HARDING-LAWSON ASSOCIATES

SOIL AND FOUNDATION INVESTIGATION
HAWAIIAN INDEPENDENT REFINERY, INC.
(HIRI) HARBOR TERMINAL
HONOLULU, OAHU, HAWAII

H-LA Job No. 3959,001.06

Prepared for

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by

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January 23, 1974

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I INTRODUCTION

This report presents the results of our Soil and Foundation Investigation for Hawaiian Independent Refinery's proposed Harbor Terminal in Honolulu. The 4.1-acre site is located on the west side of Sand Island Access Road between the Kalihi Channel and the Texaco Tank Farm, as shown on the Vicinity Map, Plate 1.

The Harbor Terminal is planned to be a bulk fuel storage facility consisting of a tank yard (15 tanks) and associated support facilities. A four-foot high concrete, dike wall will be constructed around the tank yard. The locations and configurations of the tanks and support facilities are shown on the Site Plan, Plate 1.

Tanks 1 through 9 will be 85 feet in diameter and 60 feet high. Tank 10 and Tanks 13 through 15 will be 40 feet in diameter and 60 feet high. Tanks 11 and 12 will be 55 and 44 feet in diameter, respectively, and 48 feet high. Tanks 11 and 12 will be constructed immediately. The other tanks will be built during subsequent construction phases. Steel tanks were originally planned, however, due to problems in steel deliveries, prestressed and post-tensioned concrete shells and bottoms with aluminum or steel roofs are being considered as an alternative. The tanks will be water tested before being put into service. The specific gravity of the stored products will vary from 0.72 to 0.92.

The tank yard will be graded so that surface drainage will flow from west to east. The high point will be in the northwest corner at Elevation +7.4 feet (MLLW Datum). The low point will be in the southwest corner at Elevation +4.8. The tanks will be constructed on compacted fill pads raised about 12 to 24 inches above yard grade. There will be asphalt coated berms, approximately 2 feet wide at the top, around the perimeter of the tank pads.

Our scope of work, as outlined in our proposal dated October 30, 1973, was to analyze the subsurface conditions at the site and to:

1. Recommend the most suitable foundation scheme for the tanks and support facilities and develop criteria for foundation design
2. Estimate settlement behavior of the tanks
3. Develop conclusions and recommendations regarding site preparation and grading, including: (a) an evaluation of the quality of the existing fill and criteria for its recompaction, if required; (b) a determination of the suitability of soil stockpiled on the site for reuse as fill; (c) compaction criteria
4. Estimate the stability of the slope along the Kalihi Channel, considering the planned tank loads, and develop recommendations for improving that stability, if necessary

Our work was authorized by Mr. Fred Lange of Koepf and Lange, Consulting Engineers, on November 5, 1973. During the course of our work, we discussed our conclusions and recommendations with Mr. Lange as they were developed.

II FIELD EXPLORATION AND LABORATORY TESTING

Our exploration consisted of drilling ten test borings which ranged from 50 to 97 feet deep. The locations of the borings are shown on Plate 1. The borings were drilled with a truck-mounted, rotary wash, drill rig. Our field engineer logged the borings and obtained representative samples of the materials encountered for examination and laboratory testing. Samples were taken with a 2.4 inch (inside diameter) split barrel sampler driven with a 300 pound hammer falling 30 inches. The blows required to drive the sampler were recorded and converted to "equivalent standard penetration blow counts" for correlation with emperical test data. Logs of the borings, showing the various materials encountered, sample depths and converted blow counts, are presented on Plates 4 through 13 in Appendix A. The soils are described according to the Unified Soil Classification System, Plate 14.

The soils were examined in our laboratory to confirm their field classifications and to select samples for laboratory testing. The laboratory program consisted of moisture content/dry density, triaxial compression (strength), particle size analysis and consolidation tests. The test data are presented on the Logs of Borings in the manner described by the Key to Test Data, Plate 14. Detailed data from the particle size analysis tests are presented on Plate 15. The consolidation test data are presented on Plates 16 through 18.

III SITE AND SOIL CONDITIONS

The site appears to have been a tidal area which was reclaimed by filling. The present surface is nearly flat; surface elevations vary from +3 to +7. The center portion of the site is currently occupied by low concrete tanks which we understand were used at one time for fish breeding. There are stockpiles of soil and debris on the eastern portion and an open ditch, up to four feet deep, crosses the western half. The locations of the tanks, stockpiles and ditch are shown on Plate 1. Old car bodies and debris are scattered over the remaining portion of the site. Grass, weeds and brush are growing in some areas.

The entire site is blanketed with a layer of coral gravel fill, three to five feet thick, which is nonuniform in density and composition. The fill is underlain by weak and compressible lagoon deposits to depths generally ranging from 20 to 25 feet beneath the existing surface.

The lagoon deposits are underlain by a relatively competent coral ledge at all boring locations except Boring 1, located at the southwest corner of the site. The lagoon deposits in Boring 1 are underlain by weak and compressible stream and estuary soils. These soils extend to a depth of 78 feet, and are underlain by reef coral to the depth explored (97 feet). Since reef coral does not grow in a fresh water environment, it is likely that Boring 1 was drilled within the boundaries of the old Kalihi Stream. The edge of the old stream alignment, and thus the edge of the coral reef, appears to pass beneath Tank 1, and to the south of Tank 9. It may pass beneath the south edge of Tank 8.

Borings 7, 8 and 9 in the southern portion of the site penetrated the coral ledge at depths ranging from 31 to 48 feet. Coral sands and gravels were encountered beneath the coral to the depths explored (50 to 60 feet) at these locations. The coral sands and gravels are generally dense; however, a layer of loose sand was encountered at depths between 38 and 48 feet in Boring 9.

The ground water levels stabilized in the borings at about Elevation +2.0 feet.

IV DISCUSSION AND CONCLUSIONS

The factors which most affect foundation analysis for the site are the heavy tank loads and the presence of weak and compressible soils.

Tank 1, located adjacent to the Kalihi Channel, is underlain by deep stream deposits in addition to the lagoon soils and must be pile supported to prevent failure of the channel bank. Tank 8 is also close to the channel bank and may be partially underlain by deep stream deposits. An additional boring should be drilled beneath the south edge of this tank to verify the actual soil conditions before a shallow foundation scheme is considered to support it. Alternatively, Tank 8 could be relocated to the north or supported on piles.

The remaining tanks can be supported directly on compacted fill, but they will have marginal factors of safety against foundation failure. Based on our testing and analysis, we conclude that the factor of safety against foundation failure during initial loading or during light seismic activity (say, ground surface accelerations of less than 0.05g) would be close to 1.0. The factor of safety under long term conditions - after the soils have consolidated under the tank loads - would be about 1.1. Since the testing and analysis upon which our conclusions are based are not precise, the above factors of safety constitute some risk of foundation failure. This risk would be greatest during initial loading (water testing) or during an earthquake.

The tanks will experience appreciable settlements as the underlying lagoon deposits consolidate under the tank loads. Based on the consolidation test data presented on Plates 16 through 18, we computed that the center of the tanks will settle 2.0 to 2.8 feet and the edge of the tanks will settle 1.0 to 1.5 feet under full water loads. Estimated settlement contours for the entire tank yard are presented on Plate 3. Actual settlements monitored at the adjacent Shell Oil Terminal for similar tanks containing 40 feet of water were about half of these values. We judge that actual settlements at this site will be somewhere between our values and those measured at the Shell site.

The lagoon deposits are relatively free draining and settlements should occur fast. We anticipate that all but about two inches of the settlements will occur during water test loading if the tanks are filled very slowly. Actual settlements should be monitored during loading to check the predicted settlements and to allow for modification of design criteria, if appropriate.

Significant settlements and the risk of foundation failure can be eliminated by supporting the tanks on driven piles. Driven, end-bearing, displacement piles bottomed in the coral ledge beneath the lagoon deposits would be most suitable. Precast, prestressed concrete piles appear most economical because of their local availability and local experience with their installation.

Selection of the foundation scheme should be based on (1) economics, (2) the settlement tolerance of the tanks and (3) consideration of the risk involved with supporting the tanks directly on the fill. Reinforced concrete tanks would probably not tolerate the anticipated settlements and would have to be pile supported. Steel tanks can tolerate some settlement and can be releveled as the settlements occur.

We discussed the above foundation schemes with Mr. Fred Lange, Design Engineer for the project. We mutually anticipate that, if steel tanks are used, the risk of foundation failure will be acceptable to the Refinery in view of the lower cost of supporting the tanks directly on the fill. Also, since the lighter tanks (11 and 12) will be constructed first, actual soil behavior can be carefully monitored by instrumentation, and foundation schemes for the larger tanks can be modified if settlements are too severe or if the risk of foundation failure appears too great.

V RECOMMENDATIONS

A. Site Preparation and Grading

Remove existing structures, including the concrete tanks, manholes and underground culverts before grading. Remove the debris which is scattered throughout the site and strip grass and other vegetation from the surface. Soft soil, vegetation and debris in the bottom of the drainage ditch in the western portion of the site should also be removed.

The existing fill should be excavated to Elevation +3 within and 10 feet beyond the perimeters of tanks which will not be pile supported, and within and five feet beyond the perimeters of structures which will be supported on spread footing or slabs-on-grade.

The soils exposed by stripping or excavation should be scarified to a depth of 6 inches, moisture conditioned to a moisture content suitable for compaction and rolled with a vibratory roller or other suitable equipment to achieve at least 95 percent relative compaction*.

Fill material should be free of organic matter and debris and should conform to the following criteria:

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* Relative compaction refers to the dry density of the fill expressed as a percentage of the maximum dry density of the same material as determined by the ASTM D1557 (C) procedure.

Sieve Size	Percent Passing (By Weight)
4 inches	100
1-1/2 inches	80 - 100
No. 4	50 - 100
No. 200	5 - 20

Liquid Limit - 40 Maximum

Plasticity Index - 15 Maximum

California Bearing Ratio _ 60 Minimum

Most material obtained from on-site excavations, as well as most of the material stockpiled on the site, will meet the above criteria. We should check the suitability of fill material during construction.

Fills should be placed in thin layers (less than 8 inches thick), moisture conditioned to a moisture content suitable for compaction and compacted to at least 95 percent relative compaction.

B. Foundations

1. Tanks (On-Grade Foundations)

The surface of the tank pads should be rolled with a smooth-wheel roller to provide a uniformly dense, nonyielding subgrade. The tanks will settle as discussed in Paragraph IV. Provisions should be made to relevel the tanks intermittently, as required, during and after filling.

2. Tanks (Pile Foundations)

Pile sizes can be selected based on the optimum structural capacities for the piles. Piles for Tanks 1 and 8 can be either 12 inch square or 16-1/2 inch octagonal, precast, prestressed concrete. The remaining tanks can also be supported on 10 inch square piles, since the depth to supporting coral in these areas is not great and piles will be relatively short. We recommend that pile capacities be no greater than 80 tons.

Piles can be driven to develop their full structural capacities by end-bearing in the coral ledge which underlies the site. We estimate that most piles will reach refusal after penetrating less than five feet into the ledge. Therefore, piles for Tanks 1 and 8 will range from about 30 to 85 feet long. Piles for the remaining tanks, if they are used, will range from about 25 to 30 feet long.

We should develop driving criteria when actual pile sizes and capacities have been determined. The Uniform Building Code, ammended by the City and County of Honolulu, requires that a pile load test be run when any of the piles on a project exceed a capacity of 40 tons. It is our opinion that a pile load test will not provide usefull data for this project, even if pile loads exceed 40 tons, and that it can be eliminated. This will require approval by the City and County of Honolulu.

3. Building Foundations

Buildings, as well as retaining walls and other relatively light structures, can be supported on spread footings. Footings should be designed according to the following criteria

Allowable Bearing Pressures	
Dead plus reduced live loads	2000 psf
Total design loads, including wind or seismic forces	3000 psf
Resistance to Lateral Loads	
Passive pressure	500 psf
Friction factor	0.5

Passive pressure in the top foot should be neglected when footings are not confined by floor slabs or pavements. Frictional resistance to sliding should be determined by multiplying the indicated friction factor by the downward dead load.

C. Tank Loading

We recommend that all tanks be water tested prior to filling with product. We recommend that the tanks be initially filled slowly, in increments, to allow the underlying soft soils to consolidate and gain strength. We recommend the following sequence:

Water Depth	Time Delay after Loading
20 feet	30 days
30 feet	30 days
40 feet	15 days
50 feet	15 days
55 feet	15 days
60 feet	15 days

4 months!

We should determine if these intervals are appropriate when the actual rate of loading (rate at which water is pumped into the tank) has been determined.

Actual settlements should be monitored by reading settlement marks periodically on each tank. We recommend that at least four settlement marks be located at equal distance around the base of each tank. We should review all settlement data and may elect to modify the rate of loading, or the interval between loading increments, based on the actual settlement readings.

D. Instrumentation

We recommend that pore water pressures and lateral deflections in the soft foundation soils be monitored, at least for the first two tanks (Tanks 11 and 12). We should monitor the pore water pressures by installing two piezometers at each of the two tank locations. The lateral deflections in the soft soils should be monitored at one location adjacent to each of the first two tanks by taking readings in two boreholes with deflection instruments.

The piezometer readings will enable us to determine if the soil is consolidating and gaining strength as we anticipate. The lateral deflection readings will help us to detect excessive strain in the soft soils and thus, to anticipate a possible failure.

We should determine if instrumentation is necessary for subsequent tanks after the first tanks have been filled and their behavior monitored.

E. Dike Wall

A trench type footing, or cutoff wall, can be used beneath the dike walls down to the ground water level (about Elevation +2). A trench to this elevation will generally stand without shoring and the concrete can be placed in-the-dry, against undisturbed fill. Below this depth, soft and caving soils will be encountered and it will be difficult to construct a cast-in-place wall without extensive shoring. If the trench must extend below Elevation +2, a sheetpile cutoff wall would be more suitable. We can develop recommendations for sheetpiles if a deeper cutoff wall is necessary.

VII SUBSEQUENT SOIL ENGINEERING SERVICES

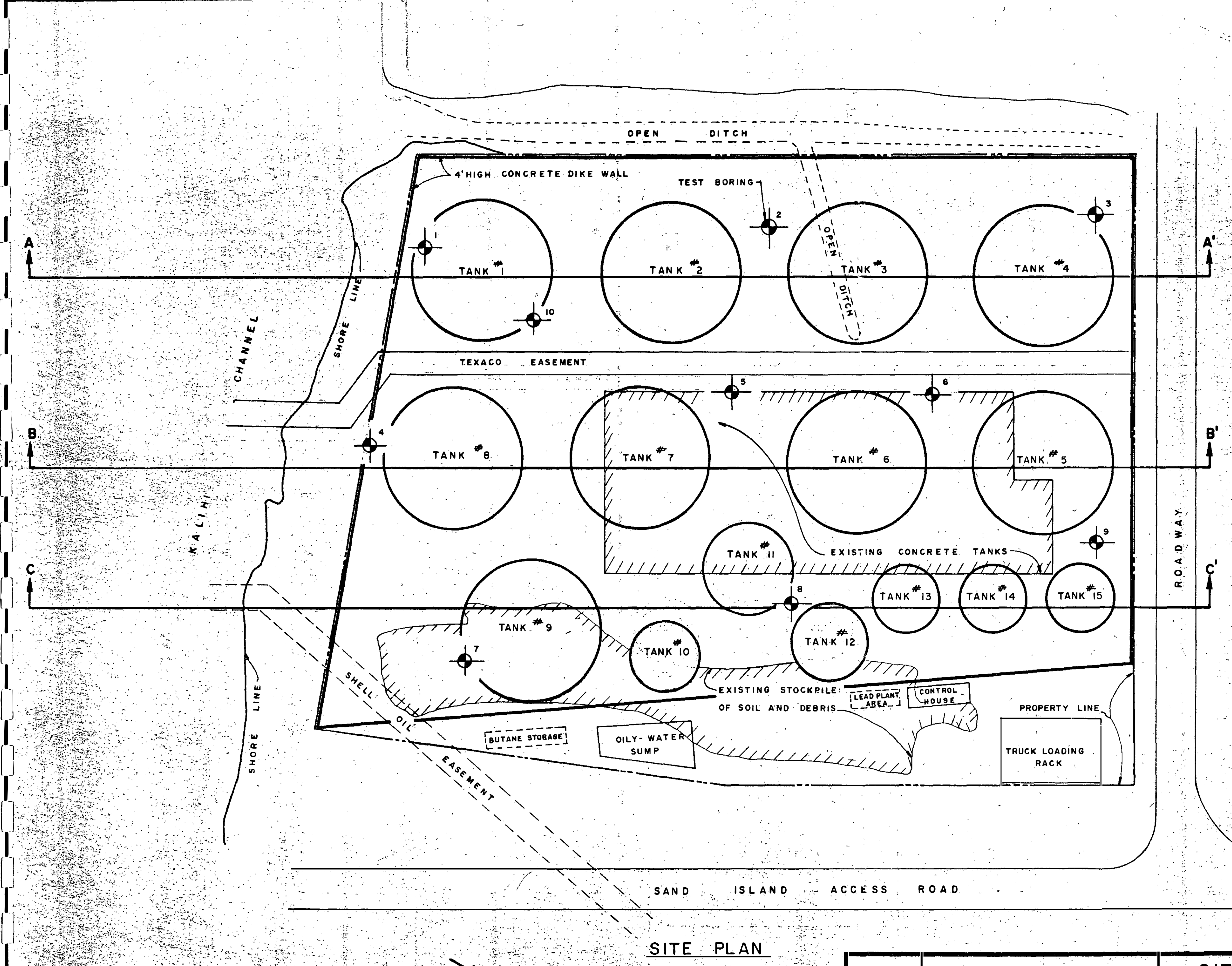
Before final design of the development is completed, we should:

1. Consult with you to select actual pile sizes and capacities for tanks which will be pile supported
2. Drill and log an additional boring at the south edge of Tank 8, unless it will be relocated or pile supported
3. Review the final plans and specifications for correlation with the intent of our recommendations

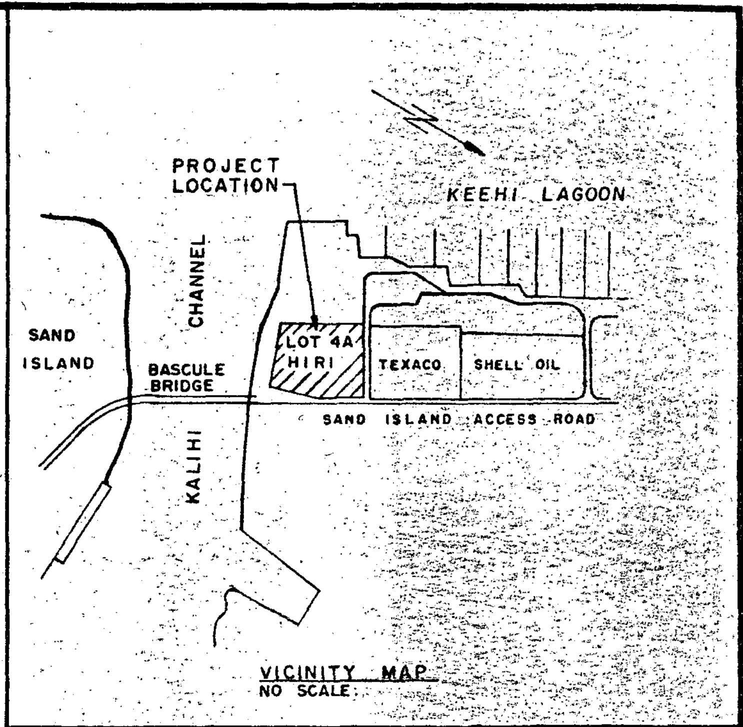
During construction we should:

1. Inspect the site preparation and grading and perform field and laboratory tests to evaluate fill quality and compaction
2. Inspect the installation of piles and building foundations
3. Install and monitor piezometers and bore hole deflection instruments at the first two tank locations
4. Review settlement readings at the first two tank locations
5. Determine settlement monitoring and instrumentation schemes for the remaining tanks

VIII ILLUSTRATIONS



SITE PLAN



VICINITY MAP
NO SCALE

Note: Subsurface Profiles A-A', B-B' and C-C' shown on Plate 2.

References: 1. Topographic Survey Map, by Wright, Harvey and Wright, Dated December 1973.
2 Master Plan, by Koepf and Lange, Revised date December 31, 1973.

Job No. 3959,001.06
Designed —
Drawn E.J.H
Checked G.E.S.
Approved G.E.S
Date 12-21-73
Scale 1" = 60'

HARDING - LAWSON ASSOCIATES

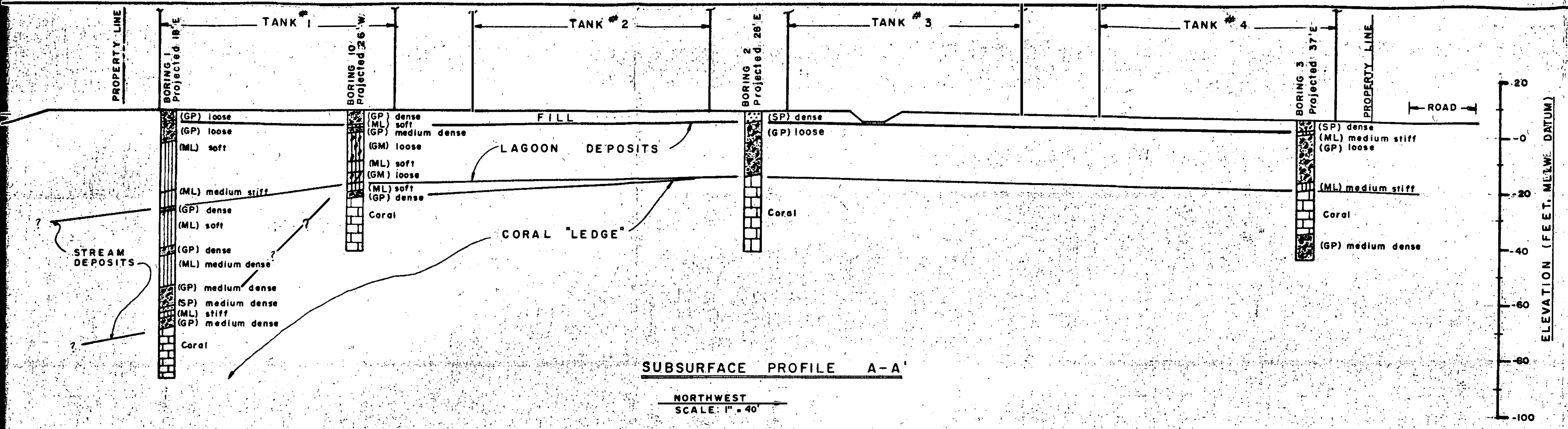
Consulting Engineers and Geologists

SITE PLAN AND VICINITY MAP

HIRI HARBOR TERMINAL

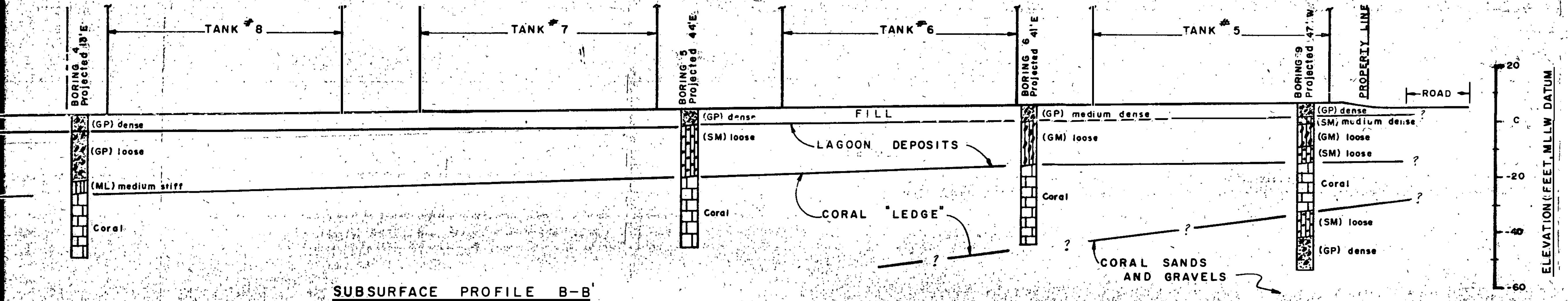
HONOLULU OAHU HAWAII

PLATE
1



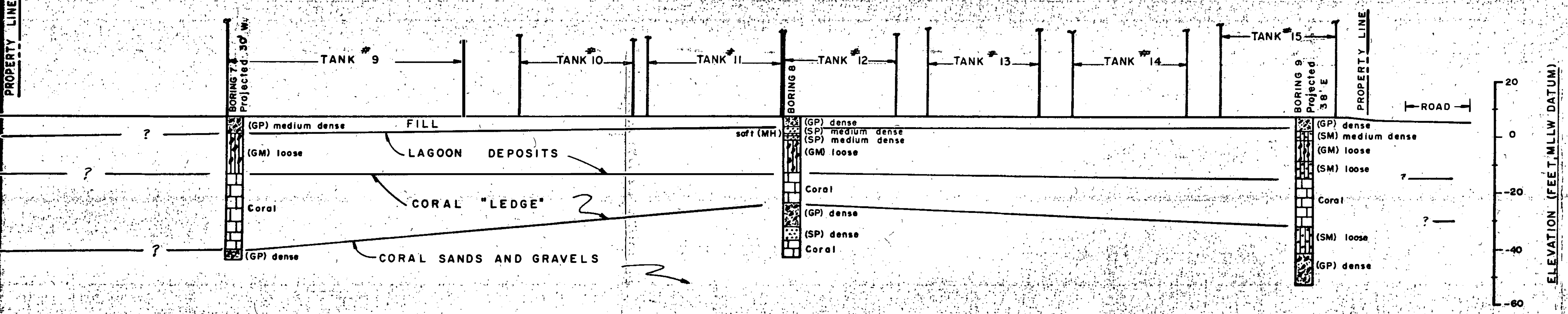
SUBSURFACE PROFILE A-A'

NORTHWEST
SCALE: 1" = 40'



SUBSURFACE PROFILE B-B'

NORTHWEST
SCALE: 1" = 40'



SUBSURFACE PROFILE C-C'

NORTHWEST
SCALE: 1" = 60'

Notes:

1. See Plate 1 for location of Subsurface Profiles A-A', B-B' and C-C.'
2. The above profiles are Harding-Lawson Associates' interpretation of subsurface conditions based on straight line interpolation between test borings. Variations from the profiles are likely.

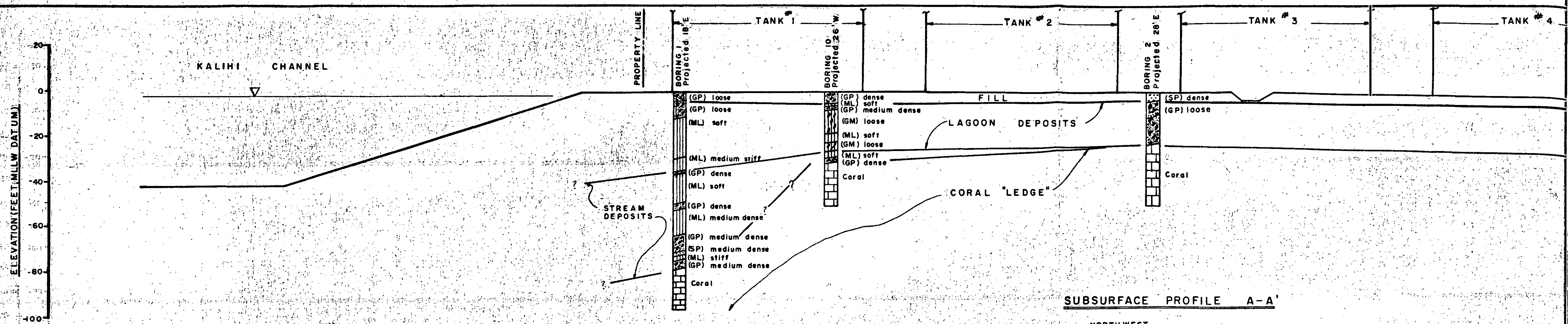
SUBSURFACE PROFILES
A-A', B-B' AND C-C'
HIRI HARBOR TERMINAL

HONOLULU OAHU HAWAII

Job No. 3959,001.06
Designed —
Drawn E. J. H
Checked G.F.S.
Approved G.F.S.
Date 1-18-74
Scale 1" = 40'

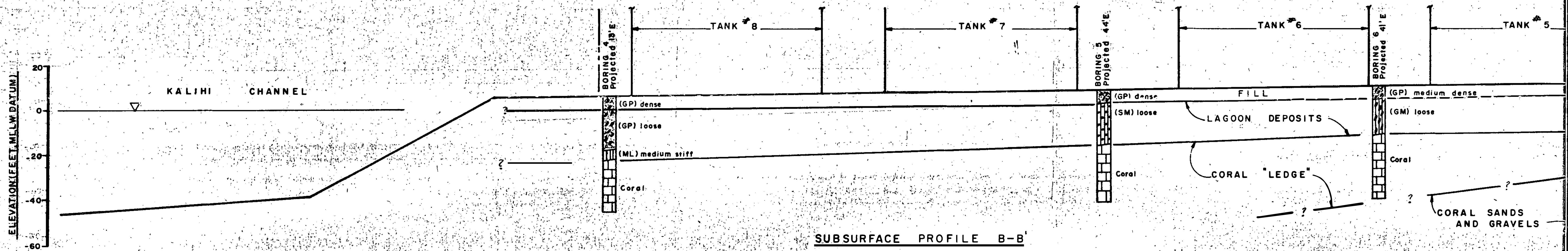
HARDING - LAWSON ASSOCIATES
Consulting Engineers and Geologists

PLATE
2



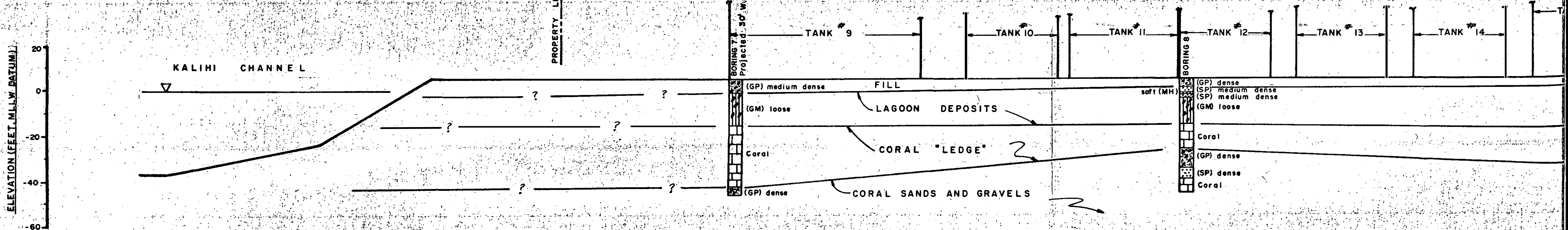
SUBSURFACE PROFILE A–A'

NORTHWEST
SCALE: 1" = 40'



SUBSURFACE PROFILE B–B'

NORTHWEST
SCALE: 1" = 40'



SUBSURFACE PROFILE C–C'

NORTHWEST
SCALE: 1" = 40'

APPENDIX A

Appendix A

FIELD AND LABORATORY DATA

BORING |

ry Wash

Date 11/13/73

LTY SANDY

rated

1/20/73

FILL

NDY GRAVEL (GP)
rated,
fragments

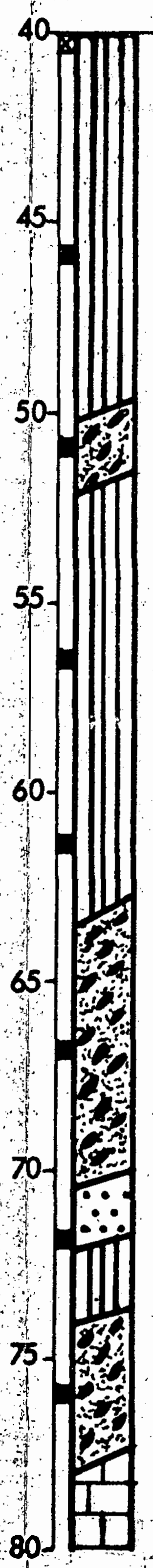
LT (ML)
ated,
and
ents

T (ML)
f, moist
onal coral

RAVEL (GP)
rated

DY SILT (ML)
ium stiff,
with coral
nd pockets
avel

Laboratory Tests	Core Recovery(%)	Cored Interval	Blows/foot	Moisture Content (%)	Dry Density (pcf)
			14		
Tx 300 (2000)			7	76.0	58
			35		
			5	33.7	71
Consol.			4	84.9	42
			17		
			10		
			19		



(Continuation of Log)

WHITE SANDY GRAVEL (GP)
dense, saturated,
with coral fragments

DARK GREY SILT (ML)
medium stiff, saturated,
(deeply weathered
volcanic ash)

GREY SILTY SANDY GRAVEL (GP)
medium dense, saturated,
with coral fragments

WHITE GRAVEL SAND (SP)
medium dense, saturated

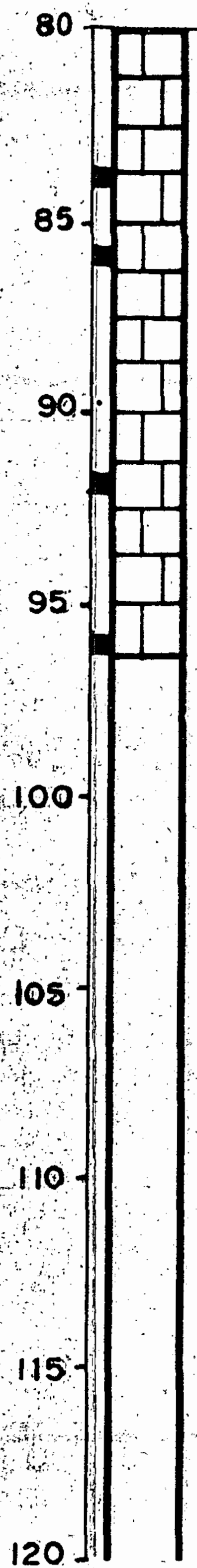
DARK GREY SANDY SILT (ML)
stiff, saturated,
with coral fragments

LIGHT BROWN SILTY SANDY
GRAVEL (GP)
medium dense, saturated

WHITE CORAL
hard, moderately strong,
with silt and sand pockets

** Field blow count converted to standard penetration blows/foot.

Laboratory Tests	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	Cored Interval
	30				
	20				
	38				
	28				



Continuation of Log

HARDING - LAWSON ASSOCIATES
Consulting Engineers and Geologists

Job No. 3959,001.06 Appr. G.F.S./cp Date 1/23/74

LOG OF BORING |

HIRI HARBOR TERMINAL

Honolulu, Oahu, Hawaii

PLATE
4

RF 2g

LOG OF BORING 1

Equipment Rotary Wash

Elevation 3.1* Date 11/13/73

Laboratory Tests	Core Recovery(%)	Cored Interval	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)
						0
			8			
						5
			6			
			4			
						10
			2			
						15
			4	30.2	95	
						20
			3	39.7	86	
						25
Consol.			6	38.8	83	
						30
			13			
						35
			25			
						40

FILL

LIGHT GREY SILTY SANDY GRAVEL (GP)
loose, saturated

WATER LEVEL 11/20/73

GREY SILTY SANDY GRAVEL (GP)
loose, saturated,
with shell fragments

GREY SANDY SILT (ML)
soft, saturated,
with gravel and
shell fragments

DARK GREY SILT (ML)
medium stiff, moist
with occasional coral
fragments

WHITE SANDY GRAVEL (GP)
dense, saturated

DARK GREY SANDY SILT (ML)
soft to medium stiff,
saturated, with coral
fragments and pockets
of silty gravel

Laboratory Tests	Core Recovery(%)	Cored Interval	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)
			14			40
						45
Tx 300 (2000)			7	76.0	58	
						50
			35			
						55
			5	33.7	71	
						60
Consol.			4	84.9	42	
						65
			17			
						70
			10			
						75
			19			
						80

(Continuation of Log)

WHITE SANDY GRAVEL (GP)
dense, saturated,
with coral fragments

DARK GREY SILT (ML)
medium stiff, saturated,
(deeply weathered
volcanic ash)

GREY SILTY SANDY GRAVEL (GP)
medium dense, saturated,
with coral fragments

WHITE GRAVEL SAND (SP)
medium dense, saturated

DARK GREY SANDY SILT (ML)
stiff, saturated,
with coral fragments

LIGHT BROWN SILTY SANDY
GRAVEL (GP)
medium dense, saturated

WHITE CORAL
hard, moderately strong,
with silt and sand pockets

* Datum: Topographic Survey Map, by Wright,
Harvey and Wright Surveyors, dated
December 1973.
MLLW Datum (Feet)

** Field blow count converted to standard penetration blows/foot.

HARDING-

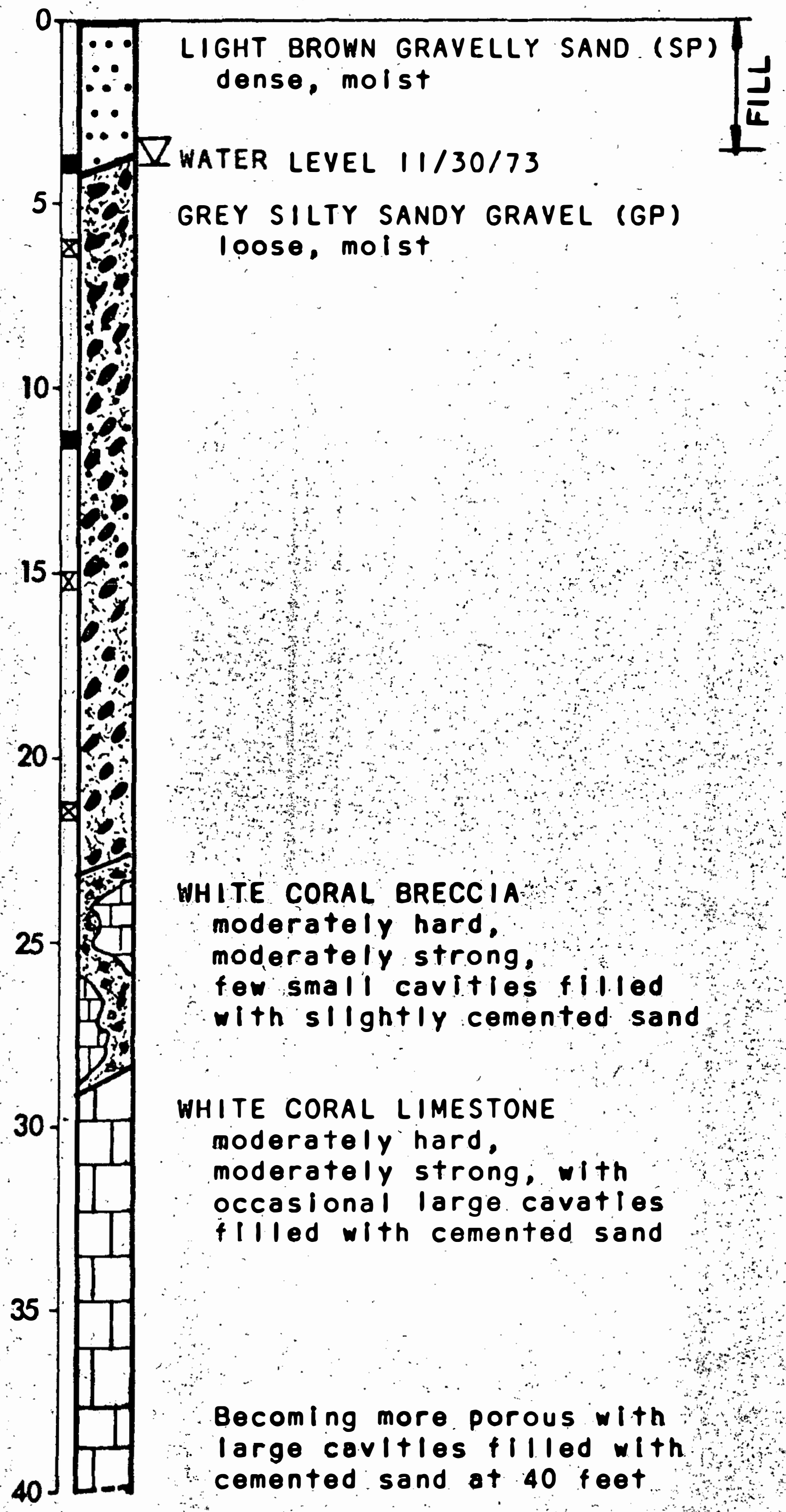
Job No. 3959,0

LOG OF BORING 2

Equipment: Rotary Wash

Elevation: 6.3 Date: 11/26/73

Laboratory Tests	Core Recovery(%)	Cored Interval	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample
Tx 345 (1000)			13	22.9	96		
			4				
			2				
			3				
			2				
	73						
	60						
	48						



LIGHT BROWN GRAVELLY SAND (SP)
dense, moist

WATER LEVEL 11/30/73

GREY SILTY SANDY GRAVEL (GP)
loose, moist

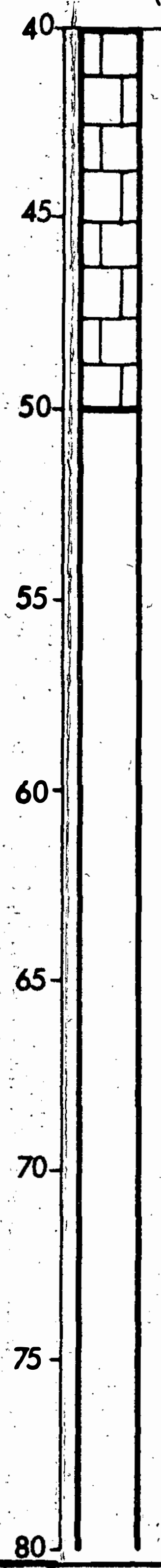
WHITE CORAL BRECCIA
moderately hard,
moderately strong,
few small cavities filled
with slightly cemented sand

WHITE CORAL LIMESTONE
moderately hard,
moderately strong, with
occasional large cavaties
filled with cemented sand

Becoming more porous with
large cavities filled with
cemented sand at 40 feet

(Continuation of Log)

Laboratory Tests	Core Recovery(%)	Cored Interval	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample
	25						
	49						



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Consulting Engineers and Geologists

Job No. 3959,001,06 Appr: G.F.S./cp Date 1/23/74

LOG OF BORING 2
HIRI HARBOR TERMINAL
Honolulu, Oahu, Hawaii

PLATE
5

N02470

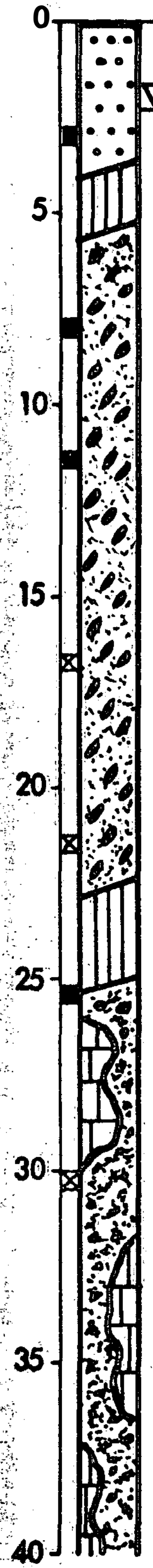
RF 2g

LOG OF BORING 3

Equipment Rotary Wash

Elevation 4.4 Date 11/14/73

Laboratory Tests	Core Recovery(%)	Cored Interval	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample
Tx 1900 (1000)			20	22.8	94		
			2				
			2				
			4				
			4				
			25				
			49/3"				
	60						



LIGHT BROWN GRAVELLY SAND (SP) FILL
dense, moist

WATER LEVEL 11/30/73

GREY SANDY SILT (ML)
medium stiff, saturated, with shells

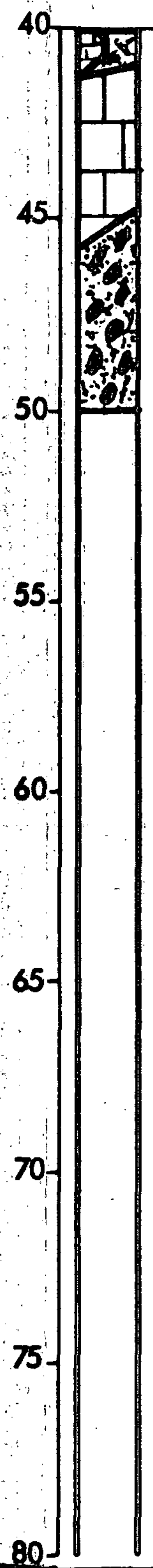
GREY SILTY SANDY GRAVEL (GP)
loose, saturated

DARK GREY SANDY SILT (ML)
medium stiff, saturated, with coral fragments

WHITE CORAL BRECCIA
moderately hard, moderately strong, with many small cavities filled very porous, moderately well cemented sand

Laboratory Tests	Core Recovery(%)	Cored Interval	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample
	100						
	10						

(Continuation of Log)



WHITE CORAL LIMESTONE
moderately hard, moderately strong, very porous

BROWN SANDY GRAVEL (GP)
medium dense, saturated

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Job No. 3959,001.06 Appr: G.F.S./cp Date 1/23/74

LOG OF BORING 3

HIRI HARBOR TERMINAL

Honolulu, Oahu, Hawaii

PLATE 6

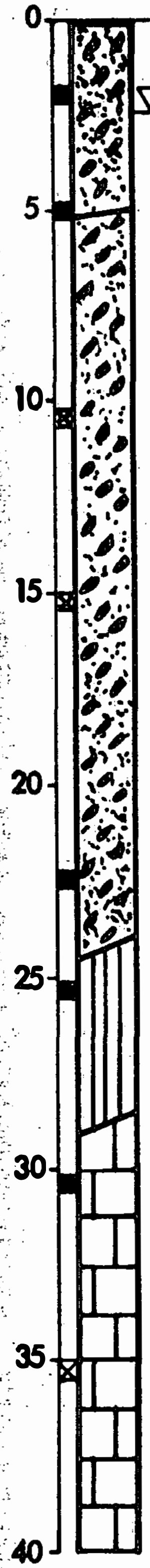
RF 2g

LOG OF BORING 4

Equipment Rotary Wash

Elevation 4.4 Date 11/21/73

Laboratory Tests	Core Recovery(%)	Cored Interval	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample
Tx 1500 (1000)			32	15.8	93		
			2				
			2				
			2				
			2				
			10				
			35/2"				
	63	I					



LIGHT BROWN SANDY GRAVEL (GP)
dense, moist

WATER LEVEL 11/30/73

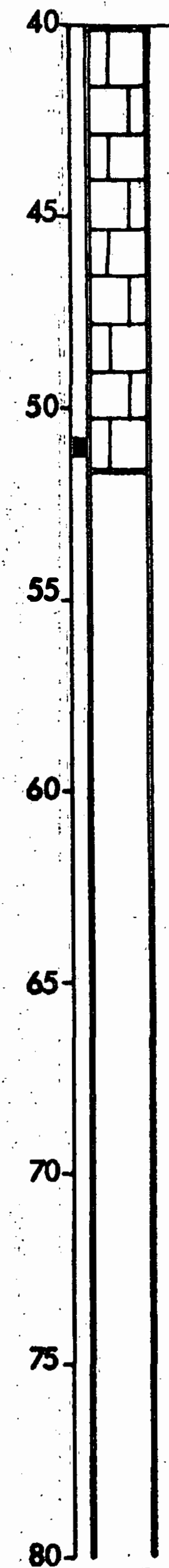
FILL

BLACK SANDY GRAVELLY SILT (ML)
medium stiff, moist, saturated, with coral fragments

WHITE CORAL LIMESTONE
moderately hard, moderately strong, with many small cavities filled with cemented sand

(Continuation of Log)

Laboratory Tests	Core Recovery(%)	Cored Interval	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample
	95	I					
	23	I					



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LOG OF BORING 4

HIRI HARBOR TERMINAL

Honolulu, Oahu, Hawaii

PLATE 7

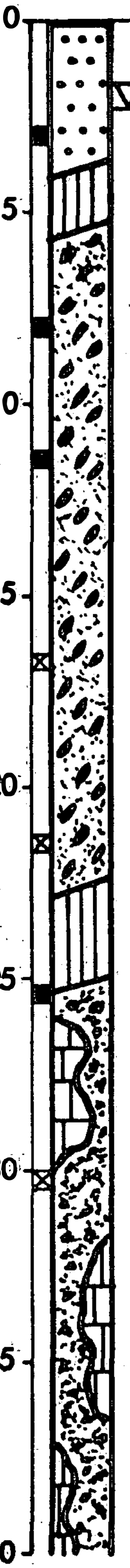
N02470

RF 2g

LOG OF BORING 3

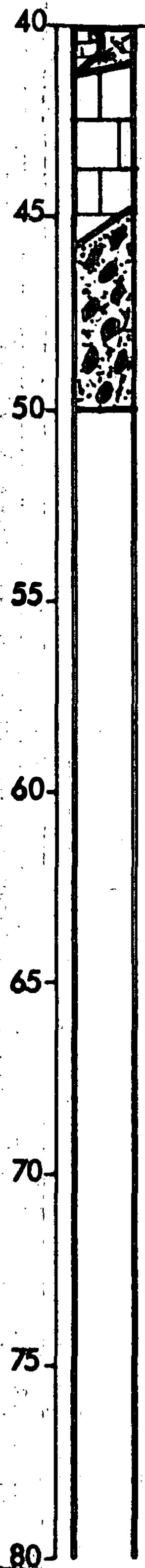
Equipment Rotary Wash

Elevation 4.4 Date 11/14/73



Laboratory Tests	Core Recovery(%)	Cored Interval	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample	
						0		LIGHT BROWN GRAVELLY SAND (SP) dense, moist (FILL)
Tx 1900 (1000)			20	22.8	94		■	▽ WATER LEVEL 11/30/73
								GREY SANDY SILT (ML) medium stiff, saturated, with shells
						5		
								GREY SILTY SANDY GRAVEL (GP) loose, saturated
			2				■	
						10		
			2				■	
						15		
			4				☒	
						20		
			4				☒	
								DARK GREY SANDY SILT (ML) medium stiff, saturated, with coral fragments
			25			25	■	
								WHITE CORAL BRECCIA moderately hard, moderately strong, with many small cavities filled very porous, moderately well cemented sand
			49/3"			30	☒	
						35		
	60							
						40		

(Continuation of Log)



Laboratory Tests	Core Recovery(%)	Cored Interval	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample	
						40		WHITE CORAL LIMESTONE moderately hard, moderately strong, very porous
	100							
						45		BROWN SANDY GRAVEL (GP) medium dense, saturated
	10							
						50		
						55		
						60		
						65		
						70		
						75		
						80		

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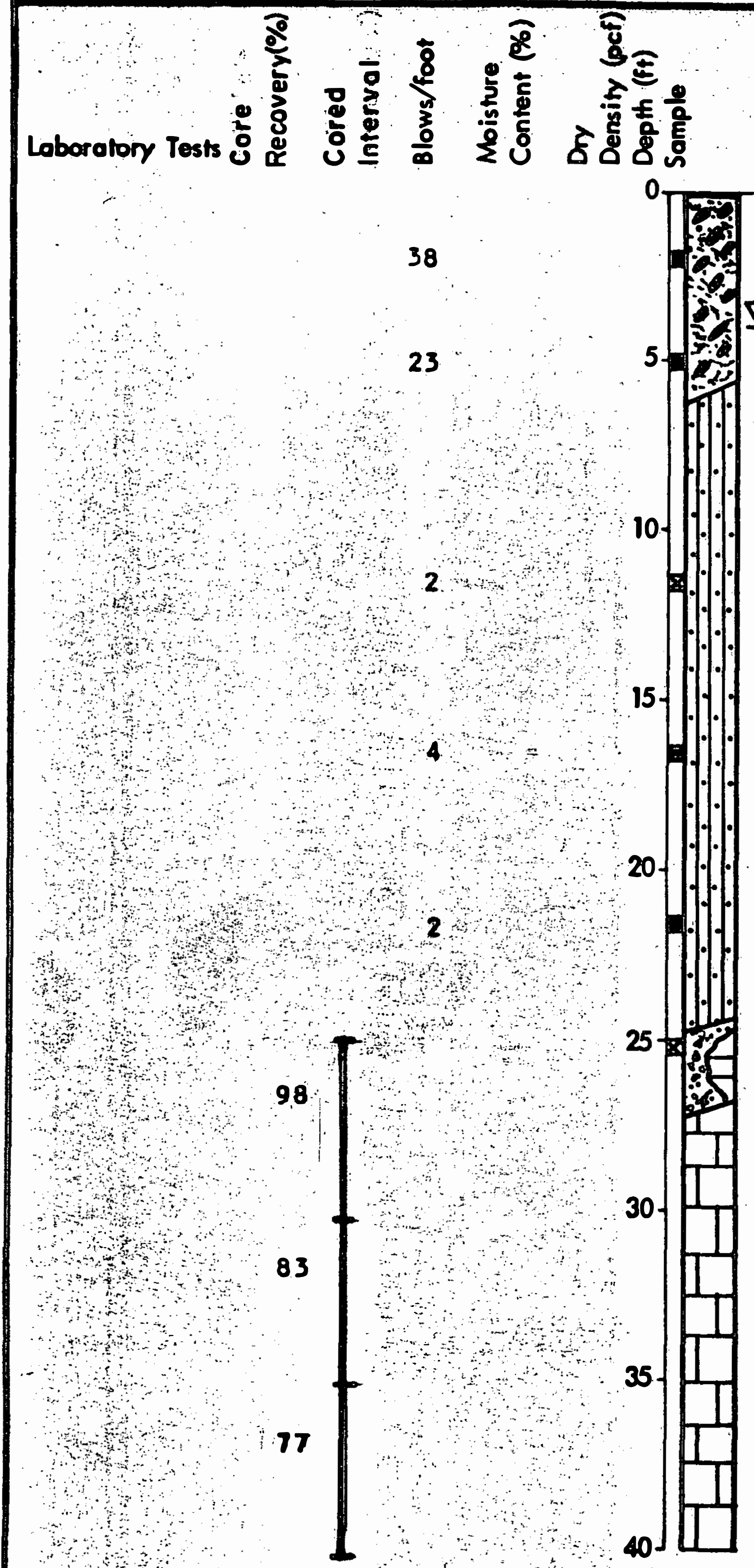
LOG OF BORING 3
HIRI HARBOR TERMINAL
Honolulu, Oahu, Hawaii

PLATE 6

LOG OF BORING 5

Equipment Rotary Wash

Elevation 5.7 Date 11/27/73



LIGHT BROWN SANDY GRAVEL (GP)
dense, moist

▽WATER LEVEL 11/30/73

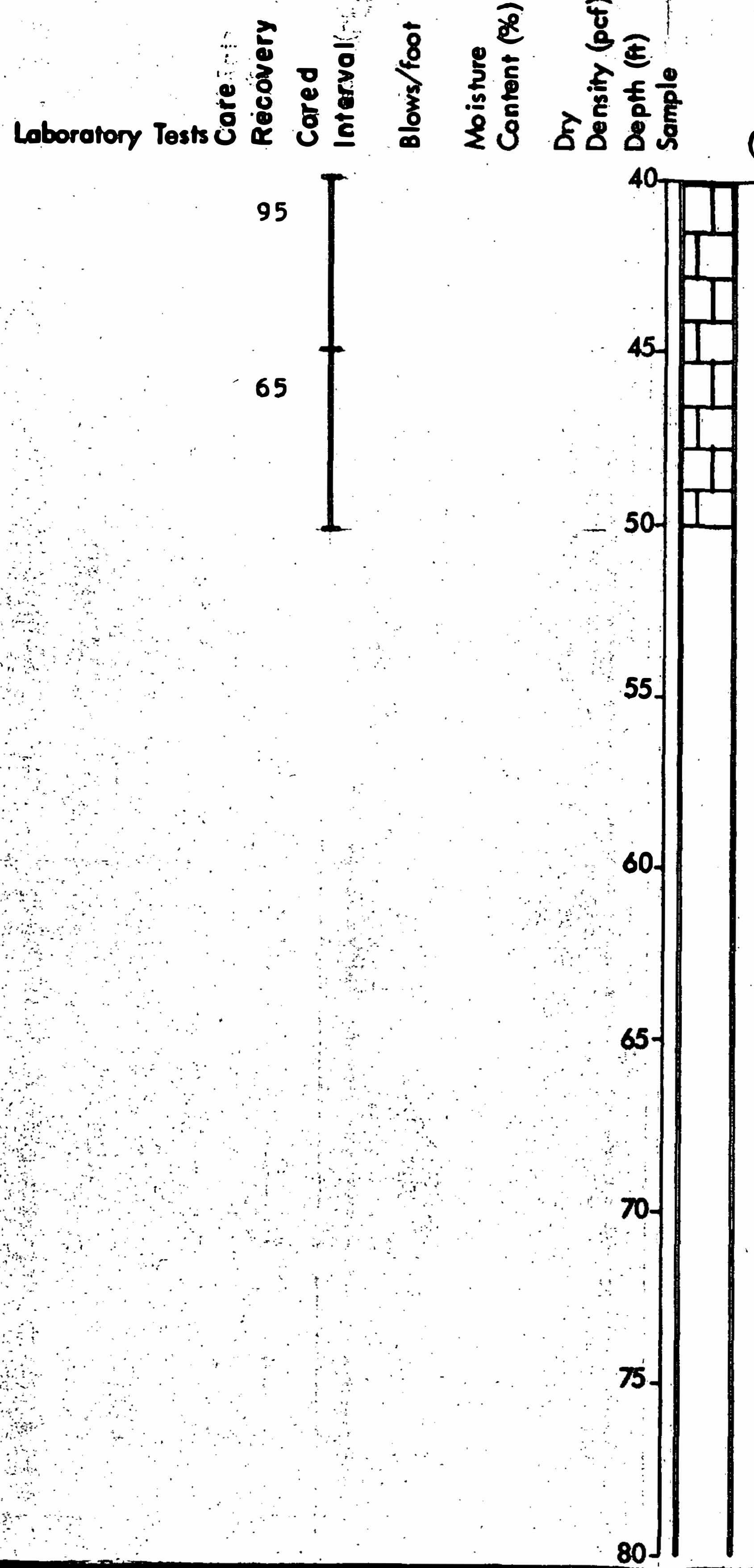
FILL

GREY SANDY SILTY GRAVELLY SAND (SM)
loose, saturated,
with shells

WHITE CORAL BRECCIA
moderately hard, moderately
strong, slightly cemented,
closely to moderately fractured

WHITE CORAL LIMESTONE
moderately hard, moderately
strong, very porous, with
very large cavaties filled
with cemented sand

(Continuation of Log)



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LOG OF BORING 5
HIRI HARBOR TERMINAL
Honolulu, Oahu, Hawaii

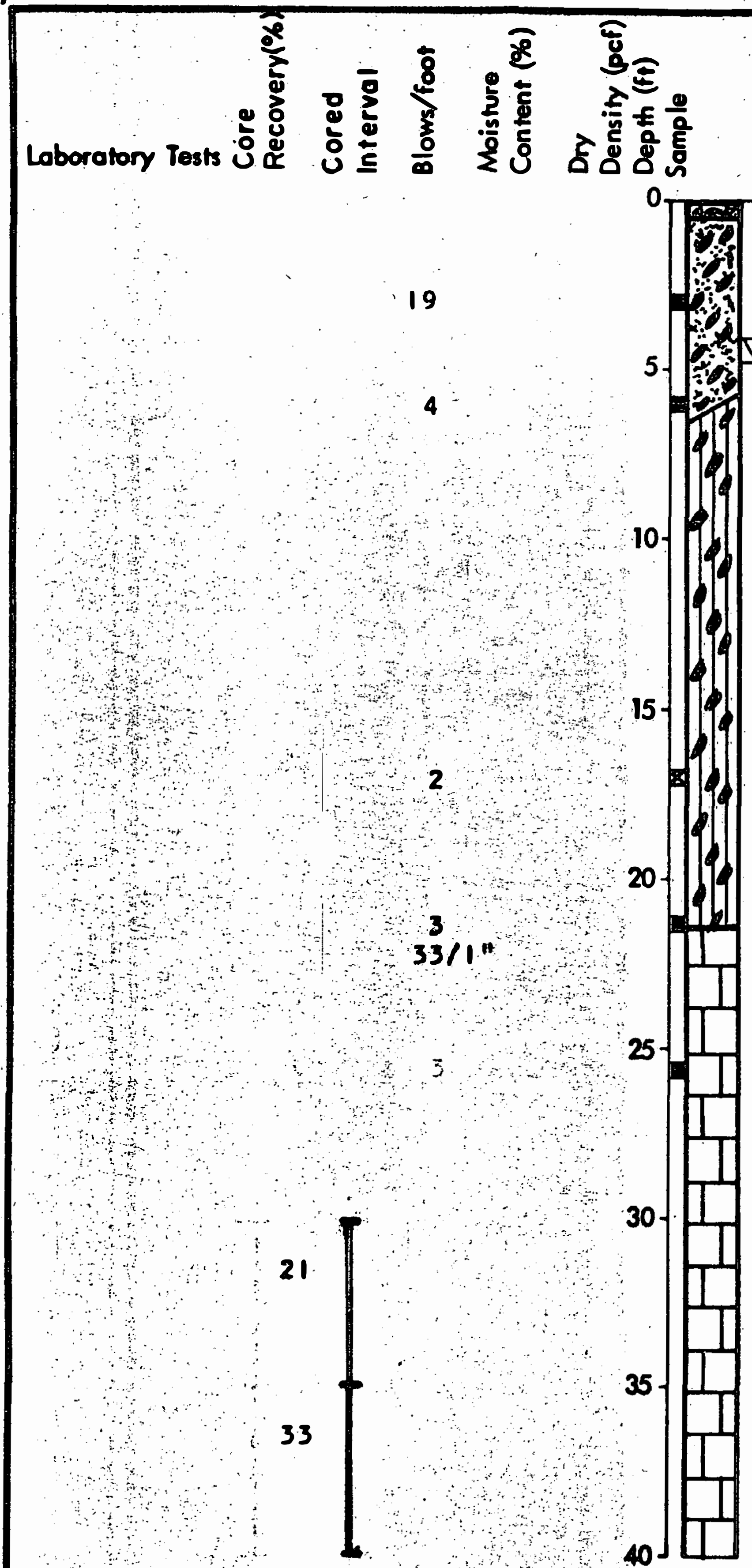
PLATE
8

RF 29

LOG OF BORING 6

Equipment Rotary Wash

Elevation 6.7 **Date** 11/28/73



4" of CONCRETE

LIGHT BROWN SILTY SANDY GRAVEL (GP)
medium dense, moist

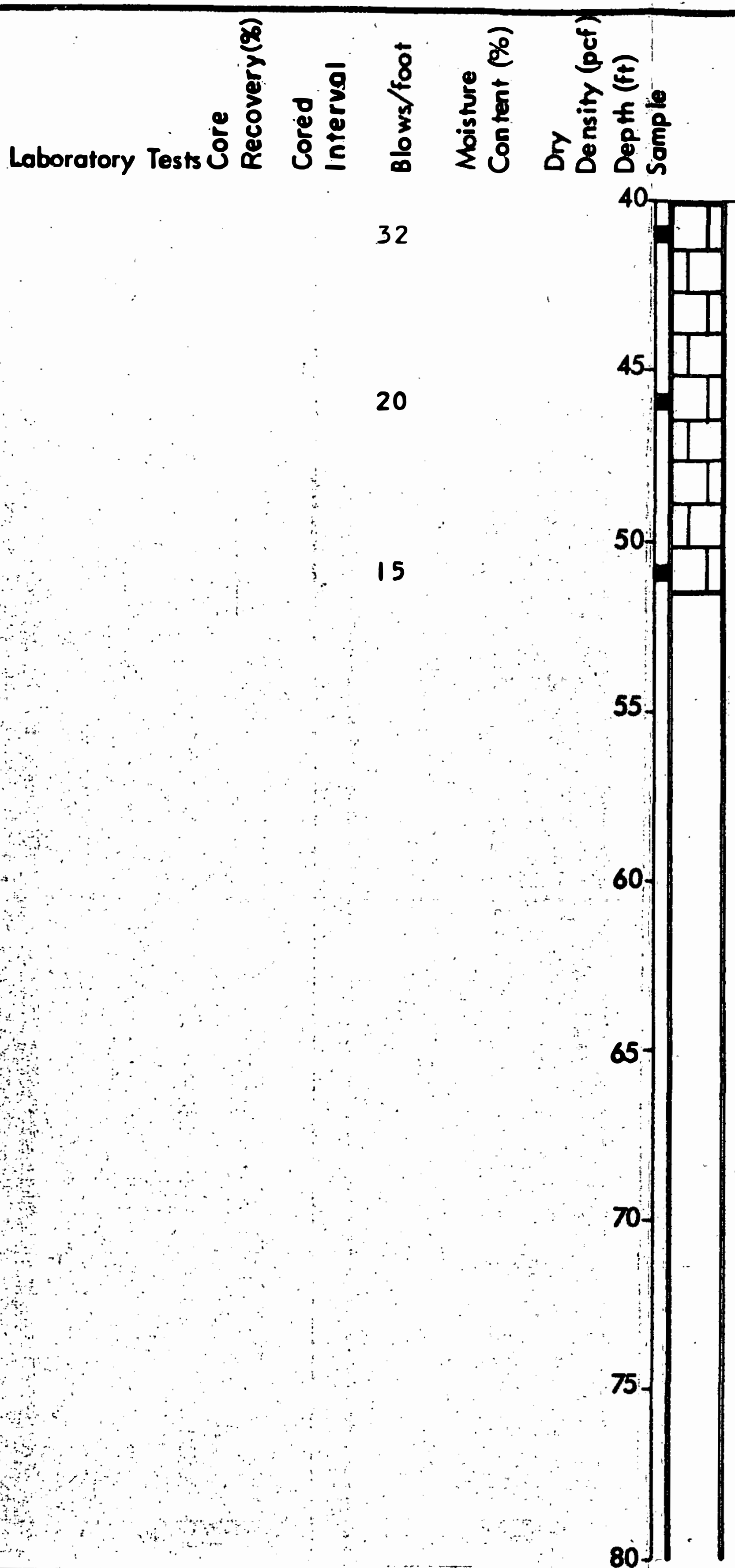
WATER LEVEL 11/30/73

FILL

LIGHT GREY SILTY SANDY GRAVEL (GM)
loose, saturated

WHITE CORAL LIMESTONE
moderately hard,
moderately strong,
with large cavities
filled with loose sand
and occasional streaks
of dense coral limestone

(Continuation of Log)



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LOG OF BORING 6
HIRI HARBOR TERMINAL
Honolulu, Oahu, Hawaii

PLATE 9

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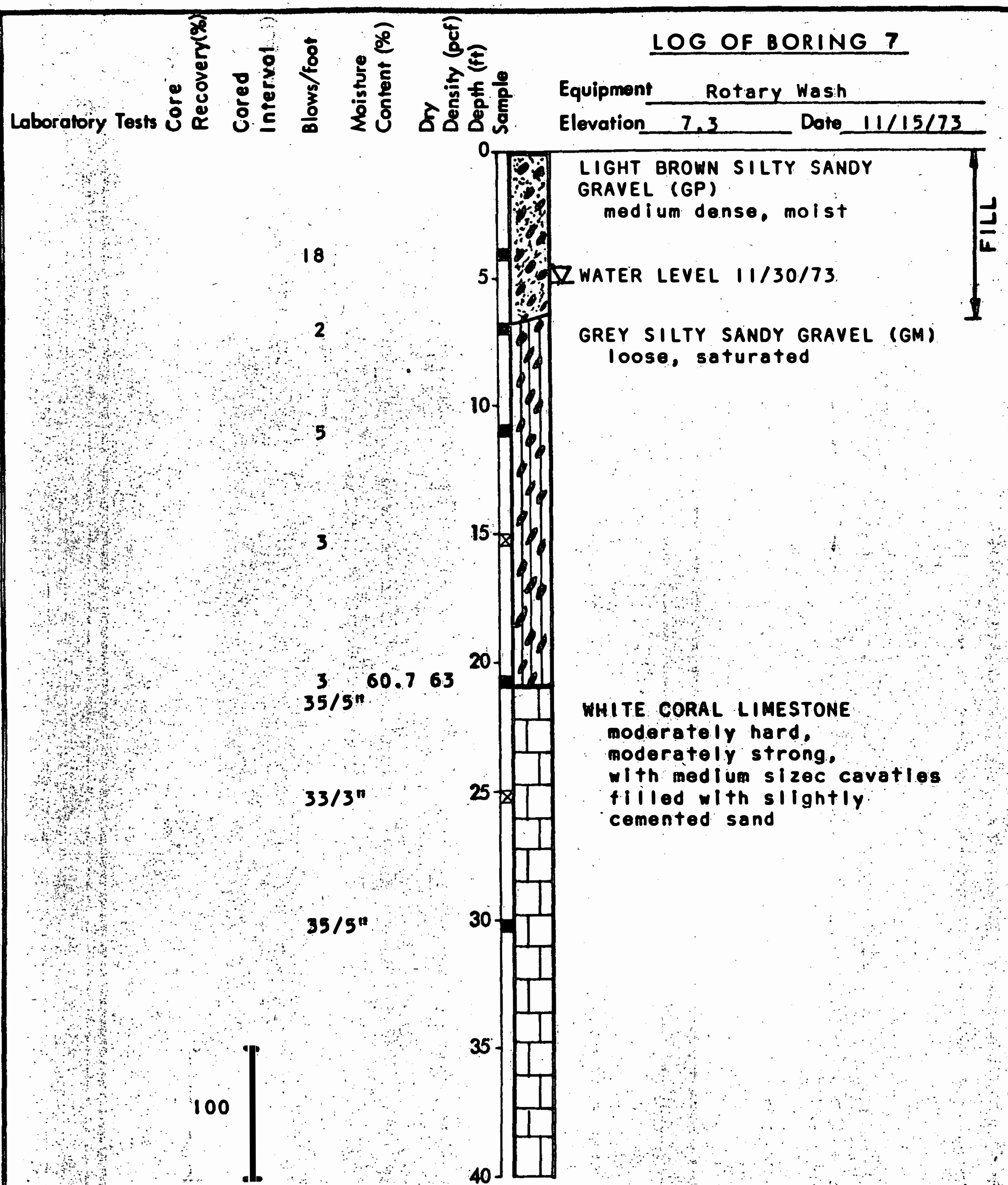
RF 2g

LOG OF BORING 7

Equipment Rotary Wash

Elevation 7.3 Date 11/15/73

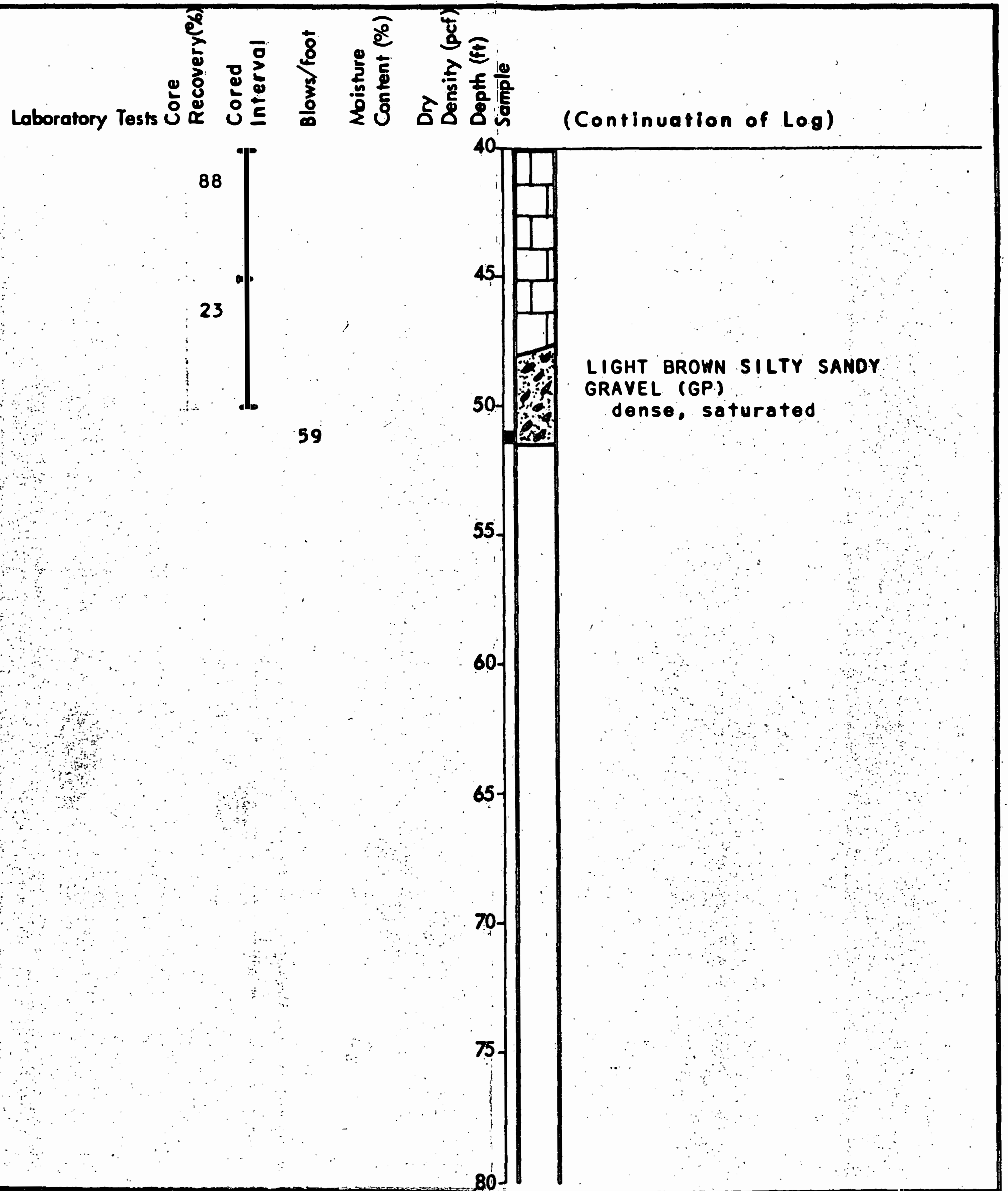


LIGHT BROWN SILTY SANDY GRAVEL (GP)
medium dense, moist

WATER LEVEL 11/30/73

GREY SILTY SANDY GRAVEL (GM)
loose, saturated

WHITE CORAL LIMESTONE
moderately hard,
moderately strong,
with medium sizec cavaties
filled with slightly
cemented sand



(Continuation of Log)

LIGHT BROWN SILTY SANDY GRAVEL (GP)
dense, saturated

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LOG OF BORING 7
HIRI HARBOR TERMINAL
Honolulu, Oahu, Hawaii

PLATE
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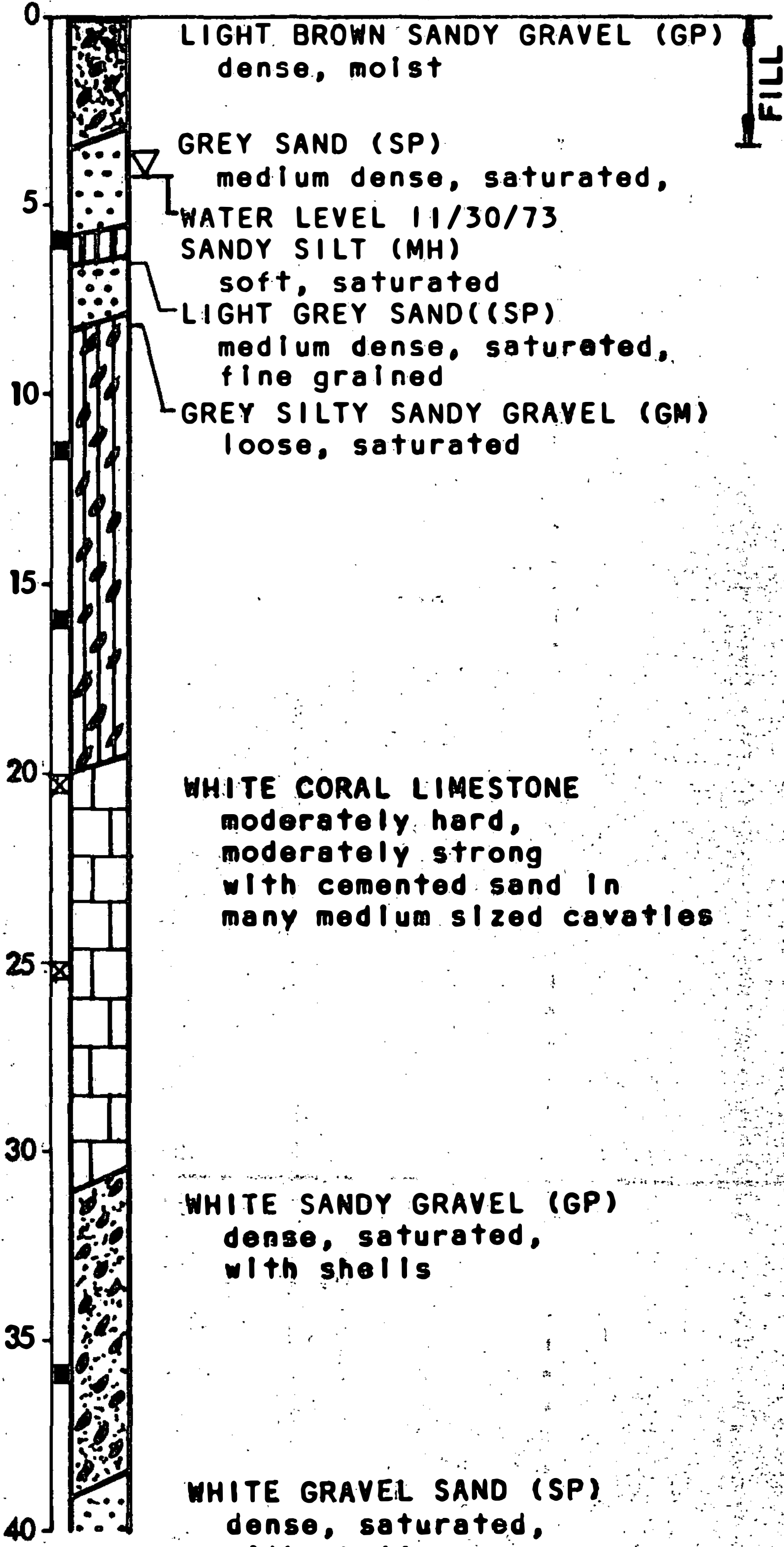
RF 2g

LOG OF BORING 8

Equipment Rotary Wash
Elevation 6.3 Date 11/20/73

Laboratory Tests	Core Recovery(%)	Cored Interval	Blows/foot	Moisture Content (%)	Dry Density (pcf)
Consol.			3	44.8	73
			2	38.6	80
			2		
			33/5"		
	100				
	35				
			52		



LIGHT BROWN SANDY GRAVEL (GP)
dense, moist

GREY SAND (SP)
medium dense, saturated,

WATER LEVEL 11/30/73

SANDY SILT (MH)
soft, saturated

LIGHT GREY SAND((SP)
medium dense, saturated,
fine grained

GREY SILTY SANDY GRAVEL (GM)
loose, saturated

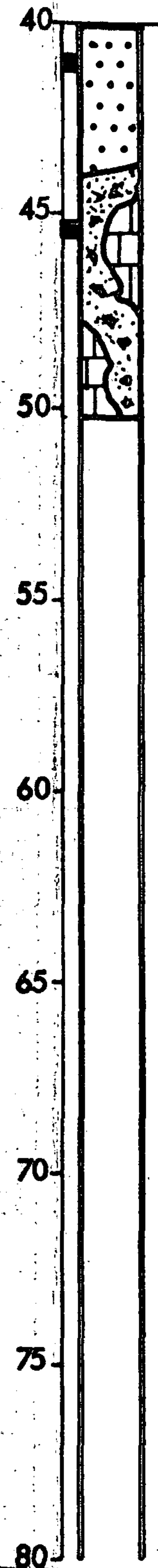
WHITE CORAL LIMESTONE
moderately hard,
moderately strong
with cemented sand in
many medium sized cavaties

WHITE SANDY GRAVEL (GP)
dense, saturated,
with shells

WHITE GRAVEL SAND (SP)
dense, saturated,
with shells

(Continuation of Log)

Laboratory Tests	Core Recovery(%)	Cored Interval	Blows/foot	Moisture Content (%)	Dry Density (pcf)
			50		
			79		



WHITE CORAL BRECCIA
moderately strong

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LOG OF BORING 8
HIRI HARBOR TERMINAL
Honolulu, Oahu, Hawaii

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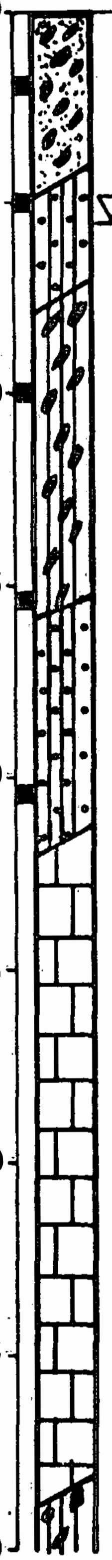
LOG OF BORING 9

Equipment Rotary Wash
Elevation 7.0 Date 11/19/73

Laboratory Tests	Core Recovery(%)	Cored Interval	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Description
						0	LIGHT BROWN SANDY GRAVEL (GP) dense, moist FILL
			48				
Tx 1300 (1000)			8	28.7	90	5	GREY SILTY SAND (SM) medium dense, saturated WATER LEVEL 11/30/73
							GREY SILTY GRAVEL (GM) loose, saturated
			7			10	
			2			15	GREY SILTY GRAVELLY SAND (SM) loose, saturated
			3			20	
							WHITE CORAL LIMESTONE moderately hard, moderately strong, very porous
	93					25	
	98					30	
	72					35	
						40	BROWN SILTY GRAVELLY SAND (SM) loose, saturated



(Continuation of Log)

Laboratory Tests	Core Recovery(%)	Cored Interval	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Description
						40	
			6			45	
			105				WHITE SANDY GRAVEL (GP) dense, saturated
						50	
			29			55	
			52				
						60	
						65	
						70	
						75	
						80	

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LOG OF BORING 9
HIRI HARBOR TERMINAL
Honolulu, Oahu, Hawaii

PLATE
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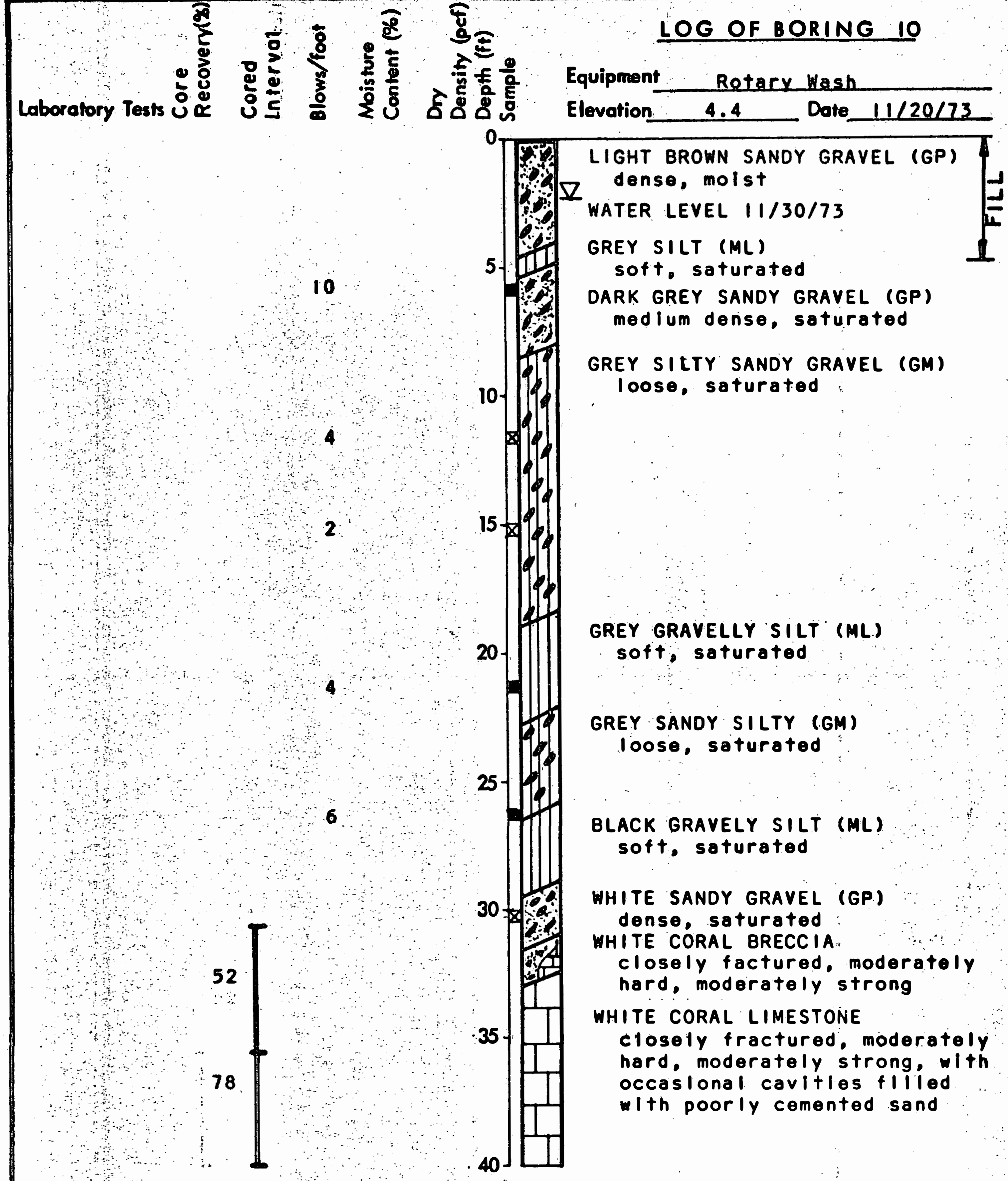
N02470

RF 29

LOG OF BORING 10

Equipment Rotary Wash
Elevation 4.4 Date 11/20/73



LIGHT BROWN SANDY GRAVEL (GP)
dense, moist

WATER LEVEL 11/30/73

GREY SILT (ML)
soft, saturated

DARK GREY SANDY GRAVEL (GP)
medium dense, saturated

GREY SILTY SANDY GRAVEL (GM)
loose, saturated

GREY GRAVELLY SILT (ML)
soft, saturated

GREY SANDY SILTY (GM)
loose, saturated

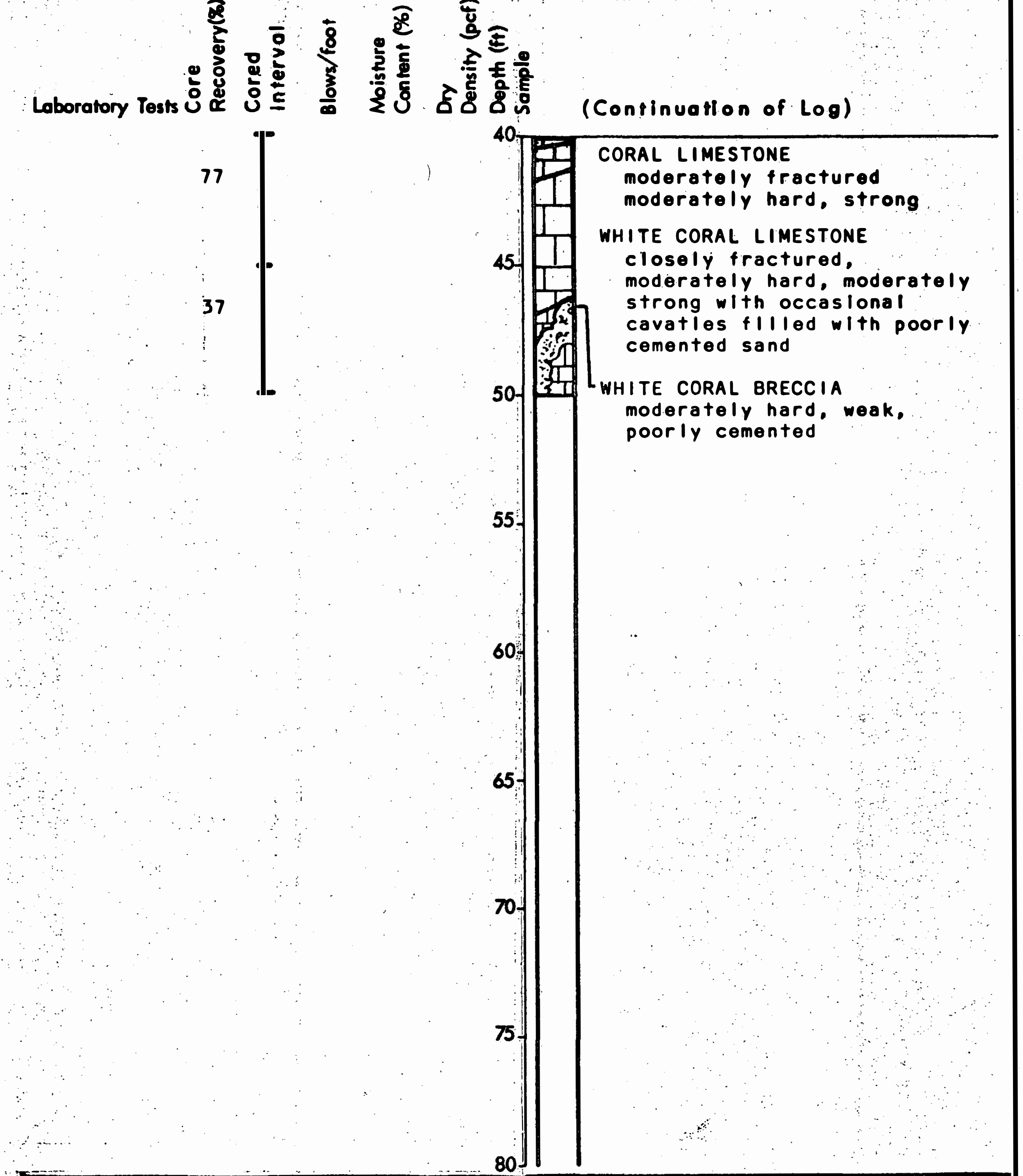
BLACK GRAVELY SILT (ML)
soft, saturated

WHITE SANDY GRAVEL (GP)
dense, saturated

WHITE CORAL BRECCIA
closely factured, moderately hard, moderately strong

WHITE CORAL LIMESTONE
closely fractured, moderately hard, moderately strong, with occasional cavities filled with poorly cemented sand

(Continuation of Log)



CORAL LIMESTONE
moderately fractured
moderately hard, strong

WHITE CORAL LIMESTONE
closely fractured,
moderately hard, moderately strong with occasional cavaties filled with poorly cemented sand

WHITE CORAL BRECCIA
moderately hard, weak,
poorly cemented

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LOG OF BORING 10
HIRI HARBOR TERMINAL
Honolulu, Oahu, Hawaii

PLATE
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RF3A

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

UNIFIED SOIL CLASSIFICATION SYSTEM

Consol — Consolidation
LL — Liquid Limit (in %)
PL — Plastic Limit (in %)
G_s — Specific Gravity
SA — Sieve Analysis
▣ "Undisturbed" Sample
☒ Bulk Sample

	Shear Strength, psf	Confining Pressure, psf	
*Tx	320	(2600)	Unconsolidated Undrained Triaxial
TxCU	320	(2600)	Consolidated Undrained Triaxial
DS	2750	(2000)	Consolidated Drained Direct Shear
FVS	470		Field Vane Shear
*UC	2000		Unconfined Compression
LVS	700		Laboratory Vane Shear

Notes: (1) All strength tests on 2.8" or 2.4" diameter samples unless otherwise indicated.

(2) * Indicates 1.4" diameter sample.

KEY TO TEST DATA

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SOIL CLASSIFICATION CHART AND KEY TO TEST DATA

HIRI HARBOR TERMINAL
Honolulu, Oahu, Hawaii

PLATE
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Boring Number	Depth (Feet)	Percent Passing No. 4 Sieve	Percent Passing No. 200 Sieve	Unified Soil Classification
1	15.7	100	63	ML
1	21.2	100	77	ML
1	25.7		79	ML
1	45.7	99	57	ML
5	21.1	62	16	SM
7	20.6	46	22	GM
8	11.2	52	18	GM
8	15.7	46	15	GM
9	9.7	66	38	GM
9	20.2	57	12	SM
9	44.3	68	18	SM

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PARTICLE SIZE ANALYSIS

HIRI HARBOR TERMINAL

Honolulu, Oahu, Hawaii

PLATE

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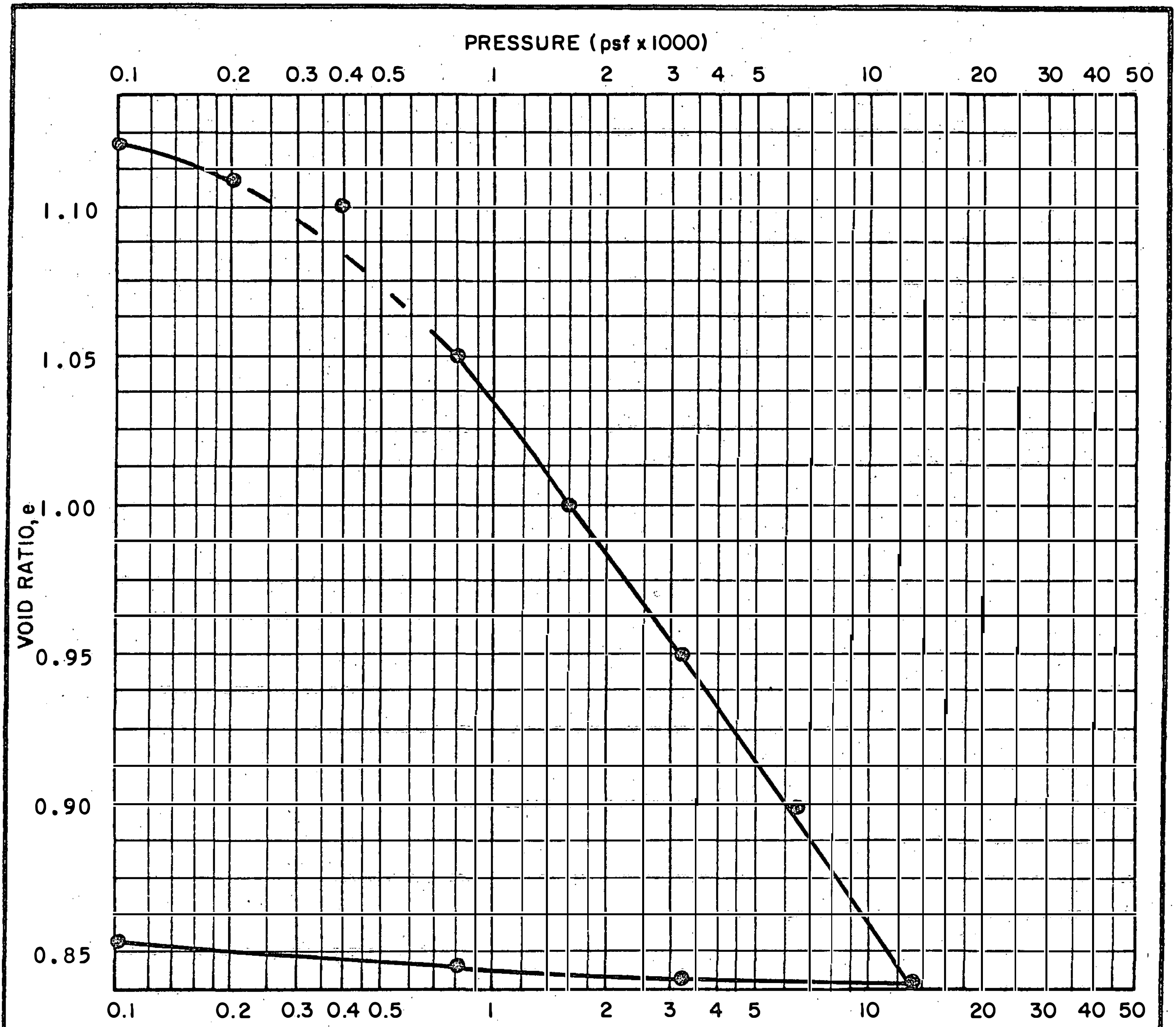

TYPE OF SPECIMEN	Undisturbed			BEFORE TEST			AFTER TEST	
DIAMETER (in.)	2.43	HEIGHT(in.)	0.80	MOISTURE CONTENT	w_o	38.8 %	w_f	29.6 %
OVERBURDEN PRESS., P_o	1500 psf			VOID RATIO	e_o	1.159	e_f	0.853
PRECONSOL. PRESS., P_c	Less than 500 psf			SATURATION	S_o	96.4 %	S_f	100 %
COMPRESSION INDEX, C_c				DRY DENSITY	γ_d	83 pcf	γ_d	97 pcf
LL		PL		PI			G_s	2.88 (Actual)

CLASSIFICATION GREY SANDY SILT (ML)

SOURCE Boring I at depth 25.7'

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CONSOLIDATION TEST REPORT

HIRI HARBOR TERMINAL
Honolulu, Oahu, Hawaii

PLATE 16

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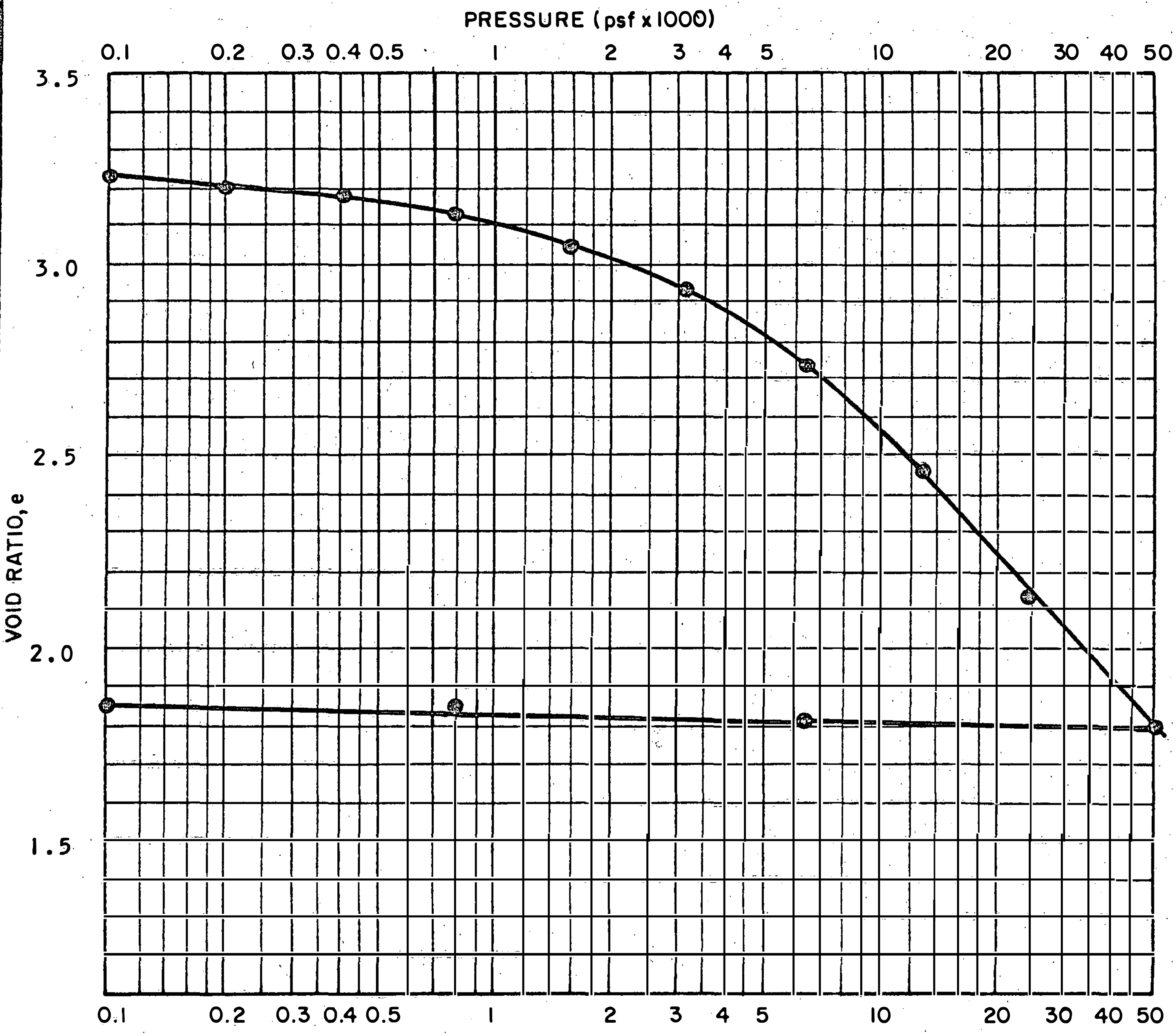

TYPE OF SPECIMEN	Undisturbed			BEFORE TEST			AFTER TEST	
DIAMETER (in.)	2.43	HEIGHT (in.)	0.80	MOISTURE CONTENT	w_o	84.9 %	w_f	64.5 %
OVERBURDEN PRESS., P_o	3780	psf		VOID RATIO	e_o	3.238	e_f	1.847
PRECONSOL. PRESS., P_c	3500	psf		SATURATION	S_o	76.0 %	S_f	100 %
COMPRESSION INDEX, C_c	1.080			DRY DENSITY	γ_d	42 pcf	γ_d	64 pcf

LL

PL

PI

G_s 2.90 (Assumed)

CLASSIFICATION DARK GREY SILT (ML)

SOURCE Boring 1 at depth 61.2'

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CONSOLIDATION TEST REPORT

HIRI HARBOR TERMINAL
Honolulu, Oahu, Hawaii

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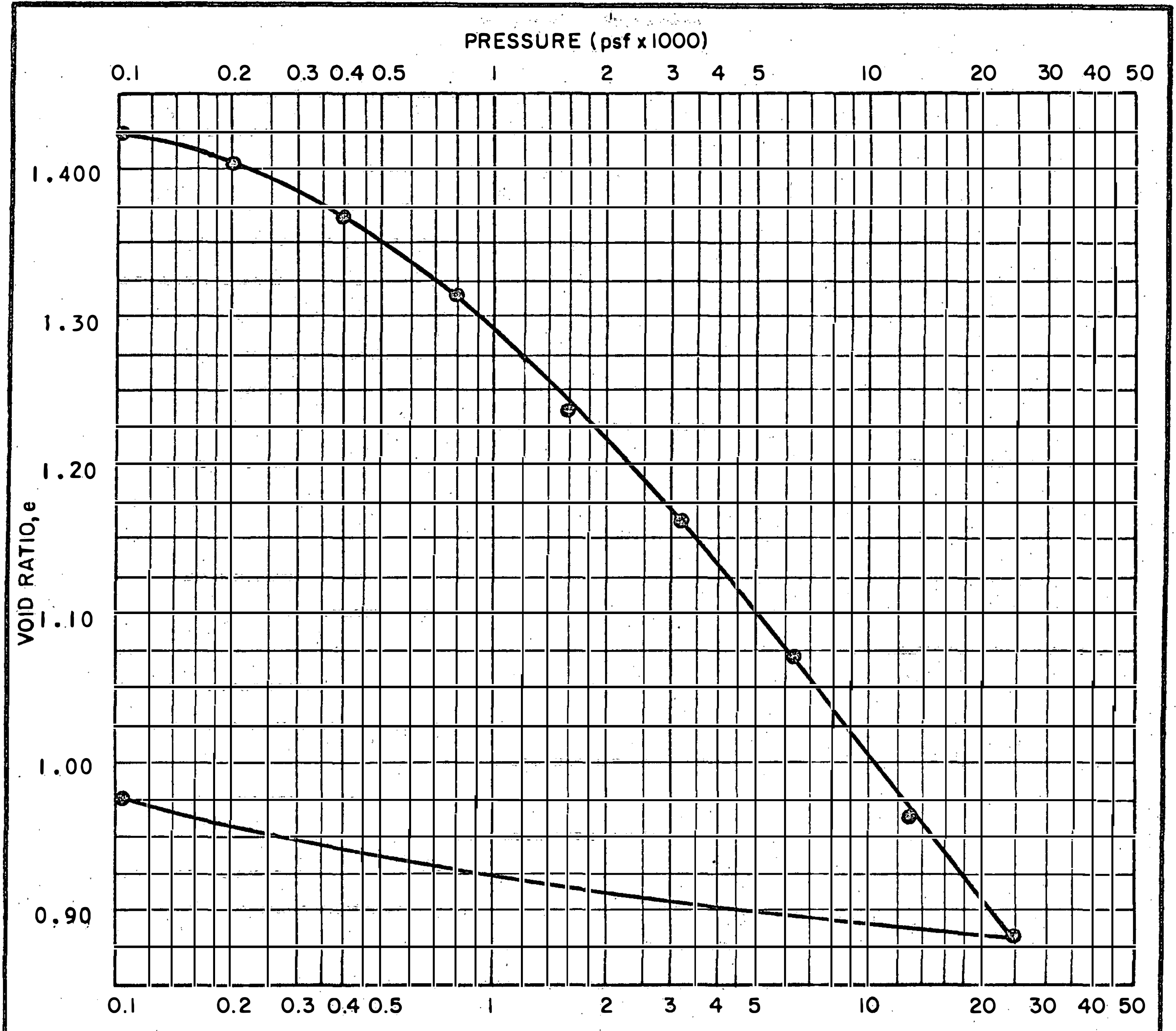
RF30



TYPE OF SPECIMEN	Undisturbed			BEFORE TEST			AFTER TEST	
DIAMETER (in.)	2.43	HEIGHT(in.)	0.80	MOISTURE CONTENT	w_o	44.8 %	w_f	34.0 %
OVERBURDEN PRESS., P_o	500 psf			VOID RATIO	e_o	1.434	e_f	0.972
PRECONSOL. PRESS., P_c	750 psf			SATURATION	S_o	89.0 %	S_f	99.7 %
COMPRESSION INDEX, C_c	0.34			DRY DENSITY	γ_d	73 pcf	γ_d	90 pcf

LL	PL	PI	G_s 2.85 (Assumed)

CLASSIFICATION GREY SANDY SILT (MH)	SOURCE Boring 8 at depth 5.7'

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CONSOLIDATION TEST REPORT

HIRI HARBOR TERMINAL

Honolulu, Oahu, Hawaii

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