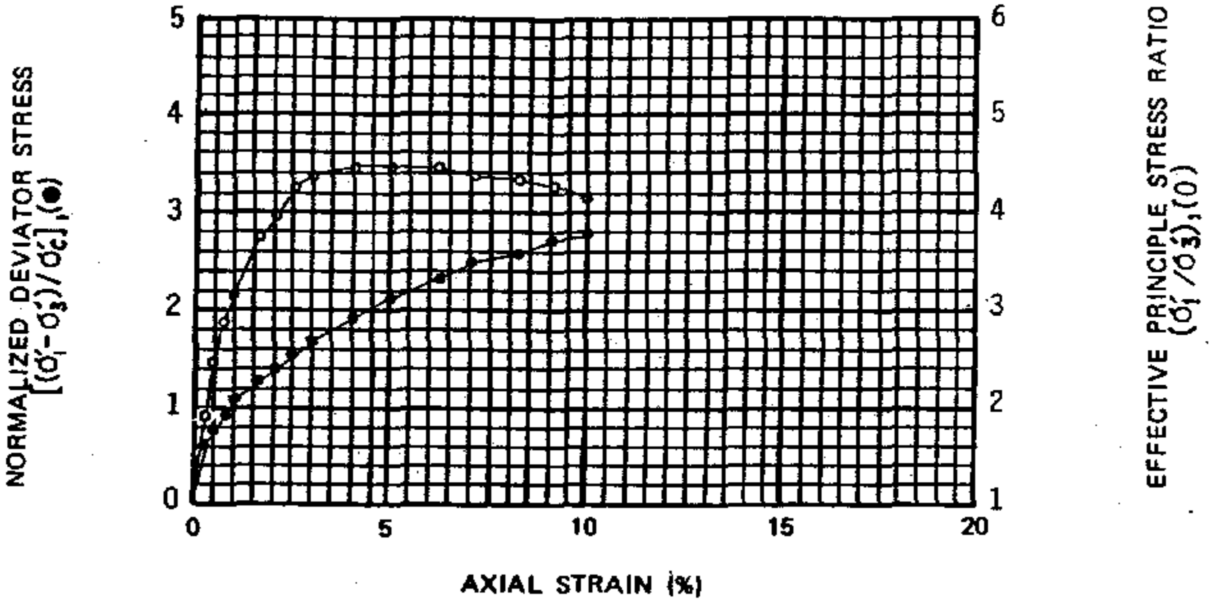

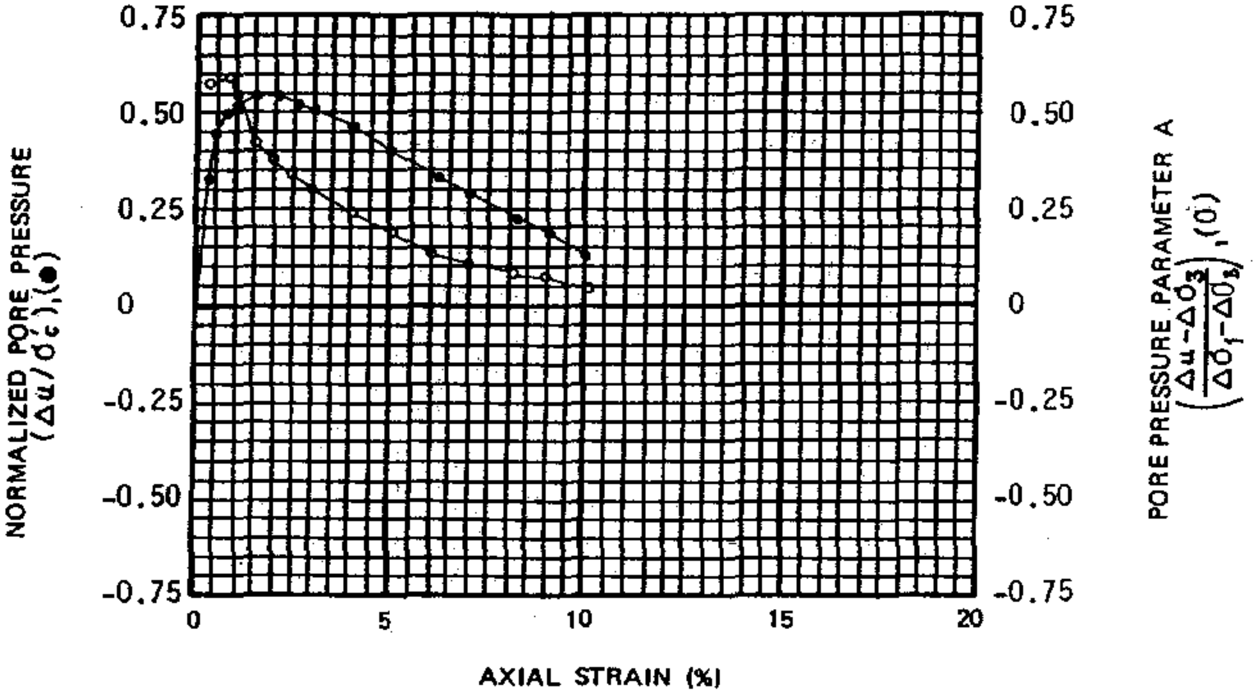

TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in.) 2.46	HEIGHT(in) 5.70	MOISTURE CONTENT	w_o	30.7 %	w_f	27.4 %
OVERBURDEN PRESS.,σ_{vo}' 210 psf		VOID RATIO	e_o	0.859	e_f	0.737
CONSOLIDATION PRESS.,) σ_c' 1500 psf		SATURATION	S_o	96 %	S_f	100 %
STRAIN RATE -- %/min		DRY DENSITY	γ_d	90 pcf	γ_d	97 pcf

LL 24	PL 21	PI 3	G_s 2.69
CLASSIFICATION SILT (ML)		SOURCE Boring 22 at 3.8'	

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PLATE
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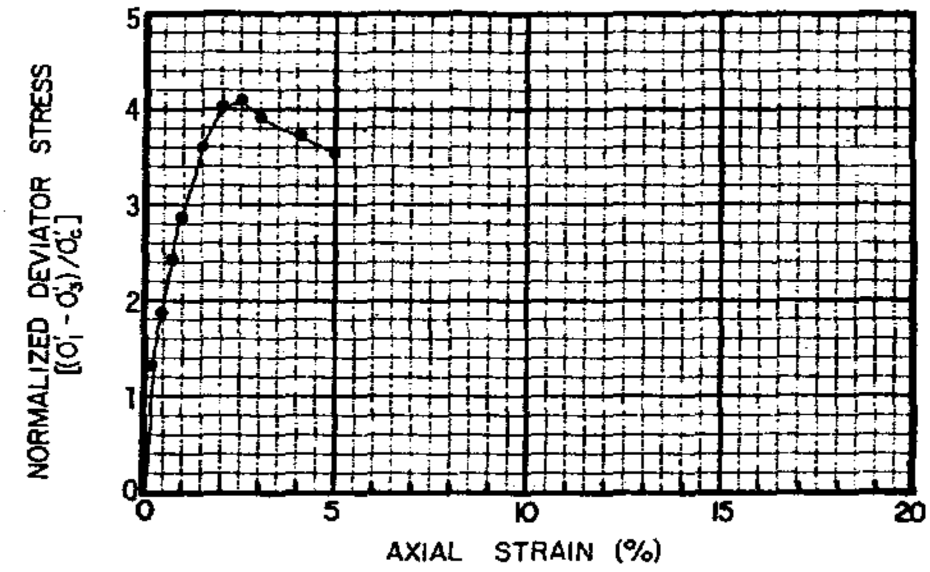
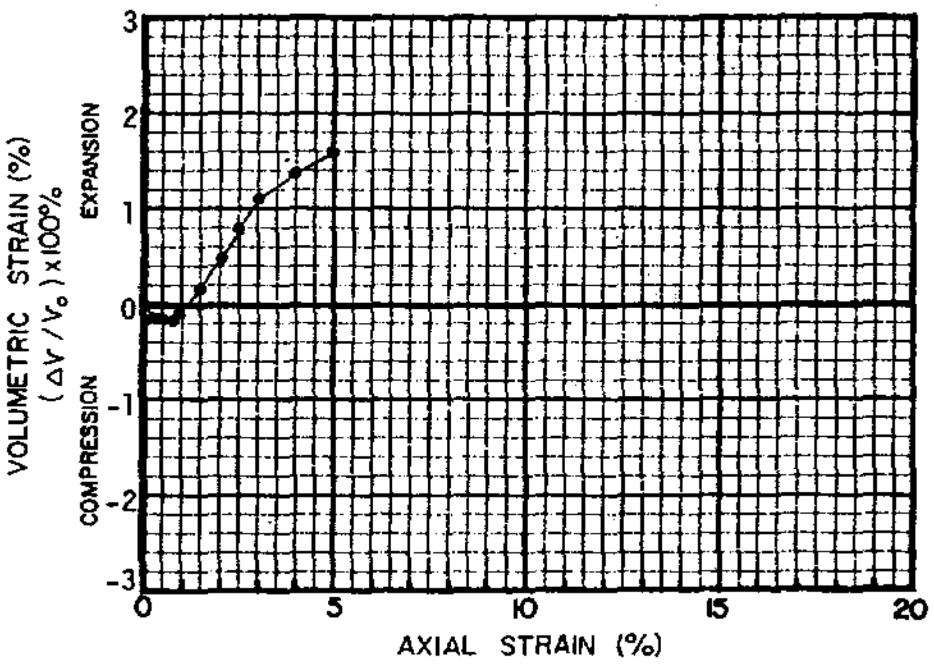
DRAWN JOB NUMBER APPROVED DATE REVISED DATE drain and consolidate. After consolidation, the drain valve was left open and the axial load applied at a constant rate of approximately 0.1 percent per minute, depending upon soil type. The test was conducted at this slow rate to prevent the development of pore pressure. Failure was defined as the point of maximum deviator stress. Results of the tests are summarized on Plate D-75. The effective strengths are plotted on a modified Mohr diameter as shown on Plate IV-16 with the data from TXCU tests. Results of the TXCU and TXCD tests are in agreement and consistently yielded a friction angle of approximately 40^0 with no cohesion intercept. Stress-strain curves of individual tests are presented on Plates D-111 through D-115.

2. Direct Shear Tests

Direct shear (DS) tests were performed to measure the consolidated-drained shear strengths of fine-grained granular soils. For these tests, a 2.43-inch diameter by 0.8-inch-high cylindrical soil specimen was first placed in split rigid rings. Next, the specimen was saturated and consolidated under a vertical (normal) stress. By using the time rates of consolidation, the test rate was determined and the shear force was slowly applied so that pore pressures did not develop.

Results of the tests are summarized on Plate D-116. Individual test results are shown on Plates D-117 through D-119. The soil is strongly dilatant at low normal stress which yielded high friction angles as shown on Plate D-114. These high friction angles are not unusual for an angular, medium dense to dense sand or silt tested at very low normal pressures. The friction angle decreases rapidly with increasing normal pressure. At the stress range of interest in this project, the friction angle is approximately 40^0 as measured from the TXCU and TXCD tests.





TYPE OF SPECIMEN Undisturbed			BEFORE TEST		AFTER TEST	
DIAMETER (in.) 2.46	HEIGHT (in.) 5.60	MOISTURE CONTENT	w_o	22.8%	w_f	23.5 %
OVERBURDEN PRESS., P_o'	20 psf	VOID RATIO	e_o	0.650	e_f	0.630
CONSOLIDATION PRESS., σ_c'	1500 psf	SATURATION	S_o	94%	S_f	100 %
STRAIN RATE --	%/min	DRY DENSITY	γ_d	102 pcf	γ_d	103 pcf

LL --	PL --	PI --	G_s 2.69
CLASSIFICATION SAND (SP)		SOURCE Boring 2 at 0.3'	

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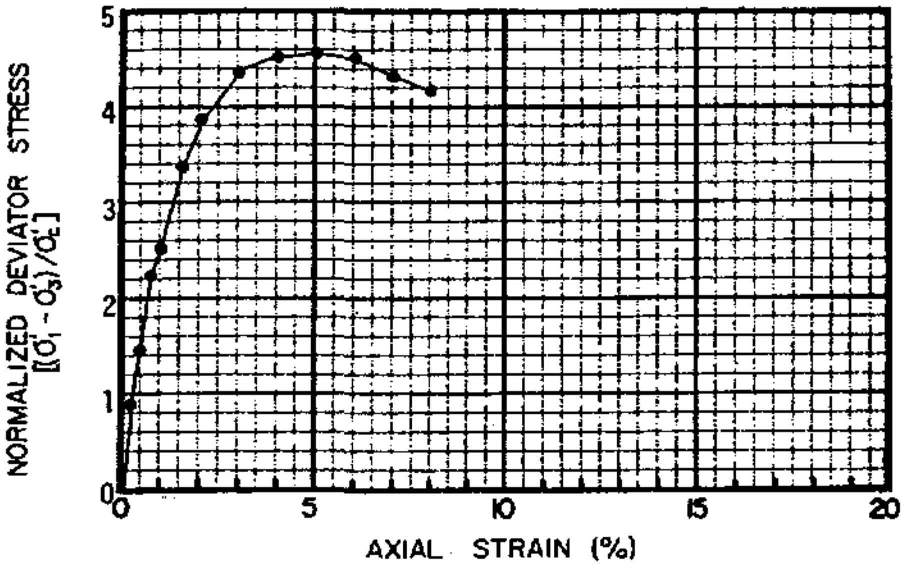
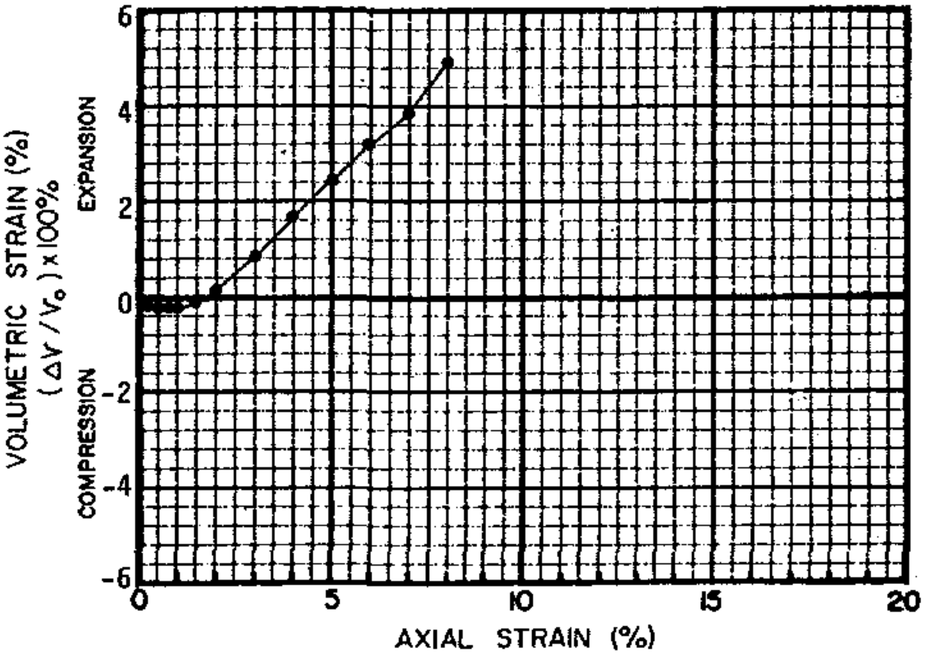
PLATE **D-11**

DRAWN JP
JOB NUMBER 9612,031.08
APPROVED DAB
DATE 4/82
REVISED
DATE

RF





TYPE OF SPECIMEN Undisturbed		BEFORE TEST			AFTER TEST	
DIAMETER (in.) 2.46	HEIGHT (in.) 5.70	MOISTURE CONTENT	w_o	22.8 %	w_f	24.4 %
OVERBURDEN PRESS., P_0' 190 psf		VOID RATIO	e_o	0.682	e_f	0.644
CONSOLIDATION PRESS., σ_c' 3000 psf		SATURATION	S_o	89 %	S_f	100 %
STRAIN RATE -- %/min		DRY DENSITY	γ_d	98 pcf	γ_d	101 pcf
LL --	PL --	PI --			G_s 2.65	
CLASSIFICATION SAND (SP)		SOURCE . Boring 2 at 3.4'				

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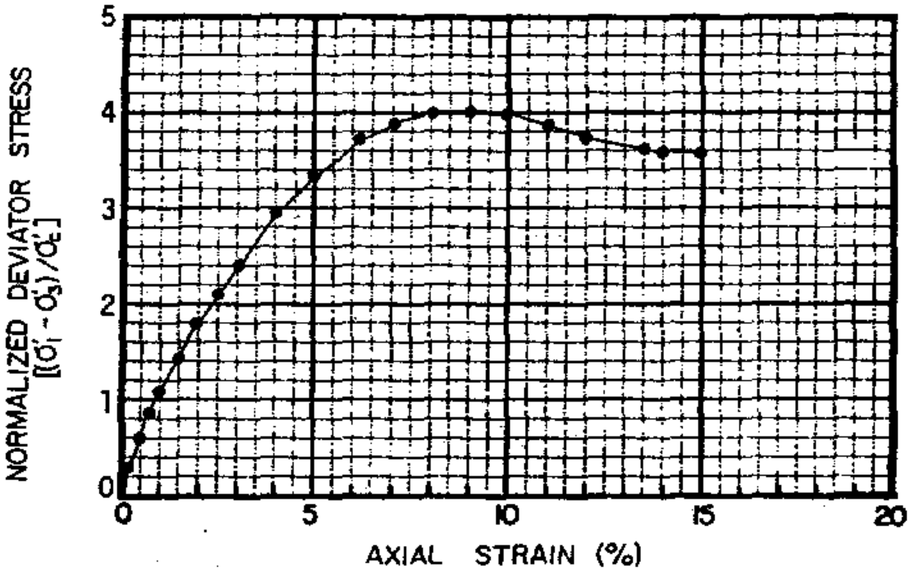
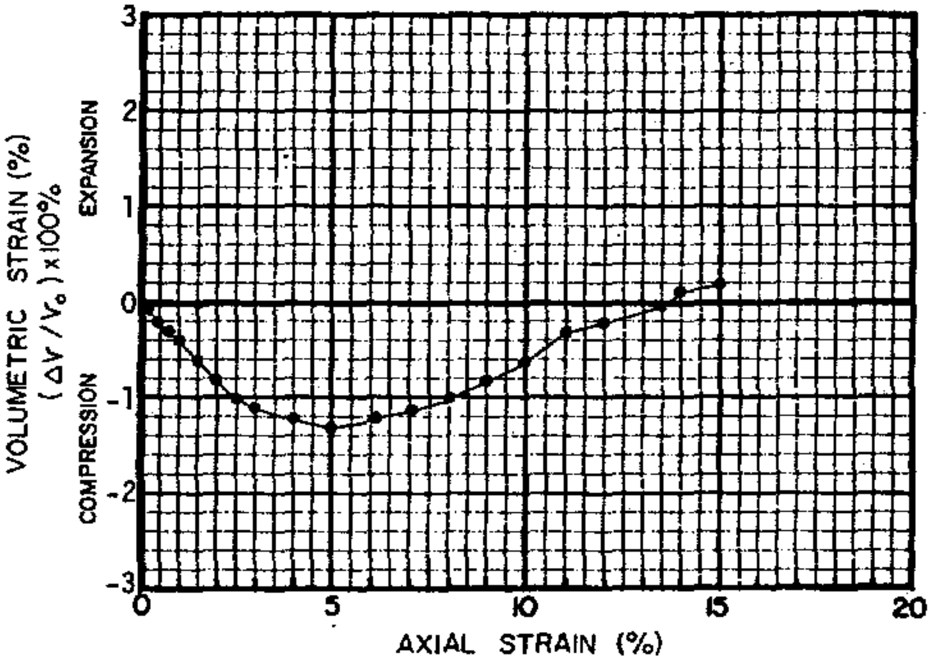
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DGB	4/82		





TYPE OF SPECIMEN Undisturbed			BEFORE TEST		AFTER TEST	
DIAMETER (in.) 2.87	HEIGHT (in.) 6.45	MOISTURE CONTENT	w_o	31.2 %	w_f	28.7 %
OVERBURDEN PRESS., P_o'	540 psf	VOID RATIO	e_o	0.886	e_f	0.799
CONSOLIDATION PRESS., σ_c'	1000 psf	SATURATION	S_o	96 %	S_f	100 %
STRAIN RATE --	%/min	DRY DENSITY	γ_d	90 pcf	γ_d	94 pcf

LL --	PL --	PI --	Gs 2.72
CLASSIFICATION SANDY SILT (ML)		SOURCE Boring 2 at 9.9'	

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JL	9612,031.08	DFB	4/82		

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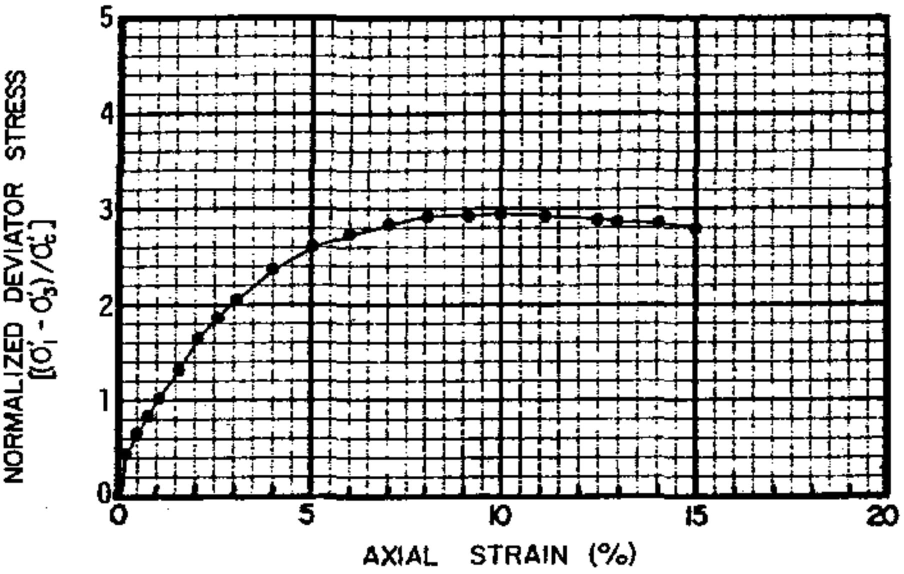

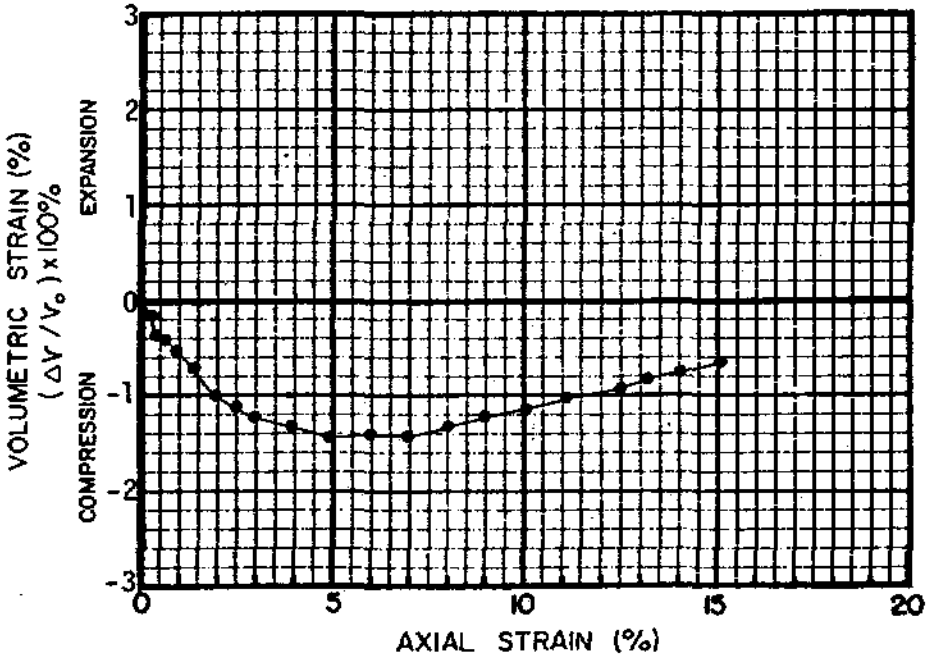

TYPE OF SPECIMEN Undisturbed			BEFORE TEST		AFTER TEST	
DIAMETER (in.) 2.87	HEIGHT (in.) 6.45	MOISTURE. CONTENT	w_o	29.0%	w_f	26.4 %
OVERBURDEN PRESS., P_o'	590 psf	VOID RATIO	e_o	0.806	e_f	0.718
CONSOLIDATION PRESS., σ_c'	2000 psf	SATURATION	S_o	98 %	S_f	100 %
STRAIN RATE --	%/min	DRY DENSITY	γ_d	94 pcf	γ_d	99 pcf
LL --	PL --	PI --	Gs 2.73			
CLASSIFICATION SANDY SILT (ML)		SOURCE Boring 2 at 10.7'				

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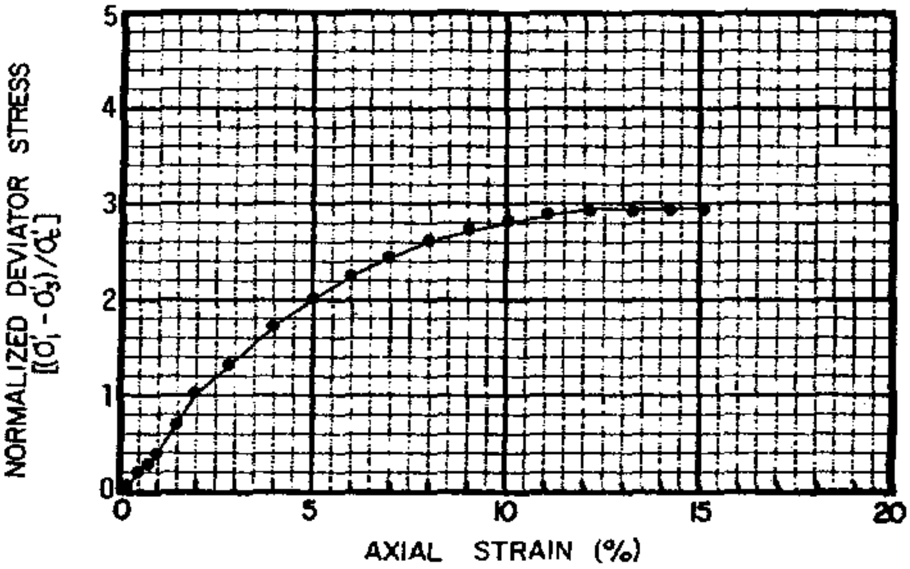
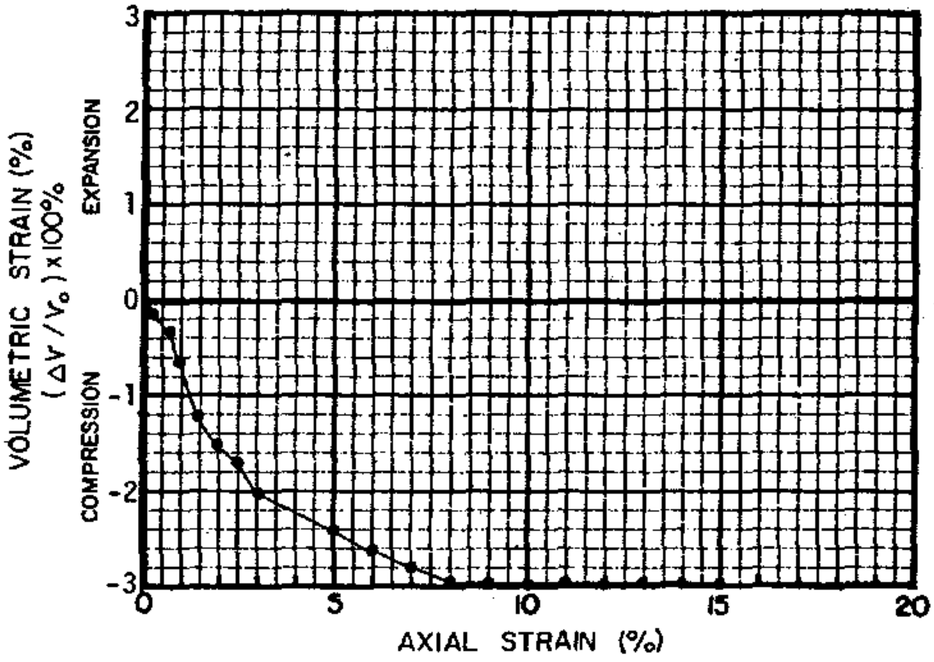
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JR	9612,031.08	DEB	4/82		





TYPE OF SPECIMEN Undisturbed		BEFORE TEST			AFTER TEST	
DIAMETER (in.) 2.87	HEIGHT (in.) 6.45	MOISTURE CONTENT	w_o	32.5%	w_f	27.8 %
OVERBURDEN PRESS., P_o'	620 psf	VOID RATIO	e_o	0.885	e_f	0.745
CONSOLIDATION PRESS., σ_c'	4000 psf	SATURATION	S_o	99%	S_f	100 %
STRAIN RATE	-- %/min	DRY DENSITY	γ_d	89 pcf	γ_d	96 pcf
LL --	PL --	PI --		G_s 2.69		
CLASSIFICATION SANDY SILT (ML)			SOURCE Boring 2 at 11.3'			

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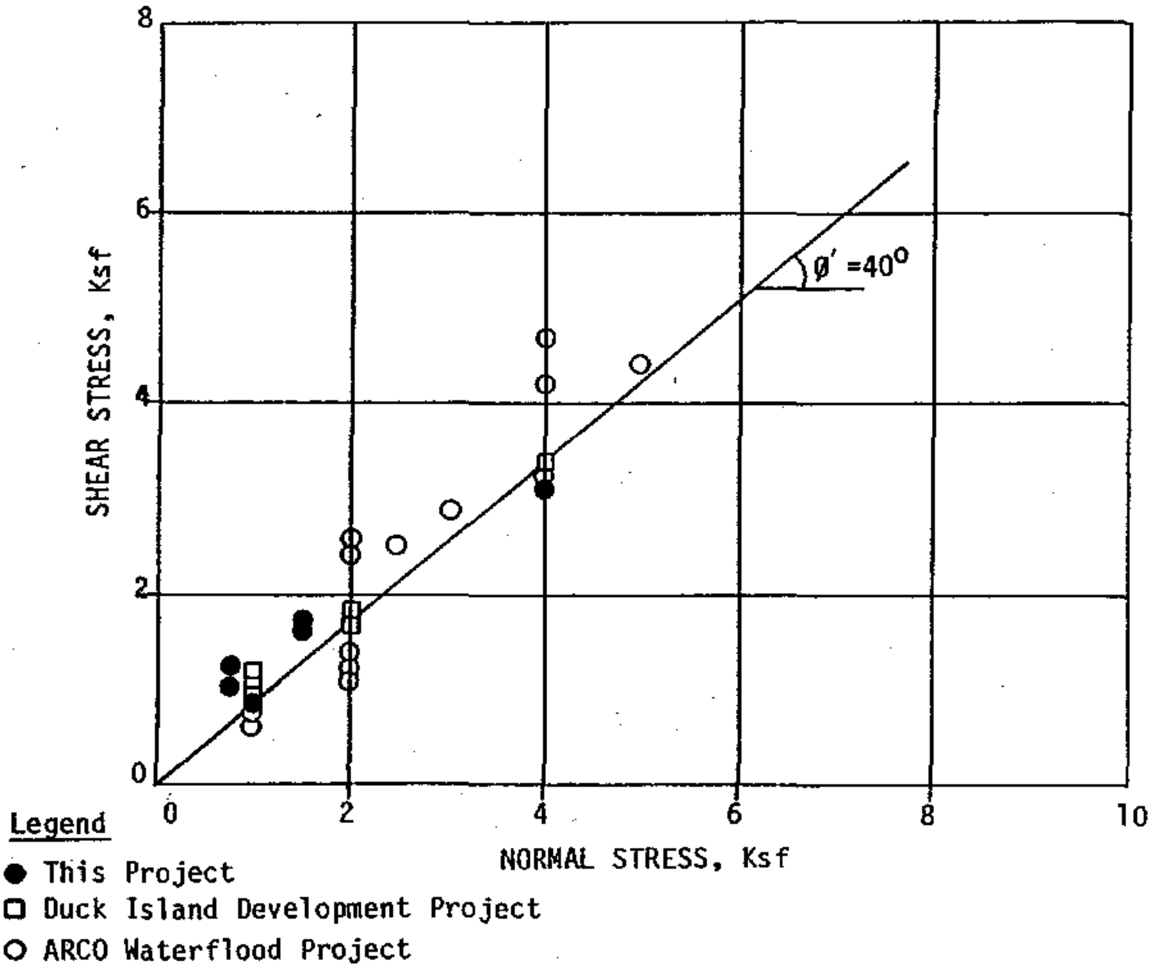
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		

Boring	Depth (Ft)	Test Number	USCS	Moisture Content (%)	Dry Density (pcf)	Normal Stress (pcf)	Maximum Shear (psf)	Ø_d* (degrees
4	1.8	A	SP	23.3	101	1000	880	39
		B	SP	22.0	102	4000	3320	39
21	0.5	A	SP-SM	20.3	102	750	1040	54
		B	SP-SM	22.2	102	1500	1680	48
21	2.0	A	SP-SM	20.7	104	750	1260	58
		B	SP-SM	20.9	106	1500	1730	49



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Direct Shear Test Report Summary

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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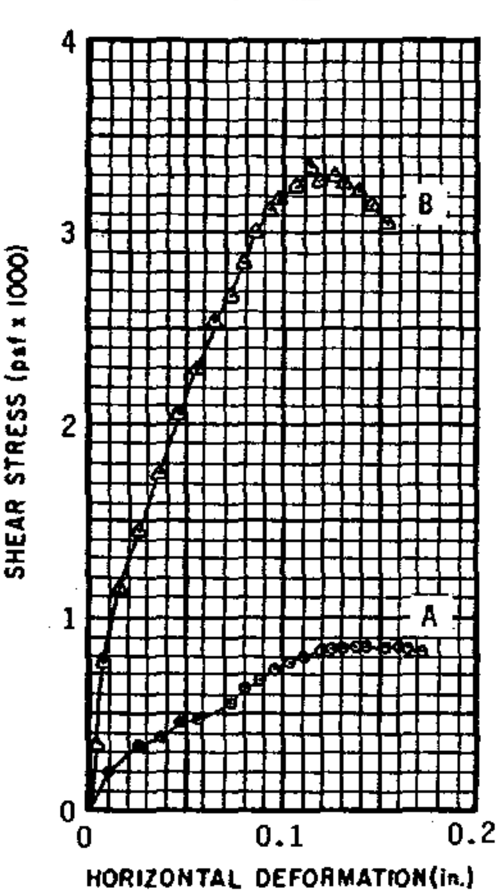

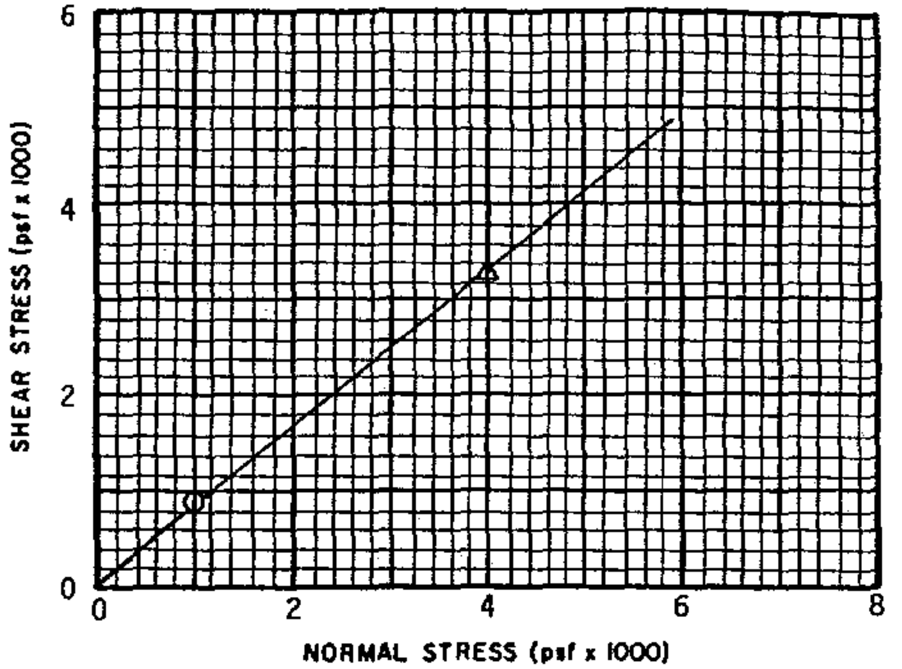

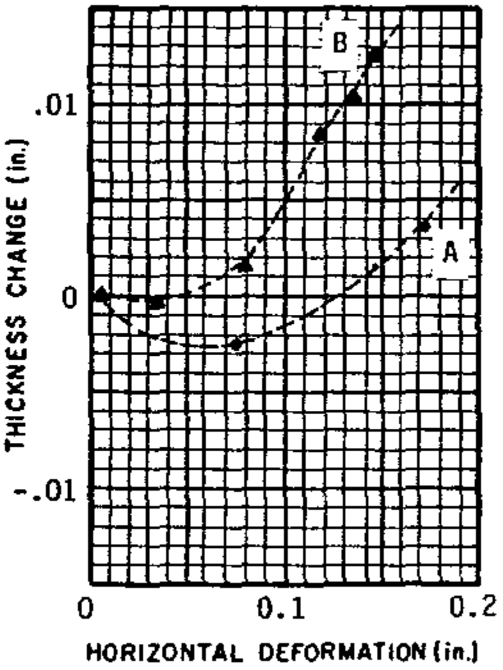

ø' = 40°
C' = 0 psf

Test Type: Consolidated Drained

Controlled Deflection

Gs 2.70

Test No.		A	B	C
Initial	Height (in.)	1.00	1.00	
	Moisture Content	23.3 %	22.0 %	%
	Void Ratio	0.674	0.649	
	Saturation	93 %	91 %	%
	Dry Density (pcf)	101	102	
Before Test	Time for 50% Consolidation (min.)	<1	<1	
	Time for 100% Consolidation (min.)	---	---	
	Void Ratio after Consolidation	0.599	0.612	
Final	Moisture Content	24.6 %	24.6 %	%
	Void Ratio	0.606	0.631	
	Saturation	100 %	94 %	%
Normal Stress (psf)		1000	4000	
Maximum Shear (psf)		880	3320	
Time to Failure (min.)		50	49	
Sample Source	Boring 4 at 1.8'			
Classification	SAND (SP)			

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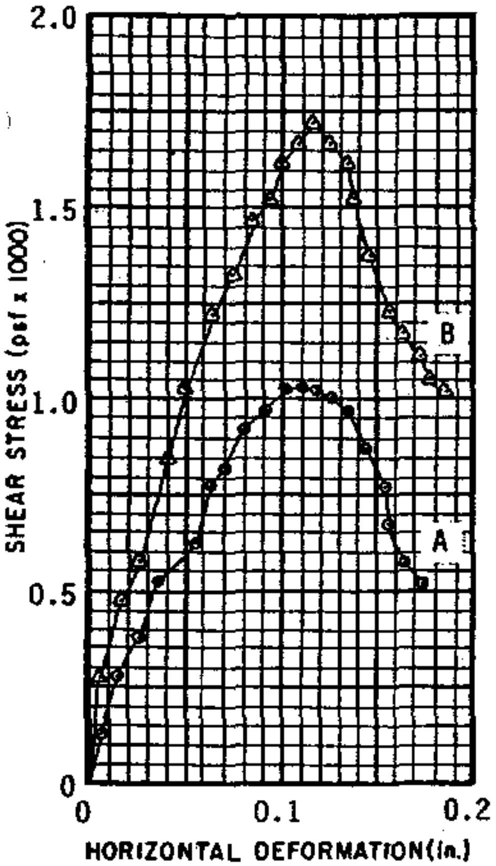
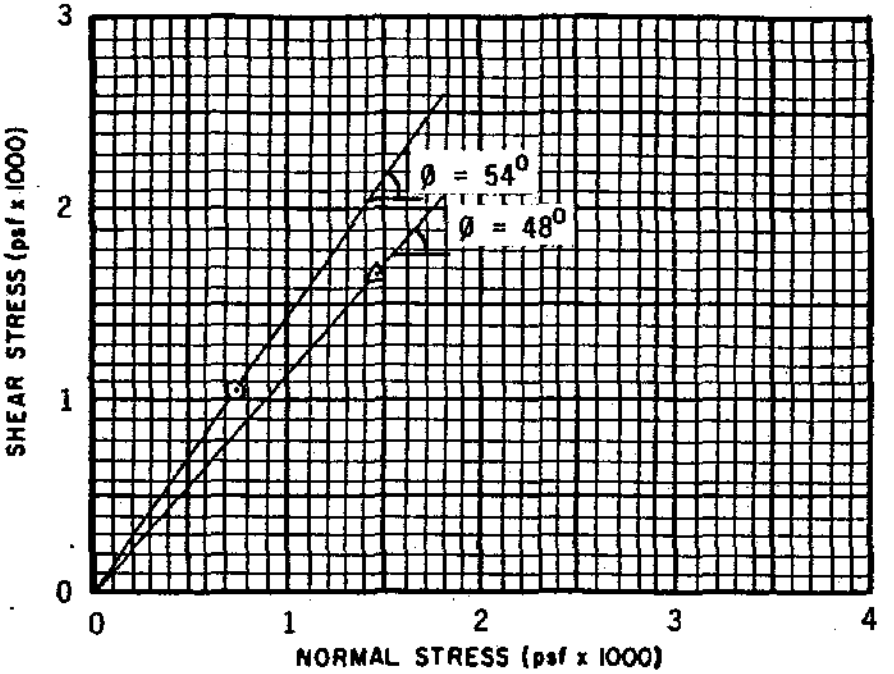
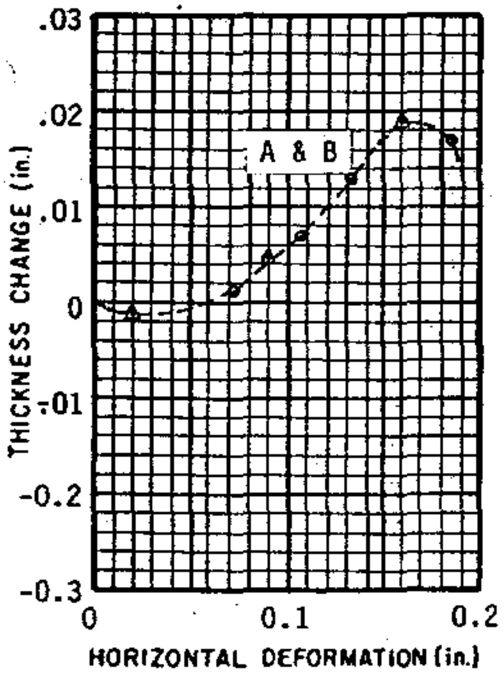
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DEB	4/82		







ϕ' =
c' = See Figure

Test Type: Consolidated Drained

Controlled Deflection

Gs 2.70

Test No.		A	B	C
Initial	Height (in.)	1.00	1.00	
	Moisture Content	20.3 %	22.2 %	%
	Void Ratio	0.587	0.656	
	Saturation	94 %	91 %	%
	Dry Density (pcf)	102	102	
Before Test	Time for 50% Consolidation (min.)	<1	<1	
	Time for 100% Consolidation (min.)	---	---	
	Void Ratio after Consolidation	0.555	0.623	
Final	Moisture Content	22.1 %	24.4 %	%
	Void Ratio	0.587	0.654	
	Saturation	94 %	92 %	%
Normal Stress (psf)		750	1500	
Maximum Shear (psf)		1040	1680	
Time to Failure (min.)		32	39	
Sample Source	Boring 21 at 0.5'			
Classification	SAND (SP-SM)			

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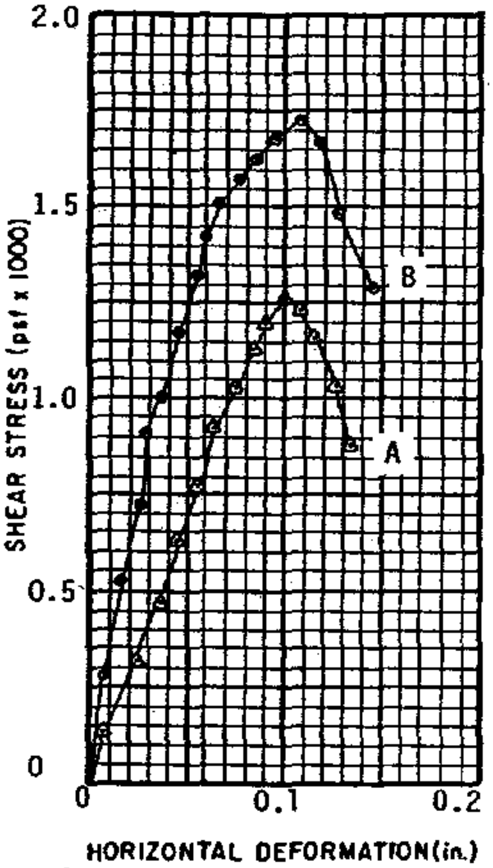
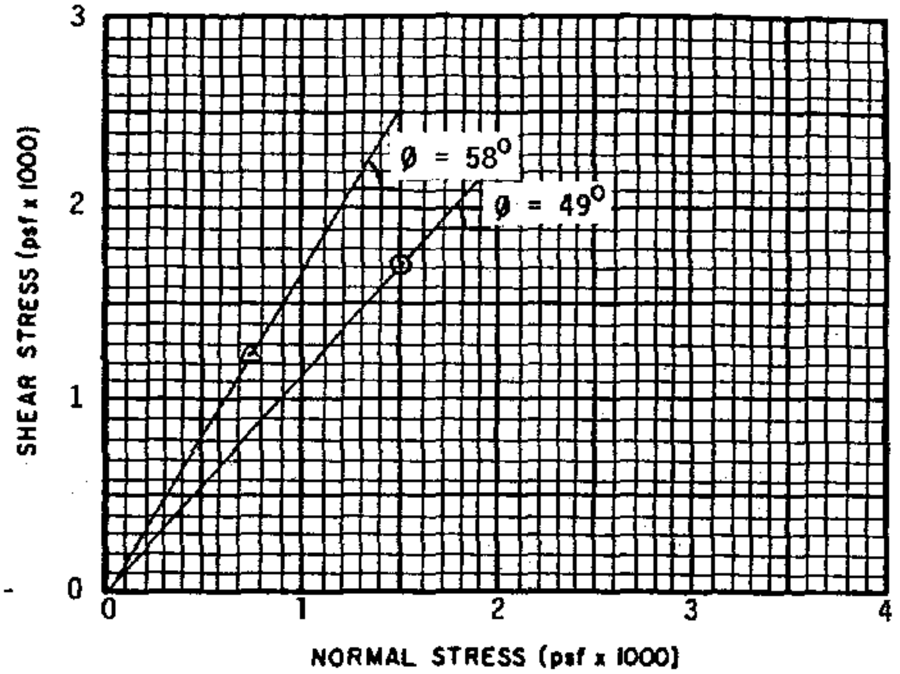
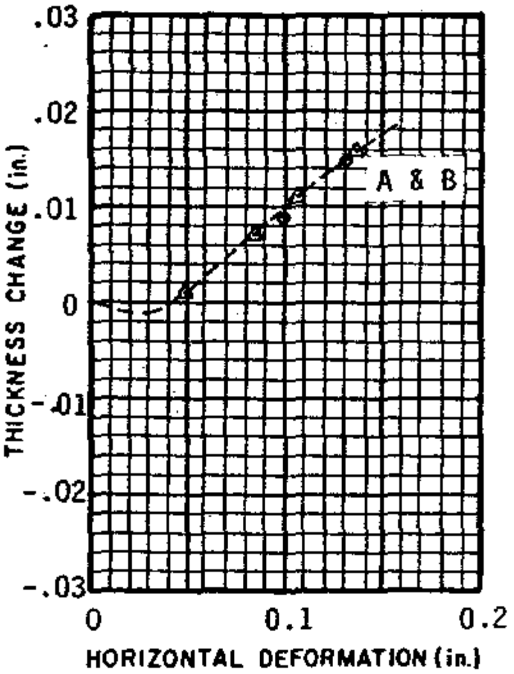
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
X	9612,031.08	DEB	4/82		







Ø' =
C' = See Figure

Test Type: Consolidated Drained

Controlled Deflection

G_s 2.72

Test No.		A	B	C
Initial	Height (in.)	1.00	1.00	
	Moisture Content	20.7. %	20.9 %	%
	Void Ratio	0.620	0.627	
	Saturation	90 %	90 %	%
	Dry Density (pcf)	104	106	
Before Test	Time for 50% Consolidation (min.)	<1	<1	
	Time for 100% Consolidation (min.)	---	---	
	Void Ratio after Consolidation	0.586	0.589	
Final	Moisture Content	22.7 %	23.1 %	%
	Void Ratio	0.610	0.617	
	Saturation	92 %	92%	%
Normal Stress (psf)		750	1500	
Maximum Shear (psf)		1260	1730	
Time to Failure (min.)		30	39	

Sample Source Boring 21 at 2.0'

Classification SAND (SP-SM)

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Direct Shear Test Report

Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
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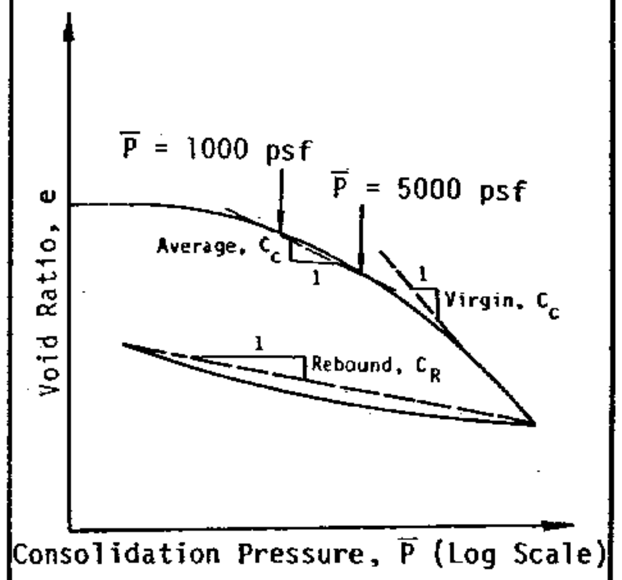
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
ℒ	9612,031.08	DEB	4/82		

Boring No.	Depth (ft)	USGS	Specific Gravity G_s	Initial Conditions			Compression Ratios			Time Rate		Permeability
				w (%)	γd (pcf)	e_o	C_{ε_c} average	C_{ε_c} virgin	C_{ε_R}	Load (psf)	$C_v \times 10^{-3}$ (cm^2/sec)	$k \times 10^{-7}$ (cm/sec)
2	0.1	SP	2.68	23.4	100	0.668	0.017	0.017	---	---	---	---
2	8.5	ML	2.68	26.3	100	0.680	0.022	0.055	0.007	4230 8470	56.6 83.1	2.5 2.6
2	14.1	ML	2.70	38.8	81	1.070	0.066	0.134	0.022	1060 2120	29.0 25.1	6.0 5.7
4	3.0	SM	2.69	27.1	97	0.734	0.036	0.084	0.009	4230 8470	153 112	11.8 5.7
4	13.0	OL	2.67	36.3	80	1.081	0.075	0.102	0.024	3200 6400	51.4 61.4	12.5 8.6
4	14.4	ML	2.70	48.7	72	1.335	0.099	0.150	0.024	3200 6400	15.4 23.6	7.5 6.8
4	18.8	CL	2.66	74.7	56	1.967	0.236	0.260	0.076	2120 4230	1.06 1.02	1.7 1.0
5	19.5	CL	2.72	36.6	87	0.964	0.057	0.094	0.014	2120 4230	37.5 26.8	8.0 3.9
6	3.6	ML	2.69	30.4	92	0.819	0.041	0.114	0.012	4230 8470	28.2 27.0	2.8 1.7
6	21.7	ML	2.73	23.1	107	0.599	0.018	0.041	0.008	4230 8470	39.0 38.6	1.4 0.9
8	12.8	ML	2.73	26.0	99	0.722	0.033	0.047	0.016	2120 4230	28.8 38.7	2.7 3.0
9	5.7	SM	2.72	32.1	90	0.894	0.044	0.109	0.017	3200 6400	69.6 68.0	6.5 5.8
9	9.7	ML	2.71	35.0	86	0.971	0.047	0.109	0.017	3200 6400	25.1 24.4	3.6 2.2
9	19.3	MH	2.66	80.4	53	2.134	0.212	0.212	0.029	800 1600	0.397 0.724	1.1 1.4
9	41.2	ML	2.73	32.8	91	0.869	0.029	0.116	0.020	3200 6400	39.2 19.2	2.6 1.2



Note:

Compression Ratio, $C_{\varepsilon_c} = \frac{C_c}{1+e_o}$

Recompression Ratio, $C_{\varepsilon_R} \doteq \frac{C_R}{1+e_o}$

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D-120

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08		4/82		

E. Consolidation Testing of Unfrozen Offshore Materials

One-dimensional consolidation tests were performed on representative samples of fine-grained soil to evaluate the stress history, compressibility, and permeability of the soil. Information from the consolidation tests can be used to evaluate immediate and long-term settlements and to determine the response of the soil due to loading.

The consolidation tests were performed on 2.43-inch diameter by 0.8-inch-high samples. However, in both sequences each load increment was double the previous load. Different loading sequences were used for mechanical and pneumatic consolidometers. For mechanical consolidometers, the initial applied load was 130 psf and the maximum load was 33,870 psf. For pneumatic consolidometers, the initial load was 100 psf and the maximum load was 51,200 psf. A short loading period of 100 minutes was used in both cases because of the high permeability of the soils tested (Hsuan-Loh Su, 1958). In general, the end of primary consolidation occurred at approximately 5 minutes, and the soil samples experienced more than 200 minutes of secondary compression. Two time rate of compression readings were taken for each test to approximate the existing and anticipated overburden pressures. These data were then used to analyze the coefficient of consolidation.

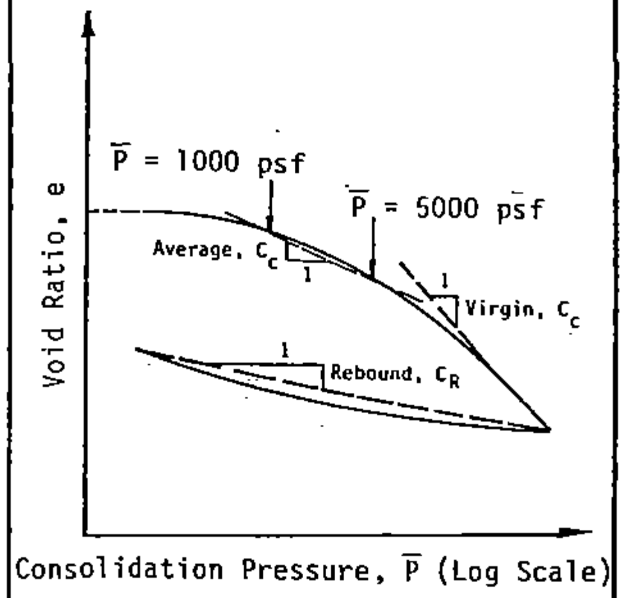
The consolidation data show that the transition from the recompression to the virgin portions of the consolidation curves is not well defined. Therefore, preconsolidation pressures are very difficult to determine from these curves. However, these non-linear plots of void ratio versus the log of pressure are a characteristic of the silty soils found in the Beaufort Sea (HLA/USGS, 1979).

Although the fine-grained sediments within the project area appear to be overconsolidated, the amount of overconsolidation varies considerably. Overconsolidated fine-grained soils are commonly encountered in the Prudhoe Bay region; the overconsolidation was probably caused by freezing and thawing (Selmann, 1979). Physico-chemical effects resulting from the interaction of organic and inorganic compounds in a marine environment could also be partially responsible for the high over-consolidation ratios (More, 1977).

Three compression indexes have been determined for this project: 1) average compression ratio, 2) virgin compression ratio, and 3) recompression index. These indexes are defined on Plate D-120. Only the average compression ratio was used in the settlement analyses. It was calculated for the range of pressures between 1000 psf and 5000 psf, and reflects the current average effective overburden pressure and the estimated effective pressure that may result from construction and development.

In predicting the rate of settlement, it is necessary to know the coefficient of consolidation, C_v. This parameter relates the decrease in volume of the soil with pressure and time. The coefficients of consolidation were determined by the square root of time curve fitting technique (Taylor, 1948). Because the first three points on the square root versus deformation plots were generally nonlinear, interpretation was required to determine C_v; this generally yields smaller values of C_v. Some of the samples tested were still in the rebound portion of the curve at the design stresses; hence, the settlement is not completely time dependent, and larger values of C_v result. We believe these factors tend to offset each other.

Boring No.	Depth (ft)	USGS	Specific Gravity G_s	Initial Conditions			Compression Ratios			Time Rate		Permeability
				w (%)	γd (pcf)	e_o	$C\epsilon_c$ average	$C\epsilon_c$ virgin	$C\epsilon_R$	Load (psf)	$C_v \times 10^{-3}$ (cm^2/sec)	$k \times 10^{-7}$ (cm/sec)
14	6.3	ML	2.71	33.1	89	0.911	0.057	0.220	0.047	1600 3200	29.0 28.7	3.8 1.9
14	16.8	CL	2.75	19.5	112	0.532	0.020	0.051	0.023	8470 16940	5.2 7.6	0.2 0.2
15	5.2	ML	2.65	40.5	81	1.034	0.080	0.102	0.024	2120 4230	7.0 5.5	2.0 1.3
15	26.8	ML	2.69	21.5	106	0.586	0.026	0.044	0.007	4230 8470	21.5 24.1	1.3 0.8
17	3.5	CL-ML	2.71	32.6	90	0.877	0.038	0.111	0.033	4230 8470	33.4 38.2	2.8 3.2
17	35.7	CL	2.78	23.9	103	0.678	0.013	0.050	0.045	6400 12800	14.2 7.1	0.4 0.2
21	3.3	CL	2.76	20.1	111	0.552	0.021	0.039	0.012	4230 8470	8.2 13.4	0.3 0.4
21	27.8	ML	2.81	27.0	100	0.758	0.034	0.063	0.011	1600 3200 6400 12800	15.3 18.9 18.4 23.0	2.1 1.7 1.1 0.9



Note:

Compression Ratio, $C\epsilon_c = \frac{C_c}{1+e_o}$

Recompression Ratio, $C\epsilon_R = \frac{C_R}{1+e_o}$

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Winter 1982, Geotechnical Study
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PLATE
D-121

DRAWN JP
JOB NUMBER 9612,031.08
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DATE

A summary of the test results is presented on Plates D-120 and D-121. A reasonable correlation between the compression and recompression ratios with the dry density is established as shown on Plate IV-20. A similar correlation between the coefficient of consolidation and dry density is presented on Plate IV-21. Results of the individual tests are presented on Plates D-122 through D-144.

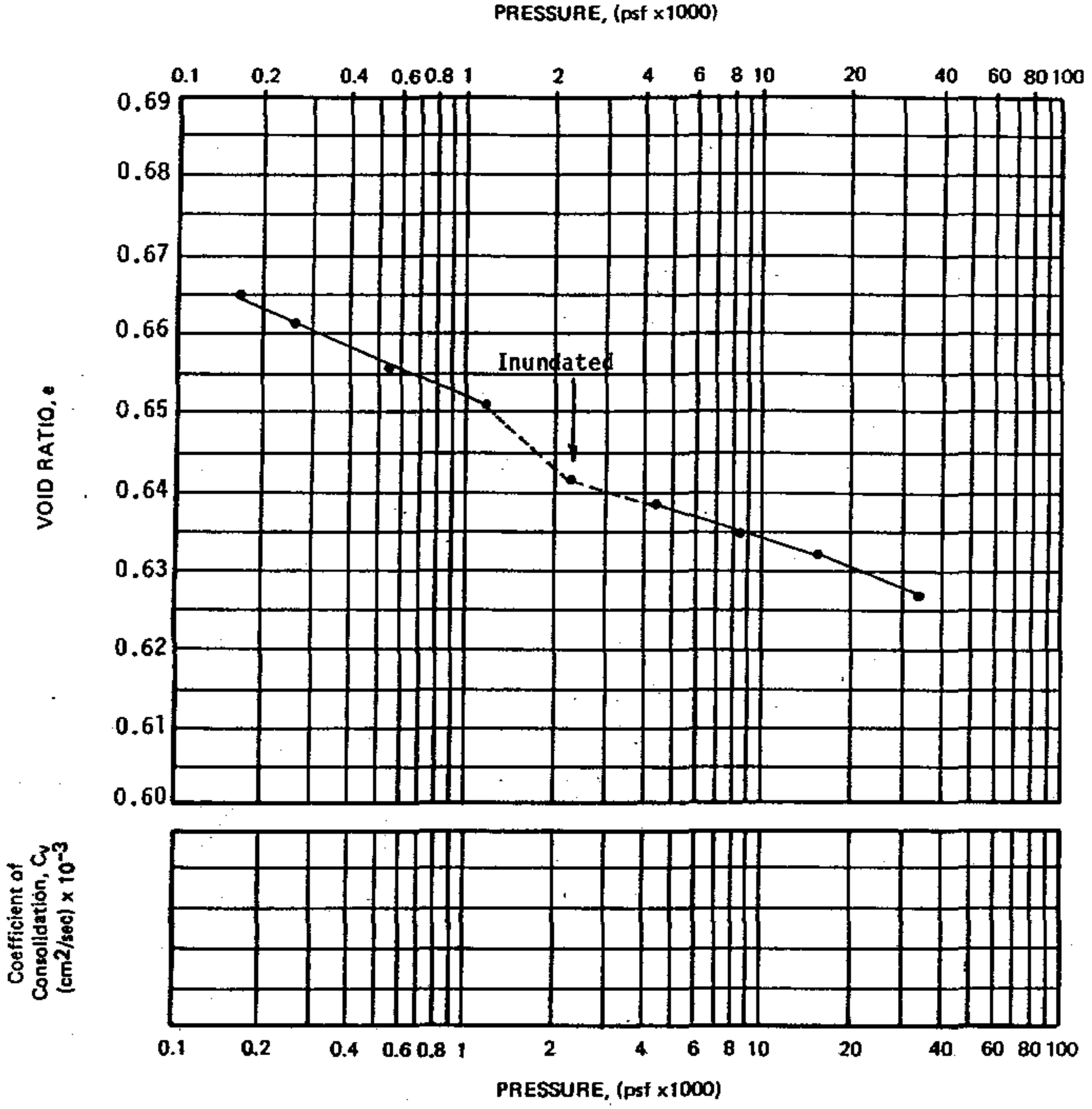
Coefficients of secondary compression were also determined from the consolidation tests. Typical plots of deformation versus log of time are presented on Plate D-145. The values shown on these graphs are representative of those obtained throughout the testing program.

F. Dredged Fill Properties of Offshore Materials

The settling rate of gravel specimen was conducted to determine the settling rate of potential gravel fill material that is dumped into sea water.

Salt water was prepared by mixing distilled water and salt to a salinity of 35 parts per thousand (Weast, 1977). The soil was then mixed with the salt water at a ratio of four parts salt water to one part soil. After mixing, the slurry was poured into a glass cylinder that was partially filled with salt water and the cylinder was agitated for one minute to mix the solution.

The sand/gravel particles settled within 30 seconds of the beginning of the test. The silt continued to settle for about 120 minutes; at the end of the test, less than 0.1 inch of sediments had accumulated.



TYPE OF SPECIMEN Undisturbed		BEFORE TEST			AFTER TEST		
DIAMETER(in) 2.43	HEIGHT(in.) 0.80	MOISTURE CONTENT	w_o	23.4 %	w_f	21.0 %
OVERBURDEN PRESS., σ'_{vo}	0 psf	VOID RATIO	e_o	0.668	e_f	0.624
PRECONSOL PRESS.,(σ'_{vo}) max	-- psf	SATURATION	S_o	94 %	S_f	100 %
COMPRESSION INDEX,C_c	0.017	DRY DENSITY	γ_d	100 pcf	γ_d	103 pcf

LL --	PL --	PI --	G_s 2.68

CLASSIFICATION SAND (SP)	SOURCE Boring 2 at 0.1'

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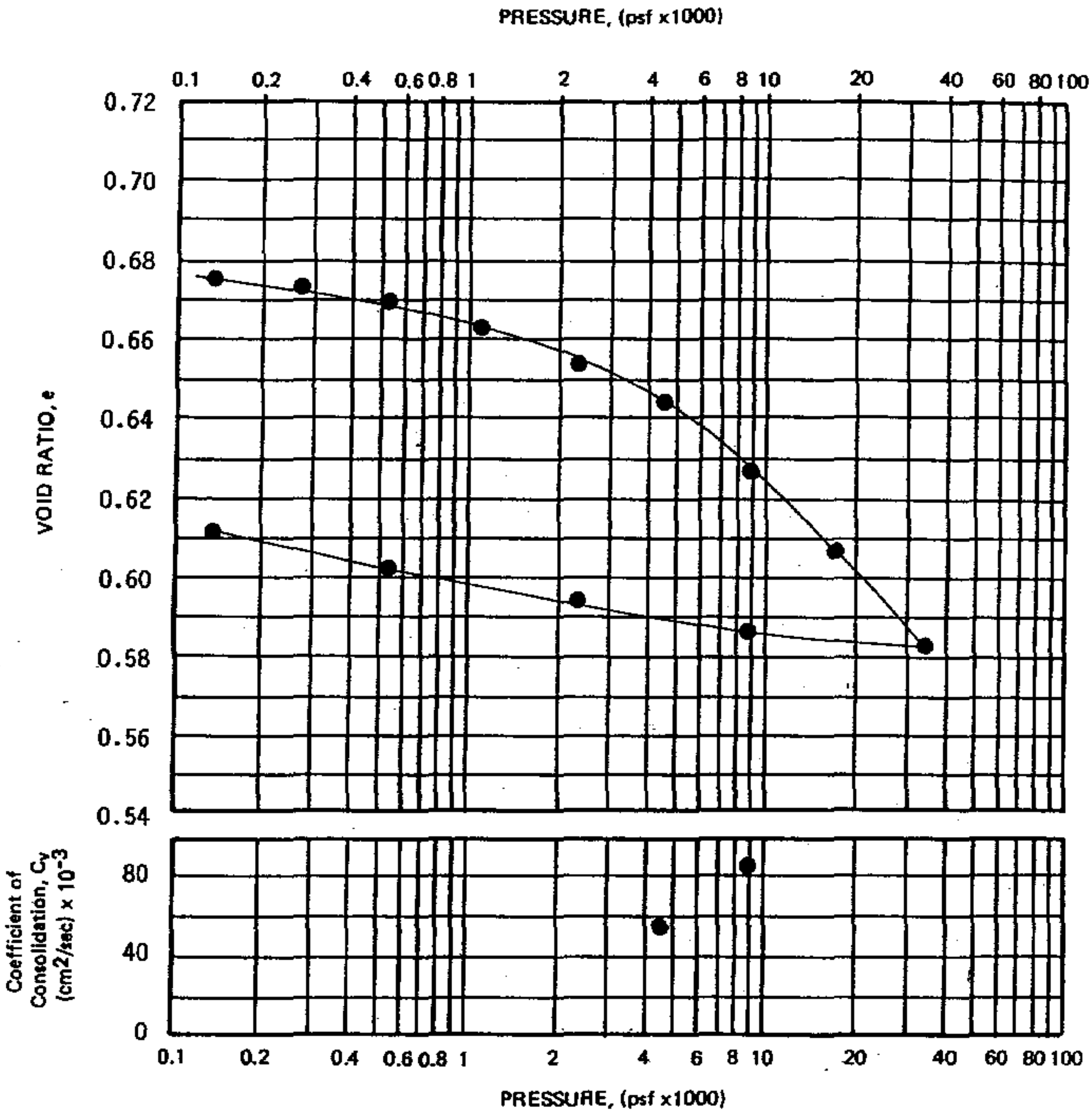
PLATE
D-122

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JR	9612,031.08	DEB	4/82		



TYPE OF SPECIMEN	Undisturbed (trimmed)			BEFORE TEST			AFTER TEST	
DIAMETER(in)	2.43	HEIGHT(in.)	0.80	MOISTURE CONTENT	w_o	26.3 %	w_f	22.6 %
OVERBURDEN PRESS., σ'_{vo}	470 psf			VOID RATIO	e_o	0.680	e_f	0.611
PRECONSOL PRESS.,(σ'_{vo}) max	--- psf			SATURATION	S_o	104 %	S_f	99 %
COMPRESSION INDEX,C_c	0.092			DRY DENSITY	γ_d	100 pcf	γ_d	104 pcf
LL	---	PL	---	PI	---	G_s	2.68	
CLASSIFICATION	SANDY SILT (ML)			SOURCE	Boring 2 at 8.5'			

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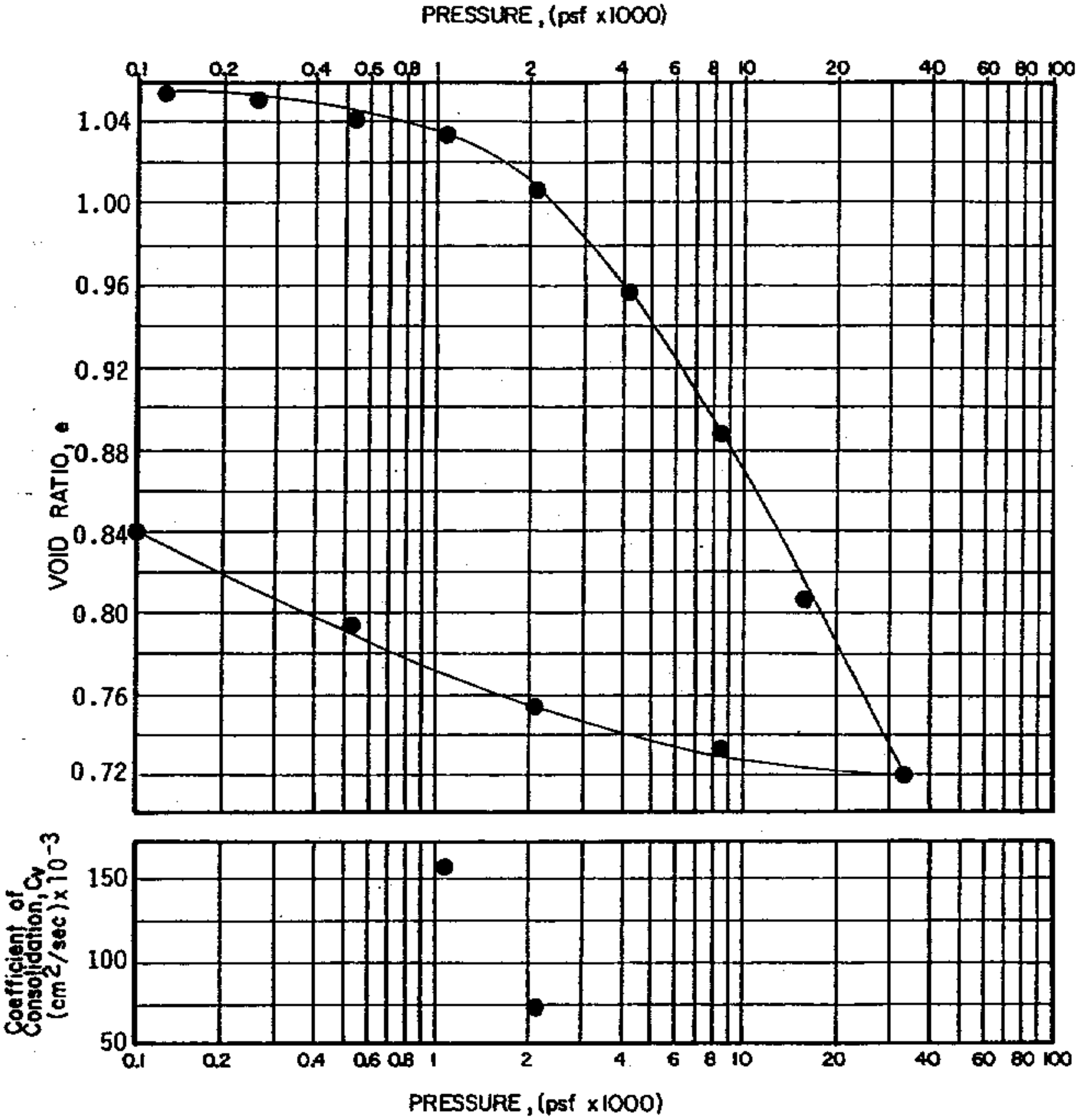
PLATE
D-123

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612.031.08		4/82		



TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in) 0.80	MOISTURE CONTENT	w_o	38.8 %	w_f	31.2 %
OVERBURDEN PRESS.,σ_{vo}' 780 psf		VOID RATIO	e_o	1.070	e_f	0.840
PRECONSOL PRESS.,$(\sigma_{vo}')_{max}$ -- psf		SATURATION	S_o	98 %	S_f	100 %
COMPRESSION INDEX,C_c 0.277		DRY DENSITY	γ_d	81 pcf	γ_d	92 pcf
LL --	PL --	PI --		G_s 2.70		
CLASSIFICATION SANDY SILT (ML)		SOURCE Boring 2 at 14.1'				

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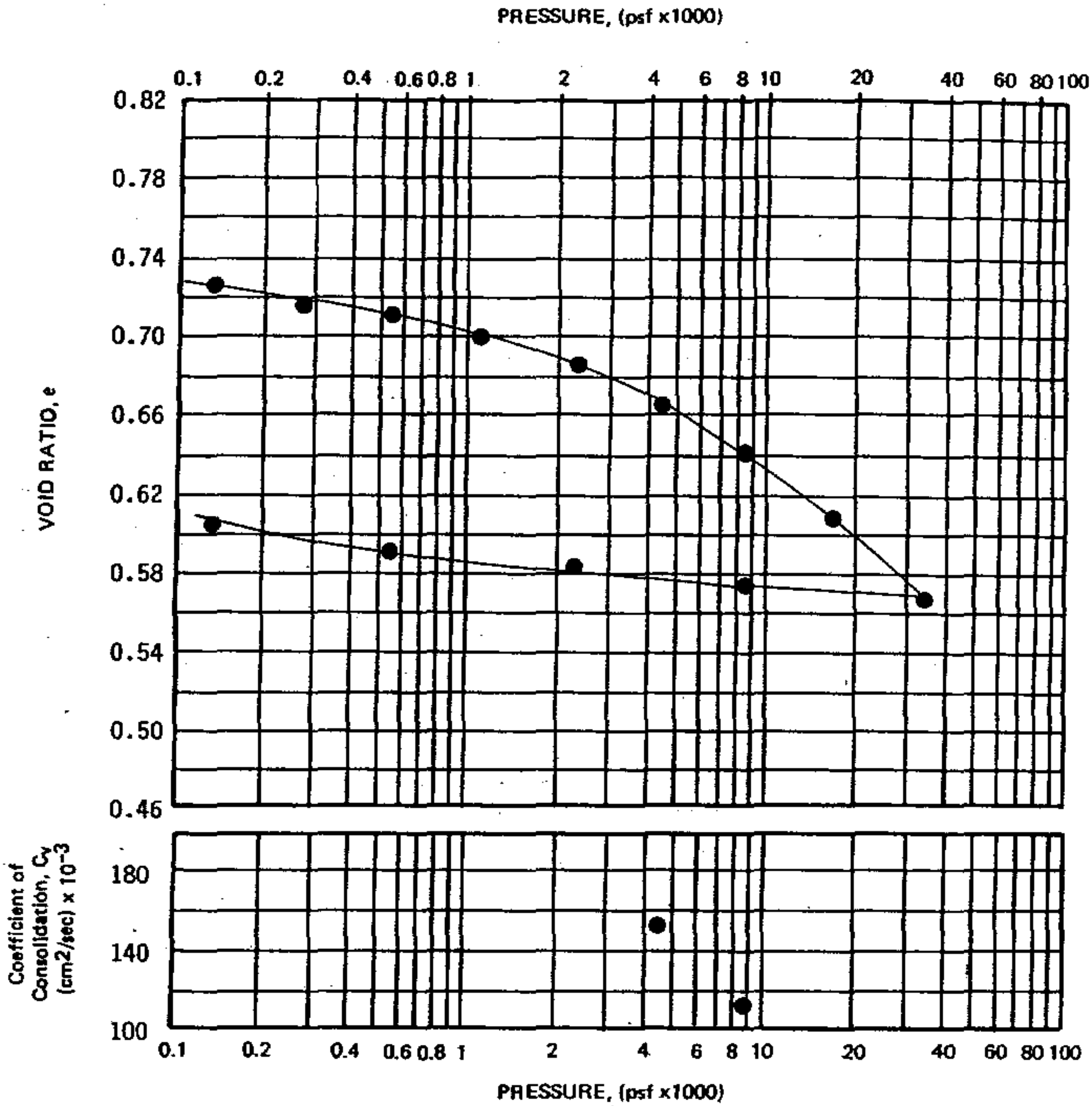
PLATE
D-124

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08		4/82		



TYPE OF SPECIMEN	Undisturbed (trimmed)	BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in.) 0.80	MOISTURE CONTENT	w_o	27.1 %	w_f	22.6 %
OVERBURDEN PRESS., σ'_{vo}	170 psf	VOID RATIO	e_o	0.734	e_f	0.604
PRECONSOL PRESS., (σ'_{vo}) max	-- psf	SATURATION	S_o	99 %	S_f	101 %
COMPRESSION INDEX, C_c	0.145	DRY DENSITY	γ_d	97 pcf	γ_d	105 pcf

LL --	PL --	PI --	G_s 2.69

CLASSIFICATION SILTY SAND (SM)	SOURCE Boring 4 at 3.0'

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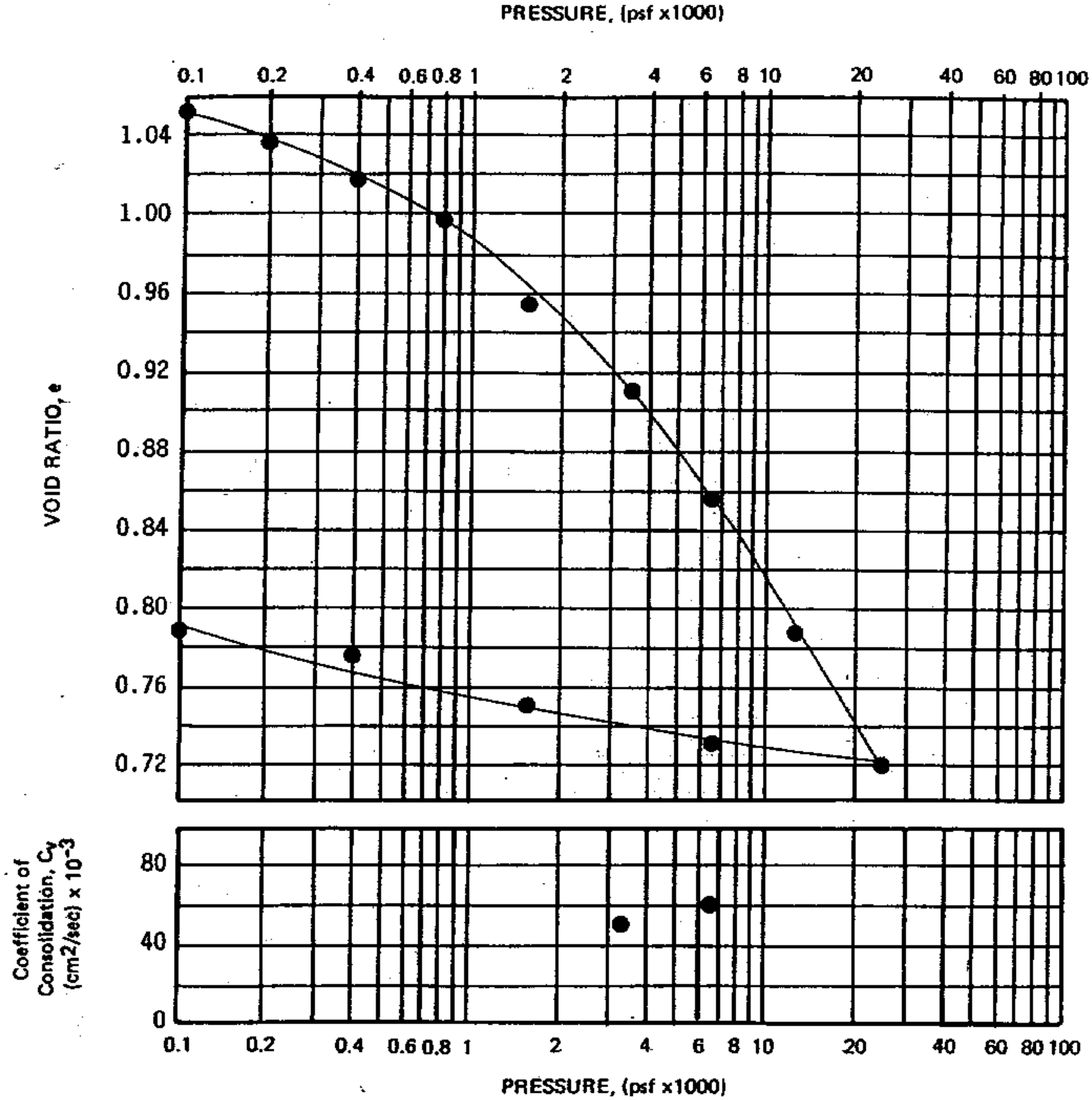
PLATE
D-125

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JY	9612,031.08	DEB	4/82		



TYPE OF SPECIMEN	Undisturbed(trimmed)			BEFORE TEST			AFTER TEST	
DIAMETER(in)	2.43	HEIGHT(in.)	0.80	MOISTURE CONTENT	w_o	36.3 %	w_f	29.5 %
OVERBURDEN PRESS., σ'_{vo}	720 psf			VOID RATIO	e_o	1.081	e_f	0.787
PRECONSOL PRESS.,(σ'_{vo}) max	-- psf			SATURATION	S_o	90 %	S_f	100 %
COMPRESSION INDEX,C_c	0.213			DRY DENSITY	γ_d	80 pcf	γ_d	93 pcf

LL	--	PL	--	PI	--	G_s	2.67

CLASSIFICATION ORGANIC SILT (OL)

SOURCE Boring 4 at 13.0'

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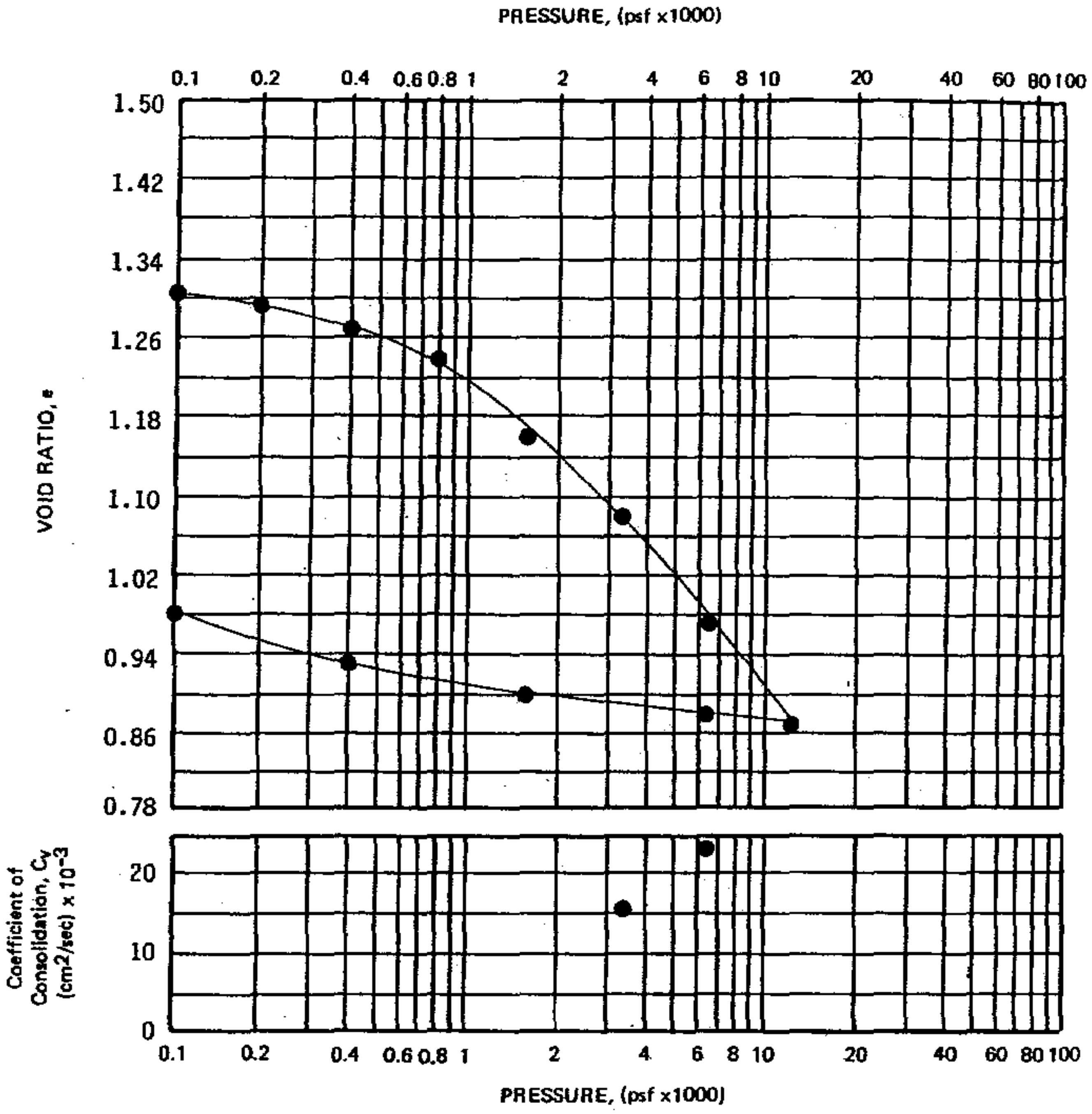

TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in.) 0.80	MOISTURE CONTENT	w_o	48.7 %	w_f	36.8 %
OVERBURDEN PRESS., σ'_{vo} 790 psf		VOID RATIO	e_o	1.335	e_f	0.982
PRECONSOL PRESS.,(σ'_{vo}) max -- psf		SATURATION	S_o	99 %	S_f	101 %
COMPRESSION INDEX, C_c 0.350		DRY DENSITY	γ_d	72 pcf	γ_d	85 pcf

LL --	PL --	PI --	G_s 2.70
CLASSIFICATION SILT (ML)		SOURCE Boring 4 at 14.4'	

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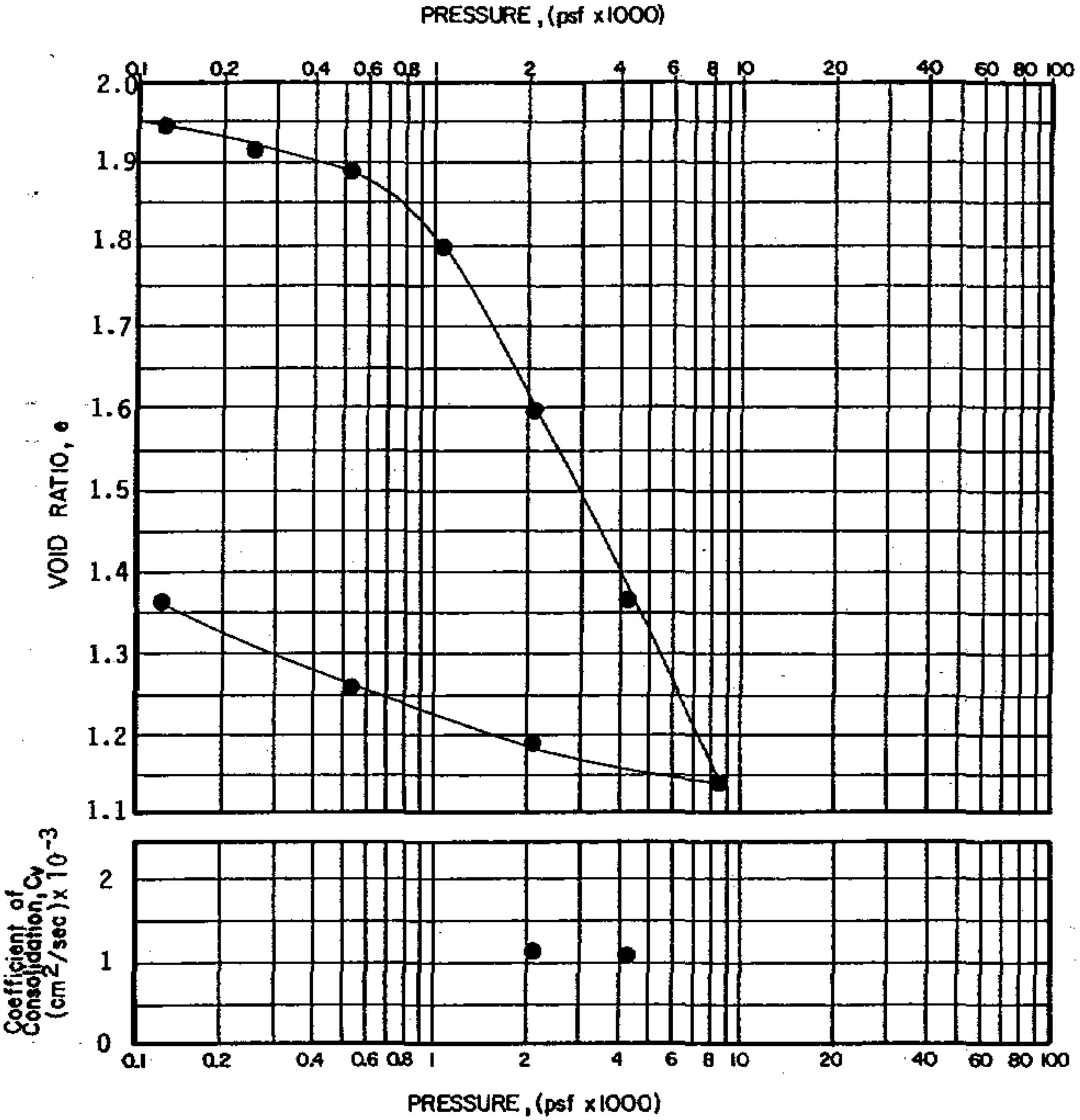
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DWB	4/82		



TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in) 0.80	MOISTURE CONTENT	w_o	74.7 %	w_f	50.4 %
OVERBURDEN PRESS., σ'_{vo} 1030 psf		VOID RATIO	e_o	1.967	e_f	1.364
PRECONSOL PRESS., $(\sigma'_{vo})_{max}$ -- psf		SATURATION	S_o	100 %	S_f	100 %
COMPRESSION INDEX, C_c 0.770		DRY DENSITY	γ_d	56 pcf	γ_d	70 pcf
LL --	PL --	PI --		G_s 2.66		
CLASSIFICATION CLAY (CL)		SOURCE Boring 4 at 18.8'				

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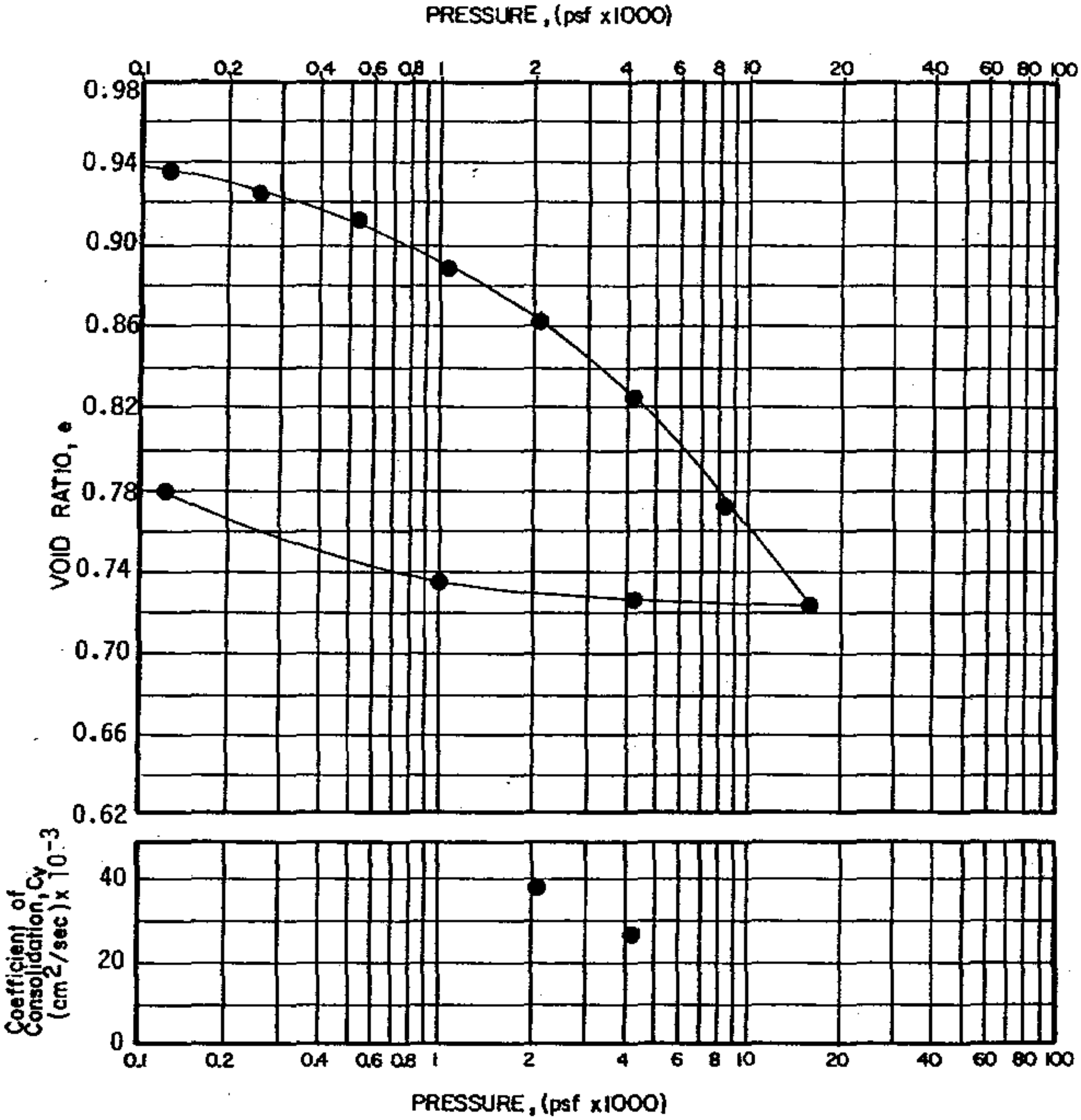
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JR	9612,031.08	DES	4/82		



TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in) 0.80	MOISTURE CONTENT	w_o	36.6 %	w_f	29.4 %
OVERBURDEN PRESS., σ_{vo}'	1070 psf	VOID RATIO	e_o	0.964	e_f	0.780
PRECONSOL PRESS., $(\sigma_{vo}')_{max}$	-- psf	SATURATION	S_o	100 %	S_f	100 %
COMPRESSION INDEX, C_c	0.185	DRY DENSITY	γ_d	87 pcf	γ_d	96 pcf

LL 31	PL 21	PI 10	G_s 2.72
CLASSIFICATION SILTY CLAY (CL)		SOURCE Boring 5 at 19.5'	

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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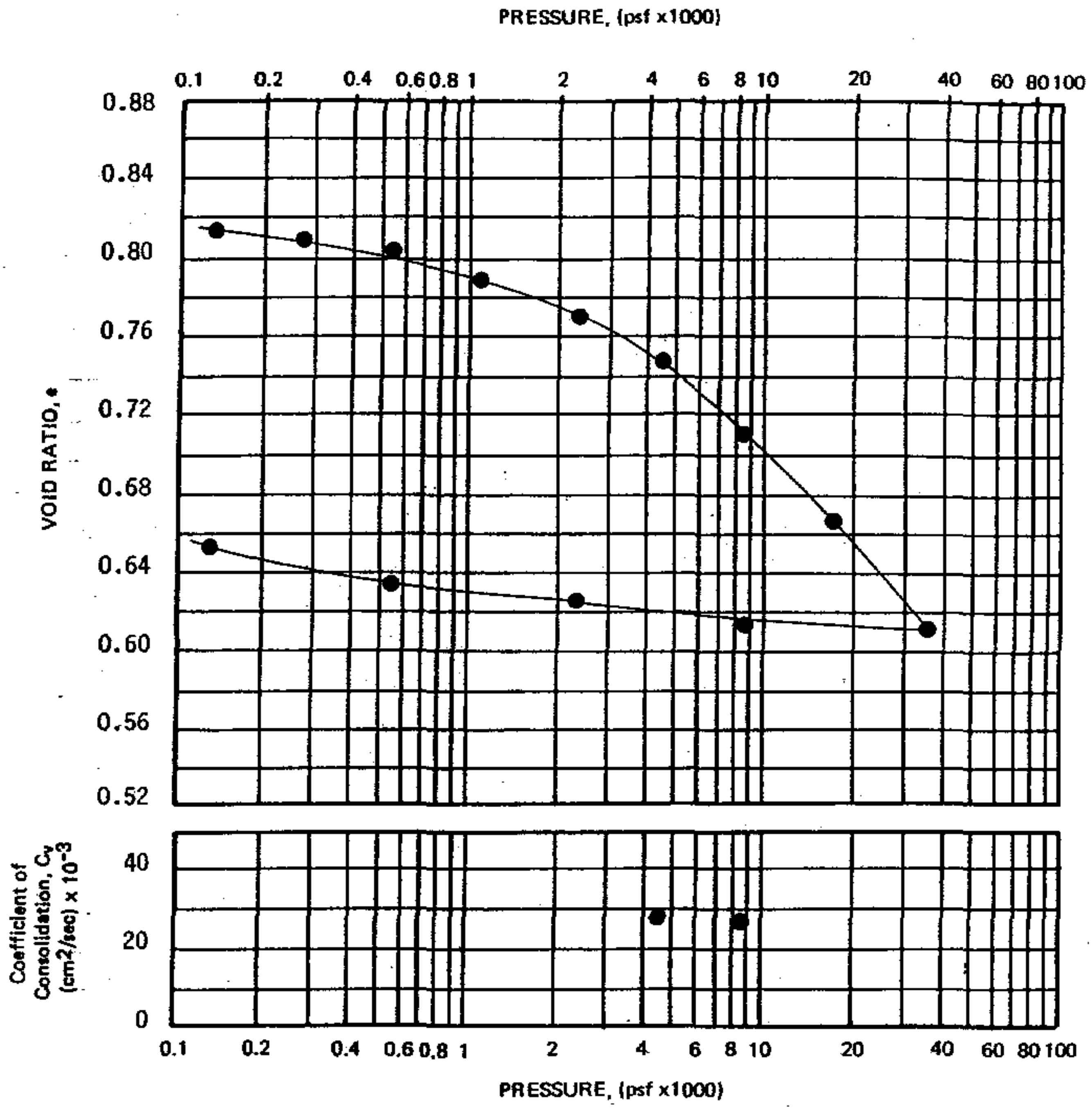

TYPE OF SPECIMEN Undisturbed (trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in.) 0.80	MOISTURE CONTENT	w_o	30.4 %	w_f	24.4 %
OVERBURDEN PRESS., σ'_{vo} 200 psf		VOID RATIO	e_o	0.819	e_f	0.655
PRECONSOL PRESS.,(σ'_{vo}) max -- psf		SATURATION	S_o	100 %	S_f	100 %
COMPRESSION INDEX,C_c 0.209		DRY DENSITY	γ_d	92 pcf	γ_d	101 pcf

LL --	PL --	PI --	G_s 2.69

CLASSIFICATION SANDY SILT (ML)

SOURCE Boring 6 at 3.6'

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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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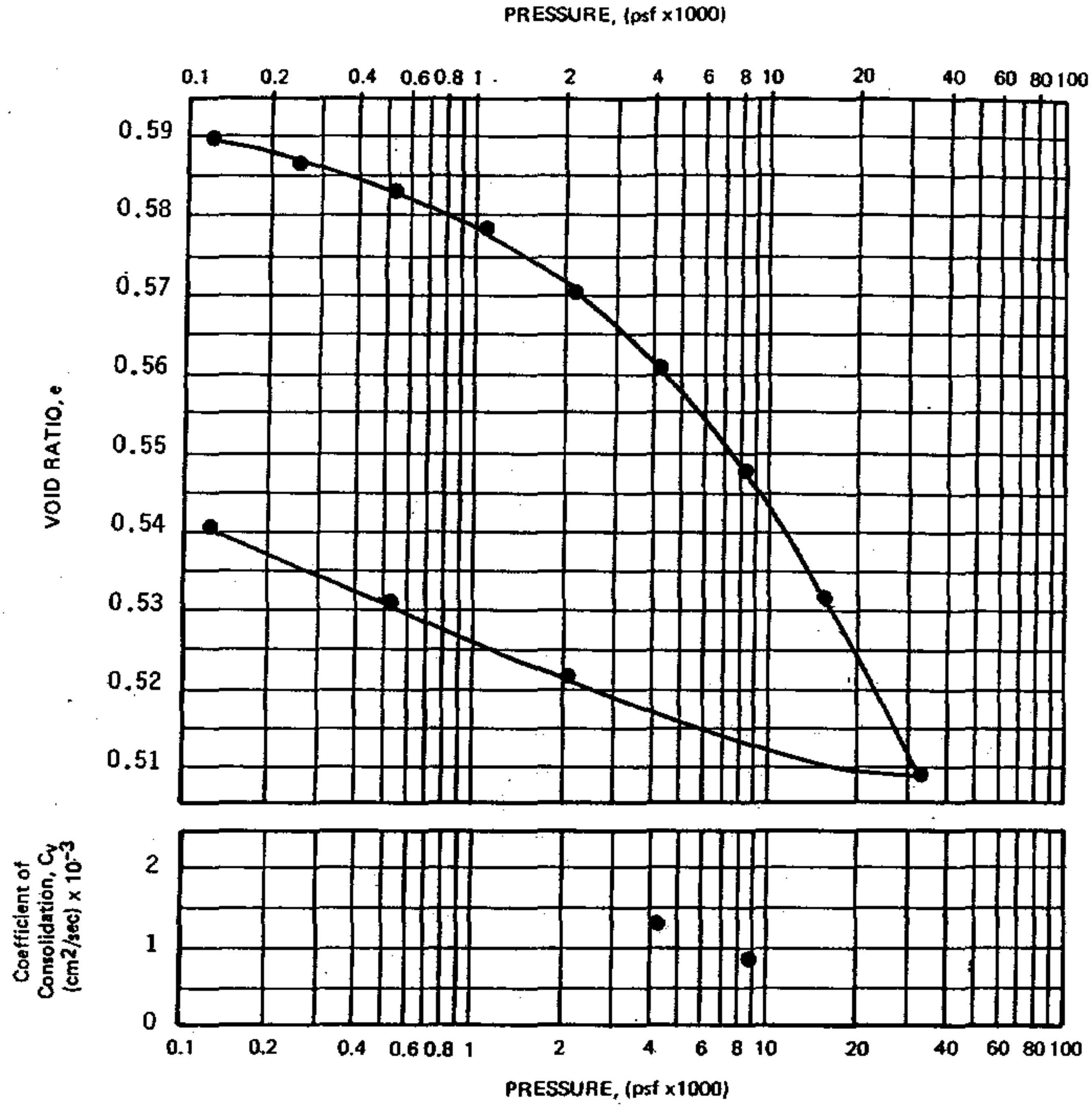

TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in.) 0.80	MOISTURE CONTENT	w_o	23.1 %	w_f	19.8 %
OVERBURDEN PRESS., σ'_{vo} 1190 psf		VOID RATIO	e_o	0.599	e_f	0.541
PRECONSOL PRESS.,(σ'_{vo}) max --- psf		SATURATION	S_o	100 %	S_f	100 %
COMPRESSION INDEX,C_c 0.066		DRY DENSITY	γ_d	107 pcf	γ_d	111 pcf

LL 29	PL 24	PI 5	G_s 2.73
CLASSIFICATION SANDY SILT (ML)		SOURCE Boring 6 at 21.7'	

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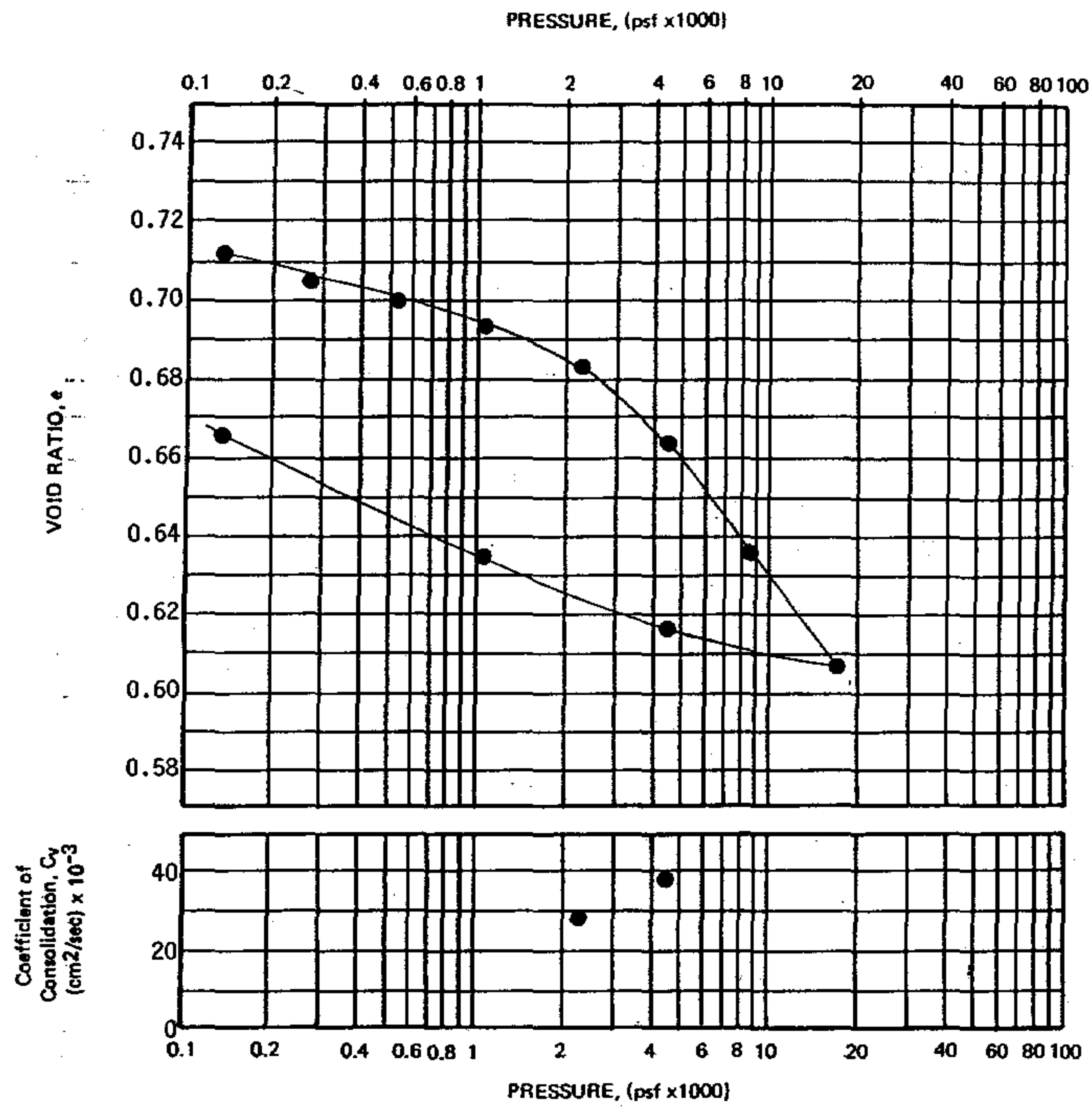
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		



TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in.) 0.80	MOISTURE CONTENT	w_o	26.0 %	wf	24.4 %
OVERBURDEN PRESS., σ'_{vo}	700 psf	VOID RATIO	e_o	0.722	ef	0.666
PRECONSOL PRESS.,(σ'_{vo}) max	-- psf	SATURATION	S_o	98 %	S_f	100 %
COMPRESSION INDEX,C_c	0.081	DRY DENSITY	γ_d	99 pcf	γ_d	102 pcf
LL --	PL --	PI --	G_s 2.73			
CLASSIFICATION SILT (ML)		SOURCE Boring 8 at 12.8'				

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PLATE
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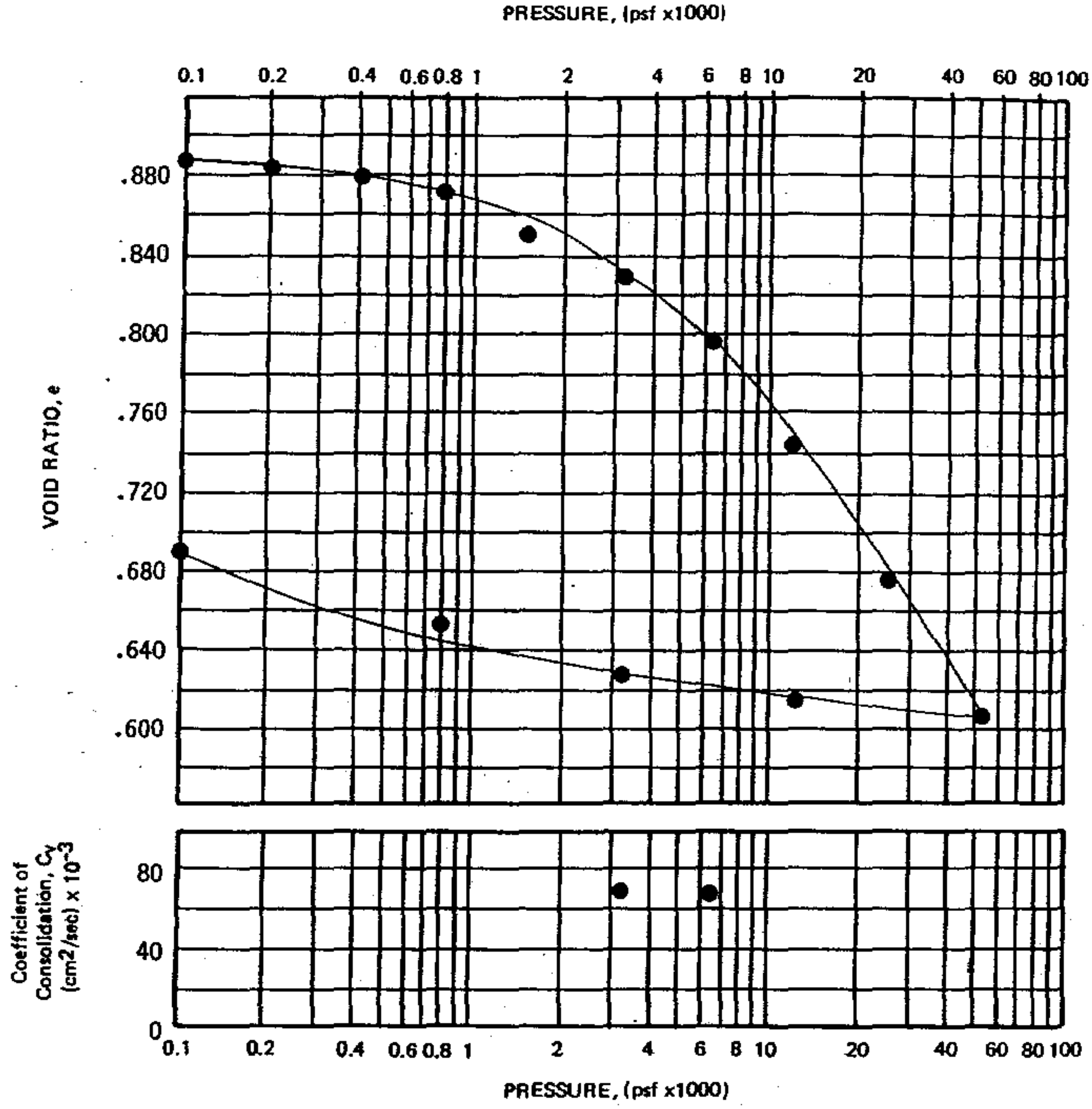
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
yo	9612,031.08		4/82		



TYPE OF SPECIMEN Undisturbed (trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in.) 0.80	MOISTURE CONTENT	w_o	32.1 %	w_f	25.3 %
OVERBURDEN PRESS., σ_{vo}' 310 psf		VOID RATIO	e_o	0.894	e_f	0.693
PRECONSOL PRESS.,(σ_{vo}') max -- psf		SATURATION	S_o	97.7 %	S_f	100 %
COMPRESSION INDEX, C_c 0.207		DRY DENSITY	γ_d	90 pcf	γ_d	100 pcf

LL --	PL --	PI --	G_s 2.72
CLASSIFICATION SILTY SAND (SM)		SOURCE Boring 9 at 5.7'	

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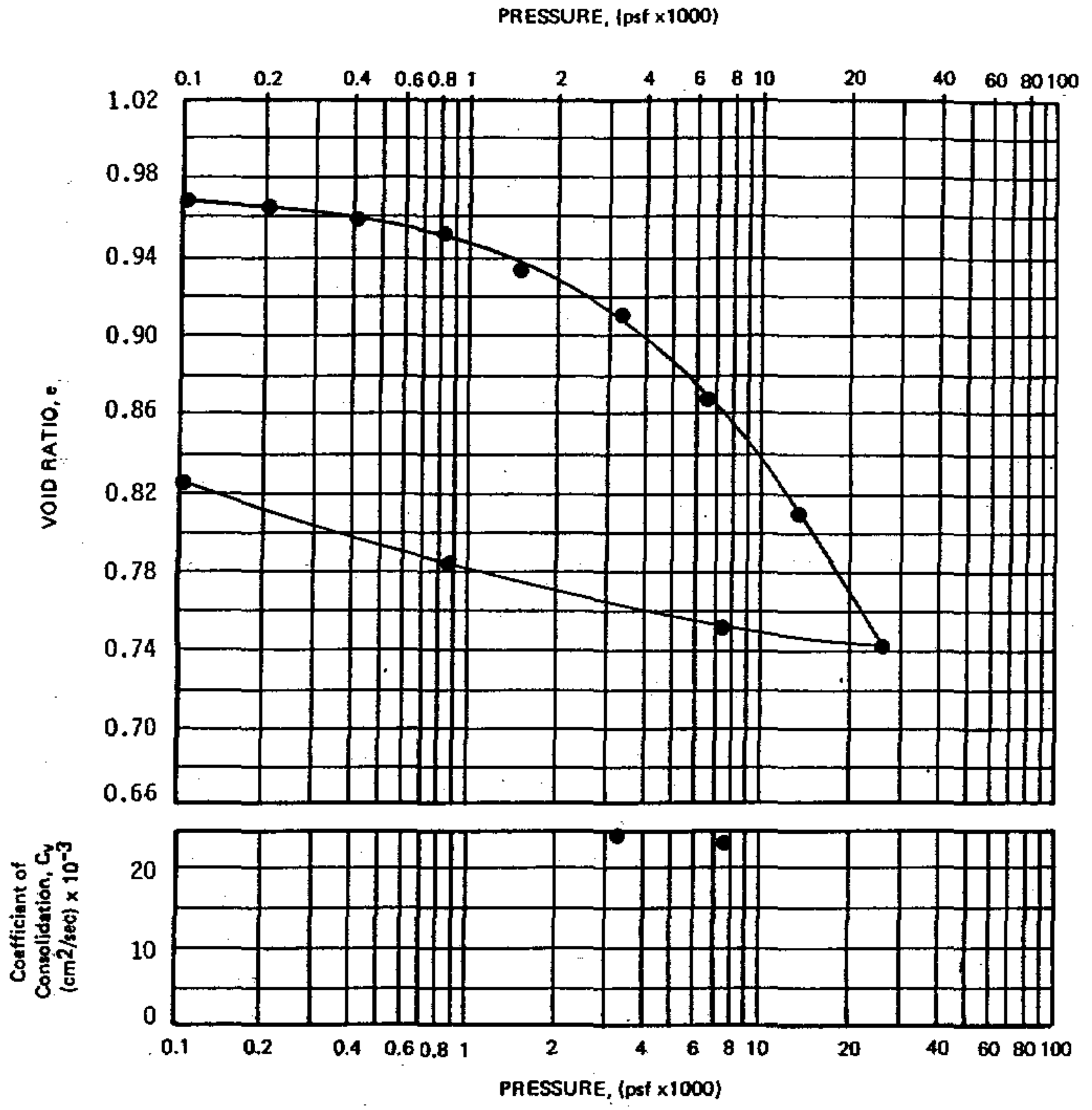
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08		4/82		



TYPE OF SPECIMEN Undisturbed (trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in.) 0.80	MOISTURE CONTENT	w_o	35.0 %	w_f	30.3 %
OVERBURDEN PRESS., σ'_{vo}	530 psf	VOID RATIO	e_o	0.971	e_f	0.824
PRECONSOL PRESS.,(σ'_{vo}) max	-- psf	SATURATION	S_o	98 %	S_f	100 %
COMPRESSION INDEX, C_c	0.215	DRY DENSITY	γ_d	86 pcf	γ_d	93 pcf
LL --	PL --	PI --		G_s 2.71		
CLASSIFICATION SANDY SILT (ML)		SOURCE Boring 9 at 9.7'				

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PLATE
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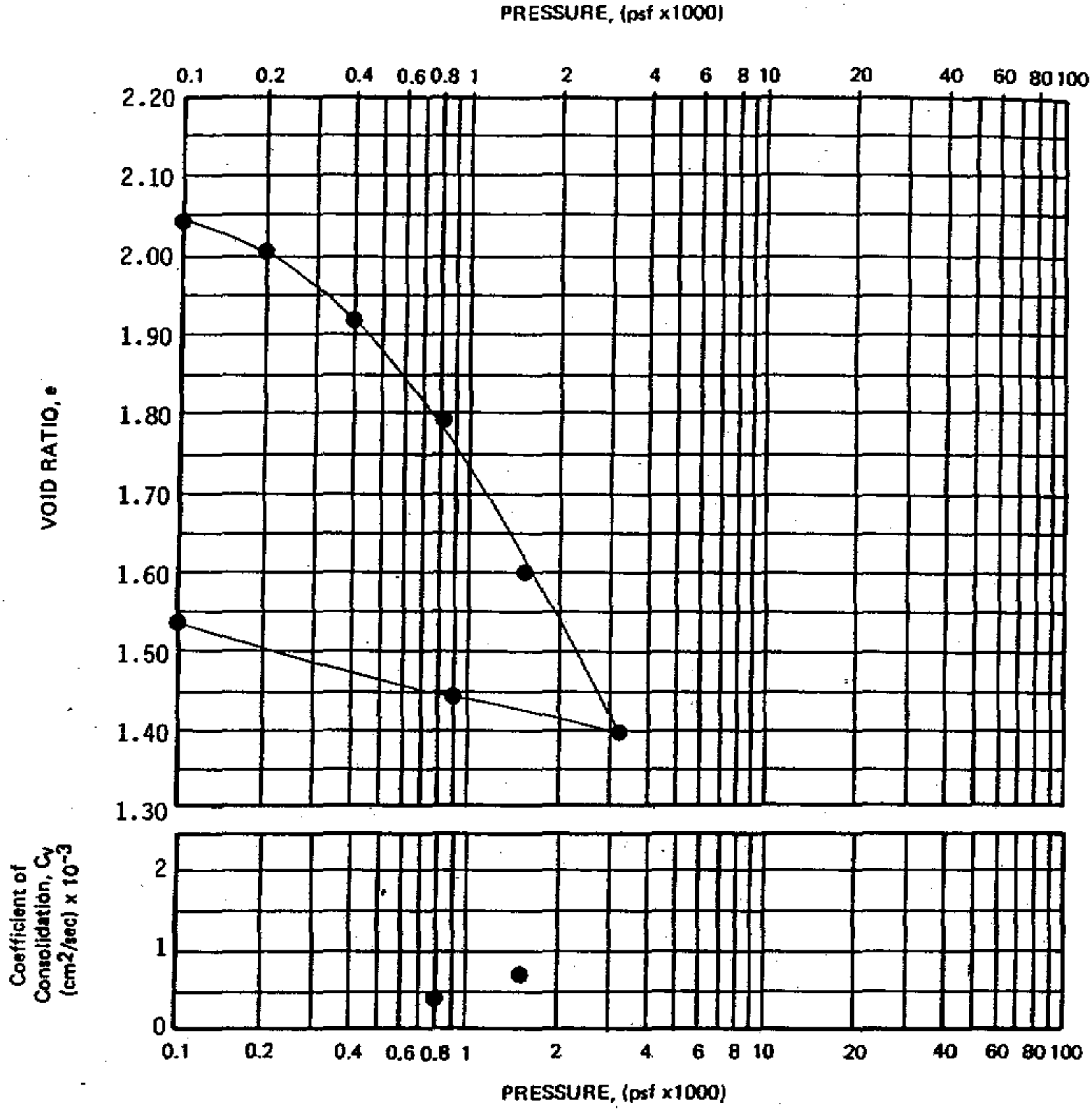
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DER	4/82		



TYPE OF SPECIMEN Undisturbed (trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in.) 0.80	MOISTURE CONTENT	w_o	80.4 %	w_f	59.4 %
OVERBURDEN PRESS., σ'_{vo} 1060 psf		VOID RATIO	e_o	2.134	e_f	1.543
PRECONSOL PRESS.,(σ'_{vo}) max -- psf		SATURATION	S_o	100 %	S_f	102 %
COMPRESSION INDEX,C_c 0.665		DRY DENSITY	γ_d	53 pcf	γ_d	65 pcf
LL --	PL --	PI --			G_s 2.66	
CLASSIFICATION SILT (MH)		SOURCE Boring 9 at 19.3'				

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PLATE
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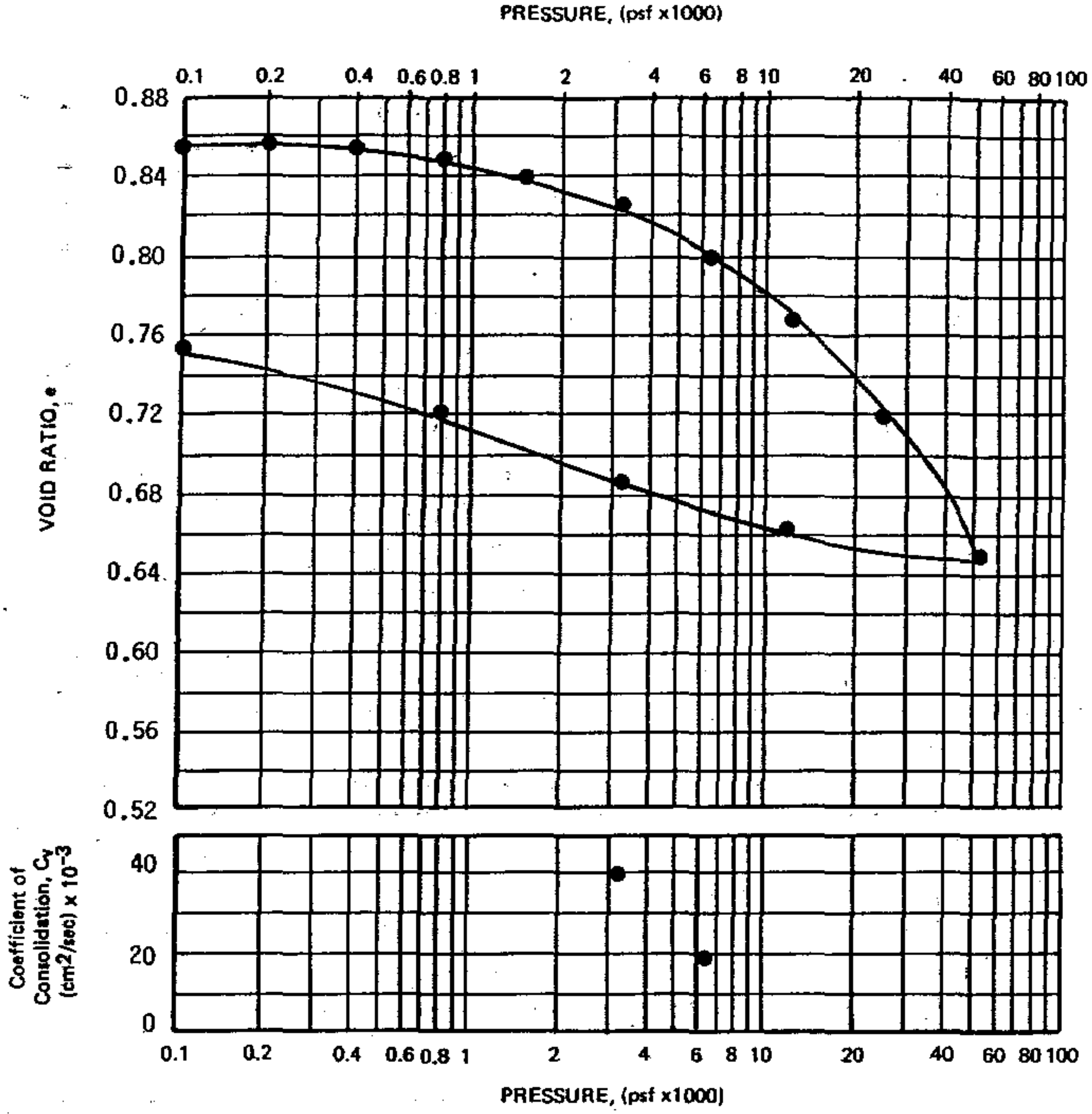
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		



TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in.) 0.80	MOISTURE CONTENT	w_o	32.8 %	w_f	27.7 %
OVERBURDEN PRESS., σ'_{vo} 2270 psf		VOID RATIO	e_o	0.869	e_f	0.754
PRECONSOL PRESS.,(σ'_{vo}) max --- psf		SATURATION	S_o	103 %	S_f	100 %
COMPRESSION INDEX,C_c 0.218		DRY DENSITY	γ_d	91 pcf	γ_d	97 pcf

LL ---	PL ---	PI ---	G_s 2.73

CLASSIFICATION CLAYEY SILT (ML)

SOURCE Boring 9 at 41.2'

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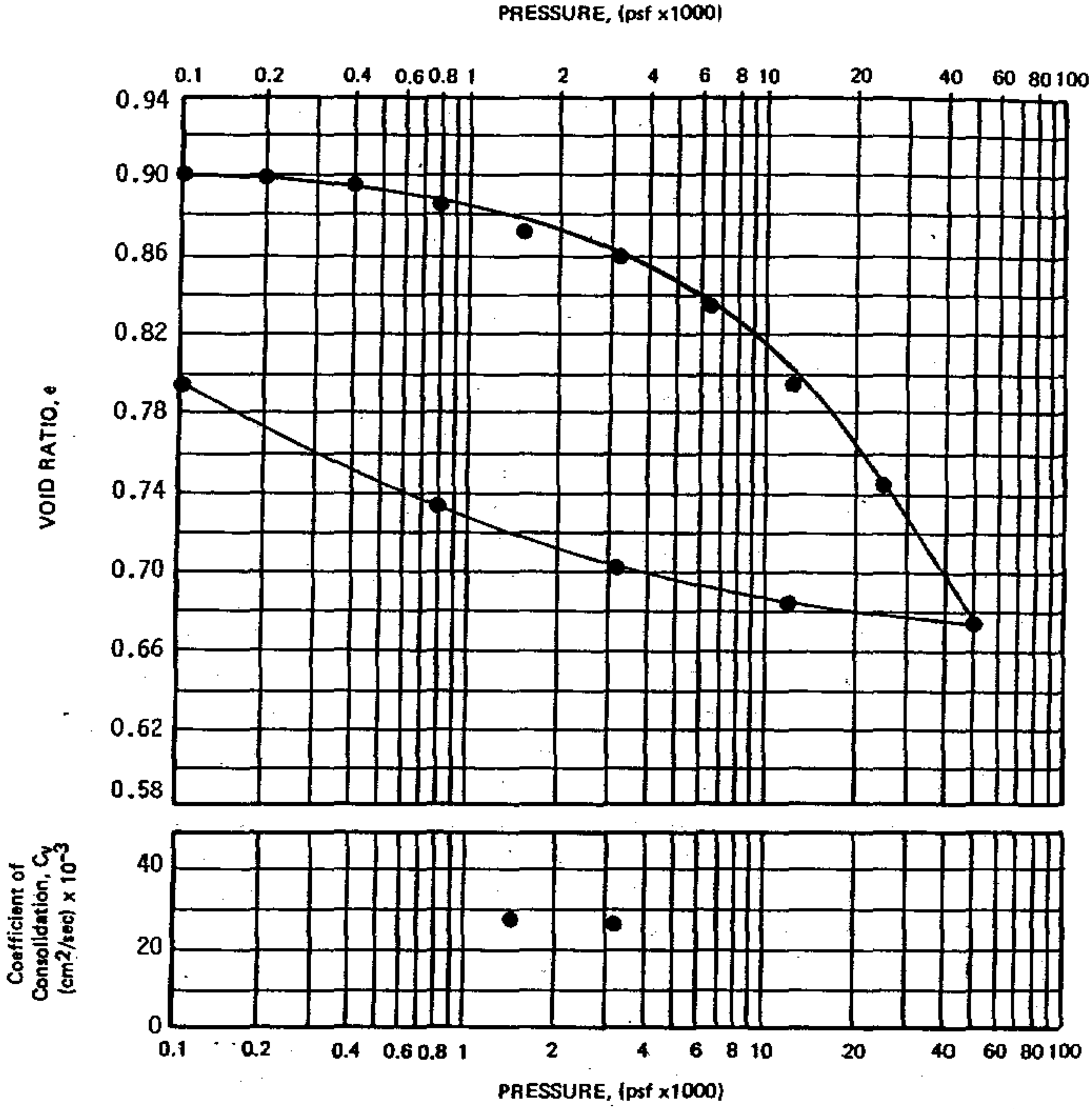
PLATE
D-136

DRAWN
JOB NUMBER 9612,031.08
APPROVED
DATE 4/82
REVISED
DATE



TYPE OF SPECIMEN	Undisturbed (trimmed)			BEFORE TEST			AFTER TEST	
DIAMETER(in)	2.43	HEIGHT(in.)	0.80	MOISTURE CONTENT	w_o	33.1 %	w_f	29.7 %
OVERBURDEN PRESS., σ'_{vo}	350 psf			VOID RATIO	e_o	0.911	e_f	0.796
PRECONSOL PRESS.,(σ'_{vo}) max	-- psf			SATURATION	S_o	99 %	S_f	101 %
COMPRESSION INDEX,C_c	0.220			DRY DENSITY	γ_d	89 pcf	γ_d	94 pcf
LL	32	PL	26	PI	6	G_s	2.71	
CLASSIFICATION	SILT (ML)			SOURCE	Boring 14 at 6.3'			

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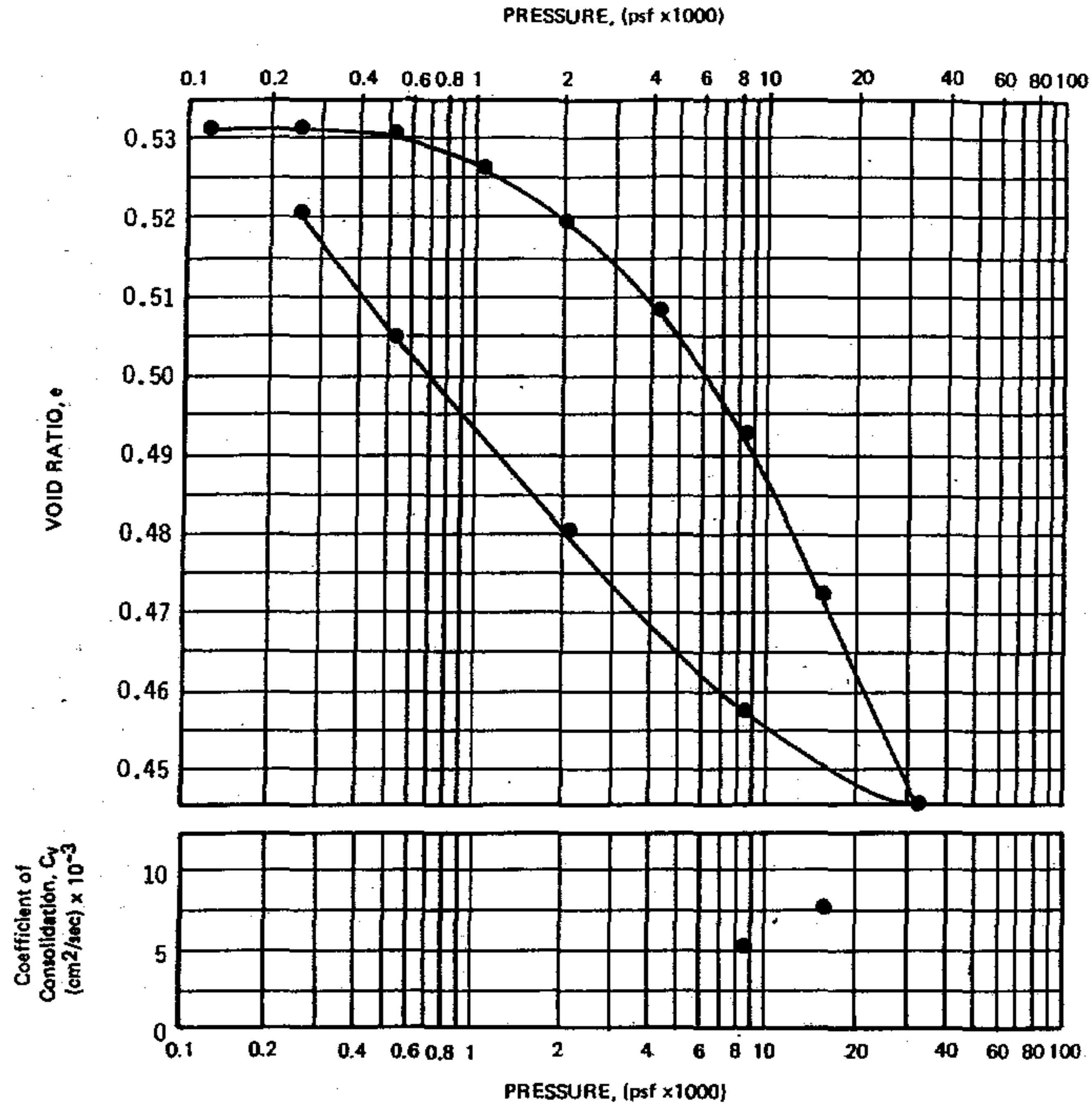
PLATE
D-137

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
X	9612,031.08	DEB	4/82		



TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in.) 0.80	MOISTURE CONTENT	w_o	19.5 %	w_f	19.1 %
OVERBURDEN PRESS., σ'_{vo} 920 psf		VOID RATIO	e_o	0.532	e_f	0.521
PRECONSOL PRESS.,(σ'_{vo}) max psf		SATURATION	S_o	100 %	S_f	100 %
COMPRESSION INDEX,C_c 0.079		DRY DENSITY	γ_d	112 pcf	γ_d	119 pcf
LL 33	PL 19	PI 14		G_s 2.75		
CLASSIFICATION CLAY (CL)			SOURCE Boring 14 at 16.8'			

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PLATE
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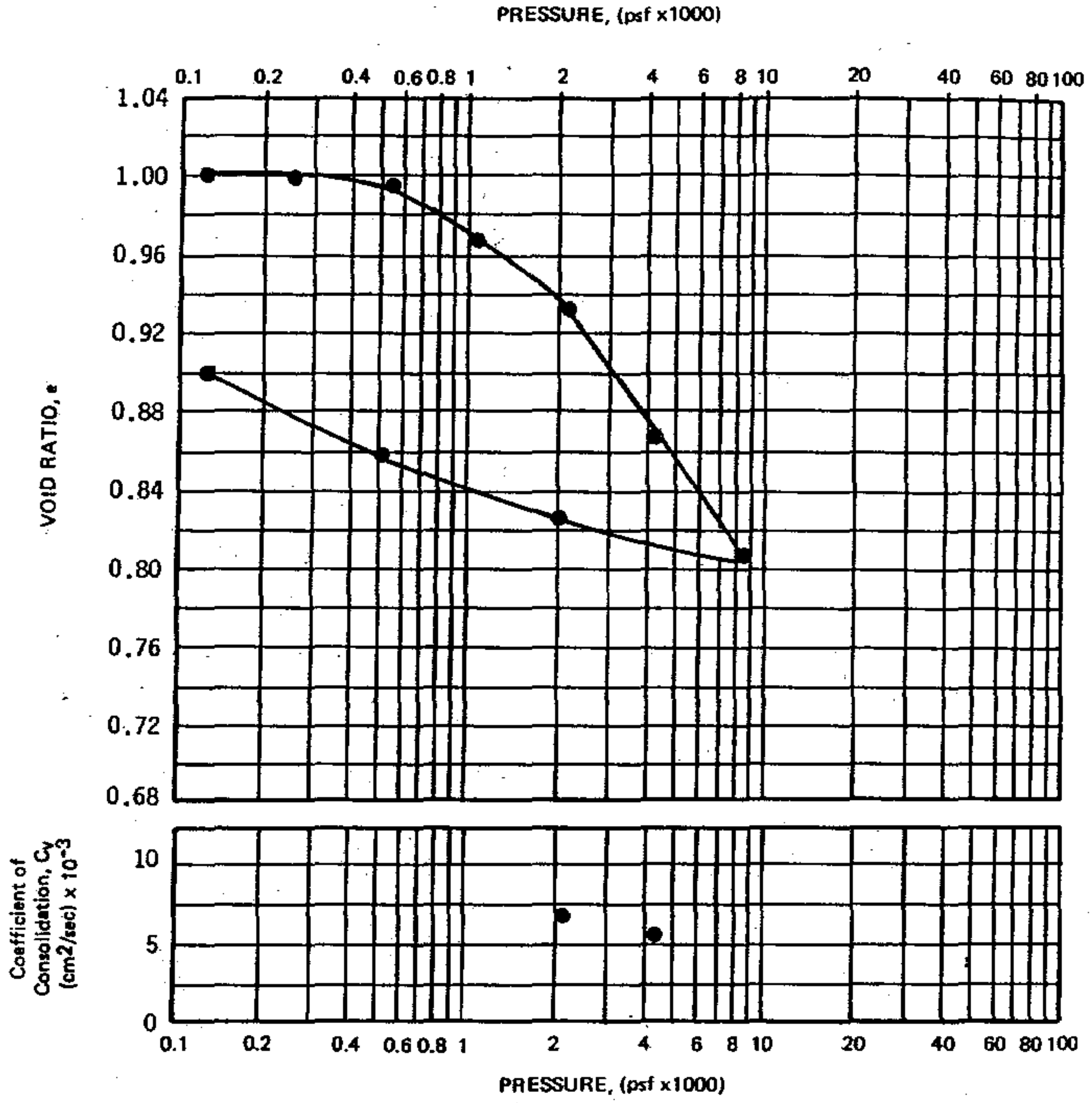
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612.031.08	DEB	4/82		



TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in.) 0.80	MOISTURE CONTENT	w_o	40.5 %	w_f	34.8 %
OVERBURDEN PRESS., σ'_{vo} 290 psf		VOID RATIO	e_o	1.034	e_f	0.900
PRECONSOL PRESS.,(σ'_{vo}) max --- psf		SATURATION	S_o	100 %	S_f	102 %
COMPRESSION INDEX,C_c 0.204		DRY DENSITY	γ_d	81 pcf	γ_d	87 pcf

LL 46	PL 31	PI 5	G_s 2.65
CLASSIFICATION SILT (ML)	SOURCE Boring 15 at 5.2'		

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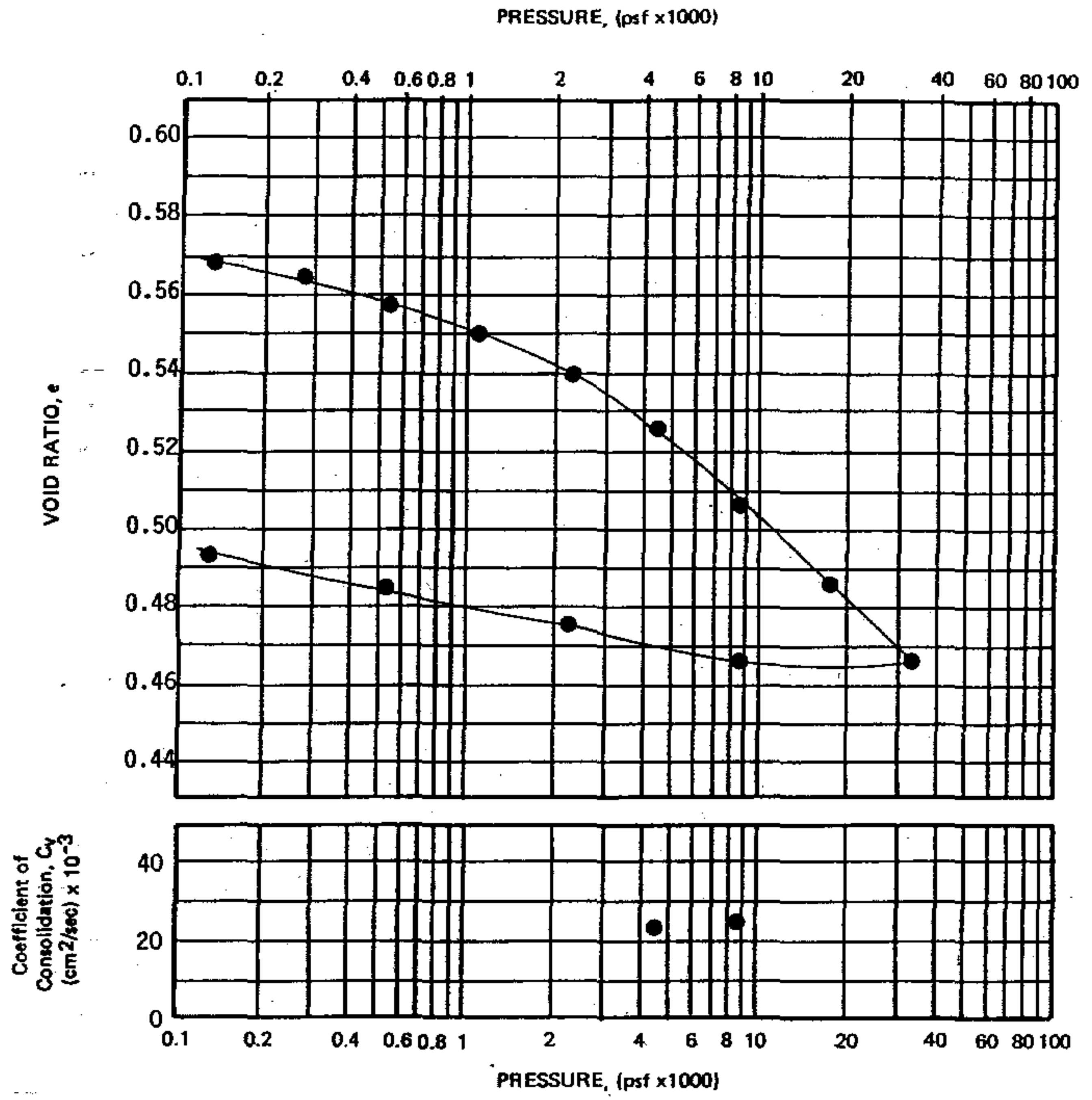
PLATE
D-139

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DBB	4/82		



TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST
DIAMETER(in) 2.43	HEIGHT(in.) 0.80	MOISTURE CONTENT	w_o	21.5 %	w_f 18.6 %
OVERBURDEN PRESS., $\bar{\sigma}_{vo}'$ 1470 psf		VOID RATIO	e_o	0.586	e_f 0.492
PRECONSOL PRESS.,$(\bar{\sigma}_{vo}')$ max -- psf		SATURATION	S_o	99 %	S_f 102 %
COMPRESSION INDEX,C_c 0.071		DRY DENSITY	γ_d	106 pcf	γ_d 113 pcf

LL --	PL --	PI --	G_s 2.69
CLASSIFICATION SANDY SILT (ML)		SOURCE Boring 15 at 26.8'	

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PLATE
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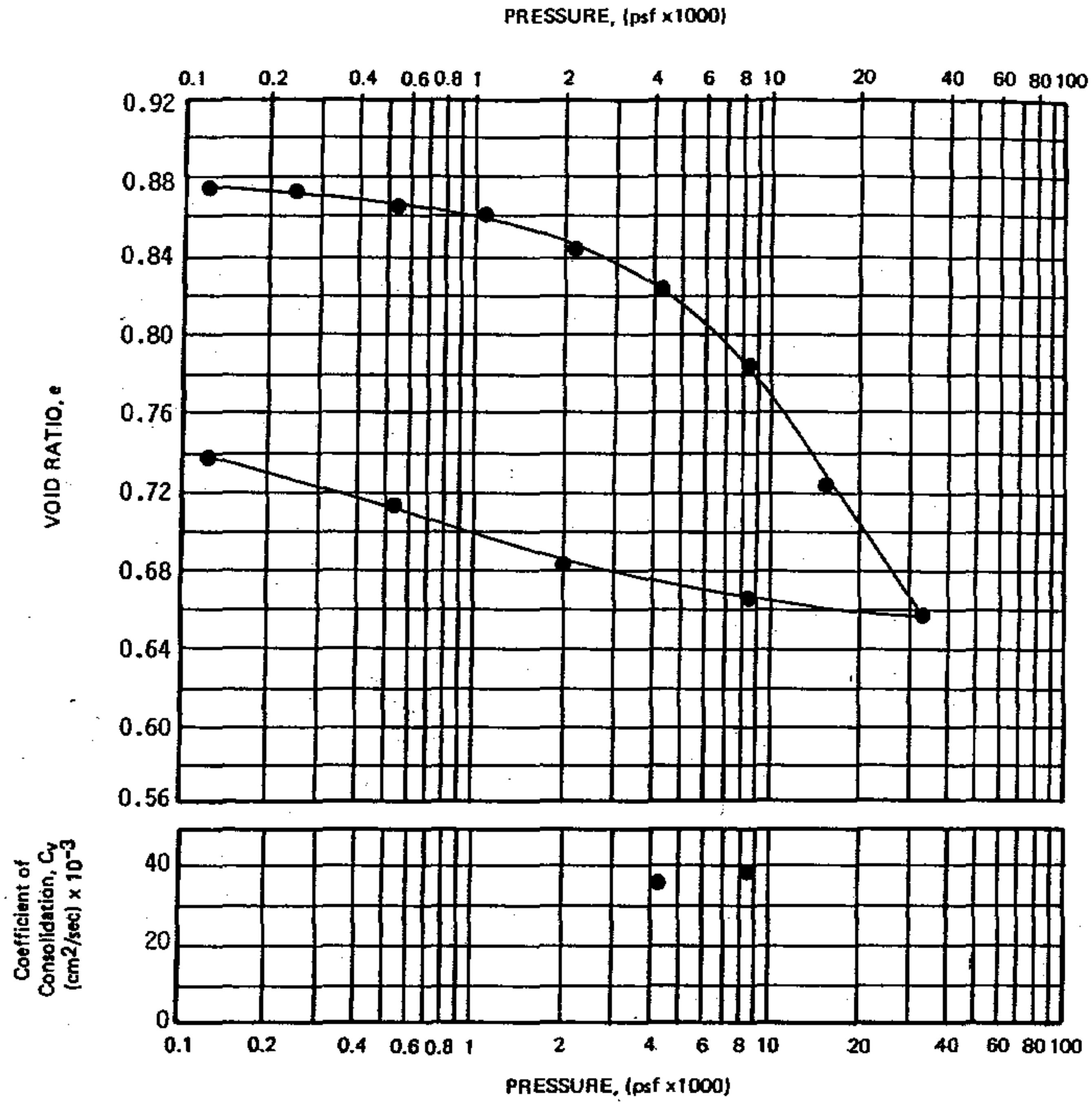
DRAWN | JOB NUMBER 9612,031.08 | APPROVED | DATE 4/82 | REVISED | DATE



TYPE OF SPECIMEN Undisturbed (trimmed)			BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in.) 0.80		MOISTURE CONTENT	w_o	32.6 %	w_f	26.8 %
OVERBURDEN PRESS., σ'_{vo}	190	psf	VOID RATIO	e_o	0.877	e_f	0.739
PRECONSOL PRESS.,(σ'_{vo}) max	---	psf	SATURATION	S_o	100 %	S_f	103 %
COMPRESSION INDEX,C_c	0.208		DRY DENSITY	γ_d	90 pcf	γ_d	97 pcf

LL 25 PL 21 PI 4 G_s 2.71

CLASSIFICATION CLAYEY SILT (CL-ML) SOURCE Boring 17 at 3.5'

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PLATE
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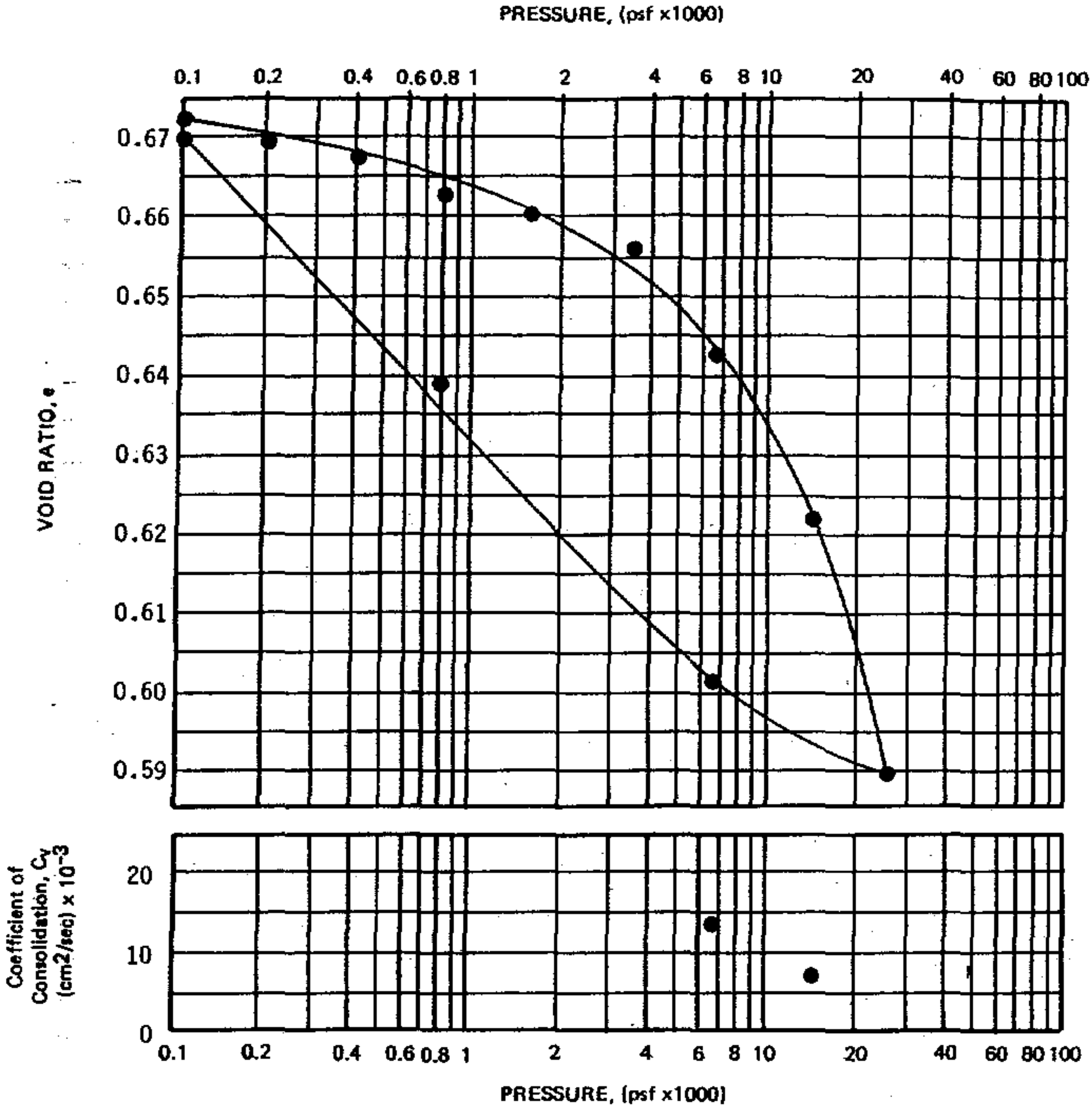
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DGB	4/82		



TYPE OF SPECIMEN	Undisturbed (trimmed			BEFORE TEST			AFTER TEST	
DIAMETER(in)	2.43	HEIGHT(in.)	0.80	MOISTURE CONTENT	w_o	23.9 %	w_f	24.1 %
OVERBURDEN PRESS., σ'_{vo}	1960 psf			VOID RATIO	e_o	0.678	e_f	0.670
PRECONSOL PRESS.,(σ'_{vo}) max	-- psf			SATURATION	S_o	98 %	S_f	100 %
COMPRESSION INDEX,C_c	0.084			DRY DENSITY	γ_d	103 pcf	γ_d	104 pcf

LL --	PL --	PI --	G_s 2.78
CLASSIFICATION CLAY (CL)	SOURCE Boring 17 at 35.7'		

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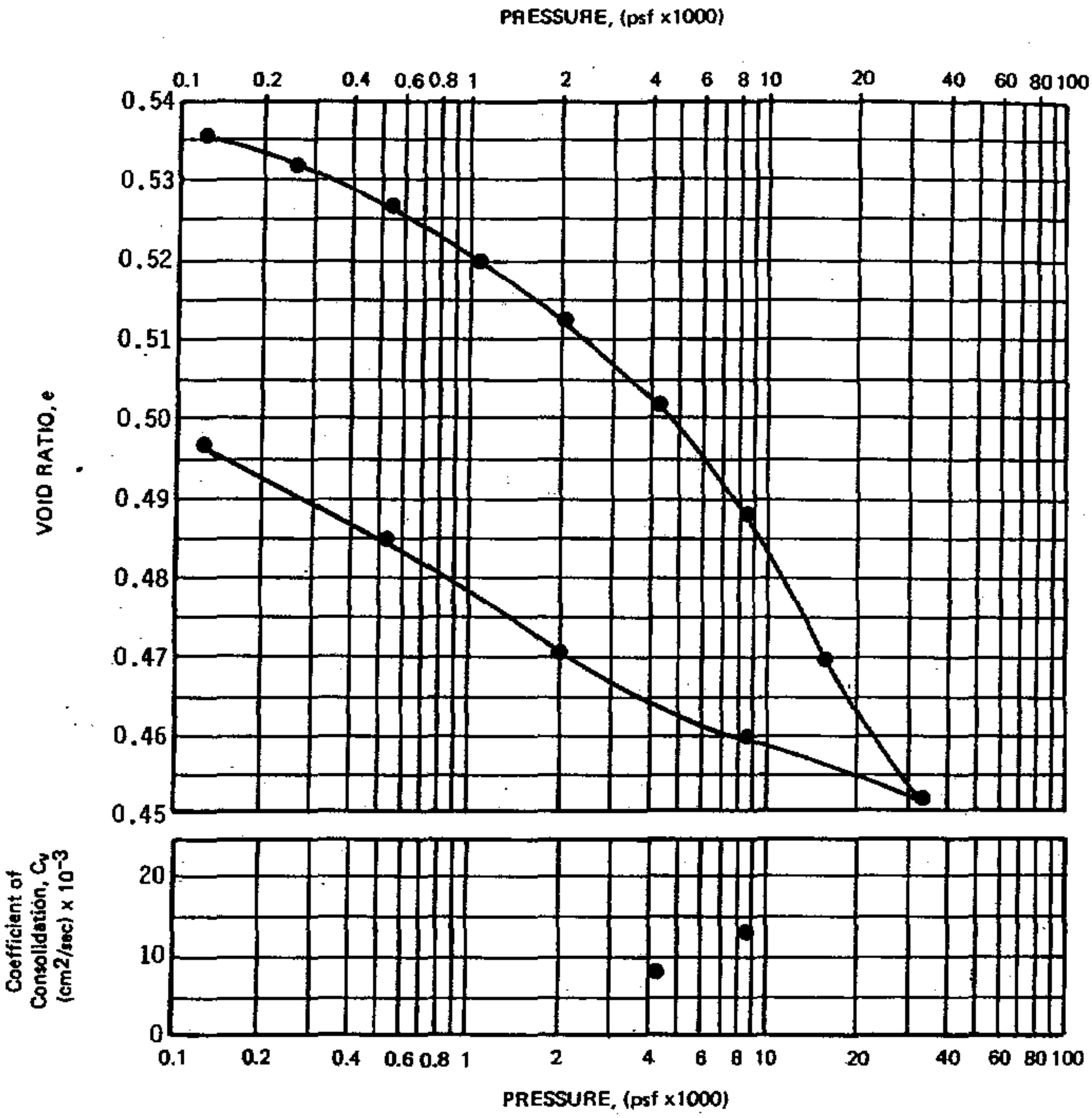
PLATE
D-142

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JY	9612,031.08	DEB	4/82		



TYPE OF SPECIMEN Undisturbed(trimmed)		BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in.) 0.80	MOISTURE CONTENT	w_o	20.1 %	w_f	17.9 %
OVERBURDEN PRESS., σ'_{vo} 180 psf		VOID RATIO	e_o	0.552	e_f	0.497
PRECONSOL PRESS.,(σ'_{vo}) max --- psf		SATURATION	S_o	100 %	S_f	100 %
COMPRESSION INDEX,C_c 0.061		DRY DENSITY	γ_d	111 pcf	γ_d	115 pcf
LL 26	PL 19	PI 7	G_s 2.76			
CLASSIFICATION CLAY (CL)		SOURCE Boring 21 at 3.3'				

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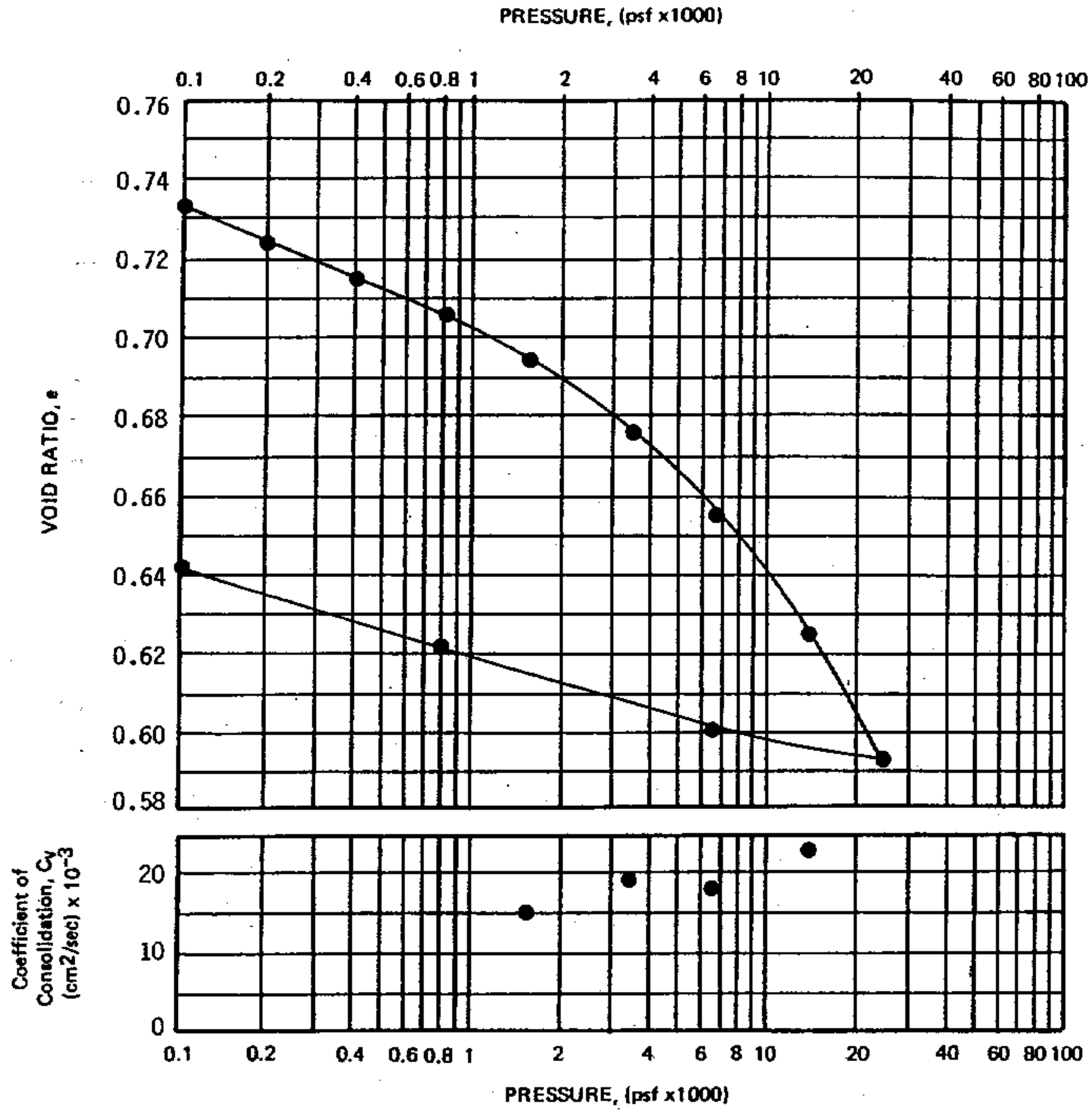
PLATE
D-143

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DGB	4/82		



TYPE OF SPECIMEN	Undisturbed (trimmed)	BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in.) 0.80	MOISTURE CONTENT	w_o	27.0 %	w_f	22.8 %
OVERBURDEN PRESS., σ'_{vo}	1530 psf	VOID RATIO	e_o	0.758	e_f	0.641
PRECONSOL PRESS.,(σ'_{vo}) max	-- psf	SATURATION	S_o	100 %	S_f	100 %
COMPRESSION INDEX,C_c	0.110	DRY DENSITY	γ_d	100 pcf	γ_d	107 pcf
LL --	PL --	PI --		G_s 2.81		
CLASSIFICATION	SANDY SILT (ML)	SOURCE	Boring 21 at 27.8'			

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PLATE
D-144

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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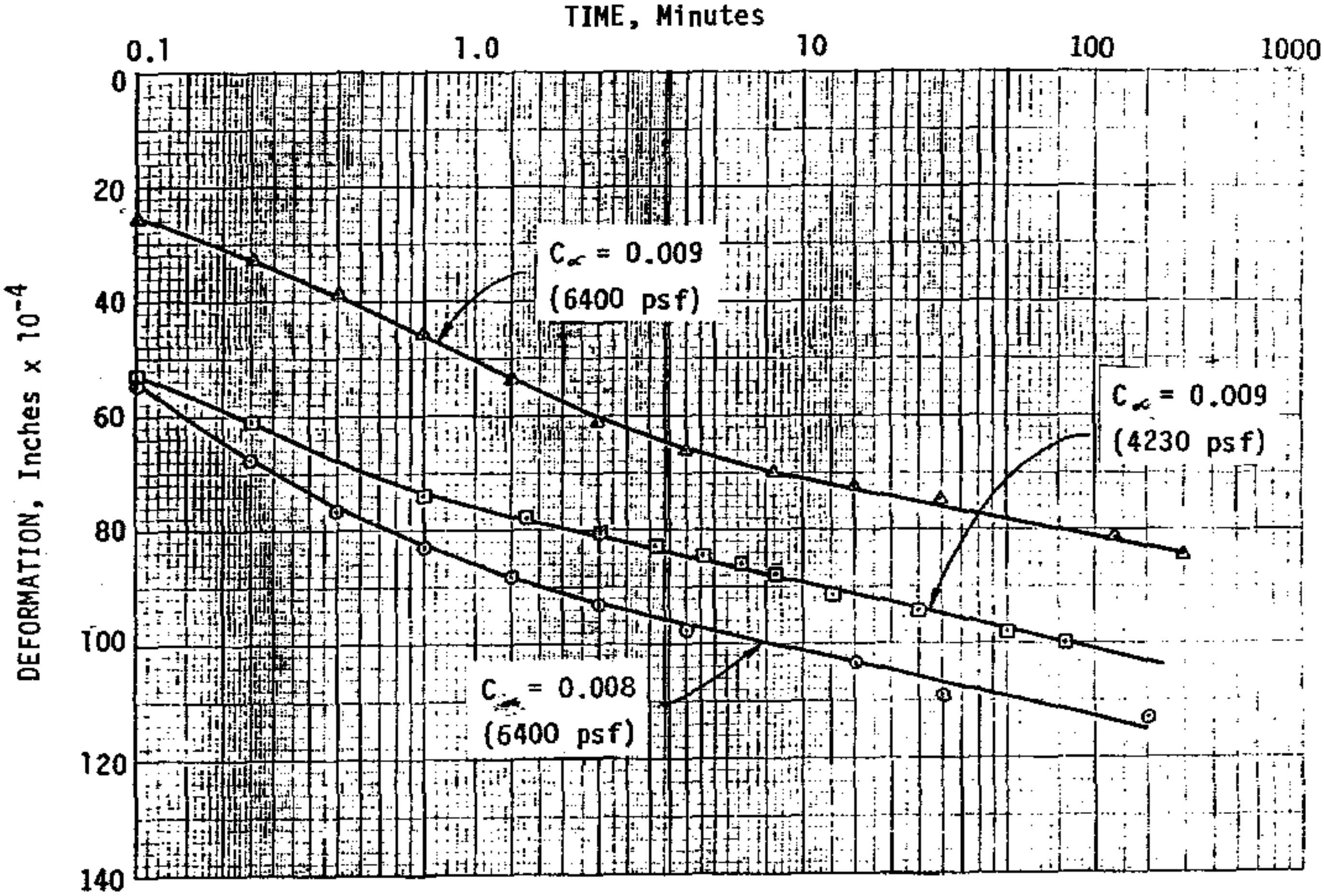

$$C_{\alpha} = \frac{\Delta H/H_0}{\log(t_2/t_1)}$$

Legend

- ⊡ SILTY SAND (SM), Boring 4 at 3.0'
- △ CLAY (CL), Boring 17 at 35.7'
- ⊙ SILT (ML), Boring 21 at 27.8'

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Coefficients of Secondary Consolidation
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PLATE
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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
8	9612.031.08	DEB	4/82		

G. Thaw Consolidation Testing of Bonded Soil

Uniaxial thaw consolidation tests were performed on 28 undisturbed samples of bonded permafrost in accordance with the procedures developed by HLA. The testing device was a specially developed consolidometer that was designed to satisfy the necessary stress and thermal boundary conditions during one-dimensional thaw consolidation. The apparatus consists of a rigid, steel, thick-wall cyclinder, with porous stones at the top and bottom to allow the sample to drain. A vertical load is applied to the sample using a loading hanger which bears on a load cap assembly.

The samples were prepared in our cold room at a temperature of about -8°C. Each sample was extruded from a 6-inch long brass liner having an inside diameter of 2.43-inches and approximately 1 inch of the soil was removed for electric conductivity tests. Next, the sample was trimmed to a length that varied between 4.5 and 5 inches, and the ends of the samples were cut flat. The sample was then inserted into the testing cyclinder, and the unit was transported from the cold room to the testing room. It was then mounted into the consolidation apparatus, and the sample was loaded to 500 psf and allowed to thaw at a room temperature of approximately 20°C. The load was then increased to 100 psf and the deformation recorded.

The results of the thaw consolidation tests are summarized on Plate D-146. In addition to a description of the sample, this plate contains information on the frozen state properties and the uniaxial thaw-strain. Data for thaw consolidation tests which were carried out to 58,000 psf load are presented on Plates D-147 through D-149.

			Frozen Phase				Thawed Phase			
Boring No.	Depth (ft)	USCS	Dry Density (pcf)	Ice Content (%)	Void Ratio	Saturation (%)	Dry Density (%)	Void Ratio	Thaw Load (psf)	Thaw Strain (%)
1	2.7	OL,Vx/Vr	15	301	10	78	39	3.0	1000	62
1	4.2	ML,Vx/Vr	47	92.6	2.60	97	105	0.610	1000	55
5	45.7	CL,Vr	86	33.6	0.977	93	88	0.934	1000	2
5	46.0	CL,Vr	67	36.2	1.50	65	70	1.4	1000	5
7	0.5	OL,Vx/Vr	34	108	3.80	74	40	3.1	1000	15
7	2.0	OL,Vx/Vr	19	250	7.70	88	51	2.2	1000	63
10	31.0	CL,Vr	108	21.6	0.574	100	115	0.574	1000	7
12	0.5	OL,Vx/Vr	78	27.6	1.168	70	97	0.743	1000	20
12	9.1	SM,Vx	93	19.2	0.818	70	115	0.470	1000	20
13	0.3	OL,Vx/Vr	53	54.9	2.06	78	66	1.458	1000	20
13	3.0	SP-SM,Vx	82	21.0	1.06	59	115	0.470	1000	29
13	17.5	ML,Vx/Vr	52	76.1	2.30	98	91	0.859	1000	44
15	39.6	CL,Vx/Vr	102	23.5	0.649	98	114	0.457	1000	8
15	49.1	CL,Vx/Vr	92	27.7	0.838	98	102	0.658	1000	9
16	3.1	SM,Vc/Vs	79	48.9	1.141	100	87	0.944	1000	9
16	5.1	ML,Vc/Vs	73	42.6	1.316	96	99	0.724	1000	26
16	9.1	SM,Vc/Vs	93	28.5	0.818	100	96	0.762	1000	4
16	24.6	ML,Vr	98	25.5	0.726	100	100	0.691	1000	3
18	1.0	OL, bonded	55	55.2	1.950	80	60	1.818	1000	17
19	24.5	ML,Vr	108	21.6	1.03	98	114	0.787	1000	5
23	0.0	ML,Vx	55	42.9	2.075	61	72	1.368	1000	23
23	1.0	ML,Vx	107	23.2	0.580	100	120	0.409	1000	11
23	10.8	ML,Vx	54	64.6	2.132	90	81	1.088	1000	33
23	19.0	CL,Vr	83	31.9	1.037	91	94	0.799	1000	14
23	39.5	CL,Vr	89	27.7	0.900	91	97	0.743	1000	8

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Thaw Consolidation Test Summary

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PLATE
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DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
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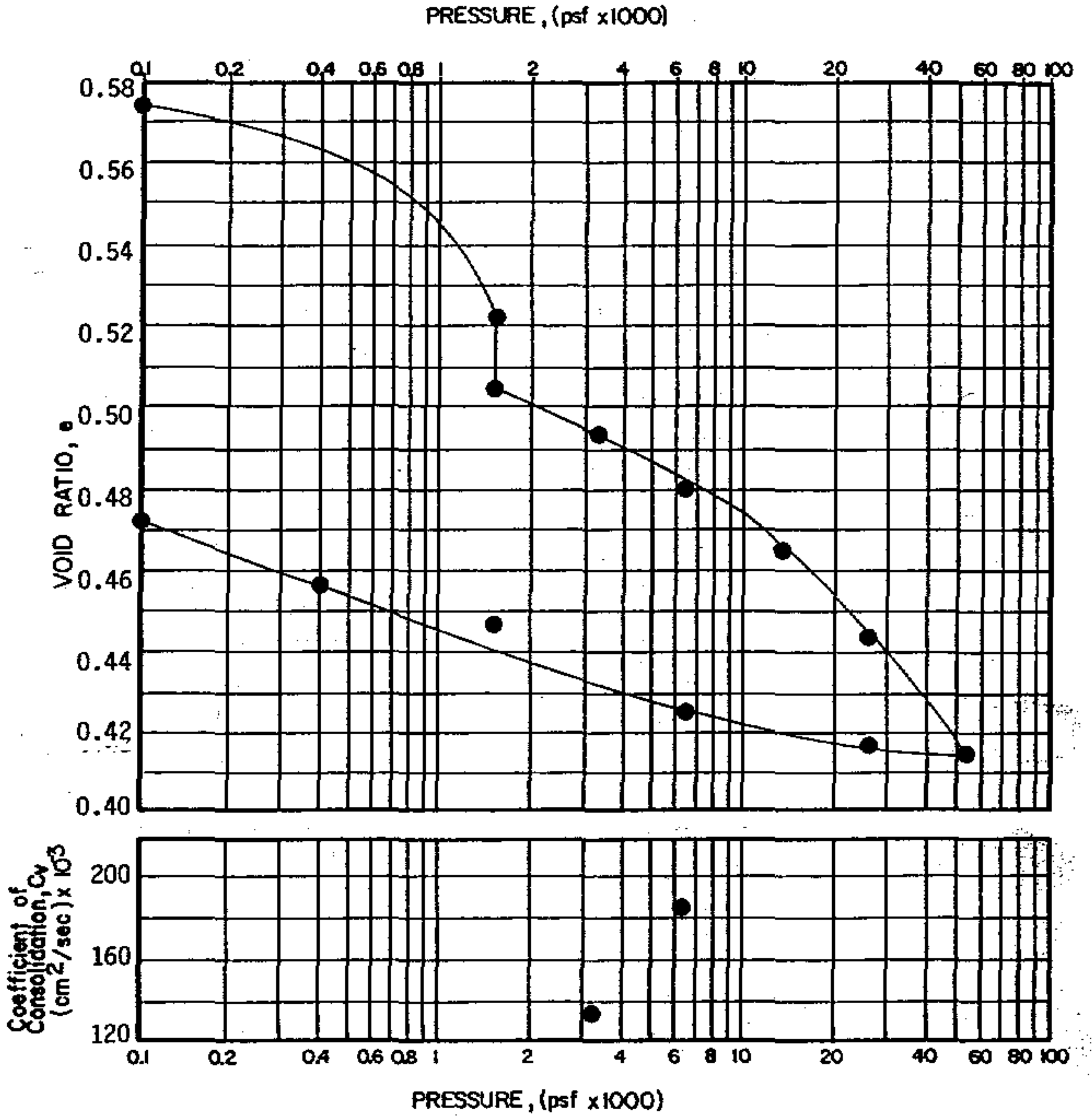

TYPE OF SPECIMEN Undisturbed (frozen)		BEFORE TEST			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in) 1.80	MOISTURE CONTENT	w_o	21.6 %	w_f	17.5 %
OVERBURDEN PRESS., σ_{vo}' 1700 psf		VOID RATIO	e_o	0.574	e_f	0.471
PRECONSOL PRESS., $(\sigma_{vo}')_{max}$ --- psf		SATURATION	S_o	100 %	S_f	100 %
COMPRESSION INDEX, C_c 0.092		DRY DENSITY	γ_d	108 pcf	γ_d	115 pcf
LL 27	PL 21	PI 6	G_s 2.70 (Assumed)			
CLASSIFICATION SILTY CLAY (CL)		SOURCE Boring 10 at 31.0'				

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PLATE
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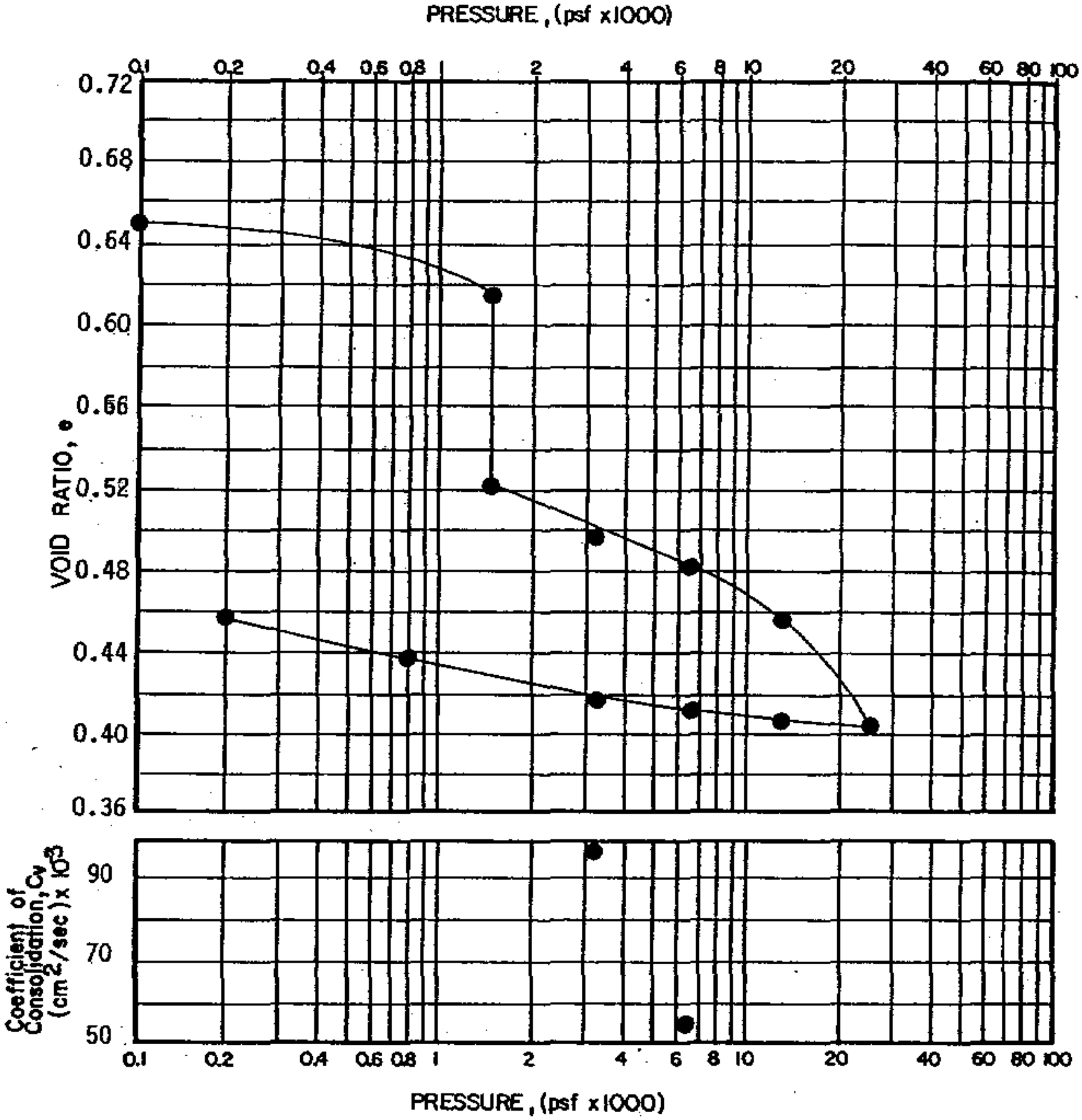
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JF	9612,031.08	DEB	4/82		



TYPE OF SPECIMEN Undisturbed (frozen)		BEFORE TEST (Frozen)			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in) 1.80	MOISTURE CONTENT	w_o	23.5 %	w_f	17.0 %
OVERBURDEN PRESS., σ_{vo}'	2170 psf	VOID RATIO	e_o	0.649	e_f	0.457
PRECONSOL PRESS., $(\sigma_{vo}')_{max}$	--- psf	SATURATION	S_o	98 %	S_f	100 %
COMPRESSION INDEX, C_c	0.230	DRY DENSITY	γ_d	102 pcf	γ_d	114 pcf

LL 28	PL 21	PI 7	G_s 2.70 (Assumed)
CLASSIFICATION SILTY CLAY (CL)		SOURCE Boring 15 at 39.5'	

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Pt. Thomson Development Project
Winter 1982, Geotechnical Study
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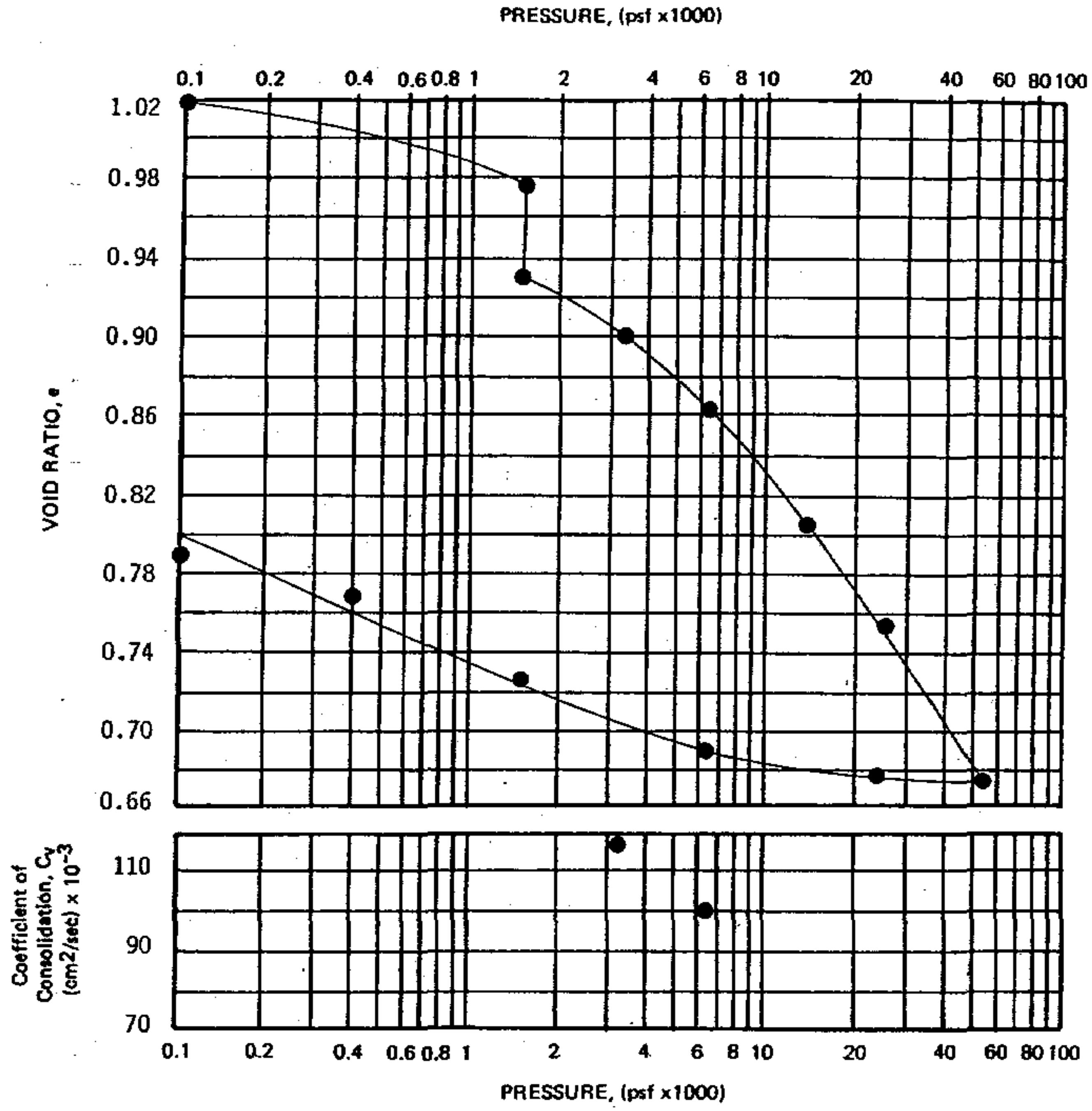
PLATE
D-148

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DEB	4/82		



TYPE OF SPECIMEN	Undisturbed (frozen)	BEFORE TEST (Frozen)			AFTER TEST	
DIAMETER(in) 2.43	HEIGHT(in.) 1.80	MOISTURE CONTENT	w_o	21.6 %	w_f	29.3 %
OVERBURDEN PRESS., σ'_{vo}	1350 psf	VOID RATIO	e_o	1.025	e_f	0.787
PRECONSOL PRESS.,(σ'_{vo}) max	--- psf	SATURATION	S_o	98 %	S_f	100 %
COMPRESSION INDEX,C_c	0.219	DRY DENSITY	γ_d	108 pcf	γ_d	114 pcf

LL 38	PL 26	PI 12	G_s 2.70 (Assumed)

CLASSIFICATION CLAYEY SILT (ML)

SOURCE Boring 19 at 24.5'

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A general relationship for thaw consolidation was obtained by comparing the values of thaw strain and frozen dry density plotted on Plate IV-22 for fine-grained soil while data for gravels are presented on Plate V-8. The data for Plate V-8 are based on other studies. Because samples having a broad range of frozen dry densities were used, it was possible to establish a curve from which thaw consolidation could be estimated. The curve on Plate IV-22 represents the mean thaw strain plus one standard deviation and shows that when the frozen dry densities are greater than approximately 95 pcf, the thaw strains are less than 8 percent. As the frozen dry densities of the samples decrease, the scatter of thaw strain values becomes greater. The increase in thaw strain is approximately 0.7 percent per pcf decrease in dry density.

Literature on thaw consolidation is very limited, particularly for Beaufort Sea soils. The results of the thaw consolidation tests that were performed for this project can be compared with the results obtained for three other Beaufort Sea projects. These results are contained in the following reports: "Subsurface Soil Investigation, Duck Island Wild Cat, Beaufort Sea, Alaska" (R & M Consultants, 1978), "Geotechnical Investigation, Beaufort Sea, Alaska" (HLA/USGS, 1979) and "Duck Island Development Project, Beaufort Sea, Alaska" (HLA, 1981). The data are in agreement with the results of our tests for this project.

H. Thermal Conductivity

Measurements of radial thermal conductivity were made using the "thermal needle method." A detailed discussion of the theory and development of this method is presented by Mitchell and Kao (1978).

In simplified terms, thermal energy is applied at a known constant rate to a probe embedded in a sample. The temperature of the probe is measured as a function of time. By plotting the temperature change versus the log of time, a straight-line relationship is produced with a slope that is proportional to the thermal conductivity. The general equation used for calculating the thermal conductivity is:

$$K = \frac{Q\,[\ln \Delta\, t]}{4\,\pi\,\Delta\, T} \qquad \text{(D-3)}$$

Where: K = thermal conductivity (Btu/ft-hr-^{o}F)

Q = thermal energy input per unit length per unit time (Btu/ft-hr)

T = temperature change corresponding to time

t = time change corresponding to temperature

By substituting specific probe information, Equation D-3 yields the following:

$$K = \frac{CI^2\, R\pi \ln\,(t_2/t_1)}{4\pi\;(T_2 - T_1)} \qquad \text{(D-4)}$$

Where: C = constant (1 watt/ft = 3.413 Btu/hr)

I^2 = current (amp)

R = probe unit resistance (4.503 ohm/ft)

By substitution:

$$K = \frac{1.223\; I^2 \ln\,(t_2/t_1)}{(T_2 - T_1)} \qquad \text{(D-5)}$$

The following equipment was used for the conductivity tests:

Thermal needle: The thermal needle consists of 1/8-inch O.D. stainless steel tube, Copper Constantan 0.003-inch-diameter thermocouple wire, Constantan #30 heat source wire, and #16 copper wire leads.

Heat source power supply: A Hewlett-Packard Model 6284A DC Power Supply, with constant voltage from 0 to 20 volts, and constant current from 0 to 3 amps, was used as the heat source.

Thermocouple signal amplifier: This device is our Omega "Omni-Amp IIB" with built-in ice point reference, that is capable of amplifying the thermocouple signal 100 times.

Recording equipment: An Omega single-channel strip chart recorder, Model 555 was used.

Most of the samples tested were unbonded soils. However, five bonded samples were tested as frozen samples. The testing procedure for these samples was as follows:

1. The bulk weight and sample dimensions were measured to determine soil density.
2. An 1/8-inch-diameter hole was drilled from top to bottom through the center of the sample, and the probe was inserted into the hole. Next, both ends were capped and the sample was immersed in a constant temperature bath, maintained at the specified initial temperature until the sample temperature was stabilized.
3. Power was applied to the Constantan line, and the change in temperature with time was recorded on the chart recorder. The input power generally varied from 0.400 to 0.450 amp for both the frozen and the thawed tests. The test was run for 10 minutes, after which the power was turned off. This procedure was repeated until consistent results were obtained at each temperature.
4. The temperature, expressed in millivolts, plotted against the log of time, and the slope of the straight line portion of this curve was determined. The radial thermal conductivity was then calculated using Equation D-5.
5. Finally, the moisture content was determined. Index property tests were also performed when necessary.

A summary of the thermal conductivity test results is presented on Plate D-150. The results of individual thermal conductivity tests, plots of millivolts versus log time, and any index tests that were performed on the sample are presented on Plates D-151 through D-163.

Two log cycles of data are produced when our test procedure is used. For this report, the first log cycle, which contains the time increment of 0.1 to 1 minute, was omitted because a nonlinear relationship was produced due to problems associated with the seating of the probe. This nonlinearity disappeared within 1 minute of applying the probe, and the thermal conductivity was determined from the straight line portion of the plot in the second log cycle. Two conductivity tests were made on each sample to ensure that the correct thermal conductivity was determined.

The variation of thermal conductivity with density is plotted for the tested samples on Plate IV-23 along with the data from the Duck Island Development project (HLA, 1981). On this plate, the two thermal conductivity values for each sample are connected by a line. It can be seen that the thermal conductivity increases with increases in dry density for both the thawed and frozen samples. Typically, the thermal conductivity will also increase with increases in moisture content. However, this was not observed in these tests, perhaps because of the small range of moisture contents tested.

In general, the thermal conductivity varies with the texture of the soil. At a given density and moisture content, the conductivity is relatively high in coarse-grained soils, such as sands and gravels, and lower in fine-grained soils, such as silts and clays. For the one thermal conductivity test that

Boring No.	Depth	USCS	Dry Density	Moisture Content (%)			Thermal Conductivity Btu/Ft-hr-°F	
	(ft)		(pcf)	LL	PL	Natural	Frozen*	Thawed
4	12.4	ML	78	---	---	38.8	---	1.09
5	19.2	CL	79	31	21	39.5	---	0.99
8	12.2	ML	103	---	---	22.6	---	1.38
9	0.5	SM	105	---	---	22.1	---	1.41
9	46.4	CL	93	---	---	29.3	---	1.30
12	0.0	OL,Vx/Vr	11	---	---	406	0.55	---
13	18.0	ML, Vx/Vr	29	34	25	154	1.20	---
14	31.1	ML	105	---	---	22.8	---	1.24
18	0.3	OL	31	---	---	149	1.07	---
21	16.1	ML	97	---	---	27.3	---	1.42
21	31.0	CL	101	---	---	24.4	---	1.49
23	0.5	ML, Vx	78	21	13	30.3	1.46	---
23	12.5	CL, Vr	70	33	22	43.9	1.17	---

* Test run at temperature of 15° F.

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Thermal Conductivity Test Summary

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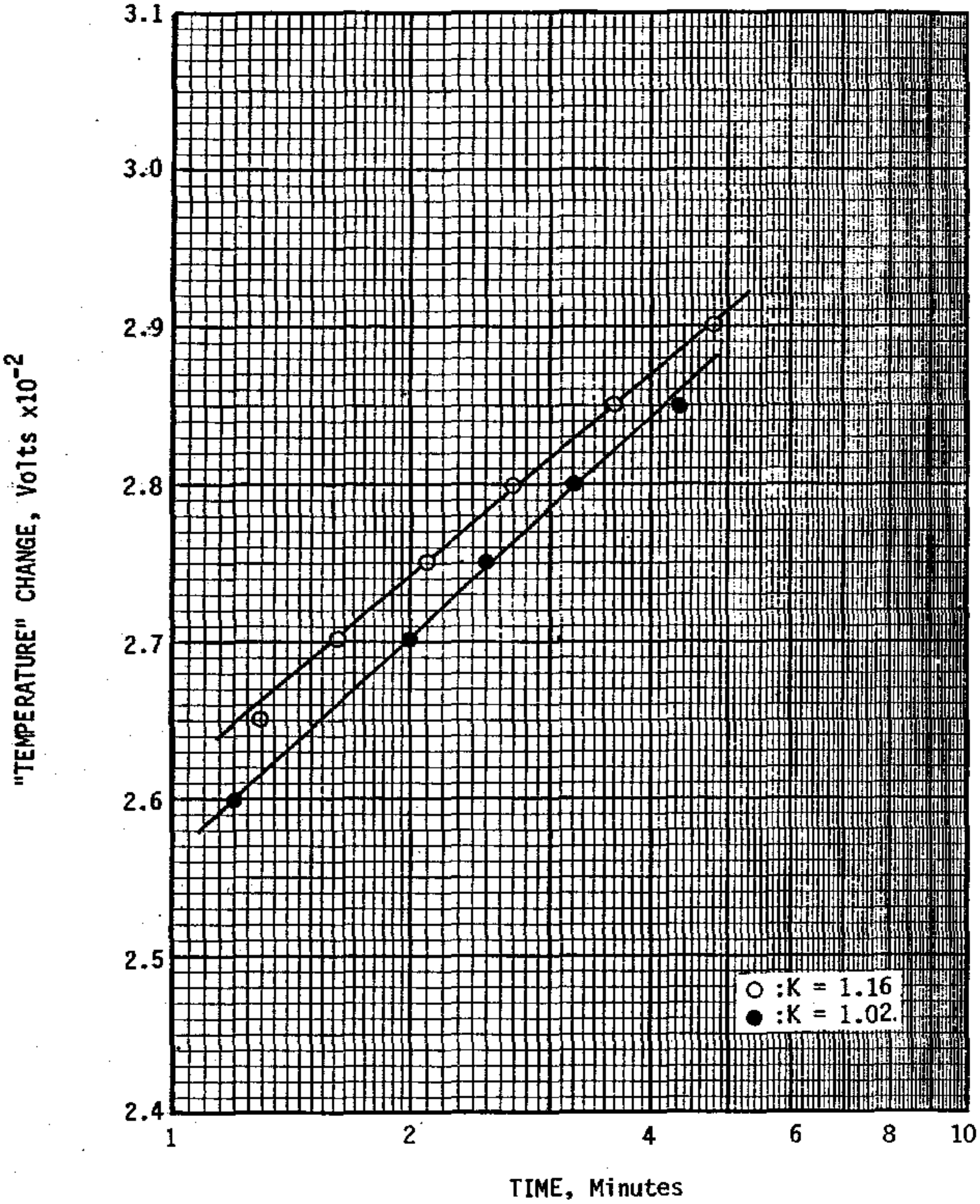
PLATE
D-150

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08		4/82		



CLASSIFICATION SILT (ML)

SOURCE Boring 4 at 12.4'

MOISTURE CONTENT 38.8 **%**

DRY DENSITY 78 **pcf**

☐ FROZEN / ■ THAWED
THERMAL CONDUCTIVITY 1.09 **Btu / Ft-hr-°F**

LL 33 **%**

PL 26 **%**

-200 sieve 90.1 **%**

ORGANIC CONTENT ---- **%**

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PLATE
D-151

DRAWN

JOB NUMBER
9612,031.08

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4/82

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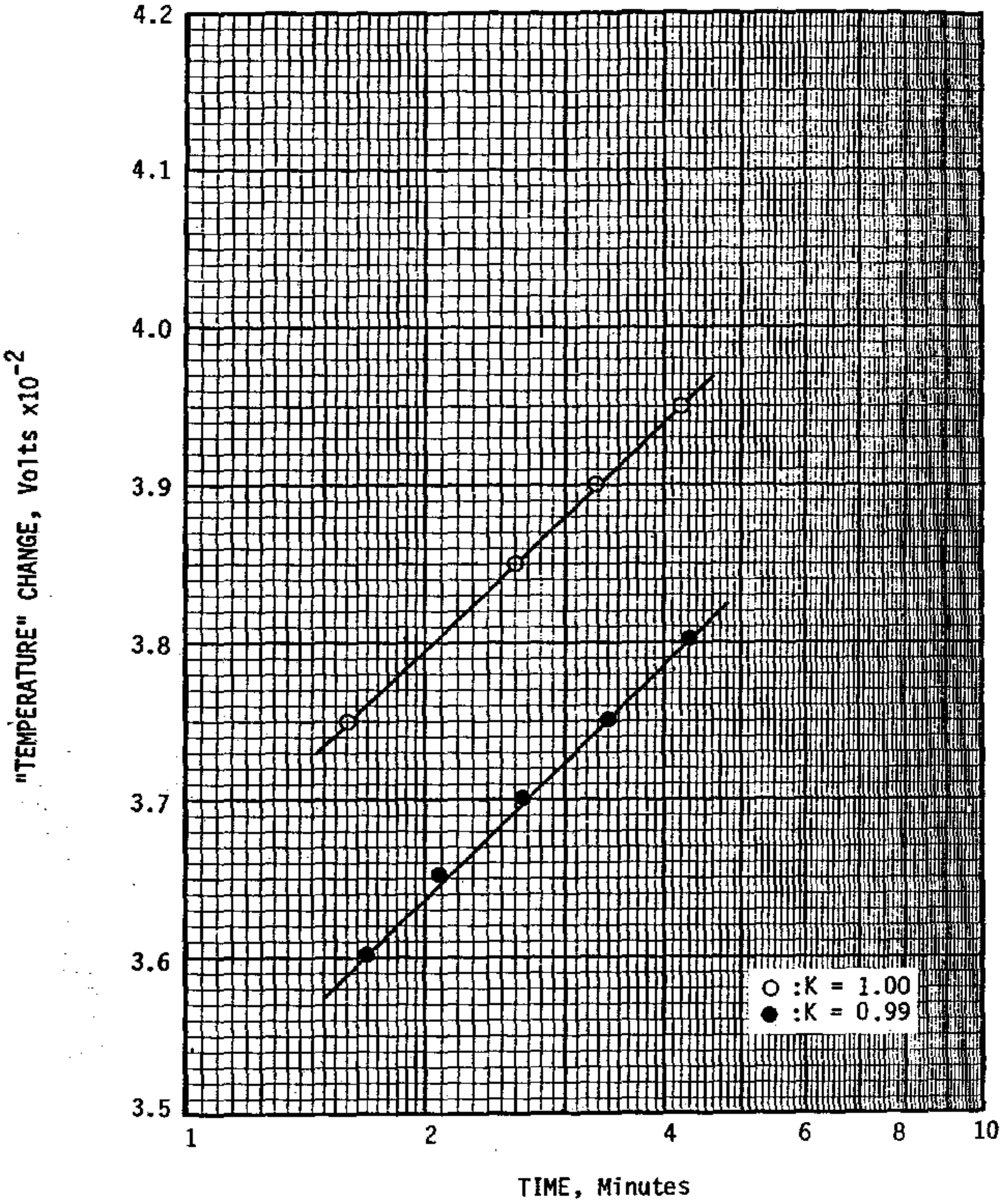
DATE



CLASSIFICATION SILTY CLAY (CL)			**SOURCE** Boring 5 at 19.2'	
MOISTURE CONTENT 39.5 %		**DRY DENSITY** 79 pcf	☐ **FROZEN** / ■ **THAWED THERMAL CONDUCTIVITY** 0.99	Btu / Ft-hr-°F
LL 31 %	**PL** 21 %	**-200 sieve** --- %	**ORGANIC CONTENT** ----	%

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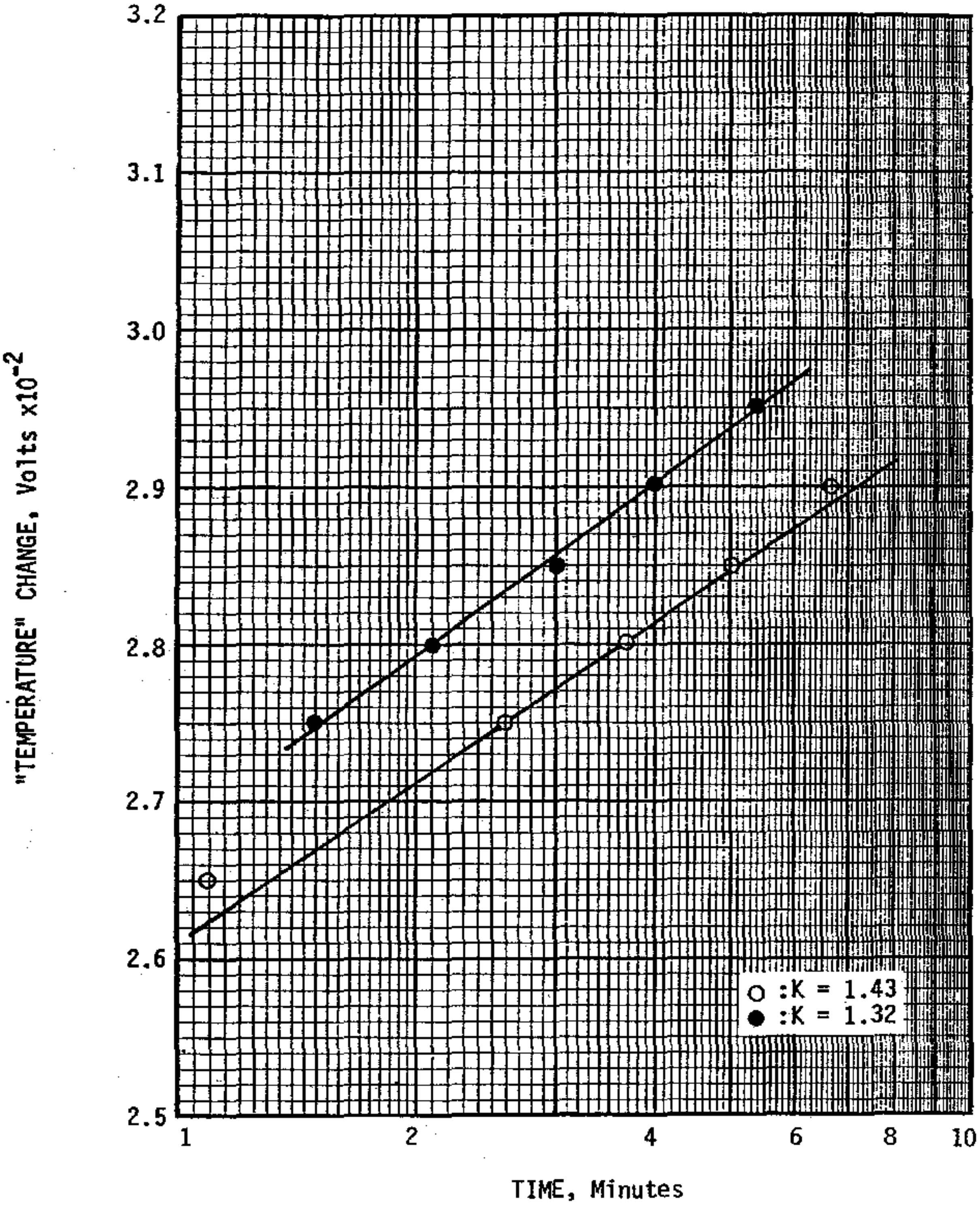
PLATE **D-152**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	JEB	4/82		



CLASSIFICATION SILT (ML)

SOURCE Boring 8 at 12.2'

MOISTURE CONTENT 22.6 **%**

DRY DENSITY 103 **pcf**

☐ FROZEN / ■ THAWED THERMAL CONDUCTIVITY 1.38 **Btu / Ft-hr-°F**

LL -- **%**

PL -- **%**

-200 sieve --- **%**

ORGANIC CONTENT ----- **%**

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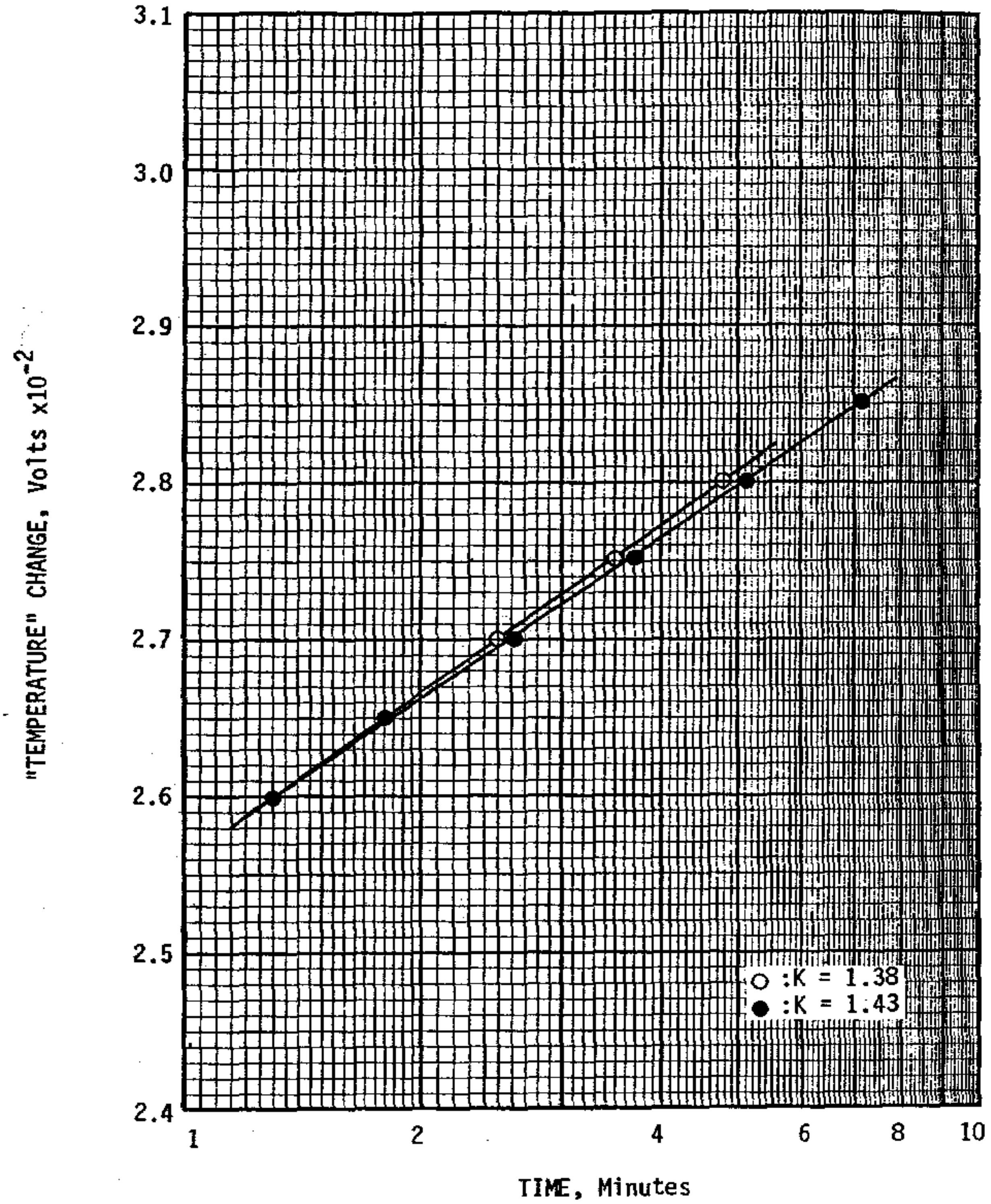
PLATE
D-153

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DGB	4/82		



CLASSIFICATION SILTY SAND (SM)

SOURCE Boring 9 at 0.5'

MOISTURE CONTENT 22.1 **%**

DRY DENSITY 105 **pcf**

☐ FROZEN / ■ THAWED THERMAL CONDUCTIVITY 1.41 $\frac{\text{Btu}}{\text{Ft-hr-°F}}$

LL -- **%**

PL -- **%**

-200 sieve --- **%**

ORGANIC CONTENT ----- **%**

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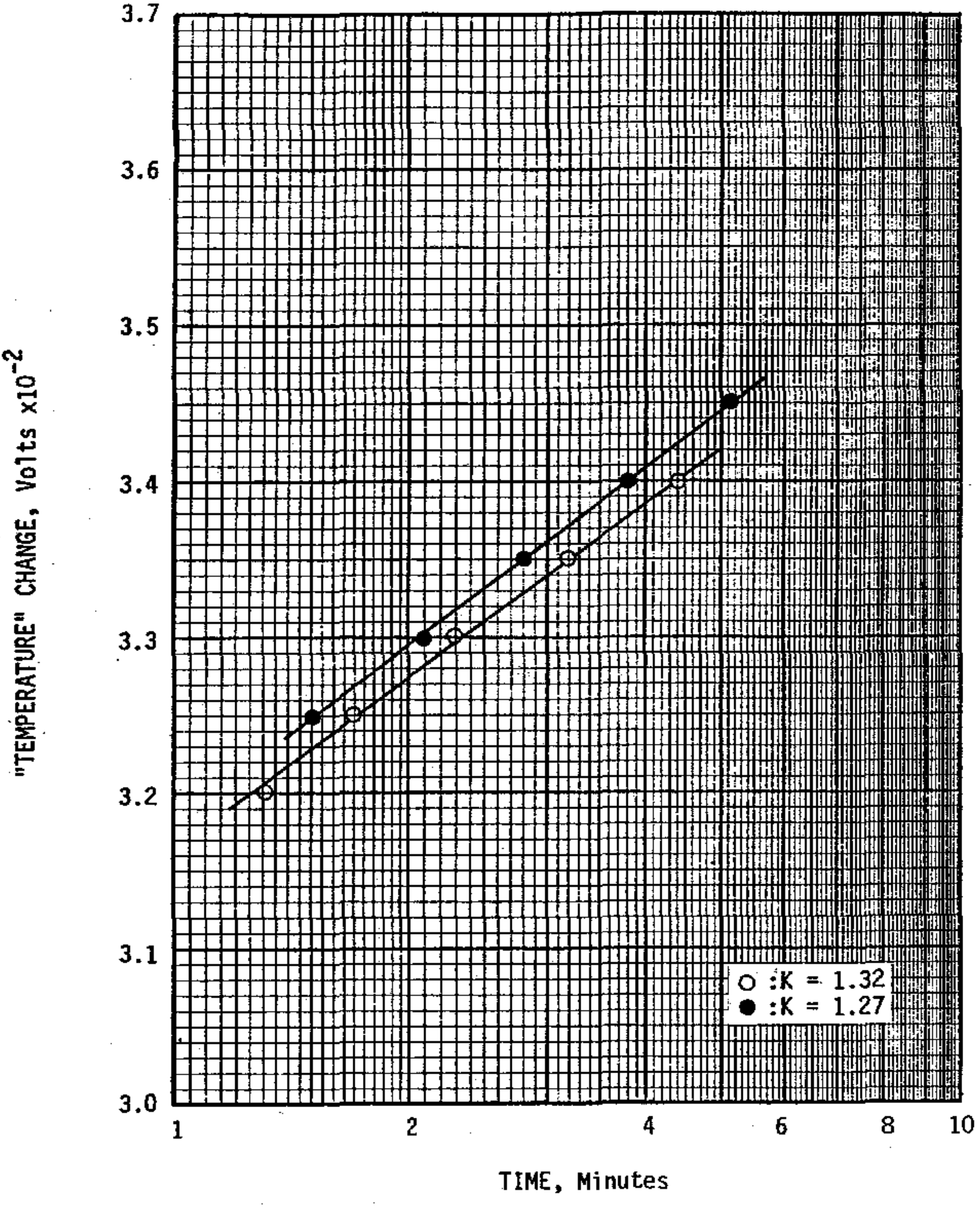
PLATE **D-154**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
X	9612,031.08	DEB	4/82		



CLASSIFICATION SILTY CLAY (CL)		**SOURCE** Boring 9 at 46.4'	
MOISTURE CONTENT 29.3 **%**	**DRY DENSITY** 93 **pcf**	☐ **FROZEN** / ■ **THAWED** **THERMAL CONDUCTIVITY** 1.30	**Btu/Ft-hr-°F**
LL -- **%** | **PL** -- **%**	**-200 sieve** --- **%**	**ORGANIC CONTENT** -----	**%**

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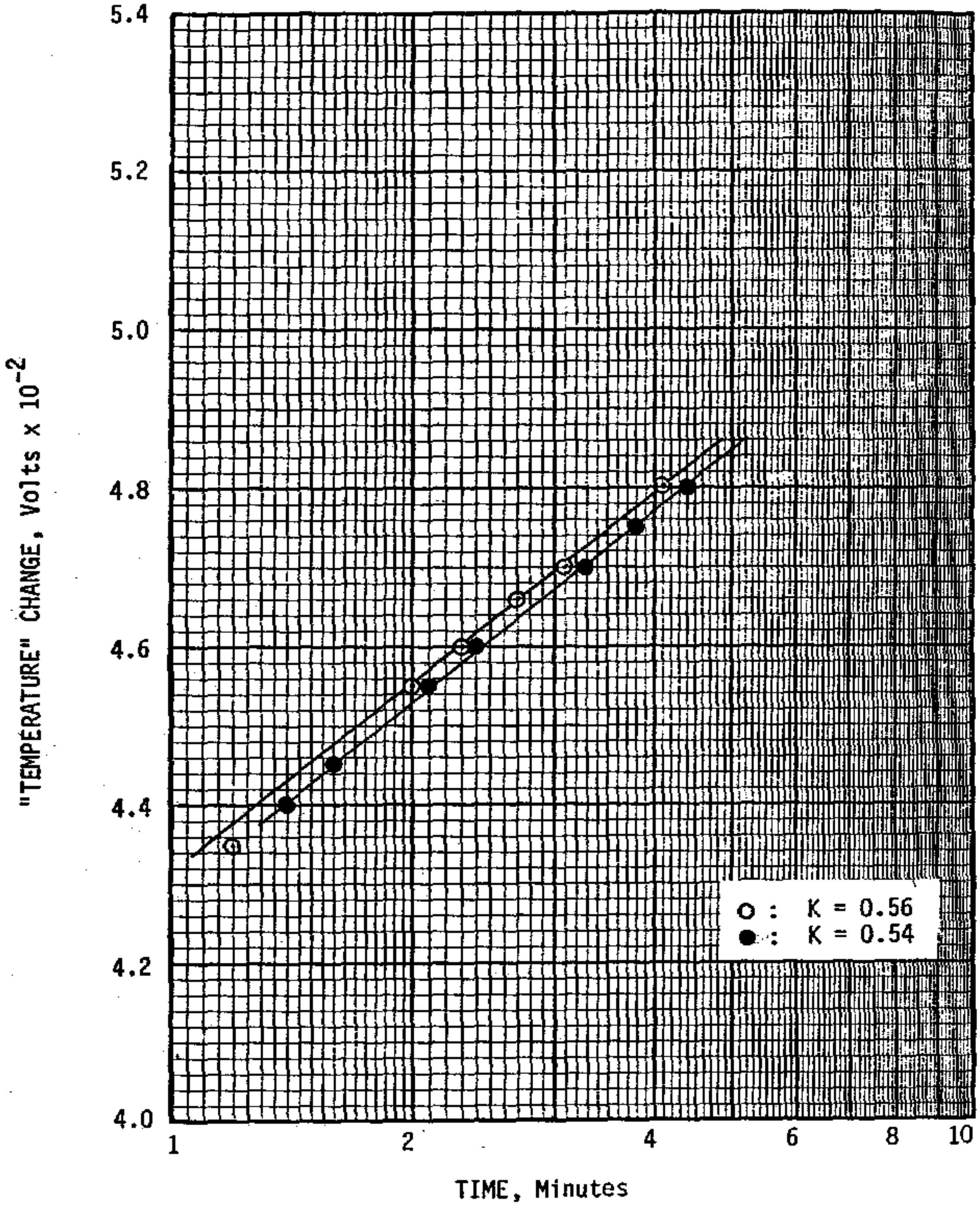
PLATE
D-155

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DAB	4/82		



CLASSIFICATION ORGANIC SILT (OL,V_x/V_r)

SOURCE Boring 12 at 0.0'

MOISTURE CONTENT 406 **%**

DRY DENSITY 11 **pcf**

■ FROZEN / ☐ THAWED THERMAL CONDUCTIVITY 0.55 **Btu/Ft-hr-°F**

LL -- **%**

PL -- **%**

-200 sieve -- **%**

ORGANIC CONTENT -- **%**

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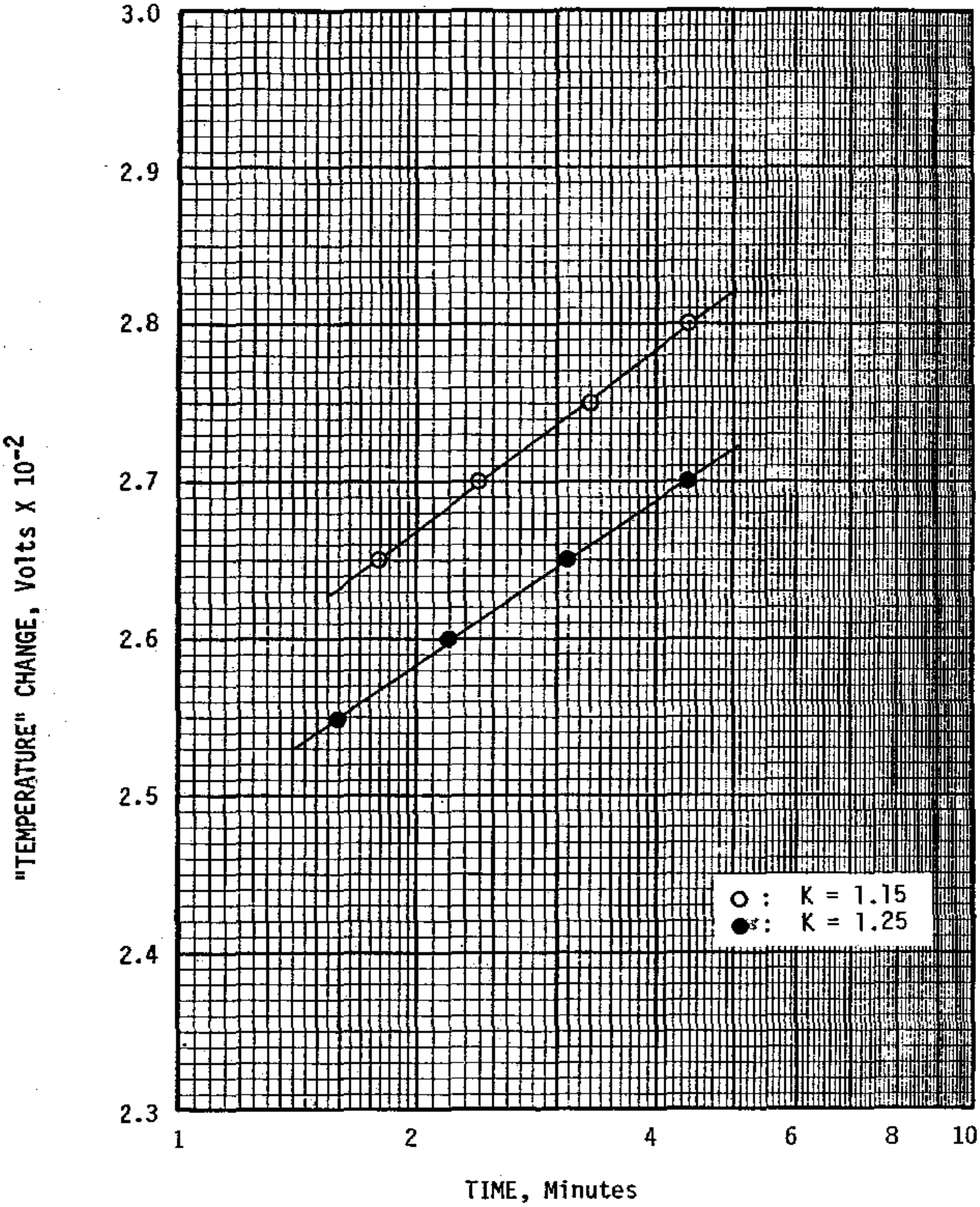
PLATE
D-156

DRAWN JT
JOB NUMBER 9612,031.08
APPROVED DEB
DATE 4/82
REVISED
DATE



CLASSIFICATION CLAYEY SILT (ML,V_x/V_r)

SOURCE Boring 13 at 18.0'

MOISTURE CONTENT 154 **%**

DRY DENSITY 29 **pcf**

■ FROZEN / □ THAWED THERMAL CONDUCTIVITY 1.20 **Btu / Ft-hr-°F**

LL 34 **%**

PL 25 **%**

-200 sieve -- **%**

ORGANIC CONTENT -- **%**

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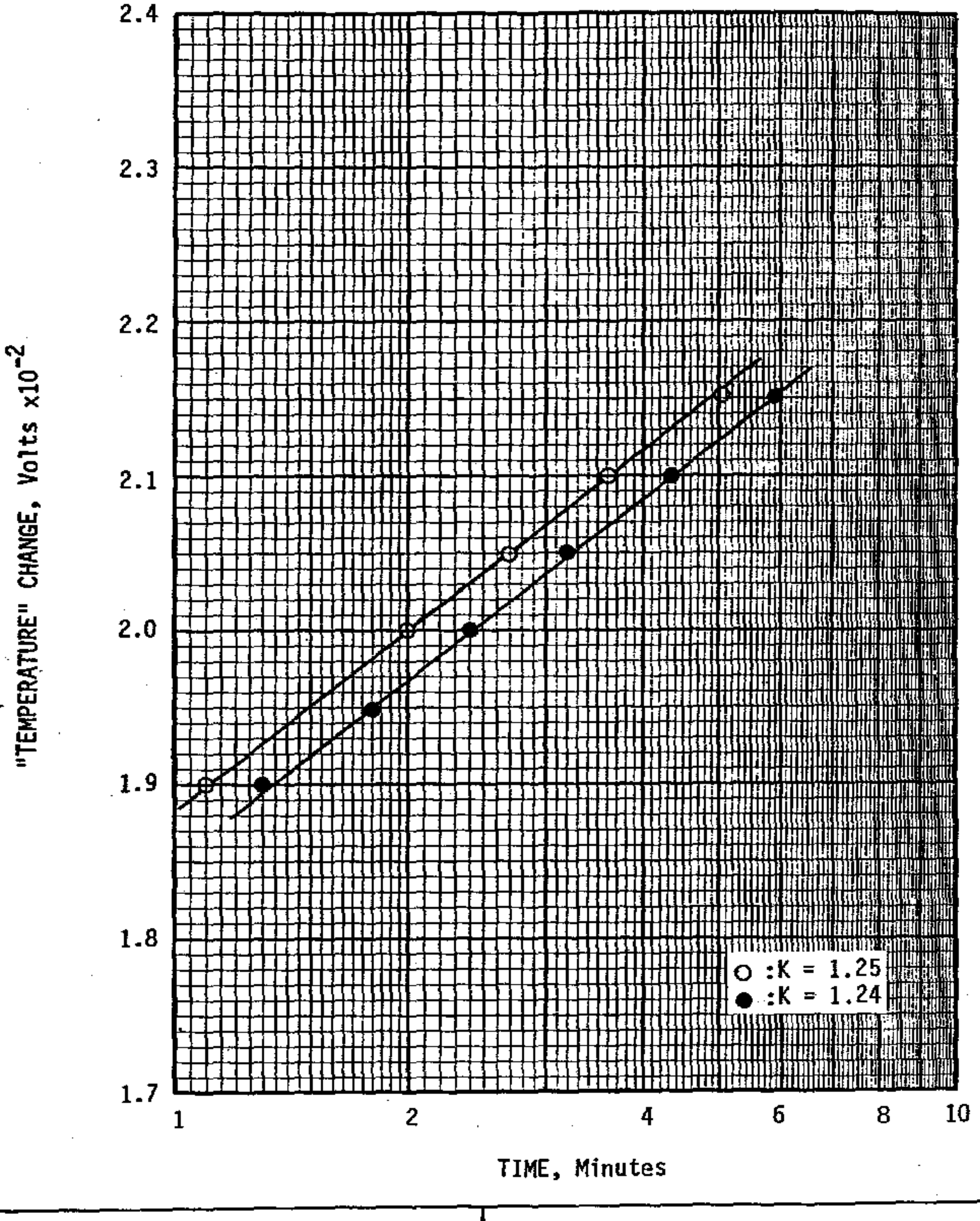
PLATE
D-157

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DEB	4/82		



CLASSIFICATION SILTY CLAY (CL)

SOURCE Boring 14 at 31.1'

MOISTURE CONTENT 22.8 **%**

DRY DENSITY 105 **pcf**

☐ **FROZEN** / ■ **THAWED THERMAL CONDUCTIVITY** 1.24 **Btu / Ft-hr-°F**

LL -- **%**

PL --- **%**

-200 sieve --- **%**

ORGANIC CONTENT ----- **%**

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PLATE **D-158**

DRAWN
JOB NUMBER 9612,031.08
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DATE 4/82
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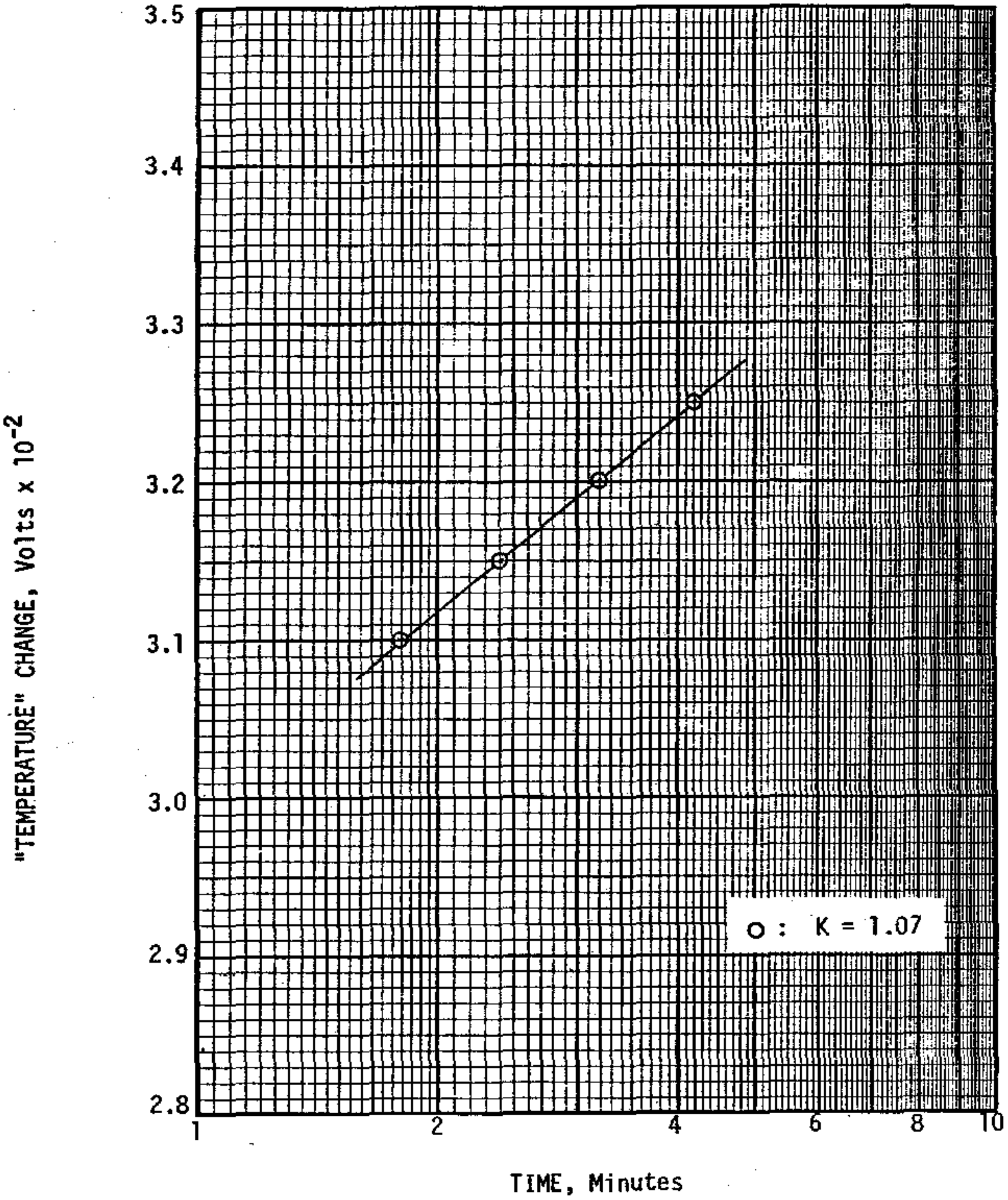
DATE



CLASSIFICATION ORGANIC SILT (OL, bonded)		**SOURCE** Boring 18 at 0.3'	
MOISTURE CONTENT 149 %	**DRY DENSITY** 31 pcf	**■ FROZEN / ☐ THAWED THERMAL CONDUCTIVITY** 1.07	Btu / Ft-hr-°F
LL -- % **PL** -- %	**-200 sieve** -- %	**ORGANIC CONTENT** -- %	

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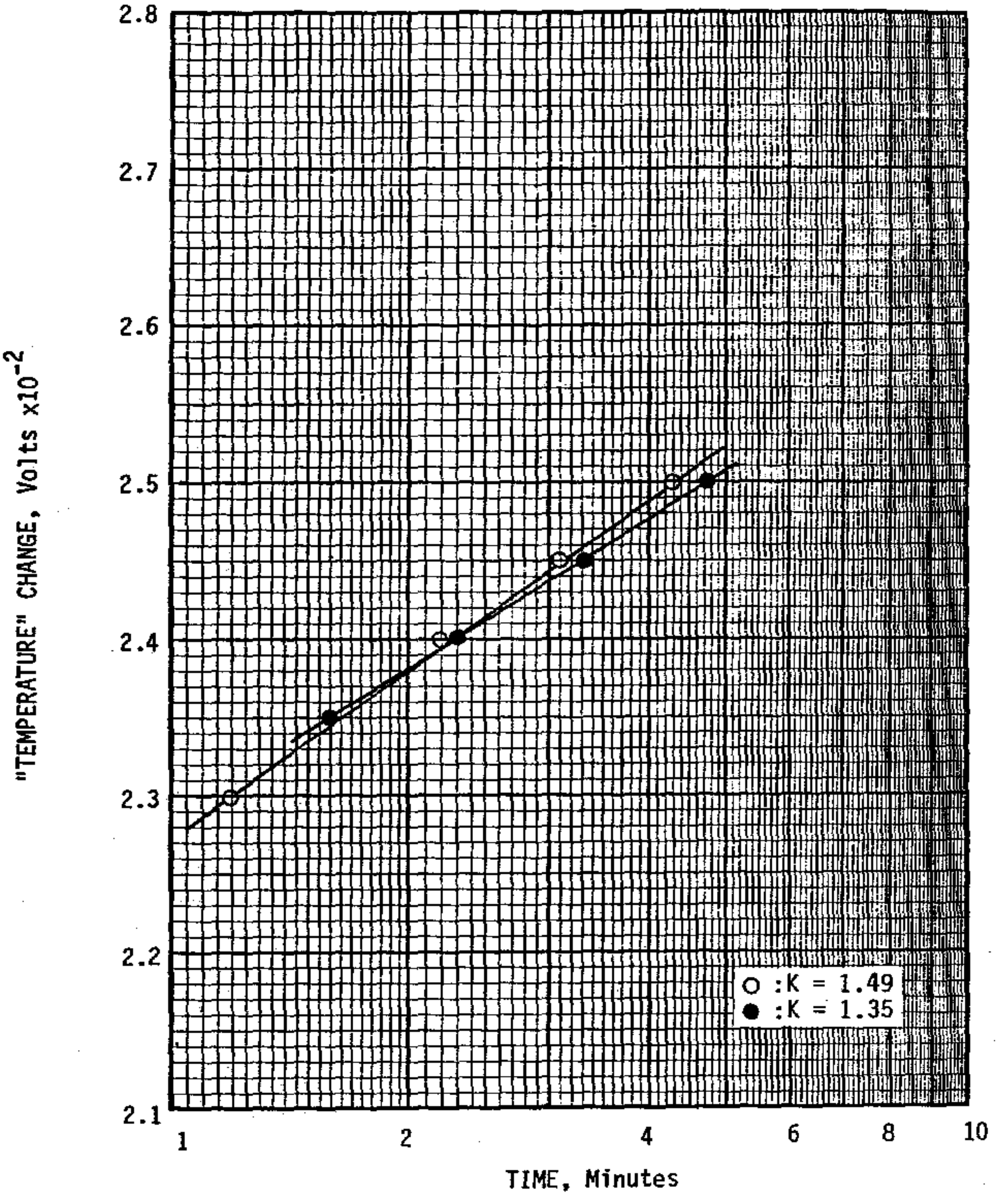
PLATE
D-159

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
Y	9612,031.08	DEB	4/82		



CLASSIFICATION SANDY SILT (ML)		**SOURCE** Boring 21 at 16.1'	
MOISTURE CONTENT 27.3 **%**	**DRY DENSITY** 97 **pcf**	☐ **FROZEN** / ■ **THAWED** **THERMAL CONDUCTIVITY** 1.42	**Btu** **Ft-hr-°F**
LL -- **%** **PL** -- **%**	**-200 sieve** --- **%**	**ORGANIC CONTENT** -----	**%**

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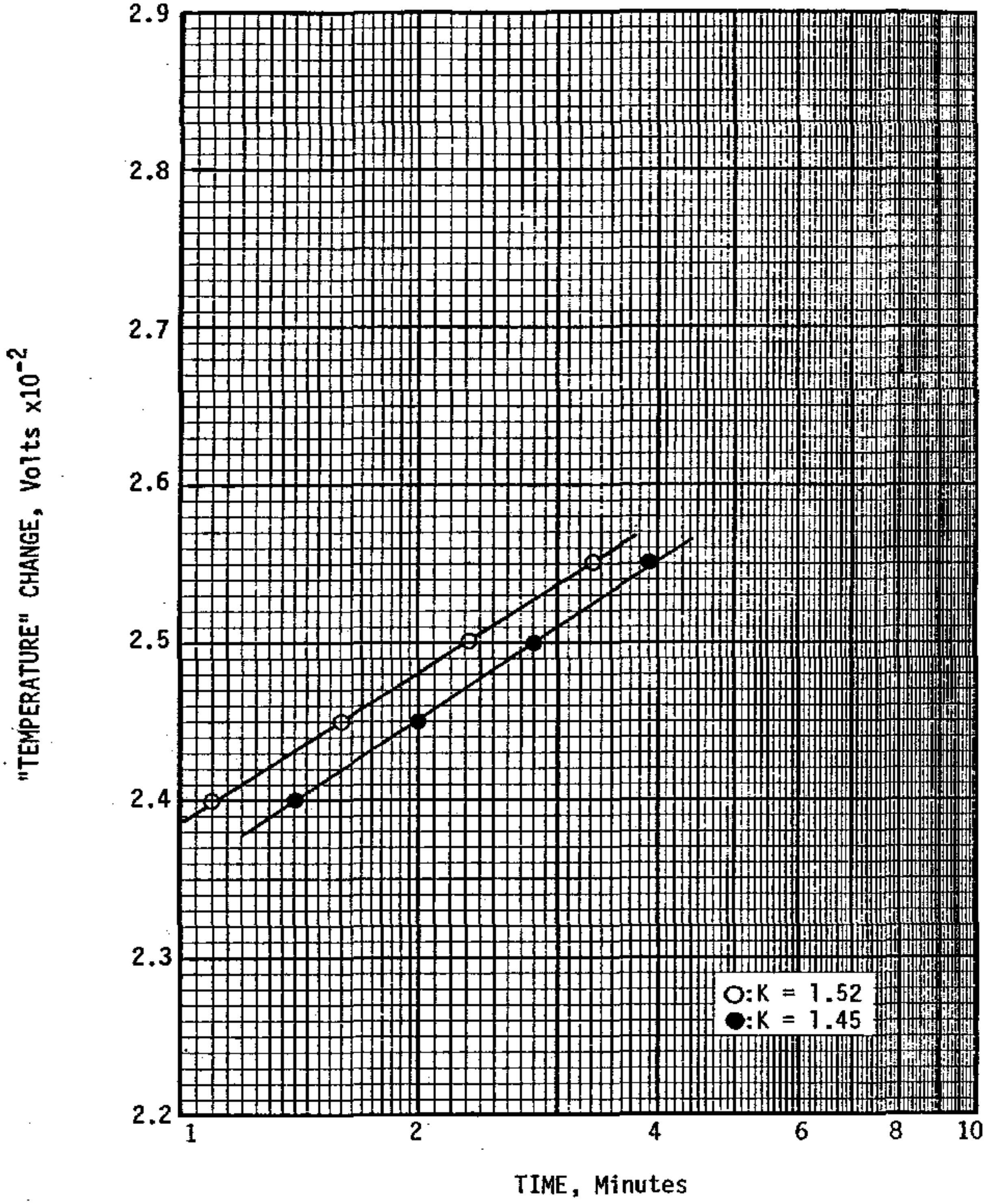
PLATE D-160

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
	9612,031.08	DEB	4/82		



CLASSIFICATION CLAY (CL)

SOURCE Boring 21 at 31.0'

MOISTURE CONTENT 24.4 %

DRY DENSITY 101 pcf

☐ **FROZEN** / ■ **THAWED THERMAL CONDUCTIVITY** 1.49 Btu/Ft-hr-°F

LL -- %

PL -- %

-200 sieve --- %

ORGANIC CONTENT ----- %

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PLATE
D-161

DRAWN
JOB NUMBER 9612,031.08
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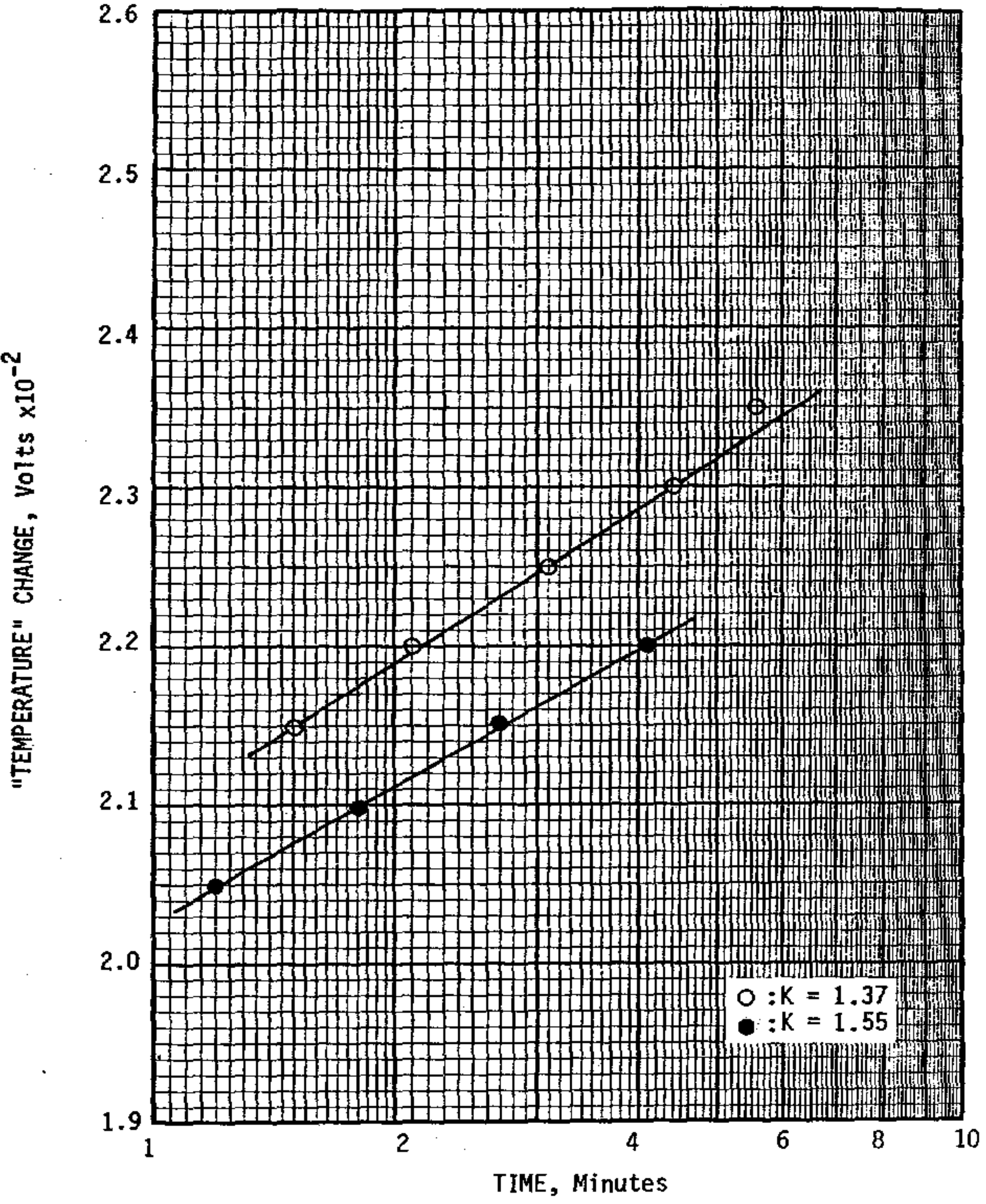

CLASSIFICATION SILT (ML, V_X)

SOURCE Boring 23 at 0.5'

MOISTURE CONTENT 30.3 **%**

DRY DENSITY 78 **pcf**

■ **FROZEN** / ☐ **THAWED THERMAL CONDUCTIVITY** 1.46 **Btu / Ft-hr-°F**

LL --- **%**

PL --- **%**

-200 sieve ---- **%**

ORGANIC CONTENT ---- **%**

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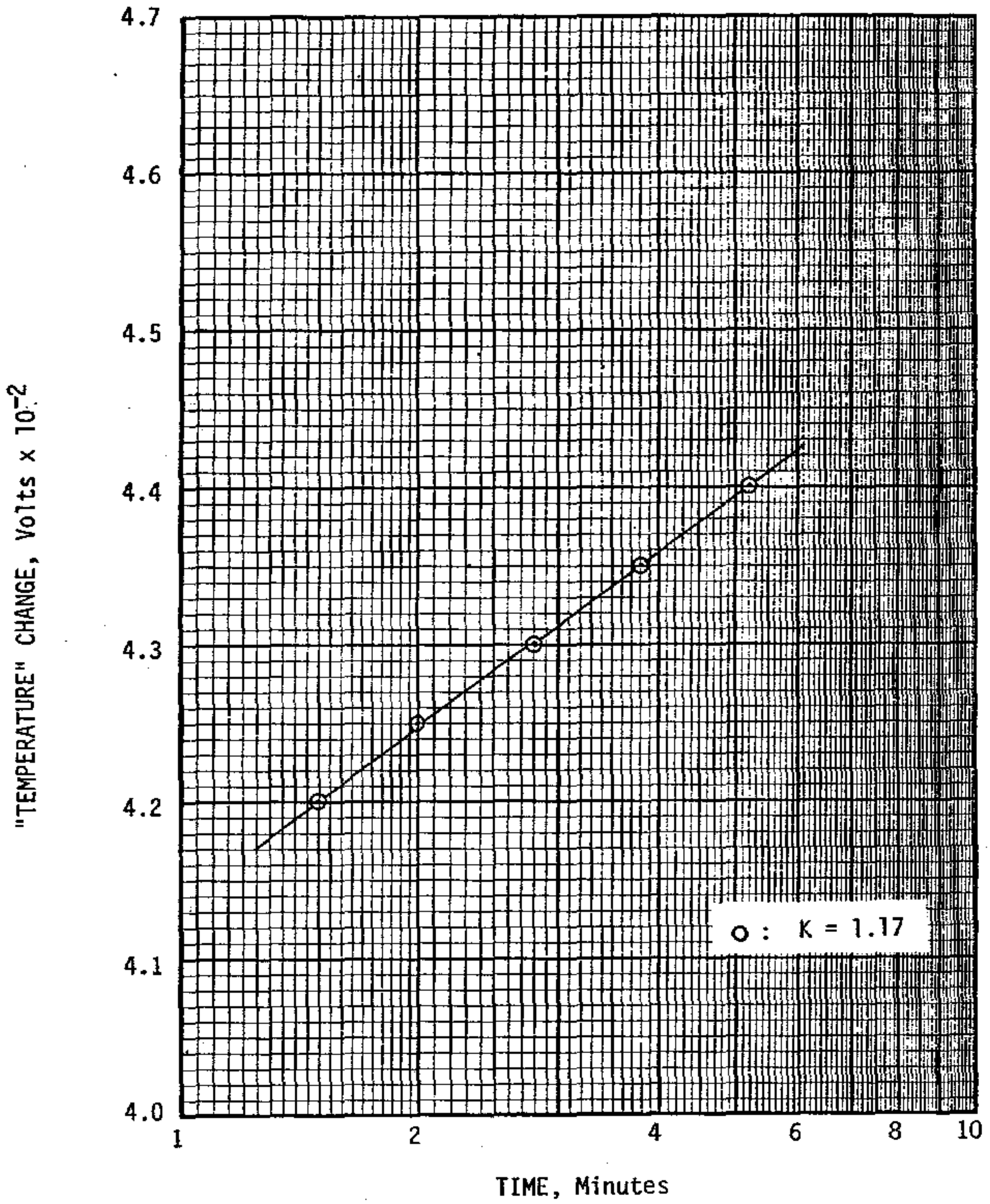
PLATE
D-162

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	DGB	4/82		



CLASSIFICATION SILTY CLAY (CL,V_r)			**SOURCE** Boring 23 at 12.5'
MOISTURE CONTENT 43.9%		**DRY DENSITY** 70 **pcf**	■ **FROZEN** / ☐ **THAWED** **THERMAL CONDUCTIVITY** 1.17 **Btu/Ft-hr-°F**
LL 33 **%**	**PL** 22 **%**	**-200 sieve** -- **%**	**ORGANIC CONTENT** -- **%**

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PLATE **D-163**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
S	9612,031.08	DEB	4/82		

was performed on silty sand (SM), the value obtained was higher than values recorded for the fine-grained soils. We observed no substantial difference between the clays, silts, and organic silts.

On Plate IV-24, thermal conductivities from this study are plotted against thermal conductivities from Kersten's work (1949). It can be observed that the thawed thermal conductivities of Beaufort Sea soils are greater than those predicted by Kersten's values. From the limited data developed during this study, it appears that the frozen thermal conductivities agree with Kersten's values.

APPENDIX E
EXPLANATION OF ANALYTICAL PROCEDURES

APPENDIX E
EXPLANATION OF ANALYTICAL PROCEDURES

This appendix contains detailed discussions of the methods used to define the mechanical properties of fill materials as presented in the Duck Island Development (DID) report (HLA, 1981), the methods used to define pile settlement and the analysis of laterally loaded piles in permafrost. Subsurface soil and gravel fill materials from the DID area are similar to those found in the PTD area; consequently, the relationships and analytical procedures used in the DID study are applicable to this study.

A. MECHANICAL PROPERTIES OF FILL MATERIALS

1. MECHANICAL PROPERTIES OF UNBONDED FILL MATERIALS

Both materials placed in the summer and gravel-ice mixtures placed in the winter will behave as unbonded soils until freezeback of free pore water. The parameters governing the behavior of fill materials in the unbonded condition include elastic modulus and Poisson's ratio, shear strength and compressibility. Estimated values for these parameters, based on index properties, laboratory test data and correlations available in the literature for similar soil types, are presented in Table IV-6.

Table IV-6. Mechanical properties of unbonded fill material

	[1] Initial Tangent Modulus		Poisson's Ratio μ	Shear Strength		[2] One Dimensional Compression Modulus	
	k	n		Friction Angle ϕ	[3] Cohesion c, psi	m	a
Ice-Free Gravel							
Placed in the dry, compacted to $R_d = 0.7$	250	0.4	0.30	40°	0	1000	0.9
Placed below sea level, $R_d = 0.5$	200	0.4	0.30	36°	0	800	0.9
Gravel-Ice Mixtures							
Placed in the dry, compacted	100	0.4	0.30	20°	0	400	0.75
Placed below sea level	60	0.4	0.35	15°	5	230	0.50
Silty Sands-Hydraulic Fill							
uncompacted, $R_d = 0.3$	75	0.25	0.45	28°	0	40	0.10
compacted, $R_d = 0.7$	150	0.25	0.45	32°	0	80	0.25

1. $E_i = \left(\frac{\sigma_1-\sigma_3}{\epsilon_1}\right)_i = k \; P_a \left(\frac{\sigma_3}{P_a}\right)^n$ (After Duncan et.al., 1980)

2. $M = \frac{\sigma_1}{\epsilon_1} = m \; P_a \left(\frac{\sigma_1}{P_a}\right)^{1-a}$ (After Janbu, 1967)

   where: P_a = atmospheric pressure in same unit as σ_1 and σ_3

3. All unbonded fill materials considered cohesionless, except gravel-ice mixtures for which a nominal cohesion is assigned to account for some ice bonding when very cold gravel-ice mixtures are deposited underwater.

The shear strength is represented by the Mohr-Coulomb failure criterion:

$$s = c + \sigma_n \tan\phi \qquad \text{(IV-8)}$$

where:
s = shear strength
c = cohesion intercept
σ_n = normal stress on the failure plane
ϕ = angle of internal friction

The elastic moduli are presented as initial tangent moduli (E_i) in the form (Duncan et al., 1980):

$$E_i = \left(\frac{\sigma_1 - \sigma_3}{\epsilon_1}\right)_i = k(P_a)\left(\frac{\sigma_3}{P_a}\right)^n \qquad \text{(IV-9)}$$

where:
σ_1, σ_3 = major and minor principal stresses, respectively
ϵ_1 = major principal strain
k = modulus number
n = modulus exponent
P_a = atmospheric pressure

Assuming a hyperbolic stress-strain relationship, the tangent modulus, E_t, for any stress condition, $(\sigma_1 - \sigma_3)$, σ_3, can be computed from

$$E_t = \left[1 - \frac{R_f (1-\sin\phi)(\sigma_1 - \sigma_3)}{2c(\cos\phi) + 2\sigma_3(\sin\phi)}\right] E_i \qquad \text{(IV-10)}$$

where: R_f = "failure ratio" ≈ 0.7 for moist soils

Similarly, compressibility is presented in terms of the one-dimensional modulus (M), i.e.,

$$M = \frac{d\sigma_v}{d\epsilon_v} = m(P_a)\left(\frac{\sigma_v}{P_a}\right)^{1-a} \qquad \text{(IV-11)}$$

in which σ_v and ϵ_v are the vertical stress and strain in one-dimensional compression, "m" is the modulus number, "a" is the stress exponent, and "P_a" is atmospheric pressure (Janbu, 1967).

2. MECHANICAL PROPERTIES OF BONDED FILL MATERIALS

Lacking reliable experimental data, the following discussion presents methods for qualitative assessment of the mechanical properties of bonded fill material. Direct measurements are needed to evaluate the validity of these methods and the results and conclusions derived from them.

a. Creep and Strength Properties of Bonded Fill Materials

The stress-strain-time behavior of bonded fill materials will be influenced by several material and environmental variables, of which the following could have a significant effect:

- Material type; i.e., silt, sand, or gravel
- Strain rate ($\dot{\epsilon}$)
- Temperature (θ)
- Void ratio (e)
- Ice saturation (S_i)
- Brine content (S_b)
- Confining pressure (σ_3)

Functionally, we may express the stress-strain-time relationship for a given material type as:

$$\sigma = \sigma\,(\dot{\epsilon}, t, \theta, R_d, S_i, S_b, \sigma_3) \qquad \text{(IV-12)}$$

where: $\sigma = \sigma_1 - \sigma_3$ = deviator stress

$\dot{\epsilon} = \frac{d\epsilon}{dt}$ = strain rate

t = time

Ladanyi (1972) has proposed the following creep law:

$$\dot{\epsilon} = \dot{\epsilon}_c \left(\frac{\sigma}{\sigma_c}\right)^n \qquad \text{(IV-13a)}$$

$$\sigma = \sigma_c \left(\frac{\dot{\epsilon}}{\dot{\epsilon}_c}\right)^{1/n} \qquad \text{(IV-13b)}$$

where: σ = applied stress

σ_c = creep modulus (a reference stress)

$\dot{\epsilon}$ = strain rate resulting from applied stress, σ

$\dot{\epsilon}_c$ = strain rate corresponding to stress, σ_c

n = creep exponent

This form of creep law assumes that steady-state creep dominates. It is assumed that primary (attenuating) creep is insignificant in comparison to steady-state creep and that the creep rate does not accelerate (tertiary creep) within the duration of loading being considered. The implication of these assumptions is illustrated on Figure IV-9.

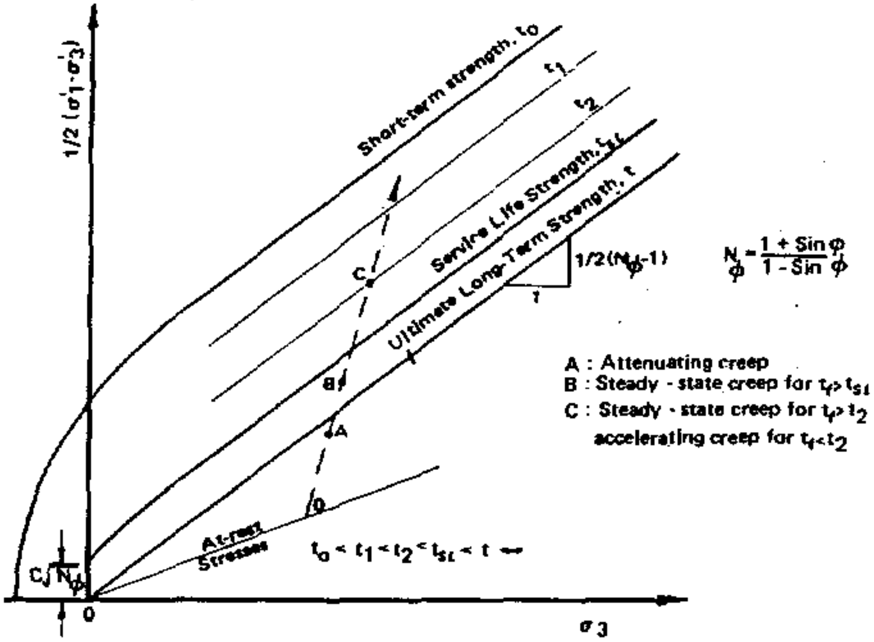


Figure IV- 9 Strength versus time behavior for frozen soils (modified after Ladanyi, 1975).

The strength of a frozen soil under various durations of loading are shown in $\frac{1}{2}(\sigma_1 - \sigma_3) : \sigma_3$ stress space on Figure IV-9. The frictional component of the frozen strength (represented by the slope of the failure envelopes) is assumed to be independent of time whereas the cohesion component (the shear strength when the confining pressure, σ_3, is zero) decreases with time and eventually vanishes when time becomes infinite.

The line OABC represents a hypothetical loading path starting from at-rest conditions (point O). Because the loading represented by OA never exceeds the ultimate long-term strength, the creep rate decreases with time and eventually stops. This is the case of attenuating creep. On the other hand, the loading OC exceeds the service life strength; failure by tertiary creep will occur at time t_2 before the service life is reached.

Loading OB exceeds the ultimate long-term strength but is less than the service life strength. It is this type of loading condition for which Equation (IV-13a,b) is assumed to be valid. The requirements for validity of the creep law are as follows:

$$\sigma_{ult} < \sigma_{app} < \sigma_{sl} \qquad \text{(IV-14)}$$

where: σ_{ult} = ultimate long-term creep strength
σ_{app} = applied stress
σ_{sl} = service life creep strength

As a practical matter, these requirements are usually satisfied because, on the one hand, proper design cannot permit the applied stress to exceed the service life creep strength and, on the other hand, the ultimate long-term (frictional) strength is generally quite low, except in the case of dense, ice-poor soils.

It is assumed that the effects of the material and environmental variables previously identified can be approximately accounted for in the creep modulus term

$$\sigma_c = \sigma_c \ (\theta, \ e \ , S_i, S_b, \sigma_3) \qquad \text{(IV-15)}$$

The effects of each of the variables are discussed below:

(1) Temperature

The qualitative effects of temperature on the creep behavior of frozen soils are well known. In general, as the temperature decreases, the creep rate decreases and the creep strength increases. The quantitative functional relationships are less well established, but generally seem to be of the form suggested by Sayles and Haines (1974):

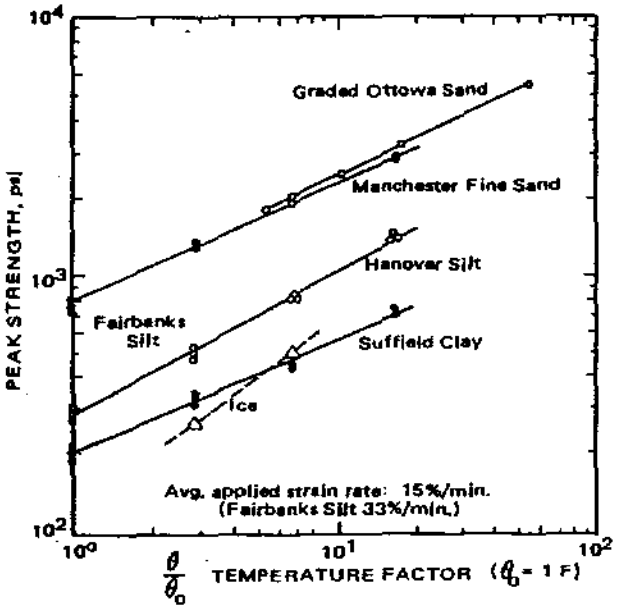
$$\left(\frac{\sigma_\theta}{\sigma_0}\right)=\left(\frac{\theta}{\theta_0}\right)^m \qquad \text{(IV-16)}$$

in which, σ_θ and σ_0 are stresses (or strengths) at temperatures of θ and θ_0 (^{0}F below freezing) and m is the temperature exponent. Figure IV-10 shows peak strength versus temperature data reported by Sayles and Haines (1974) for ice and four different types of soil.

For the four different soil types the temperature exponent, m, varies within fairly narrow limits, i.e., m = 0.48 ± 15 percent. Therefore, we have assumed that m = 0.5 can be used for the soil types expected to be used as fill for this project. The possible dependency of m on salinity is assumed to be accounted for by the brine content factor discussed below.

(2) Void Ratio

Goughnour and Andersland (1968) found that the shear strength of frozen Ottawa sand varies considerably with the volume concentration of sand in a sand-ice mixture. Sand concentration is defined as the ratio of sand volume to total volume; thus, sand concentration = 1/(1 + e). As the sand concentration was varied from zero (pure ice) to about 42 percent (e = 1.38), only a minor increase in the shear strength was observed. However, above 42 percent, the shear strength increases rapidly, continuing up to a sand concentration of about 63 percent (e = 0.59). Linell and Lobacz (1980) have presented data for Manchester fine sand that show a peak strength at an "ice content" of about 0.58, with the strength decreasing for both higher and lower ice contents. (Note: "ice content" is defined by Linell and Lobacz as the volumetric ratio of ice to soil, which is equivalent to void ratio for 100 percent ice saturation).



$$\left(\frac{\sigma_\theta}{\sigma_0}\right) = \left(\frac{\theta}{\theta_0}\right)^m$$

Soil	σ_0 (psi)	m
Graded Ottawa sand	789	0.48
Manchester fine sand	812	0.44
Hanover silt	288	0.55
Suffield clay	204	0.43
	Avg.=	0.48

Figure IV-10. Peak Strength vs. Temperature (After Sayles and Haines, 1974)

If the data of Goughnour and Andersland (1968) and Linell and Lobacz are normalized with respect to peak strength and plotted as a function of void ratio, the data appear as shown in Figure IV-11. Figure IV-11 also shows the relative strength reduction that can be expected for the various fill material types being considered for this project. These reduction factors must be considered as only rough approximations since there are no corroborating test data for the materials.

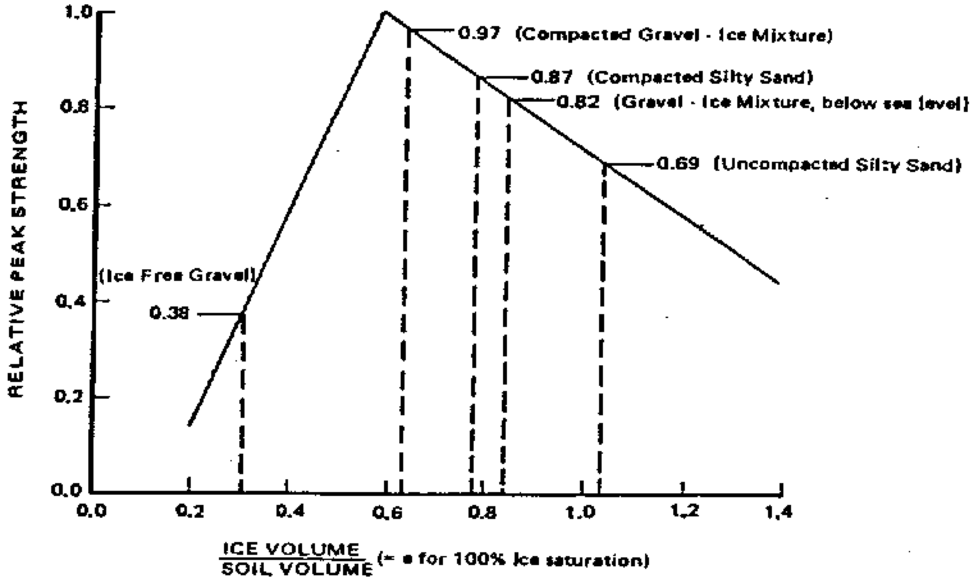


Figure IV-11. Variation of peak strength with volumetric ice content (Data from Linell and Lobacz, 1980 and Goughnour and Andersland, 1968)

(3) Ice Saturation

Alkire and Andersland (1973) have addressed the effects of ice saturation on frozen Ottawa sand-ice mixtures. Their data, reproduced in Figure IV-12, show a reduction in strength with reduction in ice saturation. Since only two values of ice saturation were used in their study, linear interpolation and extrapolation were used to develop approximate relationships. Extrapolation was confined to ice saturation in the range of 0.18 S_i 1.00 because the curve for zero confining pressure indicates zero strength for S_i 0.18.

If the data in Figure IV-12 are normalized with respect to peak strength at $S_i = 1.0$ and the effect of confining pressure omitted, the relationship in Equation IV-17 results.

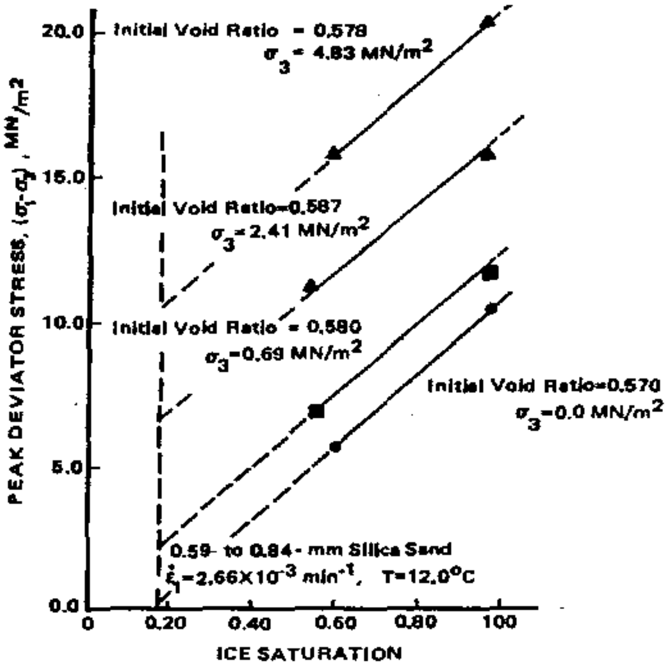


Figure IV-12 Peak deviator stress versus ice saturation for various confining pressures (After Alkire and Andersland, 1973).

The effects of confining pressure are quite apparent in Figure IV-12; this factor will be discussed below. Again, the data on the effects of ice saturation described above are for one material type only, Ottawa sand, and applying the effects to gravels and silty sands involves considerable uncertainty.

$$\frac{\sigma_{S_i}}{\sigma_{S_i=1.0}} = -0.22 + 1.22\,S_i \quad \left\{ \begin{array}{ll} \text{for} & 0.18 \le S_i \le 1.0 \\ & \sigma_3 = o \end{array} \right\} \qquad \text{(IV-17)}$$

(4) Brine Content

Fill materials from offshore sources or those from onshore sources placed below sea level will contain significant brine in the pore water. Michel (1978) has shown that brine content can have a substantial effect on the strength of sea ice. Michel's data, reproduced in Figure IV-13, show that the

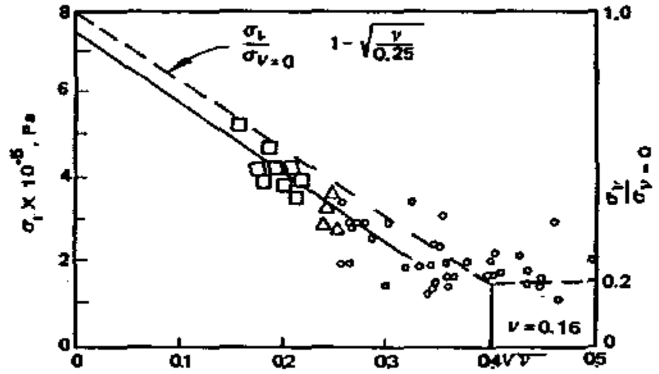


Figure IV-13. Flexure strength of sea ice vs. brine volume (After Michel, 1978).

flexural strength of sea ice is reduced to 20 percent of the strength of brine-free ice at a brine volume of about 0.16. At higher volumes, no further strength reduction occurs because the excess brine drains out of the ice. Michel suggests the following empirical relationship for strength reduction as a function of brine volume:

$$\frac{\sigma_\nu}{\sigma_{\nu=0}} = 1 - \sqrt{\frac{\nu}{0.25}} \qquad \left\{ \text{for } 0 \leq \nu \leq 0.16 \right\} \qquad \text{(IV-18)}$$

Ruedrich and Perkins (1974) investigated the effect of salt concentration on the strength of Prudhoe Bay sands and silts. Some of their results are reproduced in Figure IV-14; substantial reductions in strength with increasing salt concentrations are readily apparent.

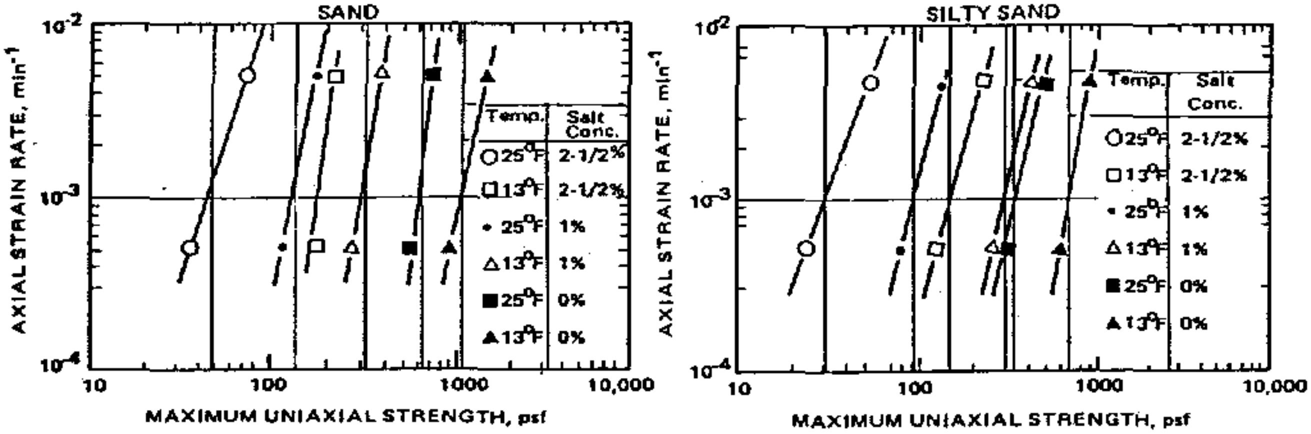


Figure IV-14. Influence of salt concentration on the strength of Prudhoe Bay sand and silty sand (After Ruedrich and Perkins, 1974).

In order to determine whether the influence of salt concentration in the frozen Prudhoe Bay sands and silty sands is similar to the effect of brine volume on sea ice, we have plotted the strength (at axial strain rate = 10^{-3} min^{-1}) from Figure IV-14 versus brine volume in the form used by Michel (1978) for sea ice. Brine volumes were estimated from the pore water salinity and test temperatures reported by Ruedrich and Perkins (1974) for the Prudhoe Bay samples. The results are shown in Figure IV-15.

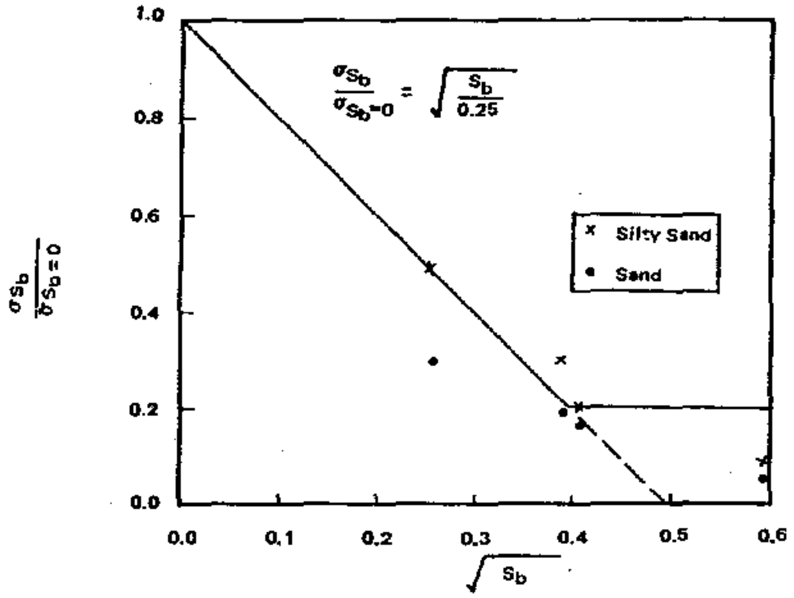


Figure IV-15. Influence of brine volume on the strength of Prudhoe Bay sand and silty sand (After Ruedrich and Perkins, 1974)

Although the data are limited, the relationship proposed by Michel (1978) appears to fit quite well. However, at brine volumes greater than 0.16, the data indicate that the strength continues to decrease because, in contrast to the natural freezing of sea ice, brine was not allowed to drain from the Prudhoe Bay test samples. It is our opinion that when the offshore fills freeze the brine will drain except possibly in the lowest portion of the fills, where brine may become trapped. For the case of gravel -ice mixtures placed below sea level, the brine volume is replaced by brine content to account for the initial freshwater ice content of the mixture (see Equation IV-5). Therefore, after replacing ν with S_b Equation IV-18 becomes:

$$\frac{\sigma_{S_b}}{\sigma_{S_b=0}} = 1 - \sqrt{\frac{S_b}{0.25}} \quad \left\{ \text{for } 0 \leq S_b \leq 0.16 \right\} \qquad \text{(IV-19)}$$

(5) Confining Pressure

To account for the effect of confining pressure on creep behavior, Ladanyi (1975) proposes to treat frozen soil as a (c, ϕ) material by replacing the creep modulus in Equation IV-13, σ_c by σ_{cf}, i.e.,

$$\sigma_{cf} = \sigma_c + \sigma_{3,\,av}\ (N_\phi - 1) \qquad \text{(IV-20)}$$

where: $N_\phi = \dfrac{1+\sin\phi}{1-\sin\phi}$

$$\sigma_c = 2c\ \sqrt{N_\phi}$$

ϕ denotes the friction angle of the frozen soil corresponding to the creep rate, $\dot{\epsilon}_c$, and c is the cohesion intercept. In this approach, c and ϕ are total stress parameters and ϕ is assumed to be relatively independent of time and temperature.

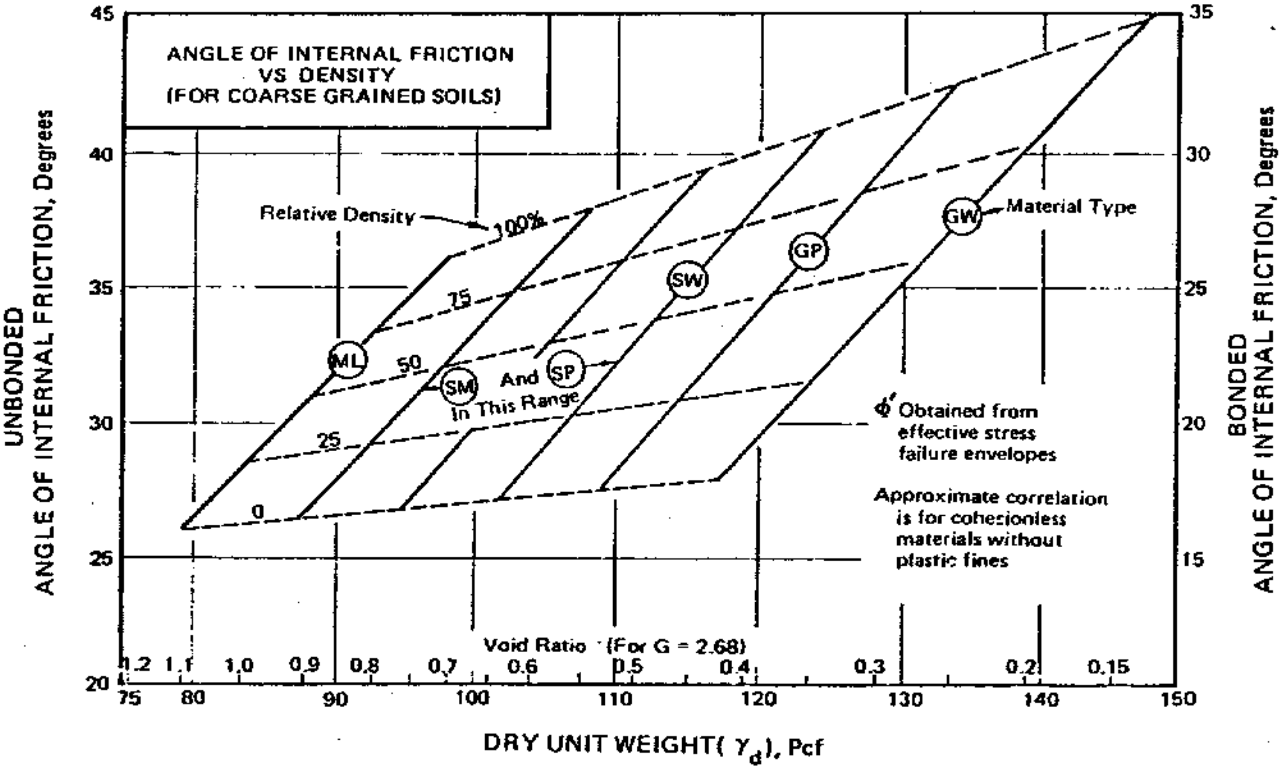


Figure IV-16. Angle of internal friction vs. density for frozen and unfrozen fill materials. Based on bonded angle of internal friction being 10 degrees less than the unbonded value (After Navdocks, 1971)

The angles of internal friction for ice-saturated frozen soils reported in the literature are typically six to ten degrees less than those for the same soil and density in the unfrozen condition (see, for example, Alkire and Andersland, 1973, Ladanyi and Johnston, 1973, and Sayles, 1973). If the difference in friction angles between the frozen and unfrozen state for the same soil and dry density is taken to be 10 degrees, the curves shown in Figure IV-16 can be used to estimate the friction angles for frozen fill materials.

The effects of temperature, void ratio, brine content in the pore fluid, ice saturation and confining pressure, as described in the preceeding discussion, can now be incorporated into the creep modulus, σ_c.

The parameters required to apply Equations IV-13 and IV-13b are as follows:

- Creep modulus, σ_c, and the corresponding strain rate, $\dot{\epsilon}_c$.
- Creep exponent, n
- Temperature factor, m (see Figure IV-10 and Equation IV-16)
- Index properties which influence the creep modulus
    - Void Ratio (e) (see Figure IV-11)
    - Ice saturation (S_i) (see Equation IV-17)
    - Brine content (S_b) (see Figure IV-15 and Equation IV-19)
    - Confining pressure σ_3 (see Figure IV-16 and Equation IV-20).

The index properties of the fill materials have been discussed previously and values for various typical conditions presented in Tables IV-4, IV-5, and IV-6. Representative values of creep modulus, creep exponents, and temperature factors are presented in Table IV-7.

The values of creep modulus are equivalent to the peak strength at a temperature of 31°F and a strain rate of 0.15 min.^{-1} and are estimated from the data of Sayles and Haines (1974) shown in Figure IV-10.

TABLE IV-7. Summary of creep properties for bonded fill materials[1]

$\dot{\epsilon} \cdot \dot{\epsilon}_c \left(\frac{\sigma}{\sigma_c}\right)^n$	Ice-FreeGravel	Gravel-Ice Mixtures		Ice-Free Silty Sands	
	placed below sea level ($R_d = 0.5$)	placed in the dry, compacted (Recrystalized)	placed below sea level, uncompacted	uncompacted ($R_d = 0.3$)	compacted ($R_d = 0.7$)
Creep Exponent, n	7.5	7.5	7.5	7.5	7.5
Creep Modulus, σ_c (ksf) (@ $\dot{\epsilon}_c = 0.15 \text{ min}^{-1}$)	115	[2]57	115	90	90
Adjustments to Creep Modulus					
(1) Temp. Exponent, m	0.5	0.5	0.5	0.5	0.5
Temp. factor	2.4	2.4	2.4	2.4	2.4
(2) Void Ratio Factor	0.38	0.97	0.87	0.69	0.87
(3) Ice Sat. Factor	—	0.34	—	—	—
(4) Brine Content	0.2	—	0.2	0.2	0.2
(5) Conf. Pressure Factor					
ϕ (degrees)	26	10	5	18	22
$(N_\phi - 1)$	1.56	0.42	0.19	0.89	1.20
Adjusted Creep Modulus	$21.0+1.56\sigma_3$	[2]$(45.0 + 0.42\sigma_3)$	$48.0 + 0.19\sigma_3$	$2.98+0.89\sigma_3$	$37.6 + 1.20\sigma_3$

Notes:

1. For average fill temperature = -5°C.
2. Depends upon degree of recrystallization.

The creep exponent was estimated from data on four different soil types ranging from Ottawa sand to Suffield clay (Sayles, 1968; Sayles and Haines, 1974). The values were obtained from Equation IV-13 rewritten as follows:

$$n = \frac{\log \left[\frac{\epsilon_f}{t_{100} \ \dot{\epsilon}_c} \right]}{\log \left[\frac{\sigma_{f100}}{\sigma_{pk}} \right]} \qquad \text{(IV-21)}$$

Where, ϵ_f = failure strain
t_{100} = 100 years
σ_{pk} = short-term creep strength
$\dot{\epsilon}_c$ = strain rate for σ_{pk}
σ_{f100} = creep strength at 100 years

Values of n were computed for several pairs of data at the same temperature for each soil type. In general, the computed n-values decreased with increasing temperatures, but varied little with soil type. A value of n = 7.5 was selected as representative of the range of soil types reported for temperatures of 25^{0} to 31^{0}F. This is believed to be a conservative value for the project fill materials.

Using the data presented in Table IV-7 and Equation IV-13b, the creep strength of the various fill materials can be estimated as a function of time. Design values for short-term (24 hours) and long-term (25 years) creep strength are presented in Table IV-8.

b. Elastic Properties of Bonded Fill Materials

Elastic moduli for frozen soils have been shown to be dependent on temperature and strain-rate much like that of stress or peak strength. For example, the data of Parameswaren, 1980 show the following approximate relationship between initial tangent modulus and strain rate for frozen Ottawa sand:

$$E_i = A \ (\dot{\epsilon})^m \qquad \text{(IV-22)}$$

Table IV-8. Mechanical properties of bonded fill materials

	Initial Tangent Modulus (ksf)		Poisson's Ratio	Shear Strength		One-Dimensional Compression	
	Short Term	Long Term	μ	Short Term (24 hrs.)	Long Term (25 yrs.)	m	a
Ice-Free Gravel Placed below sea level, uncompacted σ_3 = 1.34 ksf @ 20 ft.	1400	200	0.25	4.6	1.4	1500	0.90
Gravel-Ice Mixtures Placed in the dry, compacted (recrystallized) σ_3 = 0.61 ksf @ 10 ft.	3000	550	0.25	10.0	3.7	400	0.75
Placed below sea level, uncompacted σ_3 = 1.19 ksf @ 20 ft.	2850	400	0.15	9.5	2.8	625	0.90
Silty Sands - Hydraulic Fill Uncompacted σ_3 = 0.90 ksf @ 15 ft.	1850	250	0.25	6.1	1.8	125	0.75
Compacted σ_3 = 0.94 ksf @ 15 ft.	2300	350	0.30	7.6	2.3	220	0.90

Notes:

1. For average fill temperature = $5^{\circ}C$.
2. σ_3 assumed = 0.5 x (overburden pressure) for average depth within the fill.
3. Short-term assumed to be 24 hours; $\frac{E_i}{S_u} = 300.$
4. Long-term assumed to be 25 years; $\frac{E_i}{S_u} = 150.$
5. Properties will vary from unbonded to fully bonded depending upon degree of recrystallization.

Comparison of Equations IV-22 and IV-13 suggests that the initial tangent modulus may be estimated from the creep strength if exponents m and n are approximately equal and if temperature effects are similar. If the ratio $E_i/\ \sigma_{max}$ is evaluated over the full range of strain rates and temperatures reported by Parameswaren, the values range from $39 \leq E_i\ /\ \sigma_{max} \leq 221$ with an average value of 133. In general, the lower values correspond to lower strain rates; however, the variations with temperature are inconclusive.

Sayles and Haines (1974) reported peak strength and tangent modulus data for Hanover silt and Suffield clay for a range of temperatures and a strain rate of about 0.15 min^{-1}. For temperatures between 31^0 and 15^0F, the ratio of modulus to strength ranged from 273 to 138 for Hanover silt and 124 to 165 for Suffield clay. The values for Hanover silt are in the same range as Parameswaren's Ottawa sand data for comparable strain rates. Temperature effects for these soils are similarly inconclusive.

Based on the data discussed above, we conclude that the initial tangent modulus for bonded fill materials can be approximated by:

$$\frac{E_i}{\frac{1}{2}\left[\sigma_1 - \sigma_3\right]_{max}} = \frac{E_i}{S_u} = \begin{cases} 300 \text{ for short-term loads} \\ 150 \text{ for long-term loads} \end{cases} \qquad \text{(IV-23)}$$

Vinson (1978) has tabulated values of Poisson's ratio for a wide variety of soil types. The reported values for sands range from 0.23 to 0.28. For silts, the range is from about 0.28 to 0.39 with an average value of about 0.30.

Recommended design values of initial tangent modulus and Poisson ratio for the various bonded fill materials are presented in Table IV-8.

c. Compressibility

Tsytovich (1975) has reported measured values of the coefficient of volume compressibility, $m_v = \frac{\epsilon_v}{\sigma_v}$, for several frozen soils. These data indicate that m_v varies with soil type, density, and unfrozen water content.

Referring to Equation IV-11, it can be seen that m_v is the inverse of the compression modulus, m, i.e.,

$$m = \frac{1}{m_v} \qquad \text{(IV-24)}$$

In Figure IV-17, Tsytovich's data for a frozen sand and a silty sand are superimposed on a plot presented by Janbu (1967), for unfrozen soils, showing the variation of compression modulus number, m, and stress exponent, a, with porosity. To make this comparison, the porosity for frozen soils is related to only that portion of the pore volume not filled with ice, i.e.,

$$n = \frac{\text{non-ice pore volume}}{\text{total volume}} \qquad \text{(IV-25)}$$

$$n = \frac{e - i(G_s/G_i)}{1+e}$$

The data for frozen sand and silty sand are quite limited and cover only a narrow range of non-ice porosity. However, these data can be extrapolated by noting that as the amount of ice in the pores decreases to zero, the curves for the frozen and unfrozen conditions must converge at the porosity of the equivalent unfrozen soil. The resulting curve defines the variation of n with non-ice porosity for the frozen soils.

To obtain similar curves for the project fill materials, a family of parallel curves was constructed, each of which merges with the curve for the unfrozen condition at the expected placement porosity. The assumption that these curves should be parallel is based on Janbu's data for unfrozen soils. Values of the stress exponent, a, are obtained using the same type assumption regarding the influence of non-ice porosity.

To illustrate the compression parameters in the frozen versus unfrozen conditions, points for each of the fill materials for both conditions are plotted on Figure IV-17. The compression parameters for bonded fill materials are also tabulated in Table IV-8.

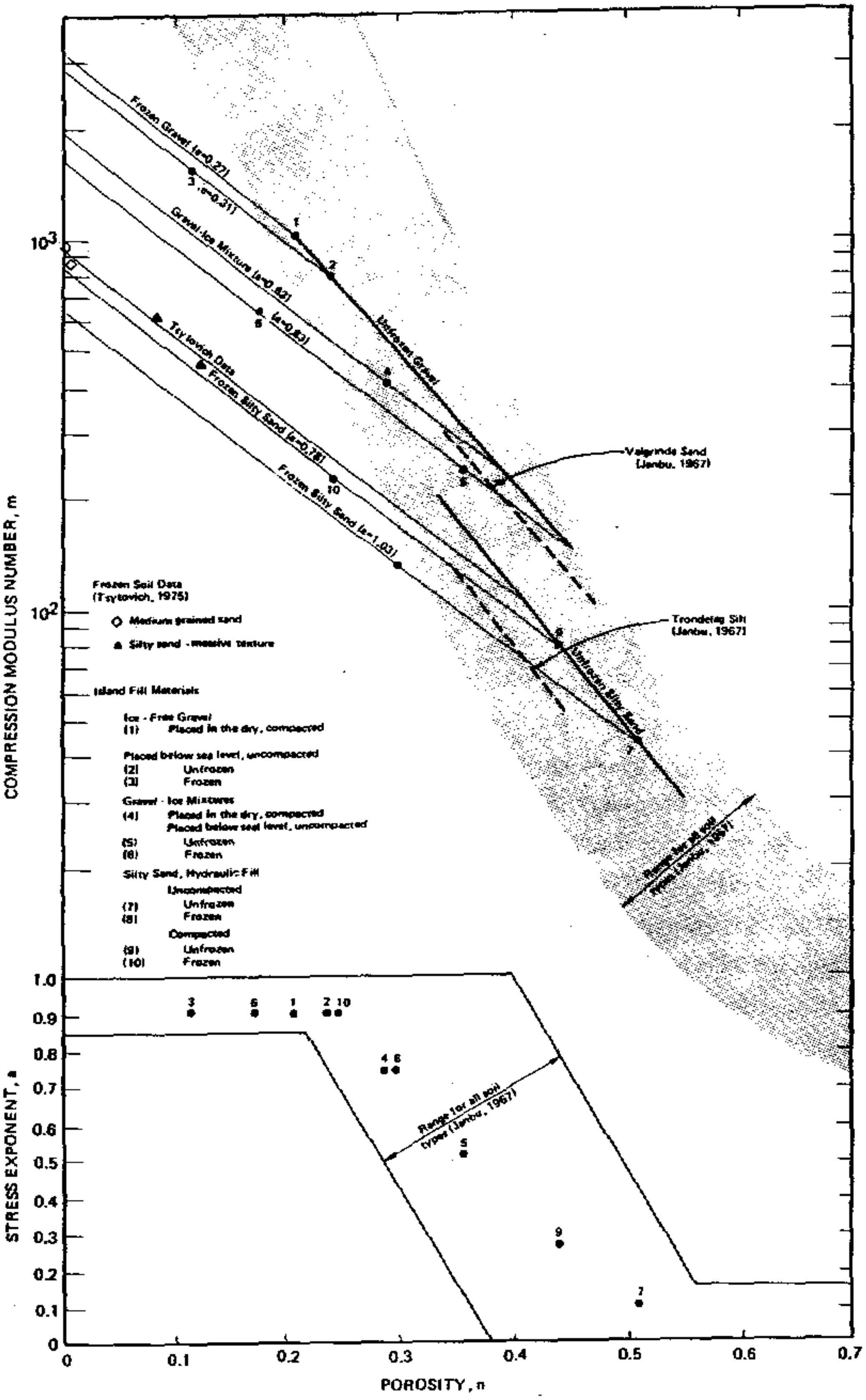


Figure IV-17. Compression parameters for island fill materials

8. PILE SETTLEMENT

As discussed in Section VII subsurface temperatures fluctuate seasonally and cause variations in pile settlement velocity. To account for this change in settlement velocity throughout the year, a representative soil temperature profile, an average for the full year, was determined. The procedure presented on Plate E-1 describes the method used to determine the "average" temperature profile for a pile embedment depth of 10 feet. This procedure was repeated for other pile embedment depths to allow development of a representative soil temperature profile. The procedure used to calculate the ground temperature profiles is presented on Plate E-2. The ice flow law presented on Plate E-3 was used to calculate pile settlement.

Procedure for determining a representative temperature profile and settlement for a 10-foot pile embedment depth.

1. The year was divided into eight time periods of equal duration as shown in Figure 1.

2. The ground temperature variation with depth was determined for each time period assuming a homogeneous soil beneath the active layer and using Equation E1 (presented on Plate E-2)for a damped, sinusoidal temperature oscillation.

3. The following was computed for the 10-foot pile embedment depth using the Ice Flow Law presented on Plate E-3.

   a. The settlement of the pile was calculated based upon an average temperature along the pile at each time period as shown in Figure 2 using Equations E2 and E3.

   δ/a = (pile settlement)/(pile diameter) Equation E2

   $\delta/a = (\dot{U}/a)\ (\Delta t) = 4.5\ (\beta \text{ave})\ (\tau \text{ave}^n)\ (\Delta t)$ Equation E3

   where $\beta\text{ave} = f(T \text{ ave})$ From Figure 1, Plate E-3

   $$\frac{\delta/a}{(\tau\text{ave}^n)\ (\Delta t)} = 4.5\ (\beta\text{ave})$$

   Note: τave^n and Δt are constant.

   b. The settlement for all time periods was added to determine the total settlement of the pile for the year using Equation E4.

   $$(\delta/a)_{ave} = \frac{\sum_{t/p=0/8}^{t/p=7/8} \frac{\delta/a}{(\tau\text{ave}^n)\ (\Delta t)}}{8}$$ Equation E4

   c. This settlement was used to compute a representative ground temperature (Trep) using Equation E5, Morgenstern's flow law, described on Plate E-3.

   $$\beta\text{rep} = \frac{\delta/a \text{ ave}}{4.5\ (\tau\text{ave}^n)\ (\Delta t)} = 3.4 \times 10^{-6} \text{ psi}^{-3} \times \text{year}^{-1}$$

   T rep = -4.7° C From Figure 1, Plate E-3

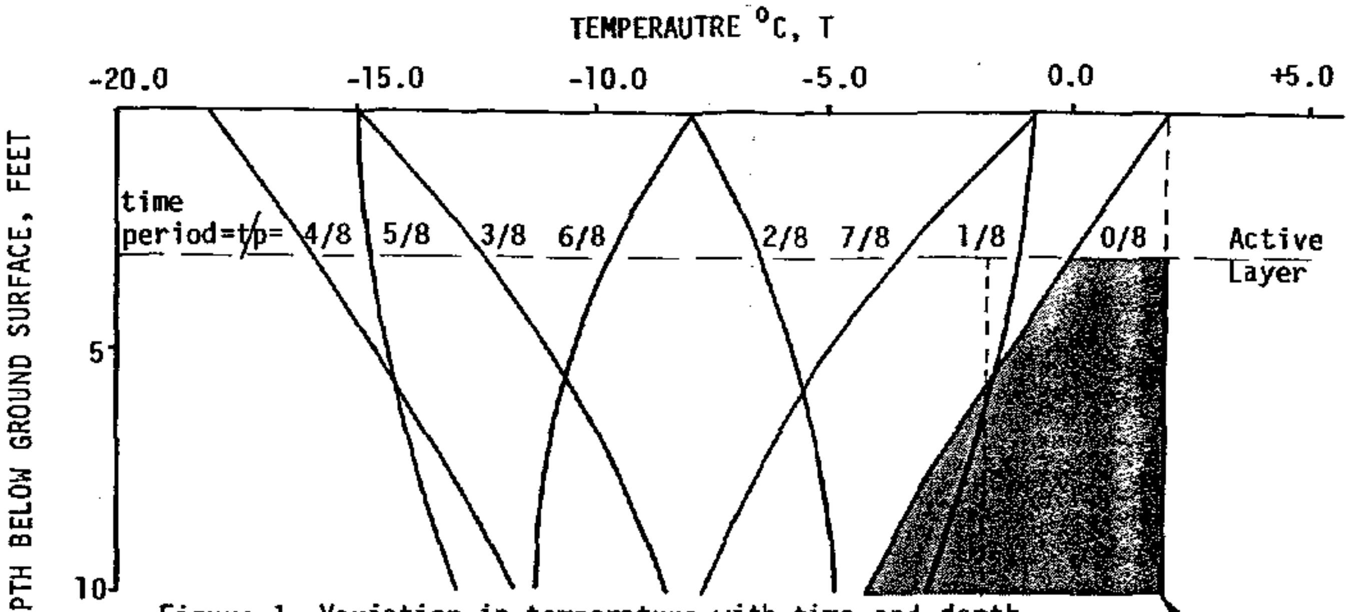


Figure 1. Variation in temperature with time and depth

Average Temperature = T ave = $\frac{\text{Shaded Area}}{\text{Depth Below Active Layer}}$

T ave = -1.8° C for t/p = 0/8

t/p	0/8	1/8	2/8	3/8	4/8	5/8	6/8	7/8
T ave	-1.8° C	-2.0	-5.4	-9.6	-14.2	-14.0	-10.6	-6.4
βave	8.4×10^{-6} psi^{-3}year^{-1}	7.6	3.0	1.7	1.2	1.2	1.6	2.6
$\frac{\delta/a}{(\tau\text{ave}^n)(\Delta t)}$	3.78×10^{-5}	3.42	1.35	0.77	0.54	0.54	0.72	1.17

Figure 2. Pile Settlement for Each Time Period

Harding Lawson Associates
Engineers, Geologists
& Geophysicists

Procedure for Determining Pile
Settlement and Temperature Profile
Pt. Thomson Development Project, Winter 1982
Geotechnical Study, EXXON Company, U.S.A.

PLATE E-

DRAWN JP
JOB NUMBER 9612,031.08
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DATE 4/82
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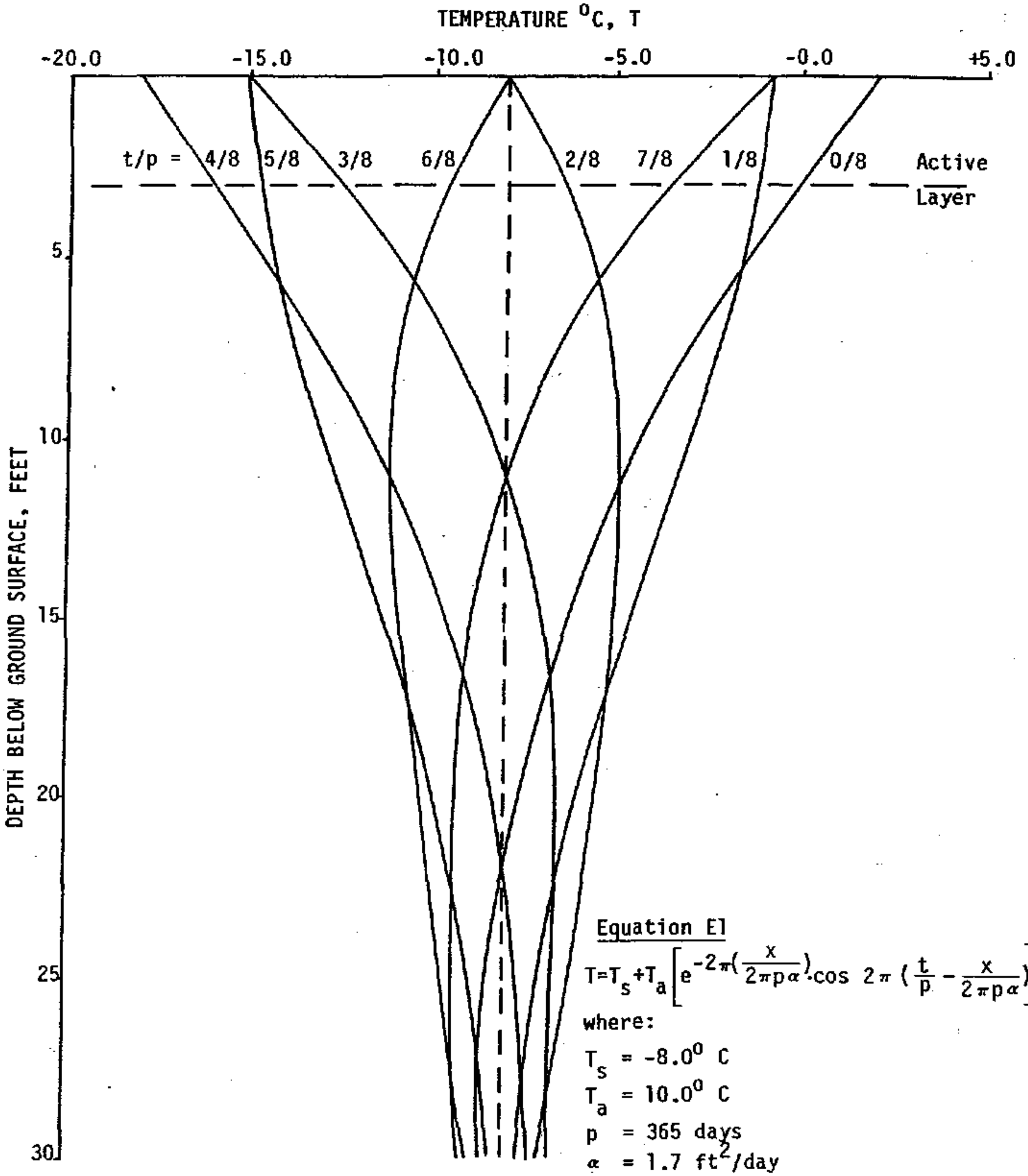

Equation E1

$$T=T_s+T_a\left[e^{-2\pi\left(\frac{x}{2\pi p\alpha}\right)}\cdot\cos 2\pi\left(\frac{t}{p}-\frac{x}{2\pi p\alpha}\right)\right]$$

where:

T_s = -8.0° C

T_a = 10.0° C

p = 365 days

α = 1.7 ft^2/day

t = time, days

x = depth below ground surface, feet

Harding Lawson Associates
Engineers, Geologists
& Geophysicists

Ground Temperature Distribution

Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
E-2

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JT	9612,031.08	DAB	4/82		

Ice-Flow Law (Morgenstern, Roggensack and Weaver, 1980)

$$\frac{\dot{U}_a}{a} = \frac{3^{\left(\frac{n+1}{2}\right)}\ \beta \tau_a^{\ n}}{n-1} = 4.5\ \beta \tau_a^{\ n} \qquad \text{Equation E5}$$

where:

U_a = pile velocity

a = pile radius

τ_a = constant tangental shear stress on ice-rich soil

n = soil creep exponent

β = soil creep constant

Temperature °C	n	K Pa^{-n} x year^{-1}	psi^{-3} x year^{-1}
-1	3	4.5×10^{-8}	1.5×10^{-5}
-2	3	2.0×10^{-8}	6.6×10^{-6}
-5	3	1.0×10^{-8}	3.3×10^{-6}
-10	3	5.6×10^{-9}	1.8×10^{-6}

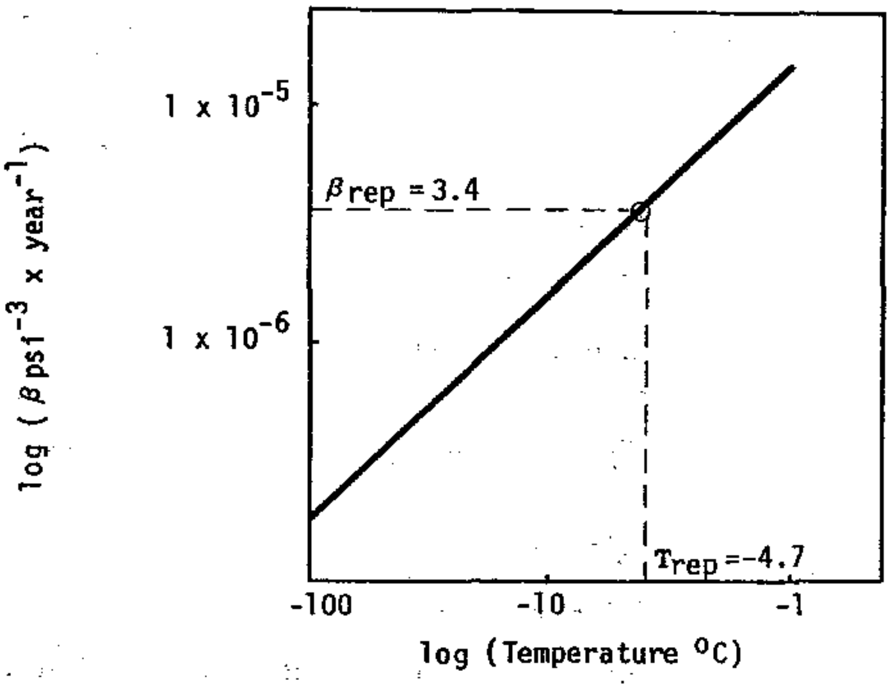

Figure 1. Temperature Vs Soil Creep Constant

Harding Lawson Associates
Engineers, Geologists
& Geophysicists

Ice Flow Law
Pt. Thomson Development Project
Winter 1982, Geotechnical Study
EXXON Company, U.S.A.

PLATE
E-3

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
JP	9612,031.08	ASB	4/82		

C. ANALYSIS OF LATERALLY LOADED PILES

ANALYSIS OF LATERALLY LOADED PILES IN PERMAFROST

The behavior of piles subjected to lateral loading may be analyzed by the subgrade-reaction method (Poulos and Davis, 1980). The method is capable of treating non-linear soil behavior, layered soils and non-uniform pile sections, and is readily adaptable to computer solution. In general, the soil response to lateral loads is modeled as a series of unconnected non-linear springs represented by "P-Y curves". The P-Y curves are a representation of the load-deflection characteristics of the soil at a given depth along the pile and depend upon the pile dimesions as well as the stress-strain and strength characteristics of the soil.

P-Y Curves

Procedures for constructing the P-Y curves for various (unfrozen) soil types and loading conditions have been summarized by Reese (1975). An example of these procedures (for soft, saturated clays) is as follows:

1. The ultimate soil resistances per unit length of pile shaft, P_{ult}, is computed using:

$$P_{ult} = N_p \cdot c_f \cdot d \qquad (1)$$

where c_f = shear strength

d = pile diameter or width

N_p = nondimensional ultimate resistance coefficient

N_p increases from a value of 3 at ground surface to a maximum value of 9 at a depth of several pile diameters; vis.,

$$N_p = 3 + \frac{\sigma_v}{c_f} + J \cdot \frac{x}{d} \tag{2}$$

where σ_v = overburden pressure at depth x

x = depth

J = empirical coefficient (typically, J = 0.5)

2. The P-Y curve is approximately by a cubic parabola:

$$P = \frac{1}{2} P_{ult} \left(\frac{Y}{Y_c} \right)^{1/3} \tag{3}$$

where P = soil reaction for lateral pile deflection, y

Y_c = lateral pile deflection at which P = 1/2 P_{ult}

Note: This procedure is based on the concept that the stress-strain curve for the soil and the P-Y curve for soil reaction on the pile should have similar shapes as illustrated in Figure 1 (Matlock, 1970).

3. Y_c is approximated by:

$$Y_c = 2.5 \, \epsilon_c \cdot d \tag{4}$$

where ϵ_c = strain at which $(\sigma_1 - \sigma_3) = 1/2 \, (\sigma_1 - \sigma_3)_{ult}$

Stress-Strain-Time Behavior of Frozen Soils

The stress-strain behavior of frozen soil depends upon, among other factors, the duration of loading and the soil temperature. For example, when a sample of frozen soil is subjected to a constant uniaxial stress, the sample continues to deform with time. As shown on Figure 2 a typical strain-time (creep) curve for frozen soil may exhibit three stages: (1)

deccelerating, or primary, creep; (2) constant strain-rate, or secondary creep; and (3) accelerating, or tertiary, creep which usually leads rapidly to failure.

Depending upon the type of frozen soil and the applied stress level, any of the three stages of creep may dominate (Figure 2a).

Ladanyi (1978) has suggested that primary creep of frozen soils can be described by the equation:

$$\dot{\epsilon} = b\left(\frac{\dot{\epsilon}_c}{b}\right)^{b}\left(\frac{\sigma_1-\sigma_3}{\sigma_c}\right)^{n} \cdot t^{(b-1)} \tag{5}$$

in which $\dot{\epsilon}$ = $d\epsilon/dt$ = strain-rate

$(\sigma_1-\sigma_3)$ = applied principle stress difference

t = elapsed time

σ_c & $\dot{\epsilon}_c$ = values of $(\sigma_1-\sigma_3)$ and $\dot{\epsilon}$ at an arbitrarily selected time

n = stress exponent

b = time exponent

σ_c, $\dot{\epsilon}_c$, n, b = temperature-dependent material constants

Equation (5) predicts that, in the primary creep stage, a plot of log ($\dot{\epsilon}$) vs. log (t) will be linear with a slope equal to (b-1).

In secondary creep, the strain-rate is independent of time (b=1 in Equation 5), so that:

$$\dot{\epsilon} = \dot{\epsilon}_c\left(\frac{\sigma_1-\sigma_3}{\sigma_c}\right)^{n} \quad \left\{\text{secondary creep}\right\} \tag{6}$$

Equations 5 and 6 both predict that a plot of log ($\dot{\epsilon}$) vs. log (σ_1-σ_3) will be linear with a slope equal to n. However, the value of the stress exponent, n, may be significantly different in the primary and secondary stages.

The constants in Equations 5 and 6 are temperature-dependent. The temperature effects may be evaluated by performing creep tests at different temperatures or estimated from published data.

Evaluation of Creep Parameters of Design

At the stress levels and load durations normally used in engineering design, it is often assumed that secondary creep dominates (Ladanyi, 1978). However, test durations of two weeks or more may be required to establish secondary creep rates at design stress levels. An alternative approach is to perform relatively short-term (a few hours) creep tests and extrapolate the primary creep behavior to the onset of secondary creep (Figure 3). This requires an estimate of the time at which the transition from primary to secondary creep will occur. If the time for this transition to occur is underestimated, the extrapolated secondary creep rate will be conservative (too fast) and, if overestimated, the secondary creep rate will be unconservative (too slow).

Figure 4 shows the primary creep behavior of a sample which was step-loaded to three different stress levels. Except for the usual experimental data scatter, the log ($\dot{\epsilon}$) vs. log (t) relationship appears to be linear as predicted by Equation 5. On the other hand, contrary to Equation 5, the curves are not parallel; i.e., $n \neq$ constant. These diverging curves suggest that n steadily increases through the primary stage to the onset of secondary creep. Thus, the steady-state n value obtained by extrapolation will be dependent upon the time estimated for the onset of secondary creep. In this context, as noted previously, underestimating the transition time from primary to secondary creep will be conservative.

For our laboratory test data, we have estimated the time to onset of secondary creep to be 24 hours. We believe this to be a conservative choice. The extrapolated 24-hour strain rates for several tests at different temperatures are plotted vs. the applied stress on a log-log scale in Figure 5. The slope of the straight lines fitted through the data points for each temperature is equal to the stress exponent, n, in Equation 6. For these data n = 3, which is consistent with published data on ice-rich soils (Morgenstern et.al, 1980). The values of $\dot{\epsilon}_c$ and σ_c can also be obtained fromm any convenient point on each line e.g., for 28^{0}F, we could choose, say $\dot{\epsilon}_c = 10^{-6}$ min^{-1} and σ_c = 20 psi.

The effect of temperature can also be deduced from Figure 5. For example, at $\dot{\epsilon} = 2 \times 10^{-4}$ min^{-1}, the corresponding stress values at 28^0, 25^0, and 20^0 are 55 psi, 78 psi and 150 psi respectively. As shown on Figure 6, the relationship between stress and temperature (for a given strain-rate) is essentially linear.

Equation 6 and the laboratory creep test results (examples of which are presented on Figures 4, 5, and 6) form the basis for establishing the P-Y curves for the ice-rich fine-grained permafrost in the upper 7.5 feet of the subsurface profile. The fact that the stress exponent, n, is equal to 3.0 for the laboratory test data is consistent with the use of a cubic parabola to represent the P-Y curves since Equation 6 can be rewritten in the form:

$$\sigma_1 - \sigma_3 = \sigma_c \left(\frac{\epsilon}{\dot{\epsilon}_c \cdot t} \right)^{1/n} \tag{7}$$

in which t = any elapsed time (short of failure). In this application "t" is the duration of loading for the various loading conditions.

To construct the P-Y curves, the soil creep parameters required are the creep shear strength (Equation 1) and the strain corresponding to half of the ultimate creep strength (Equation 4). For a given duration of loading and soil temperature, Equation 7 can be solved for:

$$(\sigma_1 - \sigma_3)_f = 2\,c_f = \sigma_c \left(\frac{\epsilon_f}{\dot{\epsilon}_c \cdot t_d} \right)^{1/n} \tag{8}$$

in which c_f = 1/2 $(\sigma_1-\sigma_3)_f$ = creep shear strength

c_f = strain at which the soil fails in creep

t_d = load duration for a particular design condition

Also, for n = 3,

$$\epsilon_c = 1/8 \cdot \epsilon_f \tag{9}$$

Consider the following example:

1. Assume $T = 28^{o}F$
   $\epsilon_f = 0.2$
   $t_d = 24$ hours

2. From Figure 5, say $\dot{\epsilon} = 2 \times 10^{-4}$ min^{-1}
   $\sigma_c = 55$ psi

3. From Equation 8, $c_f = (55)\left(\frac{0.2}{2 \times 10^{-4} \times 24 \times 60}\right)^{1/3} = 24.4$ psi

*** The following steps depend upon pile diameter and depth***

4. Substitue c_f into Equations 1 and 2 to obtain P_{ult}

5. From Equation 9, $\epsilon_c = 0.025$
   Substitute ϵ_c into Equation 4 to obtain Y_c

6. Construct the P-Y curve using Equation 3

The foregoing procedure was developed specifically for ice-rich fine-grained soils for which laboratory creep data was available. Basically the same procedure was used to develop the P-Y curves for the underlying ice-poor granular soils except that the creep parameters were estimated from published data (Sayles, 1968) due to the lack of suitable samples for laboratory testing. As can be inferred from the P_{ult} - Y_c data previously supplied, the ice-poor soils have greater creep strengths and fail at lower strains than the ice-rich soils. Also, the stress exponent, n, was estimated to be 7.5 for the ice-poor soils.

Frozen soils tend to go from ductile behavior at low strain-rates to brittle behavior at high strain-rates. Therefore, ϵ_c for three-minute loadings were taken to be one-half the values used for 24-hour and 20-year loadings.

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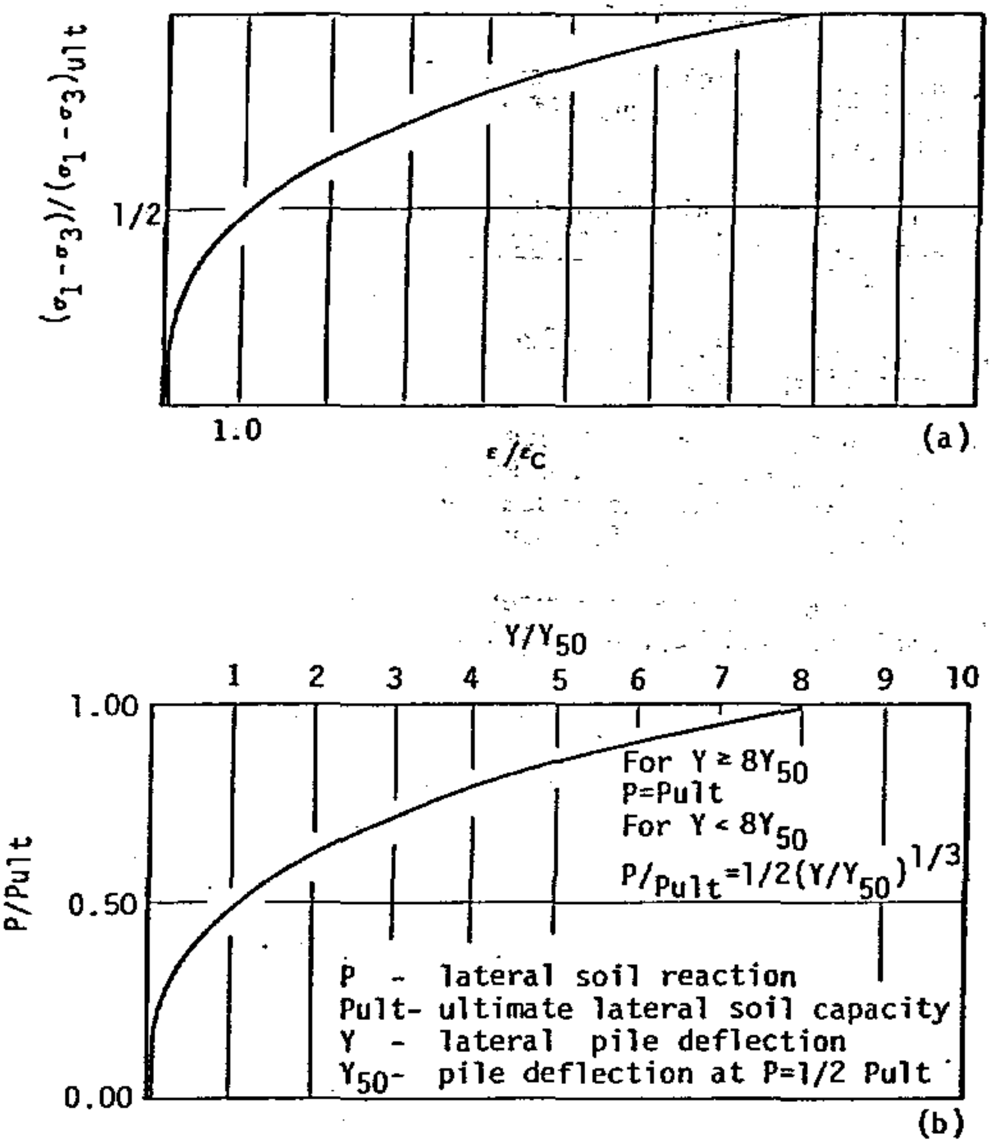

Figure 1. (a) Stress-Strain Curve, (b) P-Y Curve for Same Soil

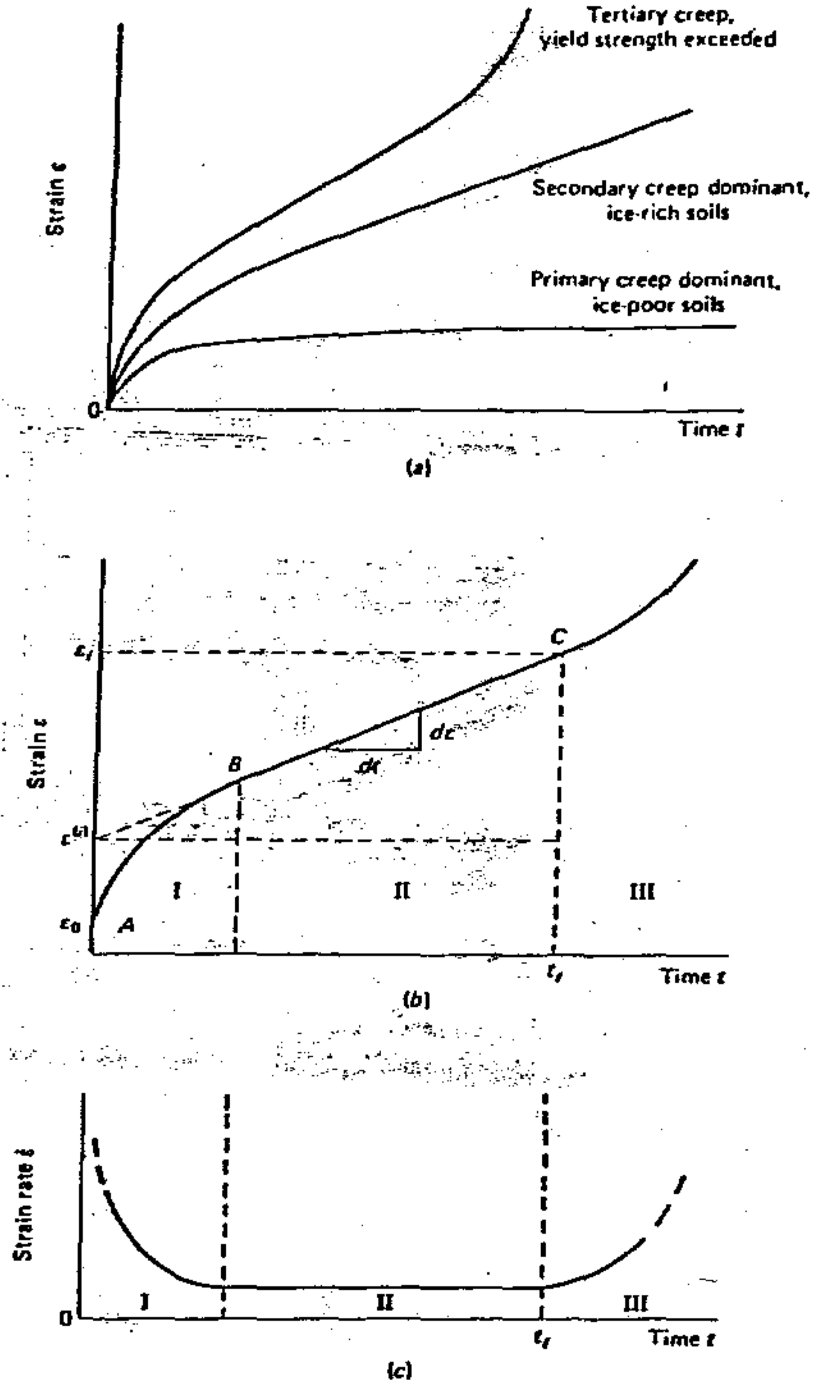

Figure 2. Constant-stress creep test: (a) creep-curve variations; (b) basic creep curve; (c) true strain rate vs. time. (after Ladanyi, 1978)

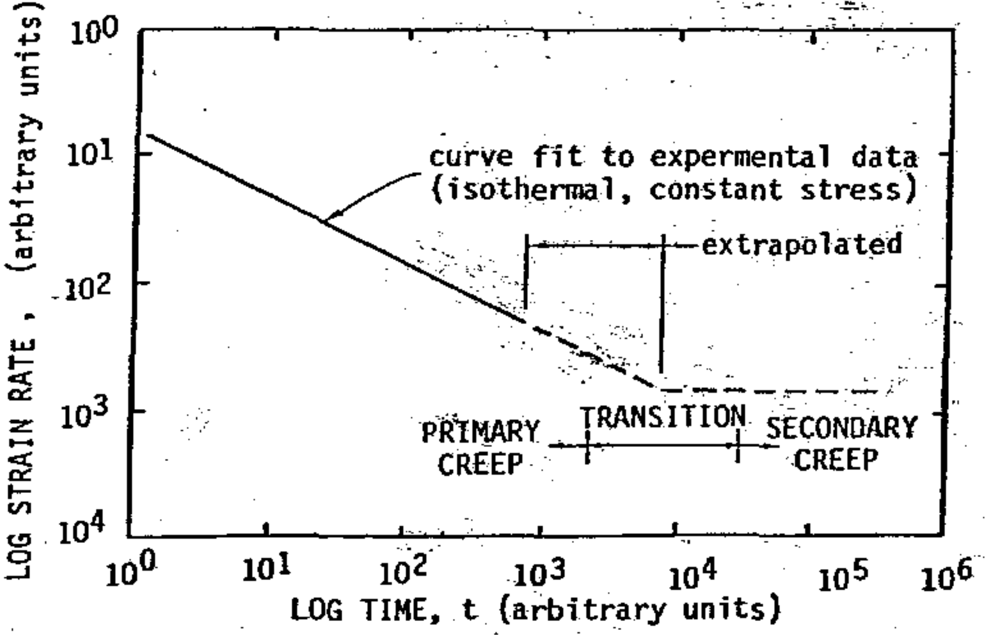

Figure 3. Extrapolation from Primary to Secondary Creep

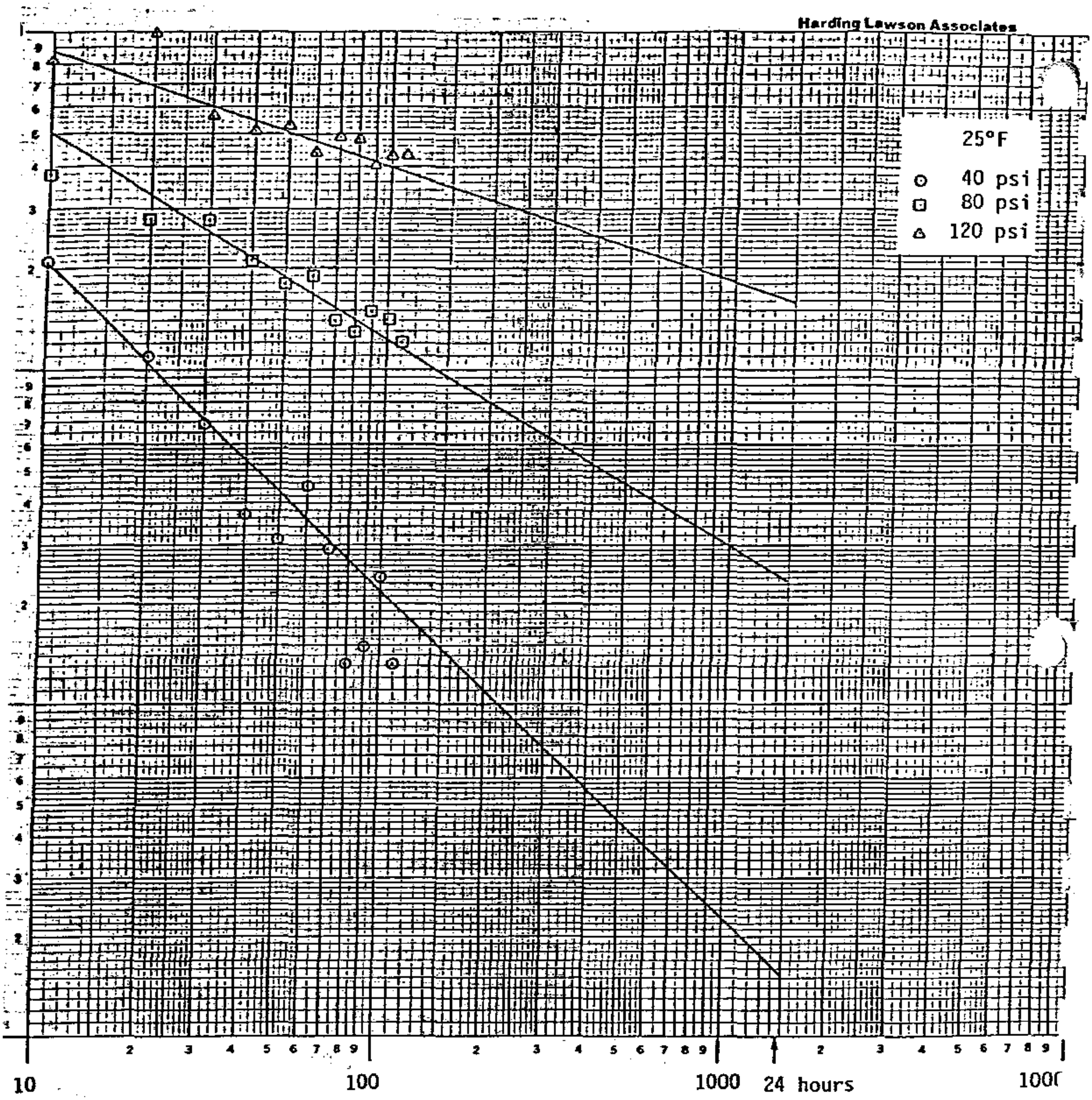

Figure 4. Primary creep behavior : Ice-Rich Soils

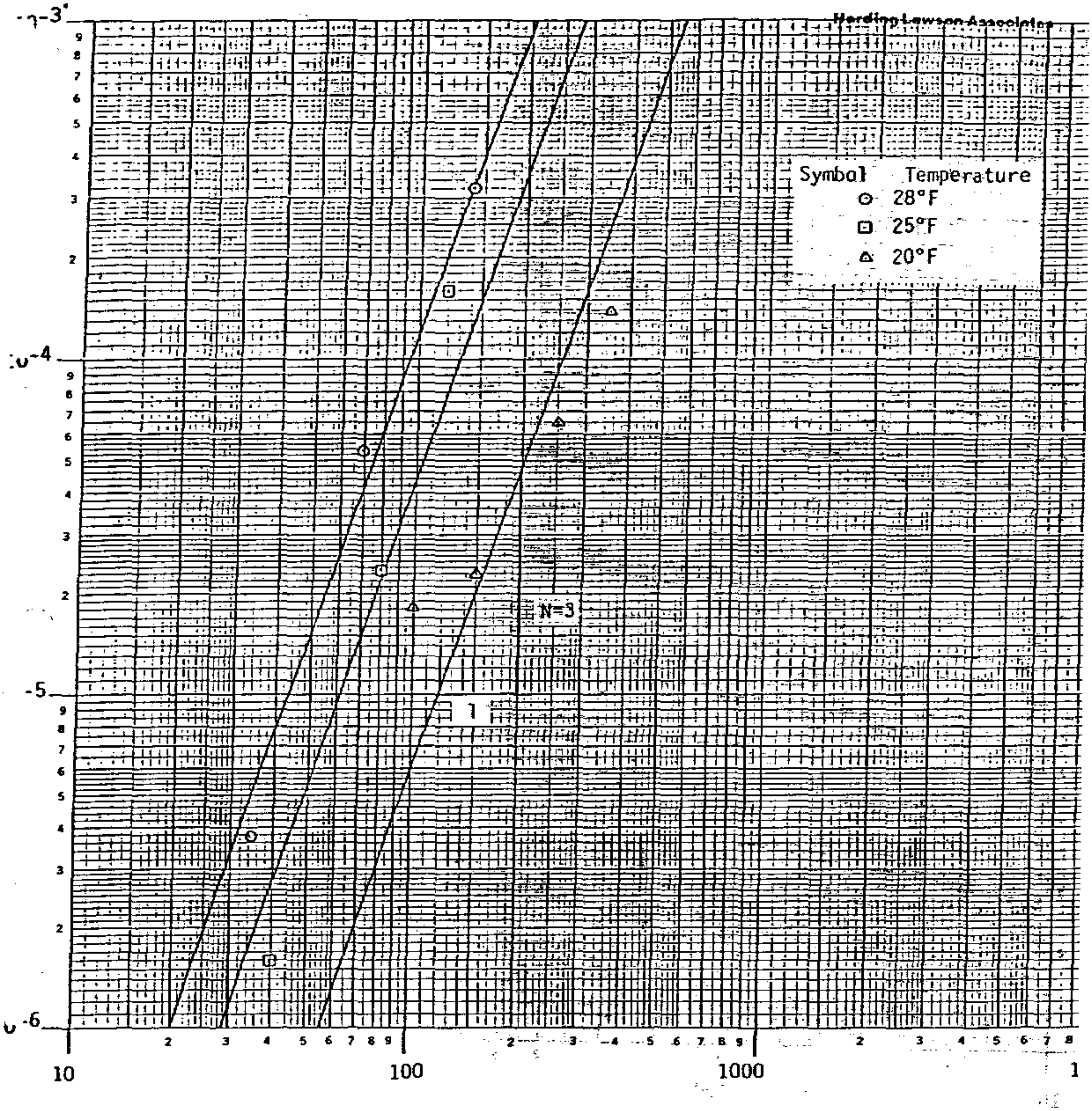

Figure 5. Secondary creep rates at 24 hours (extrapolated from primary creep data)

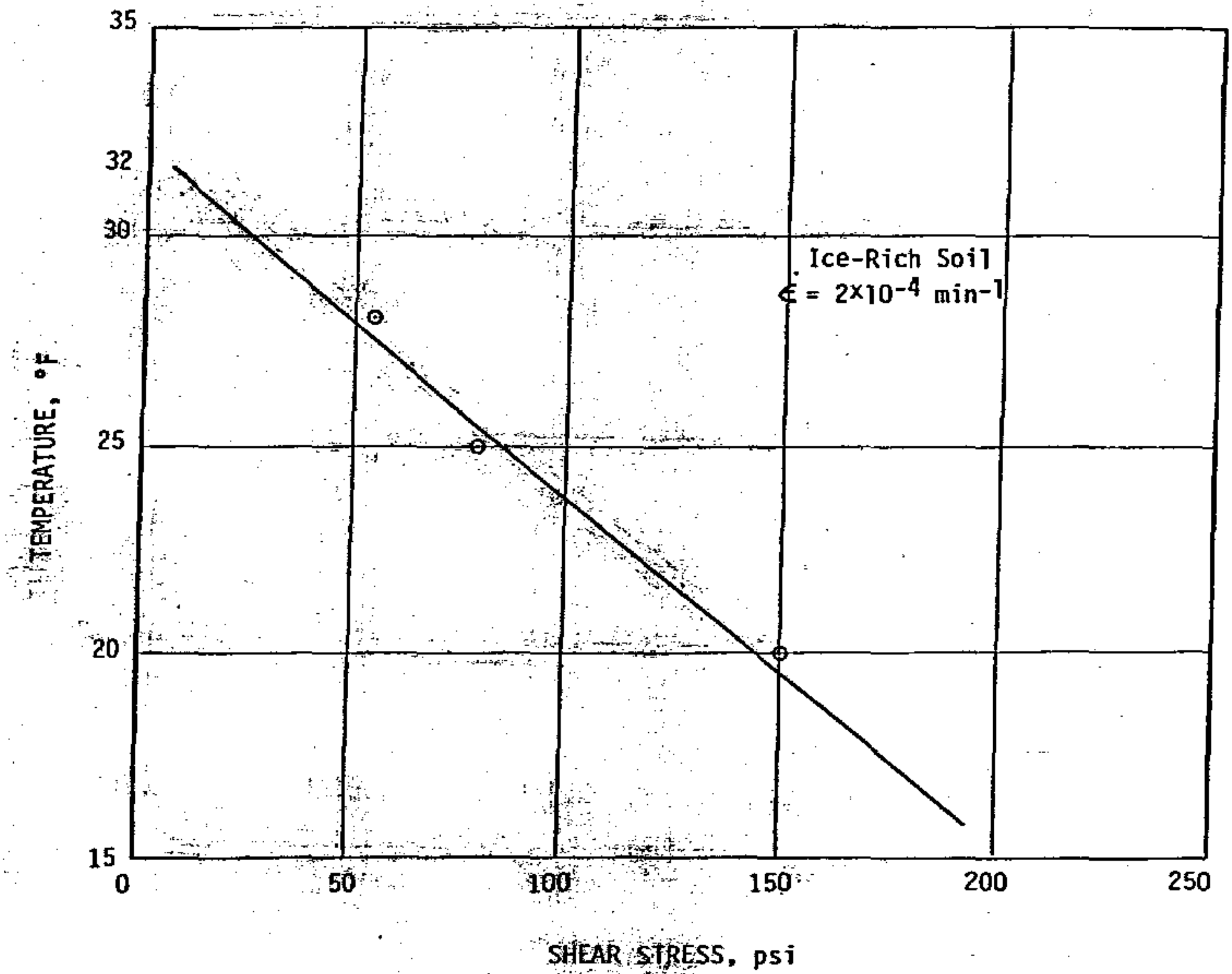

Figure 6. Effect of temperature on creep of Ice-Rich Soils