THE FEDERAL REPUBLIC OF NIGERIA

REPORT

ON
ALTERNATIVE SITES
FOR
THE NEW OCEAN TERMINAL
IN
THE EASTERN COAST
GEOLOGICAL INVESTIGATION

July, 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

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GEOLOGICAL MAP

OF

NIGERIA

1974

Compiled by the Geological Survey
C. N. Okezie, Director

SCALE 1: 2,000,000

Kms 50 0 50 100 150 Kms

P O P U L A R R E P U B L

G U L F O F G U I N E A

B I G H T O F

LAGOS

BENIN CITY

OWERRI

UYO

CALABAR

BUEA

PROJECT SITE

Iboro Area

Opobo Area

James Town Area

CONTENTS

ABBREVIATIONS AND ACRONYMS

Unless the text states otherwise, the following terms and abbreviations have the following definitions:

JICA	:	Japan International Cooperation Agency
NPA	:	Nigerian Ports Authority
FEN	:	Foundation Engineering (Nigeria) Co., Ltd.
KASCO	:	Kokusai Kogyo Co., Ltd.
ASTM	:	American Society for Testing Materials
BS	:	British Standard
SPT	:	Standard Penetration Test
(f)	:	Fine
(m)	:	Medium
(c)	:	Coarse
B/H	:	Borehole
O-1	:	Borehole No. Opobo-1
O-2	:	Borehole No. Opobo-2
I-1	:	Borehole No. Ibeno-1
I-2	:	Borehole No. Ibeno-2
J-1	:	Borehole No. James Town-1
J-2	:	Borehole No. James Town-2
DL	:	Datum Level
WL	:	Water Level
EL	:	Elevation, meters
Fig.	:	Figure
m	:	meters
cm	:	centimeters

CURRENCY EQUIVALENTS:

Currency Unit = Naira (N) and Kobo (K)

US$ 1 = 0.566 N

N 1 = 100 K

N 1 = US$ 1.7686

CHAPTER 1: GENERAL

CHAPTER 1 GENERAL

1–1 Objectives of the Survey

The object of this survey was to clarify the environmental circumstances on the Eastern coast of Nigeria and to (study) the soil conditions in Opobo, Ibeno and James Town selected by Nigeria Port Authority for the New Ocean Terminal Project.

1–2 Procedure of Field Survey

Soil investigation (by boring) was consigned to Foundation Engineering (Nigeria) Limited with the recommendation of Nigeria Port Authority (NPA) and with the approval of Japan International Cooperation Agency (JICA), and was carried out under the engineering supervision of the survey team.

The boring machines were conveyed from Lagos to the boring sites. Two boring sites were selected in each of the three areas, a total of six. The boring depth was 39.6 - 40.5 meters, a total of 80 meters in each area. Three boring machines used were of the percussion type (Pilcon Wayfarer Co.), one was of the motor drive Type and the remaining two were of the manual Type.

Drilling was conducted by Percussion method 8-in guide pipes were installed to a depth of 18 - 21 meters and 6-in. pipes in places deeper than 18 meters to prevent the collapse of bore holes.

Sandy soil was collected and tested at every 2 meters depth for the standard penetration test at the boring sites.

Samples of cohesive soil were collected in thin wall samples, which were sealed with wax to prevent leakage and moisture loss.

Cohesive soil was sampled every 2 meters depth for the unconfined compression test.

All the samples were sent back to FEN laboratory in Lagos for analysis. The Soil Classification and the laboratory testing were carried out in accordance with B.S.1377: 1975, "Methods of Test for Soils for Civil Engineering Purposes."

1–3 Members of the Survey Team

The Team, headed by Engr. Y. Itoh, consisted of the following members.

Team Leader/ Chief Engineer	YOSHIKAZU ITOH	Senior Civil Engineer	Pacific Consultants International
Member	HIROFUMI KAWABATA	Senior Soil Engineer	Pacific Consultants International

1–4 Survey Team Schedule

1981 Date	Purpose	Destination/Activity
March 22, 23	Travel	Left Tokyo for Lagos via Copenhagen
March 24 (Tue)	Courtesty call and meeting	Paid courtesy call to Nigestrain Parts Authority (NPA) and Japanese Embassy (Ambassador and 1st Sec. Kobayashi)
March 25 (Wed)	Meeting Conference	Japanese Embassy and Foundation Engineering Co., Ltd. (FEN) NPA Head Office (Mr. Anah) and Mr. Osoba/Chief Engineers
March 26 (Thu)	Meeting	FEN to draw up contract.
March 27 (Fri)	Meeting	NPA Head Office with Mr. Anah
March 28 (Sat)	Travel	Left Lagos for Eket via Port Harcort
March 29 (Sun)	Meeting	With Kasco on site conditions, arranging data
March 30 (Mon)	Reconnaissance Trip	Ibeno area [NPA Staff visit to site (Mr. Anah-NPA)]
March 31 (Tue)	"	Visit to Calaba-city, (Cross River State) area and Collecting data on CRS and James Town
April 1 (Wed)	"	Ibeno Ocean area Reconnaissance by speed boat
April 2 (Thu)	"	James Town area reconnaissance by speed boat
April 3 (Fri)	Meeting	Internal Meeting with KASCO. FEN team arrived (Eket Town) with boring equipment

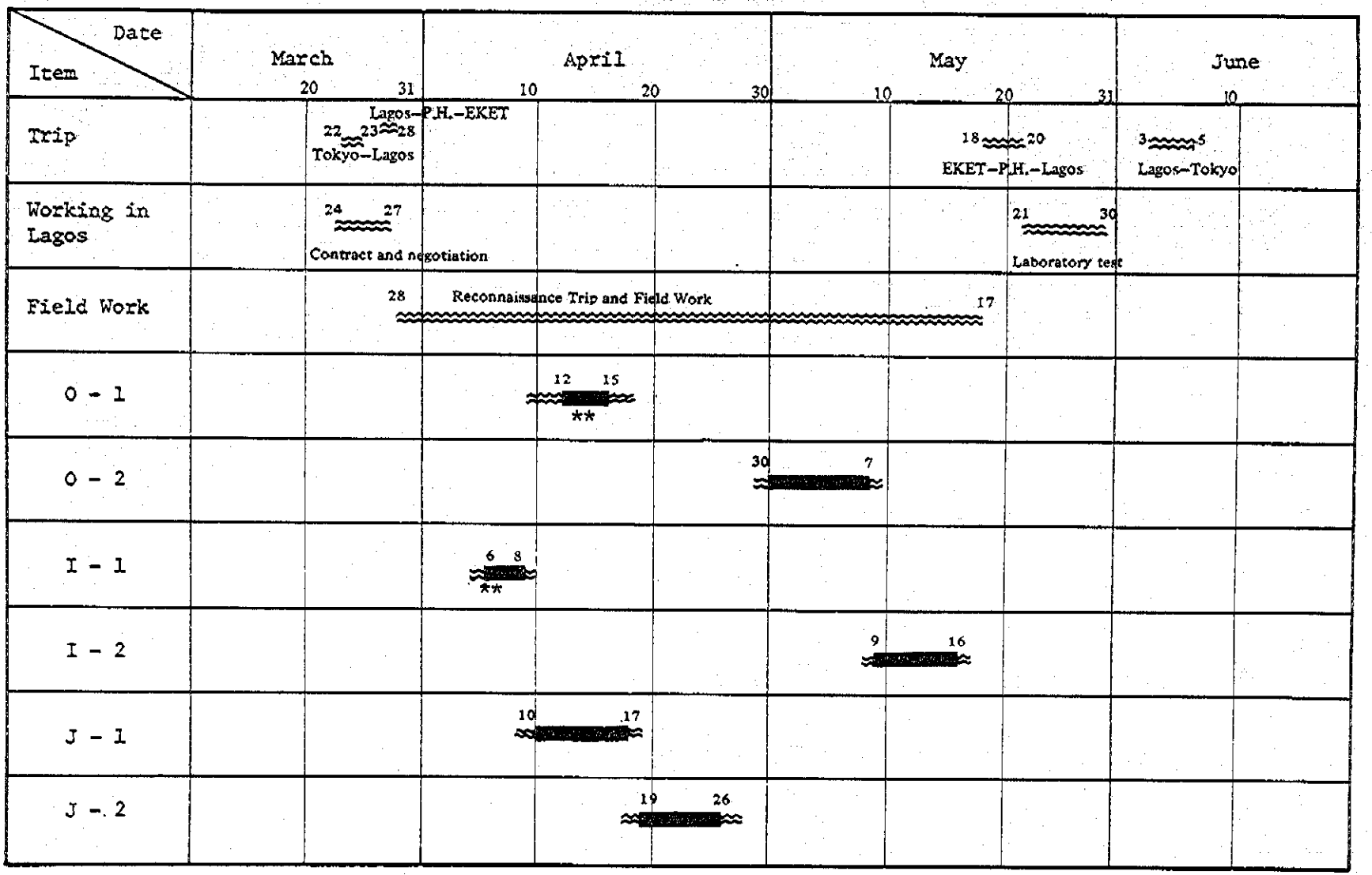
1981 Date	Purpose	Destination/Activity
April 4 (Sat)	Reconnaissance	James Town area (via ORON Town)
April 5 (Sun)	Field Work	Prepared for boring - set up equipment in Ibeno
April 6 (Mon)	"	Ibeno I-1 borehole - 12.0 m
April 7 (Tue)	"	B/H I-1 - 25.5 m
April 8 (Wed)	"	Inspection group divided into 2 groups continue work . B/H I-1 - 400 m completed, Casing removal begun
		. Boring equipment taken to James Town
April 9 (Thu)	"	. B/H I-1: casing removal completed
		. B/H J-1: boring equipment set up
April 10 (Fri)	Reconnaissance	. Opobo area
	Field Work	. B/H J-1: boring started - to 9.0 m
April 11 (Sat)	"	. B/H O-1 boring equipment installation completed
		. B/H J-1 - 18.0 m
April 12 (Sun)	"	B/H O-1 boring begun - 10.0 m B/H J-1 21.0 m progress on casing trip slow due to clayey layer
April 13 (Mon)	"	B/H O-1 - 27.9 m | Work on report for Tokyo
		B/H J-1 - 27.0 m
April 14 (Tue)	"	B/H O-1: 33.0 m
		B/H J-1: 30.0 m difficulties due to continuation of clayey layer
April 15 (Wed)	"	B/H O-1: completed at 40.0 m. Casing removal begun
		B/H J-1: 36.0 m
April 16 (Thu)	"	B/H O-1: casing removal completed
		B/H J-1: 39.0 m
April 17 (Fri)	"	B/H J-1: completed at 40.5 m. Ascertained the continuation of the clay layer instructed excavation to stop
		B/H J-2: one group started boring equipment removal begun in afternoon due to motor boat breakdown

1981 Date	Purpose	Destination/Activity
April 18 (Sat)	"	B/H J-1: casing removal completed. Arrange samples
		B/H J-2: equipment removal completed. Boring equipment set up.
April 19 (Sun)	"	B/H J-2: boring started to 12.0 m
April 20 (Mon)	"	B/H J-2: 18.0 m delayed by heavy rain in morning
April 21 (Tue)	"	B/H J-2: 24.0 m Progress slow because of hard clayey layer
April 22 (Wed)	Field Work	B/H J-2: 28.5 m
April 23 (Thu)	"	B/H J-2: Casing trip took time; boring continued in afternoon
April 24 (Fri)	"	B/H J-2: 32.0 m Rod screw twisted to the left - dropped off & recovered
April 25 (Sat)	"	B/H J-2: 38.5 m
April 26 (Sun)	"	B/H J-2: Completed at 39.6 m. Casing removal started - breakdown of jack & chain torque because of great resistance
April 27 (Man)	"	B/H J-2: boring tools brought in Casing removal completed
April 28 (Tue)	"	B/H J-2: boring equipment moved to base camp area
April 29 (Wed)	"	B/H O-2: transportation of boring equipment
April 30 (Thu)	"	B/H O-2: Transportation and installation completed. Start boring to 5.0 m
May 1 (Fri)	"	B/H O-2: 18.0 m Work interrupted by heavy rain Completed report for Tokyo
May 2 (Sat)	"	B/H O-2: 21.0 m delays because of heavy train
May 3 (Sun)	"	B/H O-2: 24.0 m
May 4 (Mon)	"	B/H O-2: 33.0 m

1981 Date	Purpose	Destination/Activity
May 5 (Tue)	"	B/H O-2: 36.0 m
May 6 (Wed)	"	B/H O-2: 38.5 m
May 7 (Tus)	"	B/H O-2: Completed at 40.0 m Casing removed
May 8 (Fri)	Transportation	B/H I-2: Transportation of boring equipment begun
May 9 (Sat)	Field Work	B/H I-2: Transportation & installment completed Boring begun to 7.0 m
May 10 (Sun)	Field Work	B/H I-2 to 15.0 m Metal object dropped in shaft and retrieved
May 11 (Mon)	"	B/H I-2 to 18.0 m Site inspection by Mr. Anah (NPA)
May 12 (Tue)	"	B/H I-2: 25.0 m Site inspection by Mr. Anah
May 13 (Wed)	"	B/H I-2: 33.0 m
May 14 (Thu)	"	B/H I-2: 35.5 m
May 15 (Fri)	"	B/H I-2: 38.25 m write report to Tokyo
May 16 (Sat)	"	B/H I-2: completed at 40.0 m Casing removal completed
May 17 (Sun)	Sample collection	Collecting, arranging borehole samples.
May 18 (Mon)	Travel	Sent samples to Lagos (FEN office) Moved to Port Harcourt
May 19 (Tue)		Courtesy call on the NPA Port Harcourt Branch Office.
May 20 (Wed)		data collection and moved to Lagos
May 21 (Thu)	Meeting and Laboratory tests	Report to Embassy (Nakamura, Counciler & Kobayashi 1st Secretary) and NPA on completion of site investigation
		Selected samples at FEN Office & began laboratory tests - examination by naked eye.
May 22 (Fri)	Laboratory tests	FEN's laboratory

1981 Date	Purpose	Destination/Activity
May 23 (Sat)	"	FEN Office. Meeting with Mr. Sheehy on report preparation
May 24 (Sun)		Arrangment of data
May 15 (Mon) May 26 (Tus)	Laboratory tests	FEN's Laboratory
May 27 (Wed)		Preparing unaccompanied baggage.
May 28 (Thu)	Data collection	Data collection
May 29 (Fri)	"	Finished laboratory tests.
May 30 (Sat)	Study meeting	Received report of laboratory tests study test results
May 31 (Sun)		Arrangement of data. Prepare report for Tokyo
June 1 (Mon)	Courtesy calls	Embassy: farewell greetings to Ambassador & Councilar & NPA
June 2 (Tue)		Arranging data and Final meeting at Embassy. (Preparators for homeward trip)
May 3 (Wed)	Travel	Lagos
May 4 (Thu)	Transit	Copenhagen
May 5 (Fri)	Travel	Arrival in Tokyo.

Fig. 1 WORK SCHEDULE



** : Motor type boring machine

No mark : Manual type boring machine

Drilling

Mobilization and Transportation

CHAPTER 2: GENERAL INFORMATION ON PROJECT AREA

CHAPTER 2 GENERAL INFORMATION ON PROJECT AREA

2-1 Project Area

The project area (lat. 4°40' - 4°27' N and long. 7°35' - 8°20' E) is located 500 km south east of Lagos City on the West Coast of Nigeria.

The three investigation areas were Opobo, Ibeno and James Town, extending over 80 km from east to west.

Based on the New Ocean Terminal Project boring was conducted at two sites in each area one on the coast and the other on a river several kilometers upcountry.

(1) Opobo Area

Opobo is located at 70 km southeast of Port Harcourt, at the mouth of the River Imo. The first boring point O-1 was situated behind a FED. Government Fisheries Office in Ebaghu, 2.5 km south of Egwanga, on a hill, 8 km north of the coast, 1.5 km upcountry along Jaja Creek from the Imo River. (Fig. 3)

O-2 was bored at the east coast end of Abazi, 11 km south of O-1.

(2) Ibeno Area

Ibeno is situated at the mouth of the River Qwa Ibo, 10 km south of the base camp Eket. I-1 was bored behind private a house 10 meters from Mobile wharf in Qwa Ibo Mission. I-2 was bored at a point 6.5 km northwest of I-1, on the coast, with a mangrove swamp to the north of it. (Fig. 4)

(3) James Town Area

James Town is situated at the mouth of the Cross River, 4 km north of Calabar.

J-1 was bored at a point 10 m north of the main street of James Town, located on a hill near the coast.

J-2 was bored at a point 9 km south of J-1, 5 km from a private house in the west end of Okposo, with a small swamp nearby. (Fig. 5)

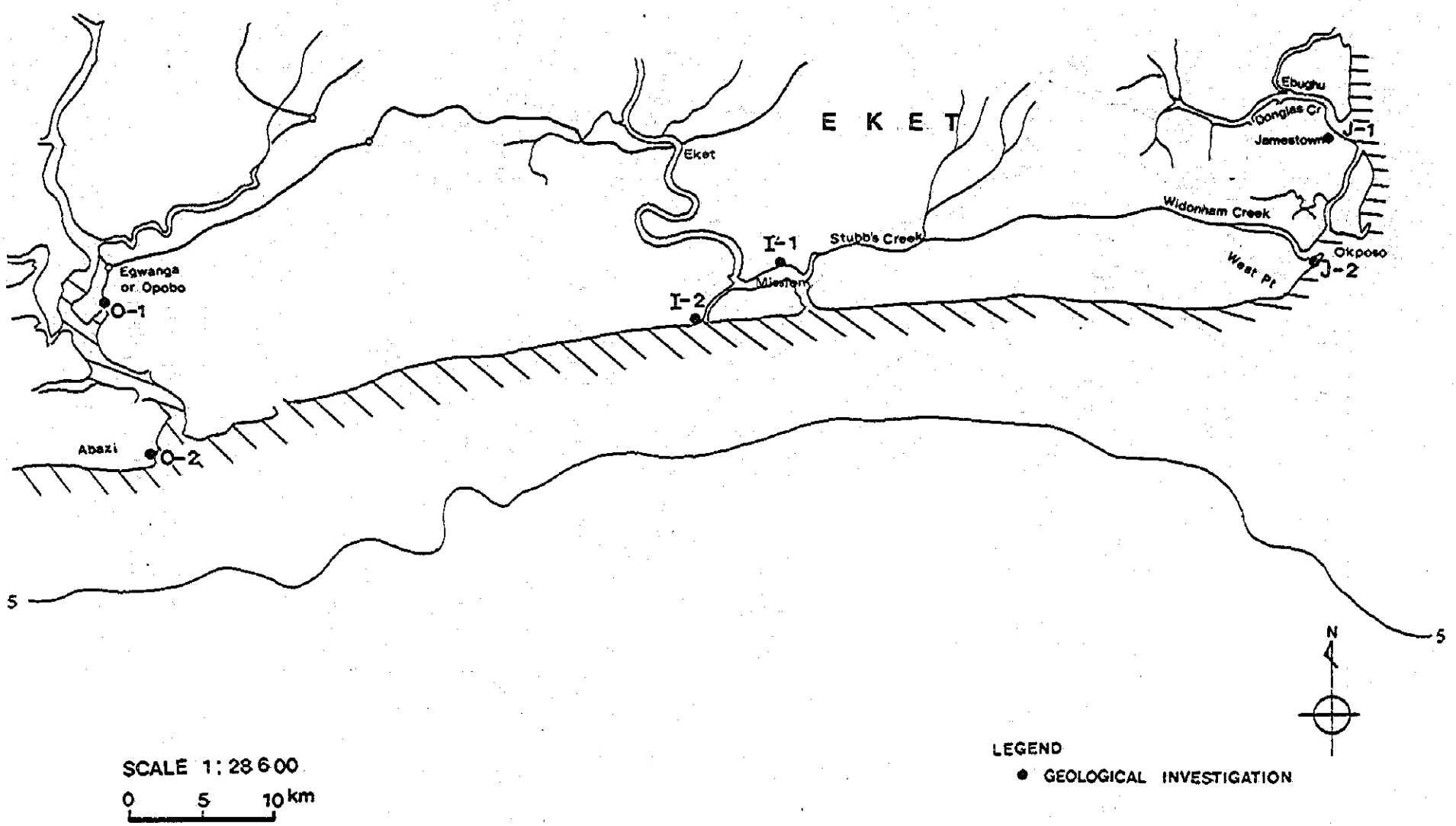
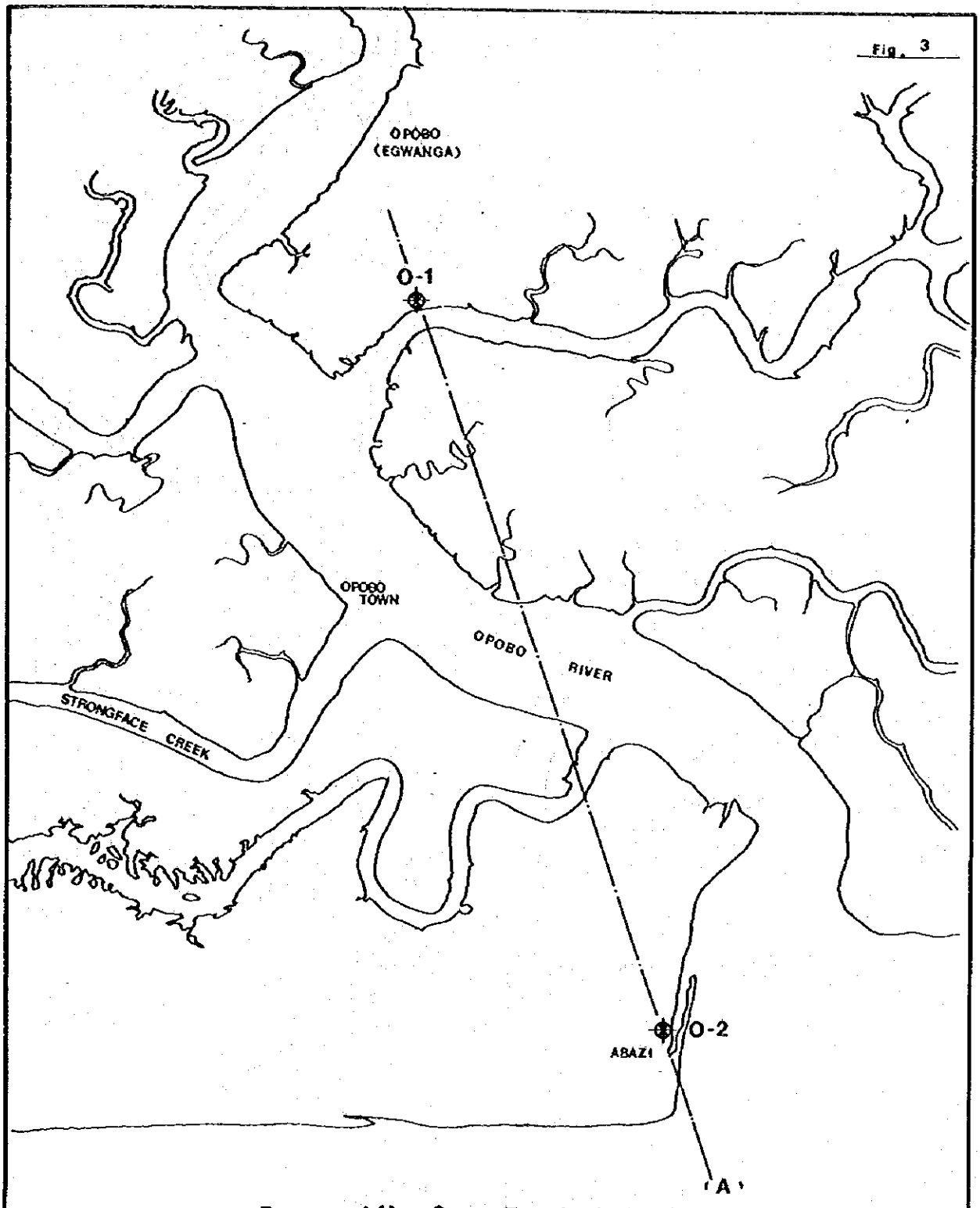


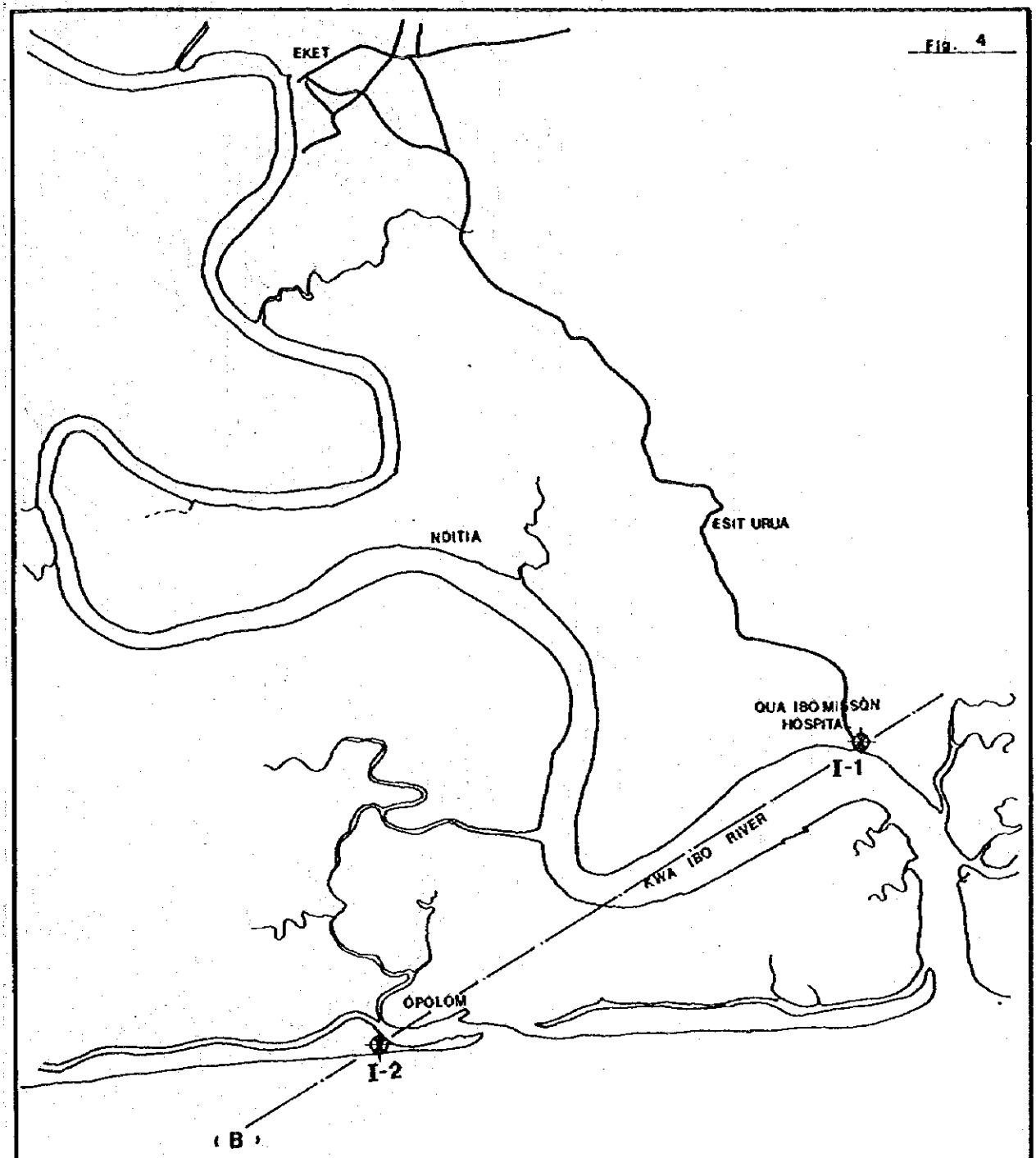
Fig. 2 Areas of the investigation of the natural conditions



Proposed New Ocean Terminal, Opobo
Geological Test Location

Scale 1 : 50,000

Borehole

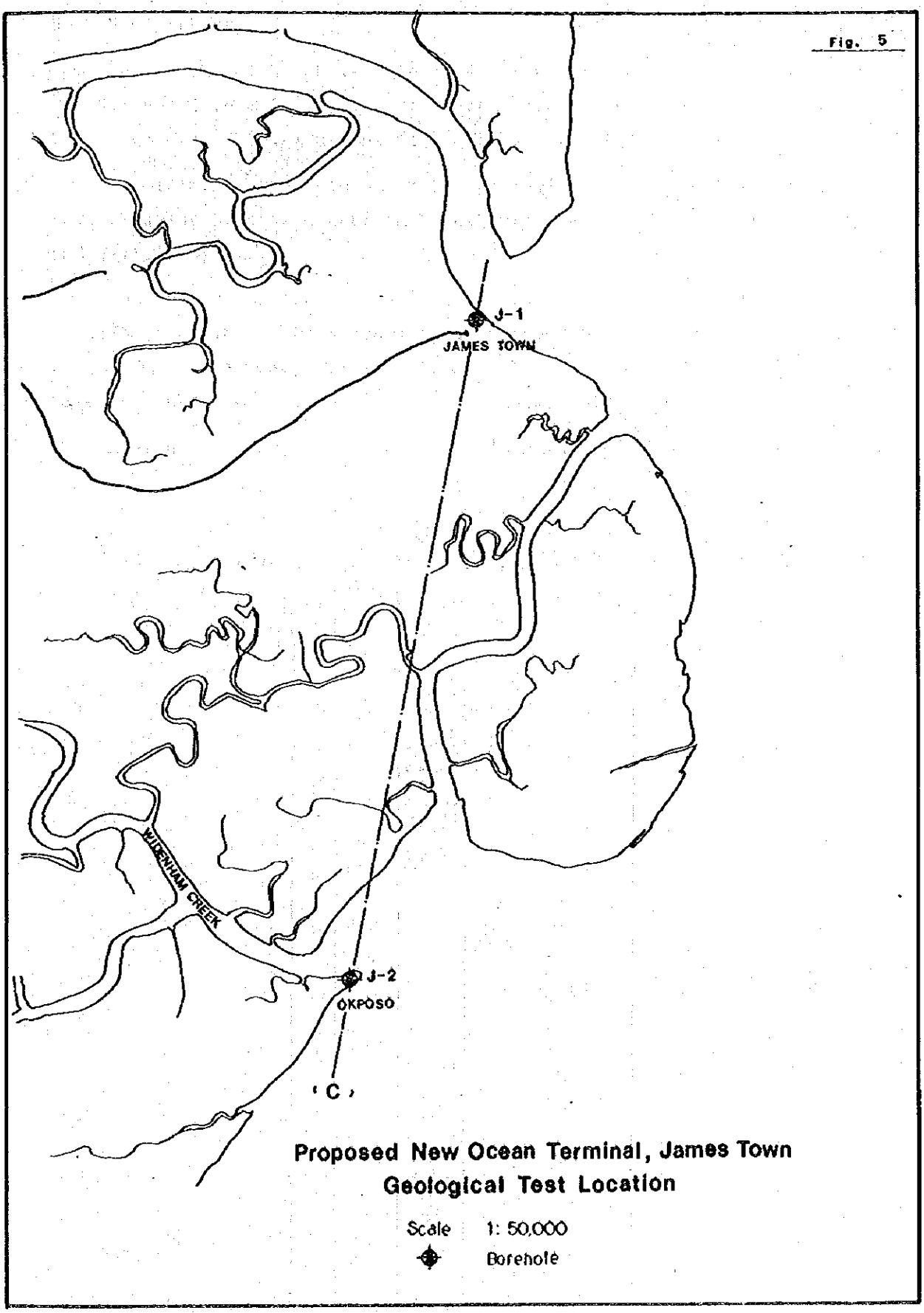


Proposed New Ocean Terminal, Ibeno
Geological Test Location

Scale 1: 50,000

Borehole

Fig. 5



Proposed New Ocean Terminal, James Town
Geological Test Location

Scale 1: 50,000

Borehole

2–2 Soil Conditions

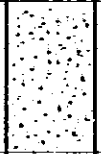
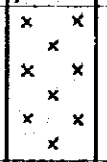
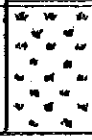
The depths of boreholes are 40.0 m for O-1, O-2, I-1 and I-2, 40.5 m for J-1 and 39.6 m for J-2. All depths referred to in this report are below the ground level at the time of the investigation.

According to the records of the geological survey of Nigeria the investigation area is underlain by alluvial deposits of littoral, lagoonal, and deltaic origin.

The results of the borings are in good agreement with the anticipated subsoil conditions. Detailed logs of the boreholes are given in Figures 7 to 15, while tentative subsoil profiles along the lines of the boreholes are shown on sketches given in Figures 3 to 5 .

A general summary of each of the investigated areas is given in next page.

Fig. 6 **SOIL CLASSIFICATION**

CLASS	TYPE	SYMBOL	GRAIN SIZE
COARSE GRAINED NON COHESIVE	BOULDERS		Larger than 200mm
	COBBLES		50 to 200mm
	GRAVEL		Coarse 20 - 60mm Medium 6 - 20mm Fine 2 - 6mm
	SAND		Coarse 0.6 - 2mm Medium 0.2-0.6mm Fine 0.06-0.2mm
FINE GRAINED COHESIVE	SILT		0.002 - 0.06mm
	CLAY		Finer than 0.002mm
ORGANIC	PEAT		Fibrous

2-2-1 Opobo Area

(1) Borehole O-1

From ground level to about 6 m depth	:	Very loose clayey silty sand.
From about 6 m to 11 m depth	:	Firm red brown sandy silty clay becoming clayey silty sand with cemented layers below 9 m depth.
From about 11 m to 18.5 m depth	:	Firm grey silty clay.
From about 18.5 m to 25 m depth	:	Dense grey clayey silty sand with a firm grey silty clay layer between 21.5 m and 22.8 m.
From about 25 m to 32 m depth	:	Medium dense to dense grey silty sand (m·f).
From about 32 m to 33.5 m depth	:	Firm to stiff grey silty clay.
From about 33.5 m to 40.0 m depth	:	Very stiff grey silty sand (m·f) with a very stiff grey sandy silty clay layer between 35.0 m and 38.4 m.

(2) Borehole O-2

From ground level to about 7 m depth	:	Loose grey silty sand with a peaty clay layer between 1.0 m and 1.5 m depth.
From about 7 m to 11 m depth	:	Firm grey very sandy silty clay partially sea shell.
From about 11 m to 28.5 m depth	:	Firm to stiff grey sandy silty clay with sand partings.
From about 28.5 m to 34 m depth	:	Medium dense to dense grey silty sand (c·m·f) with gravel (f).
From about 34 m to 35 m depth	:	Firm to stiff grey silty clay.
From about 35 m to termination of the borehole at 40 m depth	:	Very dense grey silty sand with gravel (f) below 39.0 m depth.

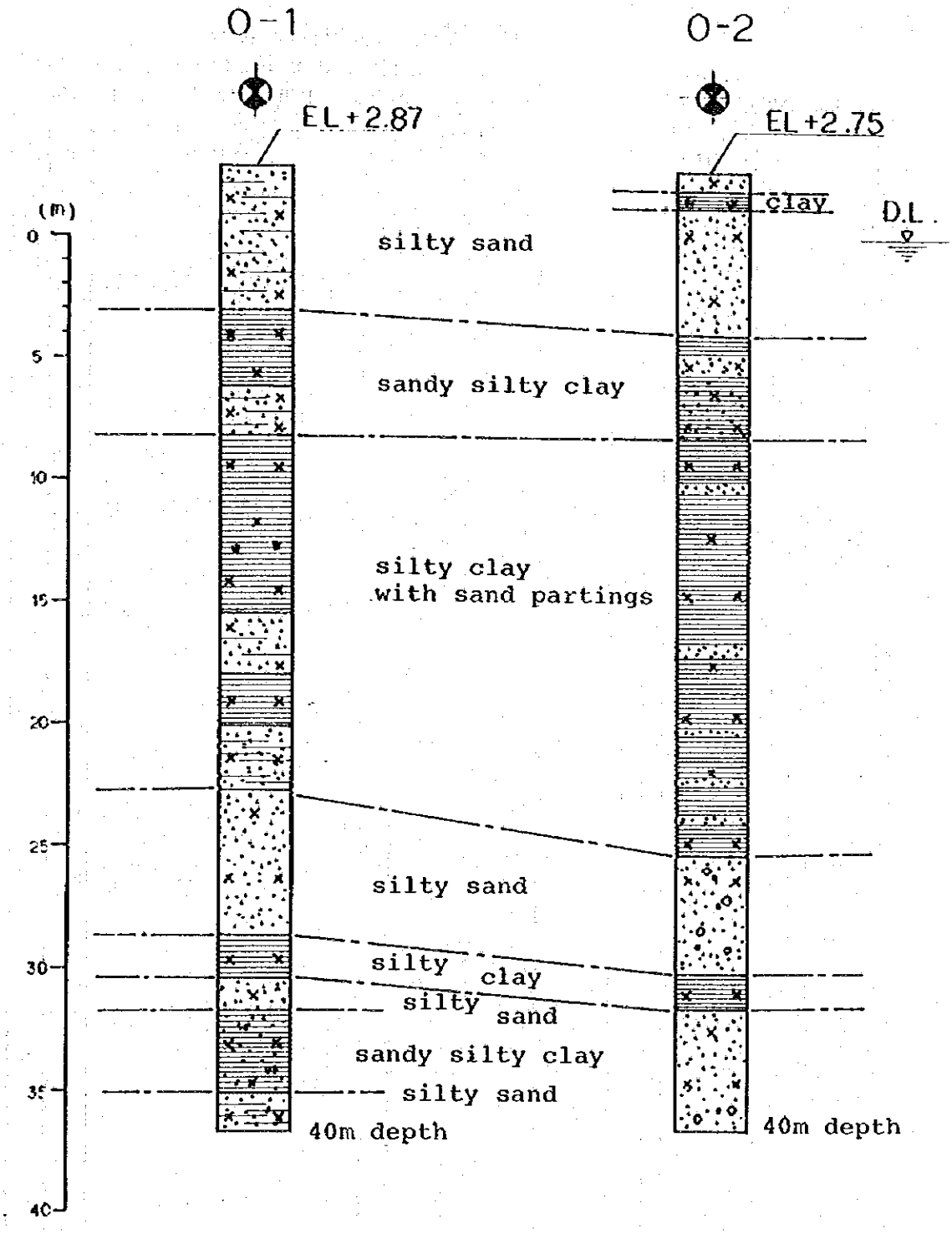


Fig. 7 PROPOSED NEW OCEAN TERMINAL, OPOBO SKETCH CROSS-SECTION 'A'

: Borehole

SCALE : Vertical = 1 : 250 approx
Horizontal = not to scale

NOTE : Broken Lines joining strata must be regarded as very tentative

Fig. 8

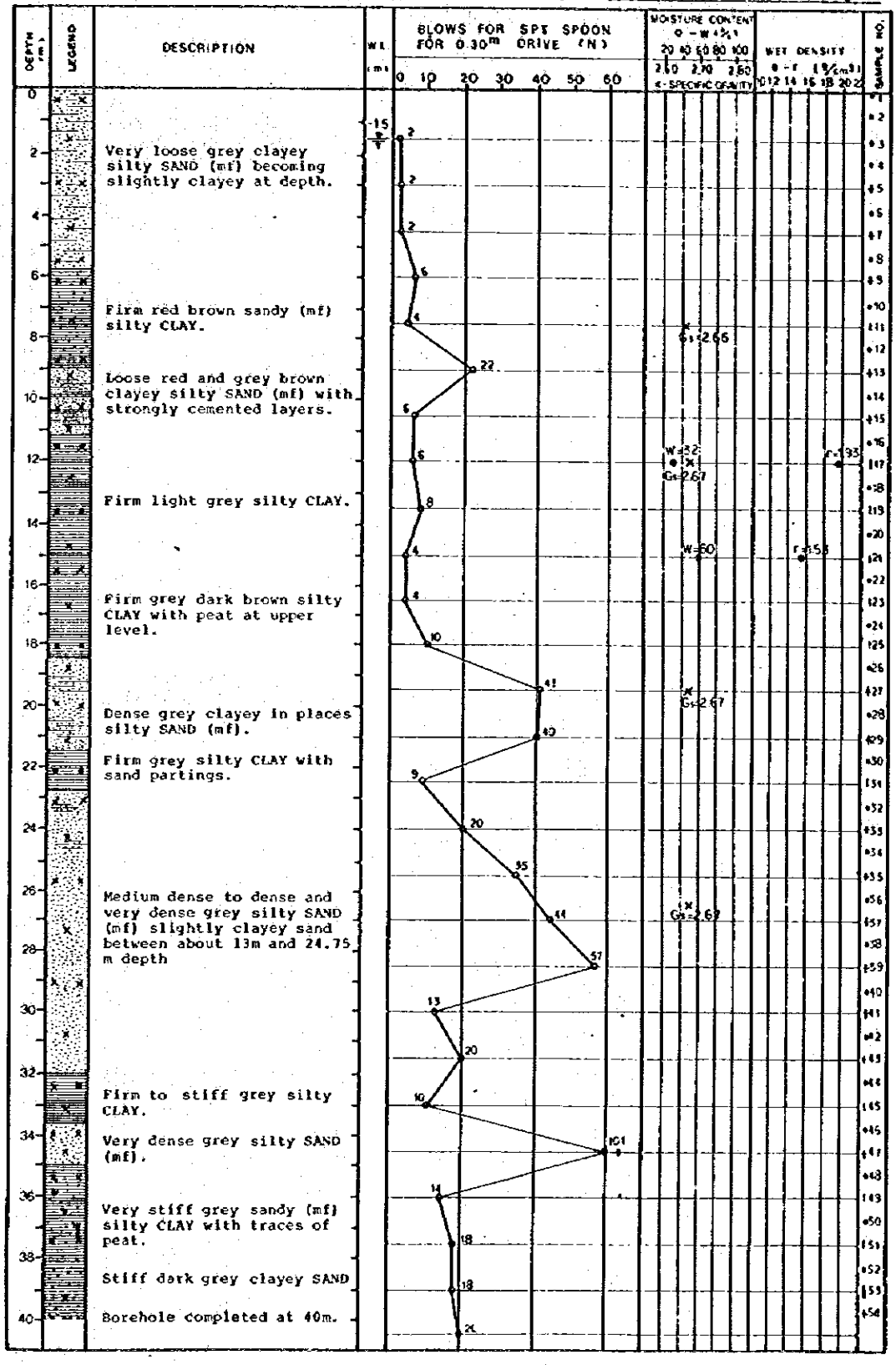
BOREHOLE LOG O-1

LOCATION : PROPOSED NEW OCEAN TERMINAL, OPOPO

GROUND LEVEL: EL. +2.87

BOREHOLE NO.: O-1 DATE: 12.4.91 - 15.4.91

BOREHOLE DIA: 0.20m & 0.15m



* DISTURBED BAG SAMPLES # UNDISTURBED 100 m/m DIAMETER SAMPLE

Fig. 9

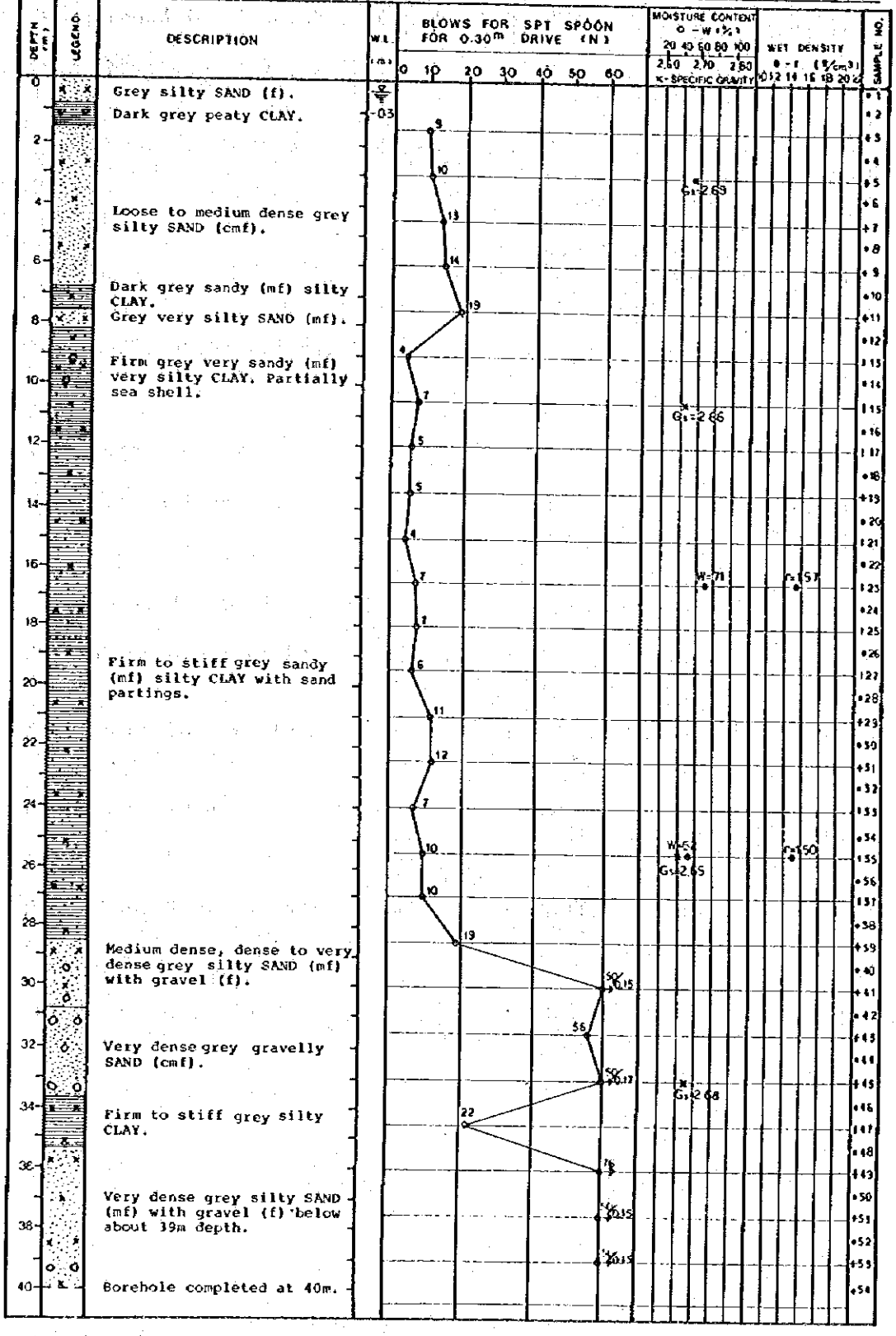
BOREHOLE LOG O-2

LOCATION : PROPOSED NEW OCEAN TERMINAL, OPOPO

GROUND LEVEL: EL. + 2.75

BOREHOLE NO.: O-2 DATE: 30.4.81 – 7.5.81

BOREHOLE DIA: 0.20m & 0.15m



* DISTURBED BAG SAMPLES § UNDISTURBED 100 m/m DIAMETER SAMPLE

2-2-2 Ibeno Area

(1) Borehole I-1

From ground level to about 6 m depth	:	Medium dense silty sand.
From about 6 m to 7.5 m depth	:	Soft to firm sandy (m·f) silty organic clay.
From about 7.5 m to 34.5 m depth	:	Generally medium dense to dense silty sand with occasional gravel. Clayey layers were encountered at about 15 m and 21 m depths and occasional loose and very dense layers were indicated.
From about 34.5 m to termination of the borehole at 40.0 m depth	:	Medium dense coarse sand with gravel (f).

(2) Borehole I-2

From ground level to about 7 m depth	:	Medium dense becoming very dense slightly silty sand (m·f).
From about 7 m to 8.5 m depth	:	Soft sandy (m·f) silty clay.
From about 8.5 m to 10 m depth	:	Medium dense silty sand with rock fragments.
From about 10 m to 13 m depth	:	Firm to stiff sandy silty clay.
From about 13 m to 32 m depth	:	Medium dense becoming dense silty sand with rock fragments in places.
From about 32 m to 35.5 m depth	:	Stiff to very stiff sandy silty clay.
From about 35.5 m to termination of the borehole at 40.0 m depth	:	Medium dense becoming dense silty sand and sandy gravel.

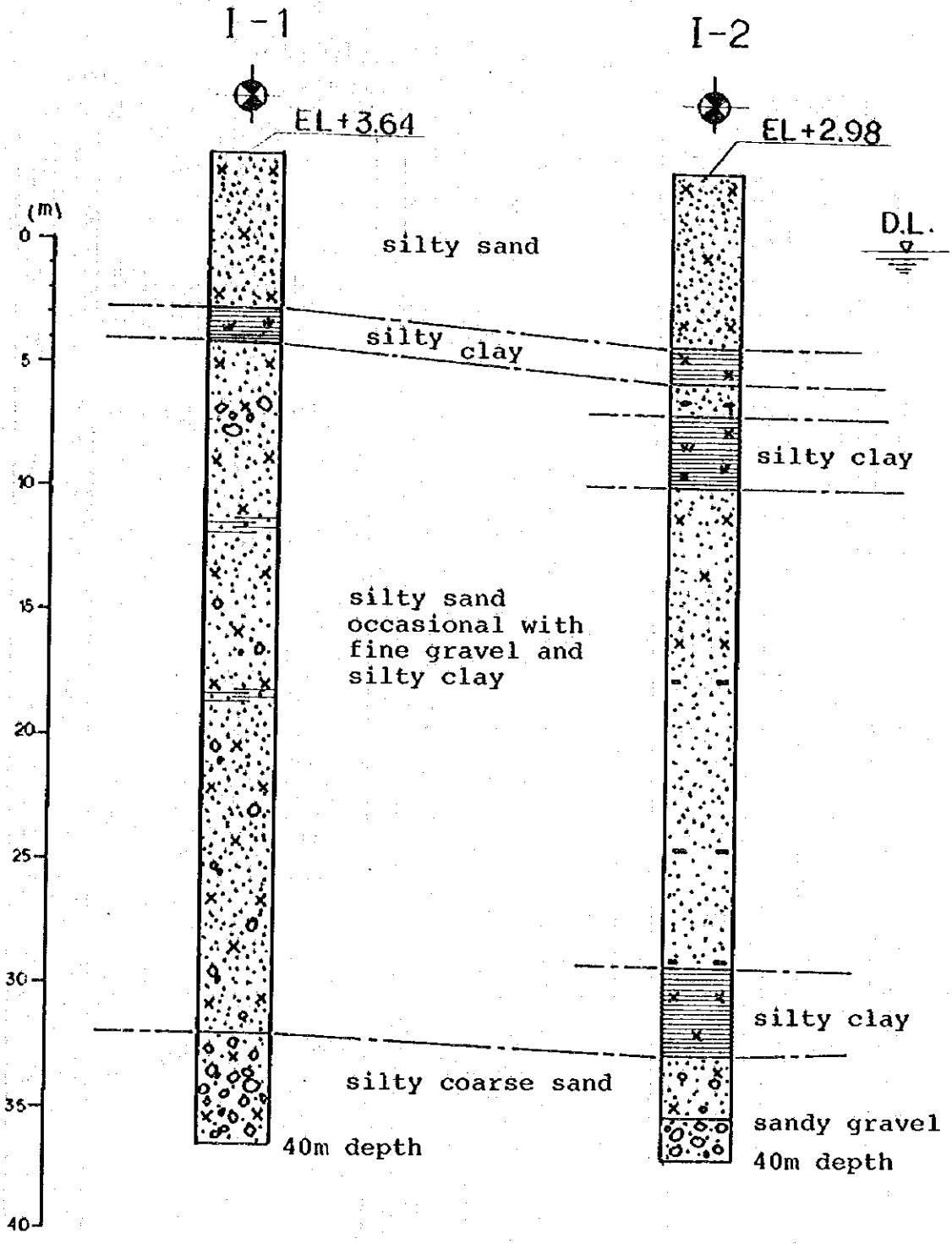


Fig. 10 PROPOSED NEW OCEAN TERMINAL, IBENO SKETCH CROSS-SECTION 'B'

: Borehole

SCALE : Vertical = 1: 250 approx
Horizontal = not to scale

NOTE : Broken Lines joining strata must be regarded as very tentative

BOREHOLE LOG I-1

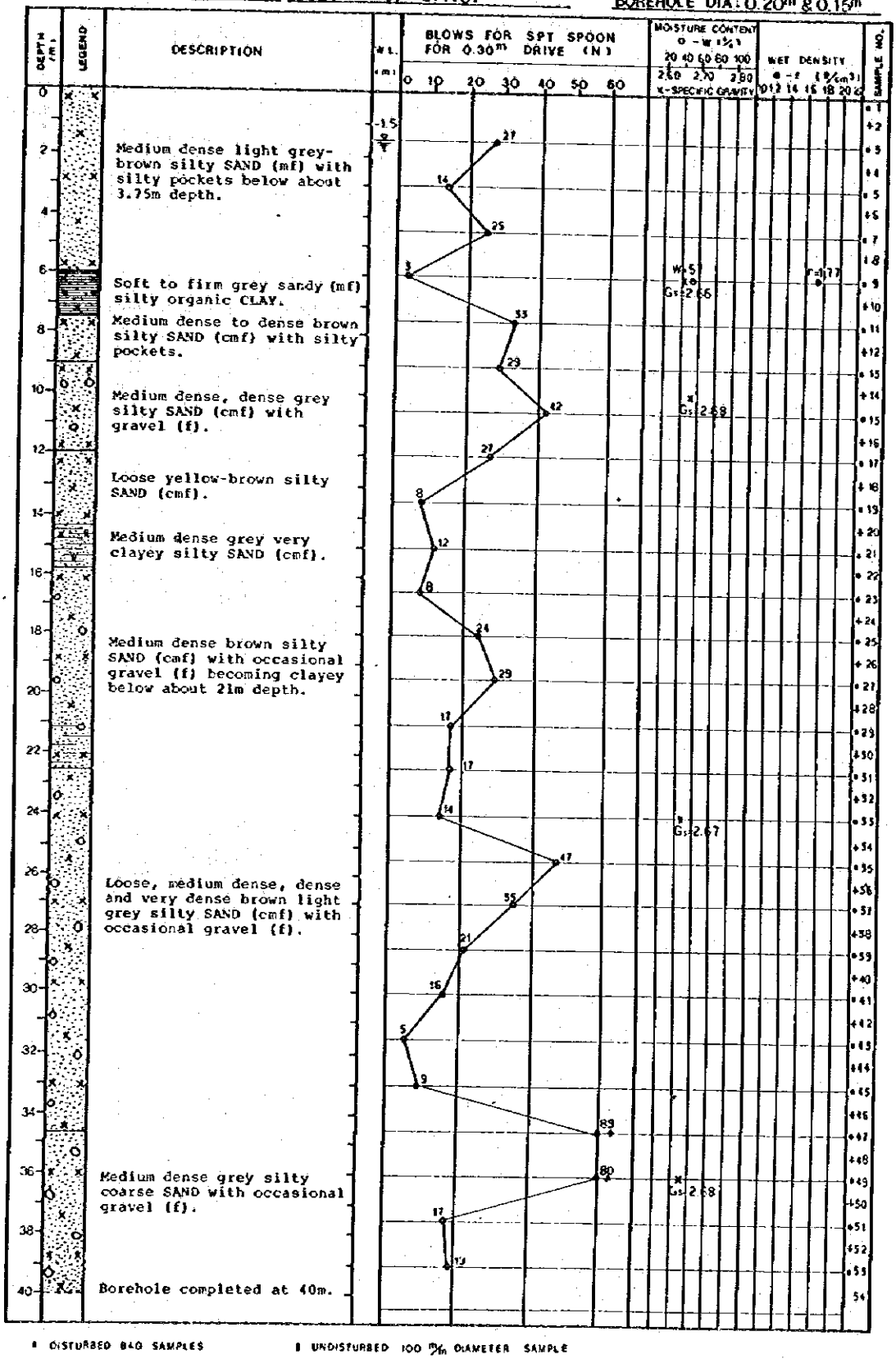
Fig. 11

LOCATION : PROPOSED NEW OCEAN TERMINAL, IBENO

GROUND LEVEL: F.L. 13.64

BOREHOLE NO.: I-1 DATE: 6.4.81 – 8.4.81

BOREHOLE DIA: 0.20m & 0.15m



* DISTURBED BAG SAMPLES

UNDISTURBED 100 m/m DIAMETER SAMPLE

BOREHOLE LOG 1-2

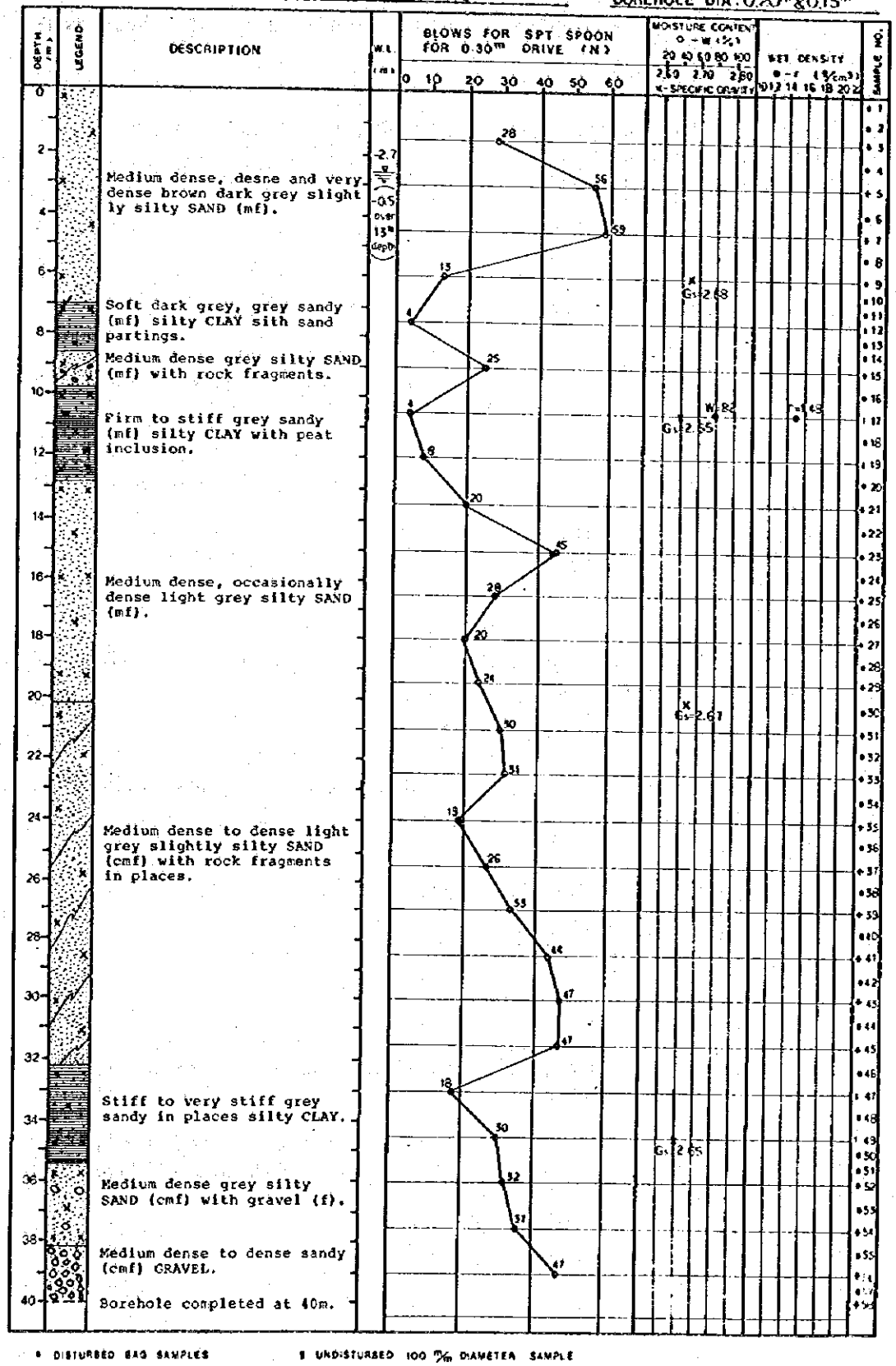
Fig. 12

LOCATION : PROPOSED NEW OCEAN TERMINAL, IBENO

GROUND LEVEL : EL. +2.98

BOREHOLE NO. : 1-2 DATE : 9.5.81 – 16.5.81

BOREHOLE DIA : 0.20m & 0.15m



* DISTURBED BAG SAMPLES § UNDISTURBED 100 m/m DIAMETER SAMPLE

2-2-3 James Town Area

(1) Borehole J-1

From ground level to about 6 m depth	:	Very loose becoming loose and medium dense sand with occasional gravel (f).
From about 6 m to 18 m depth	:	Interlayered firm to stiff sandy silty clay and medium dense clayey silty sand.
From about 18 m to 23 m depth	:	Medium dense and dense silty sand with weakly cemented layers and gravel. Strongly cemented ironstone at about 23 m depth.
From about 23 m to 30.5 m depth	:	Stiff and very stiff silty clay.
From about 30.5 m to termination of the borehole at 40.5 m depth	:	Stiff becoming very stiff sandy silty clay becoming silty clay below about 36 m depth.

(2) Borehole J-2

From ground level to about 7 m depth	:	Medium dense to dense silty sand with a soft peaty clay layer between 0.8 m and 3.0 m depth.
From about 7 m to 17.5 m depth	:	Interlayered soft to firm sandy silty clay and medium dense clayey silty sand.
From about 17.5 m to 23.5 m depth	:	Loose to medium dense grey clayey silty sand becoming dense silty sand below 20 m depth. Strongly cemented ironstone at about 23.5 m depth.
From about 23.5 m to 30.5 m depth	:	Firm to stiff becoming stiff silty clay.
From about 30.5 m to termination of the borehole at 39.6 m depth	:	Medium dense becoming very dense silty sand with gravel (f).

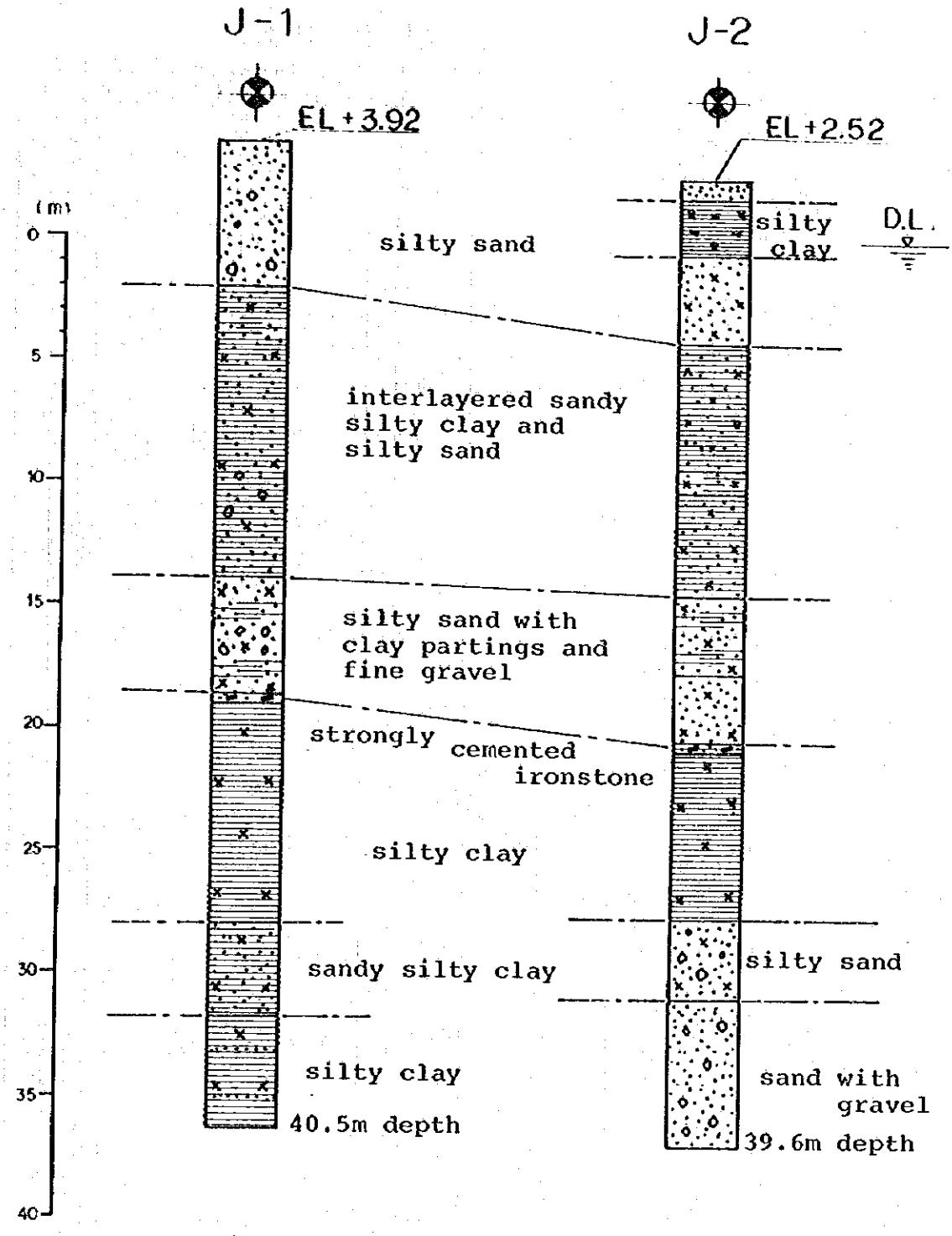


Fig. 13 PROPOSED NEW OCEAN TERMINAL JAMES TOWN SKETCH CROSS-SECTION 'C'

: Borehole

SCALE : Vertical = 1 : 250 approx
Horizontal = not to scale

NOTE : Broken Lines joining strata must be regarded as very tentative

BOREHOLE LOG J-1

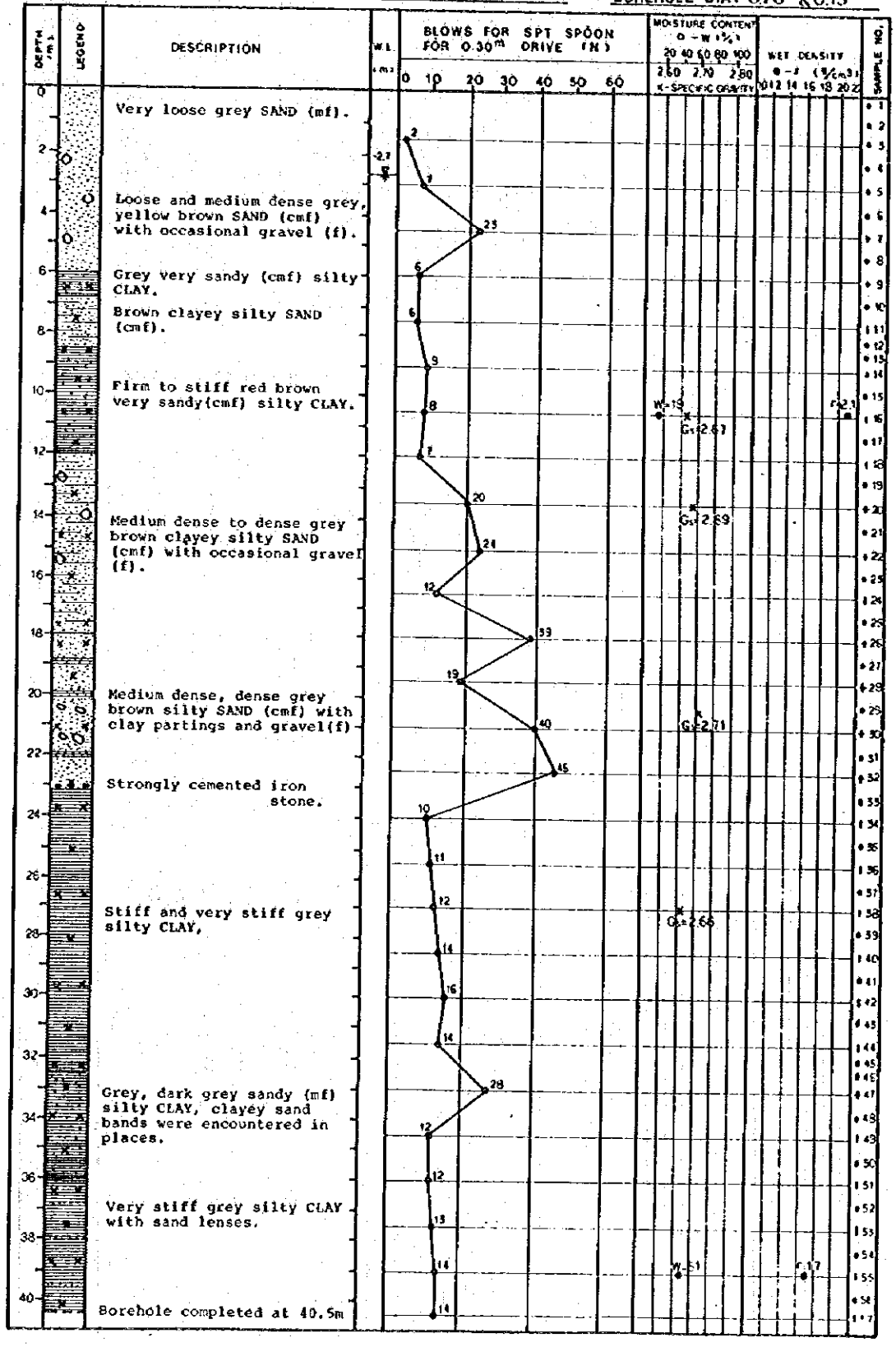
Fig. 14

LOCATION : PROPOSED NEW OCEAN TERMINAL, JAMES TOWN

GROUND LEVEL: FL. + 3.92

BOREHOLE NO.: J-1 DATE: 10.4.81 – 17.4.81

BOREHOLE DIA: 0.20m & 0.15m



D DISTURBED BAG SAMPLES U UNDISTURBED 100 m/m DIAMETER SAMPLE

Fig. 15

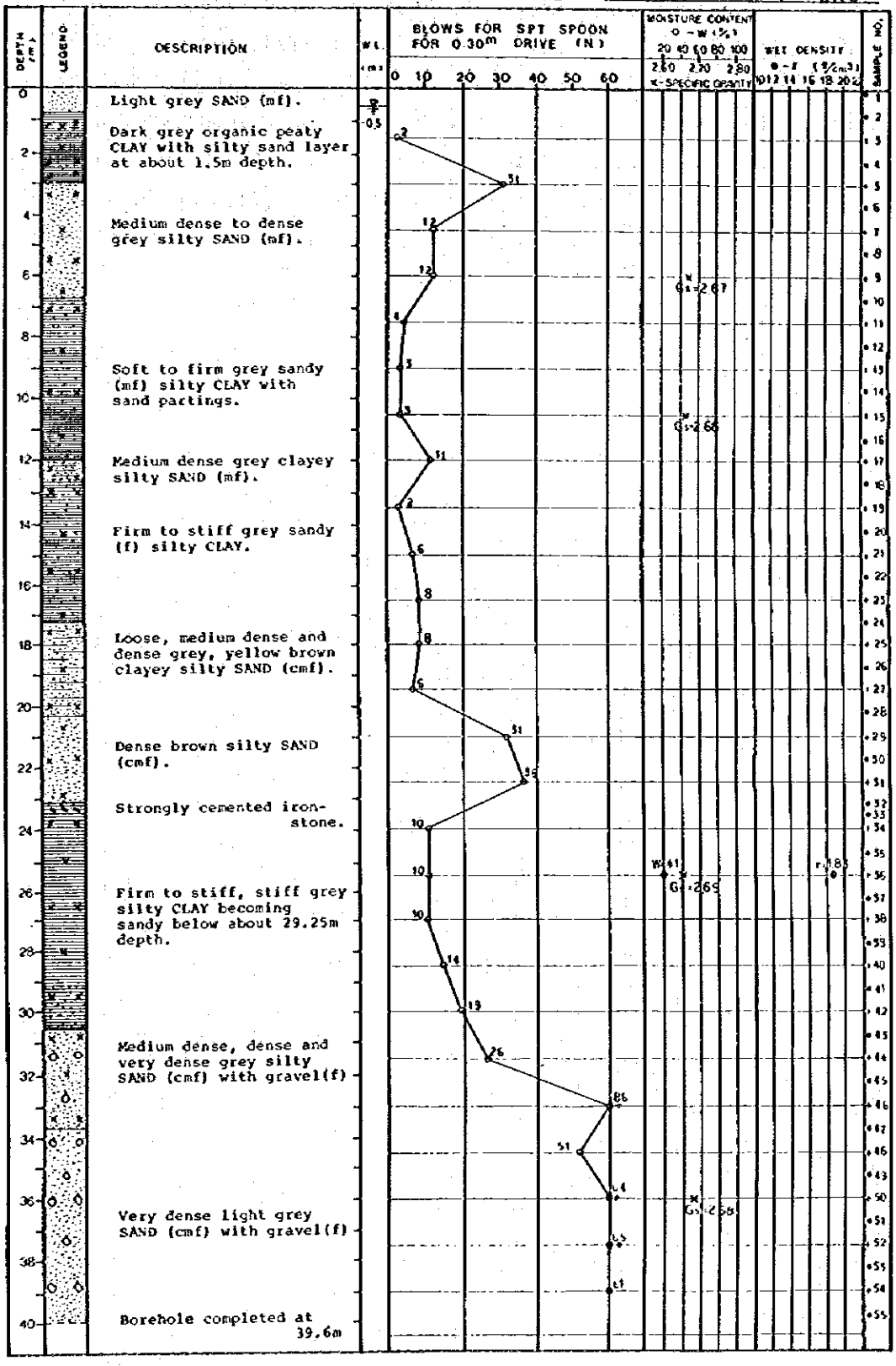
BOREHOLE LOG J-2

LOCATION : PROPOSED NEW OCEAN TERMINAL JAMES TOWN

GROUND LEVEL: EL +2.52

BOREHOLE NO.: J-2 DATE: 19.4.81 - 26.4.81.

BOREHOLE DIA: 0.20m & 0.15m



● DISTURBED BAG SAMPLES ▮ UNDISTURBED 100 m/m DIAMETER SAMPLE

2-2-4 Groundwater

At the time of the investigation, groundwater was generally encountered at about 1.5 m depth at the riverside boreholes (O-1 and I-1), about 2.7 m depth along the shoreline (I-2 and J-1), and about 0.5 m depth near swamps (O-2 and J-2). Investigation showed that the groundwater levels near swamps were about 2 meters higher than those along the shoreline. Seasonal and tidal variation in groundwater level should be anticipated with the ground possibly becoming saturated to the surface in places during or following periods of wet weather.

CHAPTER 3: CONSIDERATION AND CONCLUSION

CHAPTER 3 CONSIDERATION AND CONCLUSION

3–1 Consideration

Details of the development proposed for the site are not available and in view of the preliminary nature of the investigation, the following comments are given for general guidance only:

3-1-1 Embankment Planning

The upper sand deposits are generally of coarse to fine rather uniform grading and could be dredged out for use as fill material. However, care should be taken, especially near swamps and rivers (O-1, O-2 and J-2), to avoid using sand containing inclusions of peat and clay. It should be noted that where fill is placed over such highly compressible deposits there will be very marked settlement of the fill. Such settlement is likely to continue for sometime after placement of the fill. Great care should be taken during the filling operations to prevent shear failure of the compressible deposits.

Any structure bearing on the fill in swamp areas will, of course, settle with the fill, hence, filling should be carried out as far ahead of construction as possible. Stress increase on soft clay or peat deposits underlying fill due to structural loadings will also result in settlement.

3-1-2 Shallow Foundation

The results of the investigation suggest that light and reasonably flexible structures can be supported on reinforced concrete strip, and/or raft foundations set at about 1 metre depth in the upper sand deposits. Settlement of any form of shallow foundation in these deposits will depend on its width, loading intensity and the thickness and nature of any compressible stratum beneath the superficial sand.

The sand or sand-fill at the location of structures, roads etc. should be compacted with a heavy vibrating roller or plate before foundation construction.

After filling, the area should be left as long as possible before development and only used for light open storage or for very light, flexible sheds. Where more permanent or heavier structures are required,

the thinner areas of soft compressible swampy deposits under the area of each structure could be removed and replaced with sand fill.

3-1-3 Pile Foundation

Loading and settlement of any shallow foundation will be influenced by the properties of the underlying peat or clay deposits. Hence, where there are concentrated loads or where total settlements have to be minimized, piles may be used.

The N-value Test (SPT) results indicate that piles founded in the compact sand will be capable of carrying high working loads. Allowance should be made in the pile design for negative skin friction (down drag) caused by the consolidation of compressible deposits underlying filled areas.

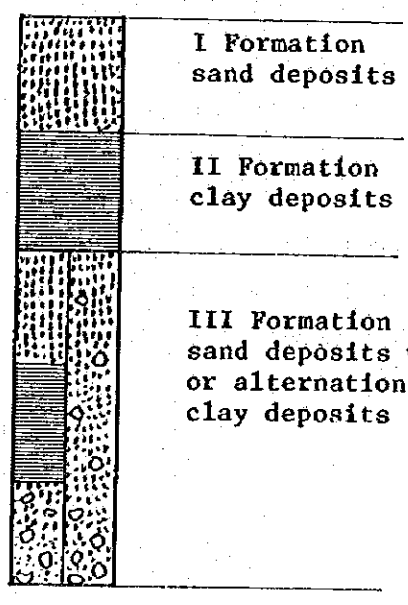
3-2 Conclusion

The investigation area is overlain by alluvium mainly composed of clay, silty sand, and coarse sand with fine gravel.

It should be noted that the borehole locations were extremely widely spaced and that lateral continuity of strata between borings is not clearly indicated, but generally the pattern of the sediments is indicated in Fig. 16.

Fig. 16 PATTERN OF FORMATION

That is, sand deposits predominated from ground level to about 6 metres depth. (I Formation).



Underlaying the sand, clay deposits of 2 to about 20 metres thickness occured, with a few bands of sand. Laboratory tests indicate this II formation to be of low plasticity.

The clay deposits are underlain by compact becoming very compact sand deposits with fine gravel (Ibeno Area), or alternation of sand and clay deposits (Opobo and James Town Area). Groundwater was generally encountered at 0.5 to 2.7 metres depth during drilling.

(1) The superficial sand deposits might be suitable for economic stabilization with cement or concrete production. However, detailed laboratory tests should be made to select good mix proportions.

(2) The presence of substantial deposits of compact sand at depth will allow piles of high load carrying capacity.

(3) The superficial sand deposits may be dredged out and used as general fill. Care should be taken to avoid contaminating the fill with peat or clay.

(4) For light and reasonably flexible structure, shallow foundations comprising reinforced concrete pad, strip or raft foundations may be used in the investigation area.

(5) The probable existence of superficial soft, highly compressible peat and clay deposits, perhaps of substantial thickness, in the swampy areas will cause marked settlement of fill and necessitate foundating all important structures on piles.

(6) Because of the relatively great distances between the boreholes, comments and recommendations given in this report are essentially of a very general nature. As soon as structure locations are known, a more detailed investigation is essential in order to allow more accurate estimates of soil bearing capacity and settlement. In any subsequent investigation, special attention must be paid to the swampy areas in order to formulate satisfactory foundation solutions since it is suspected that substantial deposits of soft highly compressible peats and clays occur in these areas.

APPENDIX

1. Results of Laboratory Tests
2. Particle Size Distribution
3. Photos of Site Works
4. Photos of Soil Samples
5. Copy of Agreement

1. Results of Laboratory Tests

PROPOSED NEW OCEAN TERMINAL EASTERN COAST
(OBOBO, IBENO AND JAMESTOWN)

SUMMARY OF LABORATORY TEST RESULTS

1. PARTICLE SIZE DISTRIBUTION - By Wet Sieve and Hydrometer

Borehole & Sample No.	Percentage Passing – By dry Weight				
	Depth (metres)	2.00 mm Sieve	425 Micron Sieve	63 Micron Sieve	2 Micron from Hydrometer Analysis
O – 1/22	0.75	100	94	20	–
O – 1/21	15.00	100	94	58	23
O – 1/36	26.25	100	83	28	–
O – 2/5	3.00	100	98	6	–
O – 2/35	25.50	100	98	42	18
O – 2/43	31.50	63	13	5	–
I – 1/3	2.25	100	99	8	–
I – 1/8	6.00	100	99	15	5
I – 1, 13	9.75	100	54	7	–
I – 1/48	36.00	90	29	8	–
I – 2/17	10.50	100	100	89	45
I – 2/30	20.25	100	87	32	–
I – 2/56	39.00	39	12	2	–
J – 1/4	2.25	91	42	5	–
J – 1/16	10.50	100	71	23	12
J – 1/29	20.25	71	18	5	–
J – 2/7	4.50	100	100	4	–
J – 2/36	25.50	100	100	96	39
J – 2/50	36.00	100	46	7	–

Note: The grading curves are shown on Particle Size Distribution.

2. NATURAL MOISTURE CONTENT DETERMINATION

Borehole & Sample No.	Depth (Metres)	Natural Moisture Content (% dry weight)
O – 1/17	12.00	73
O – 1/21	15.00	55
O – 2/23	16.50	72
O – 2/35	25.50	45
I – 1/8	6.00	48
I – 2/17	10.50	75
I – 2/49	34.50	60
J – 1/16	10.50	21
J – 1/55	39.00	56
J – 2/13	9.00	72
J – 2/36	25.50	40

3. SPECIFIC GRAVITY DETERMINATION

Borehole and Sample No.	Depth (metres)	Specific Gravity
O-1/11	7.50	2.66
O-1/17	12.00	2.67
O-1/27	19.50	2.67
O-1/36	26.25	2.67
O-2/5	3.00	2.69
O-2/15	10.50	2.66
O-2/35	25.50	2.65
O-2/45	33.00	2.68
I-1/8	6.00	2.66
I-1/13	9.75	2.68
I-1/32	24.00	2.67
I-1/48	36.00	2.68
I-2/9	6.00	2.68
I-2/17	10.50	2.65
I-2/30	20.25	2.67
I-2/49	34.50	2.65
J-1/16	10.50	2.67
J-1/20	13.50	2.69
J-1/29	20.25	2.71
J-1/38	27.00	2.66
J-2/9	6.00	2.67
J-2/15	10.50	2.66
J-2/36	25.50	2.65
J-2/50	36.00	2.68

Note: The test was carried out on material finer than 4.75 mm in accordance with B.S. 1375 : 1975.

4. QUICK UNDRAINED TRIAXIAL COMPRESSION TEST

Borehole & Sample No.	Depth (metres)	Natural Moisture Content (% dry wt.)	Wet Density (Mg/m^3)	Undrained Cohesion (Cu) (kN/m^2)	Angle of Friction (ϕu) (degrees)
I-2/12	7.50	33	1.85	17	0

Note: To determine the Cohesion (Cu) and Angle of Friction (ϕu), three 35 mm diameter by 70 mm high specimens were prepared from the 105 mm diameter undisturbed site sample. The specimens were then tested in undrained compression using cell pressures of 50, 100 and 150 kN/m^2.

5. UNCONFINED COMPRESSION TEST

Borehole & Sample No.	Depth (metres)	Natural Moisture (% dry wt.)	Wet Density (Mg/m^3)	Compressive Strength (kN/m^2)
O-1/17	12.00	32	1.93	53
O-1/21	15.00	60	1.53	33
O-2/23	16.50	71	1.57	75
O-2/35	25.50	52	1.59	57
I 1/8	6.00	57	1.77	28
I-2/17	10.50	82	1.48	37
I-2/49	34.50	63	1.64	231
J-1/16	10.50	19	2.10	79
J-1/55	39.00	51	1.70	55
J-2/36	25.50	41	1.83	50

Note: For this test, a 102 mm diameter by 203 mm high specimen was prepared from the 105 mm diameter undisturbed site sample and tested in unconfined compression.

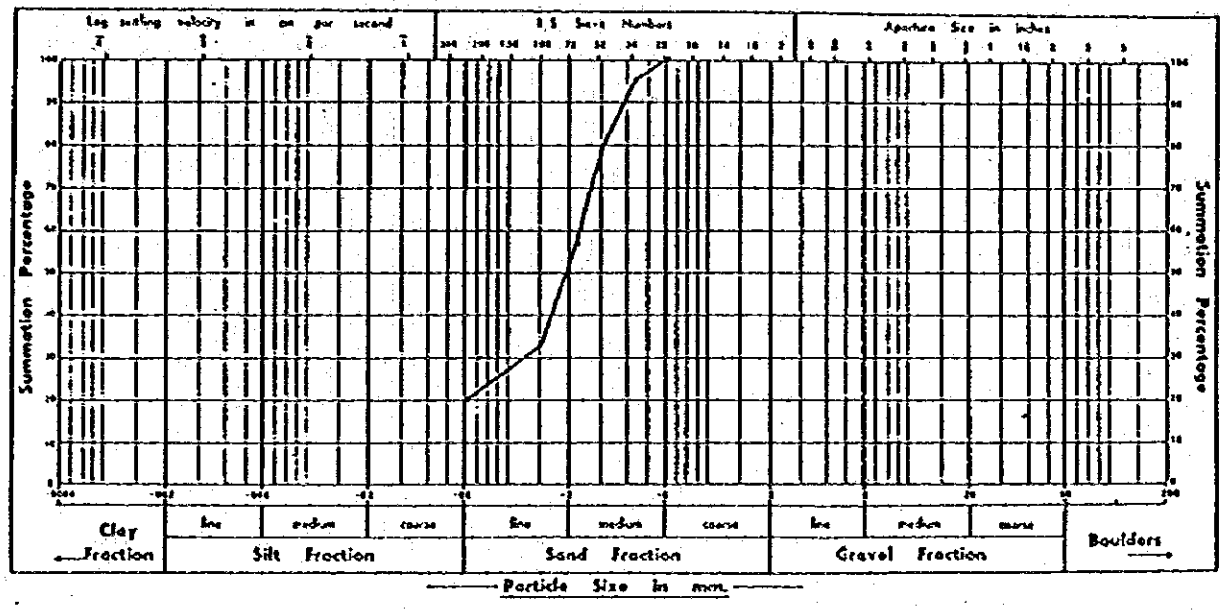
However, for sample O-1/17, a 35 mm diameter by 70 mm high specimen was used owing to shortage of material.

2. Particle Size Distribution

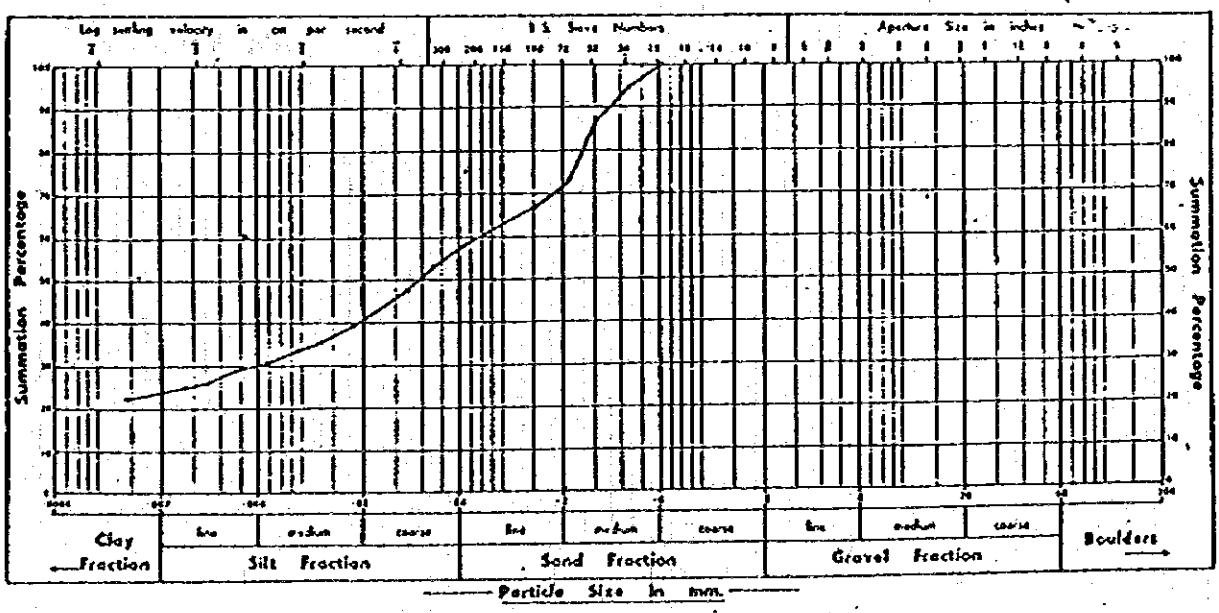
PARTICLE SIZE DISTRIBUTION

LOCATION. PROPOSED NEW OCEAN TERMINAL OPOBO. **DATE OF TEST.** MAY 1981

SAMPLE No. 0 - 1/2 **. DEPTH.** 0·75 m



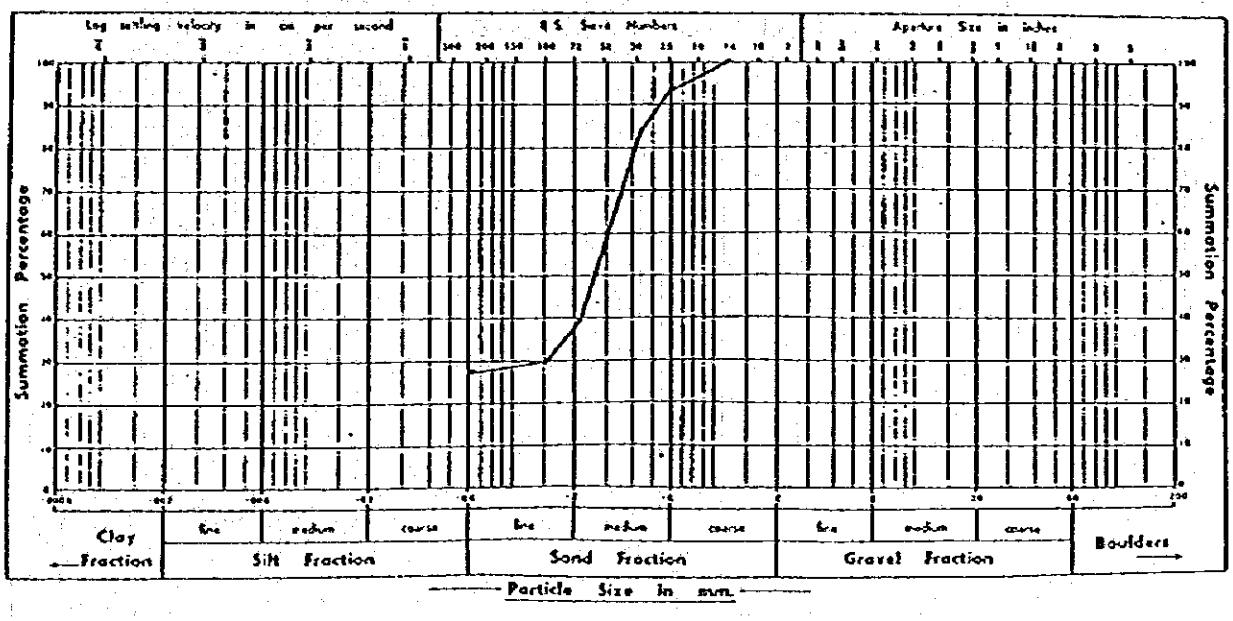
SAMPLE No. 0 - 1/21 **DEPTH.** 15·00 m



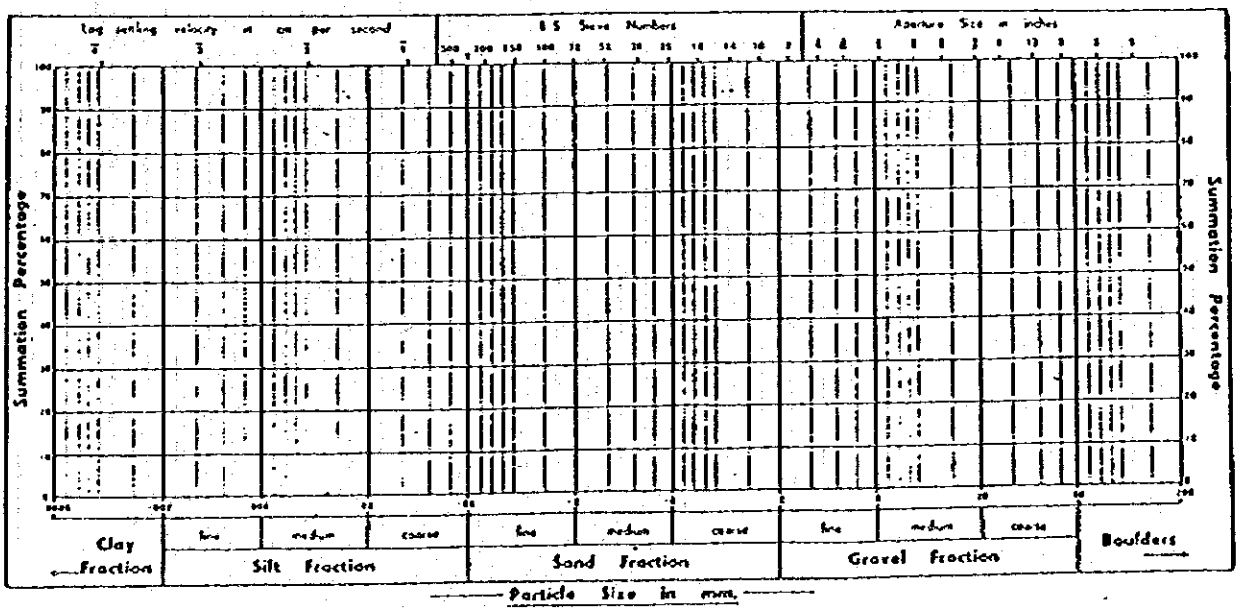
PARTICLE SIZE DISTRIBUTION

LOCATION. PROPOSED NEW OCEAN TERMINAL OPOBO. **DATE OF TEST.** MAY 1981

SAMPLE No. 0-1/36 **DEPTH.** 26·25 m



SAMPLE No. **DEPTH.**

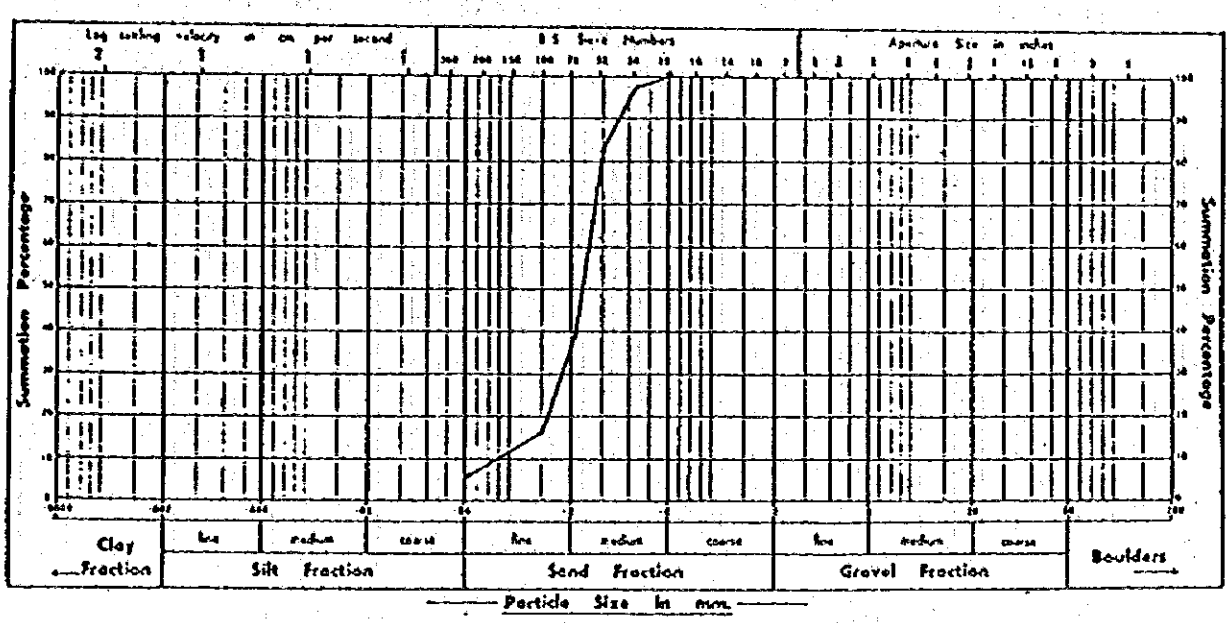


FOUNDATION ENGINEERING (NIGERIA) LTD. FIG.....

PARTICLE SIZE DISTRIBUTION

LOCATION. PROPOSED NEW OCEAN TERMINAL OPOBO. DATE OF TEST. MAY 1981

SAMPLE No. 0 - 2/5 DEPTH. 3·00 m



SAMPLE No. 0 - 2/35 DEPTH. 25·50 m

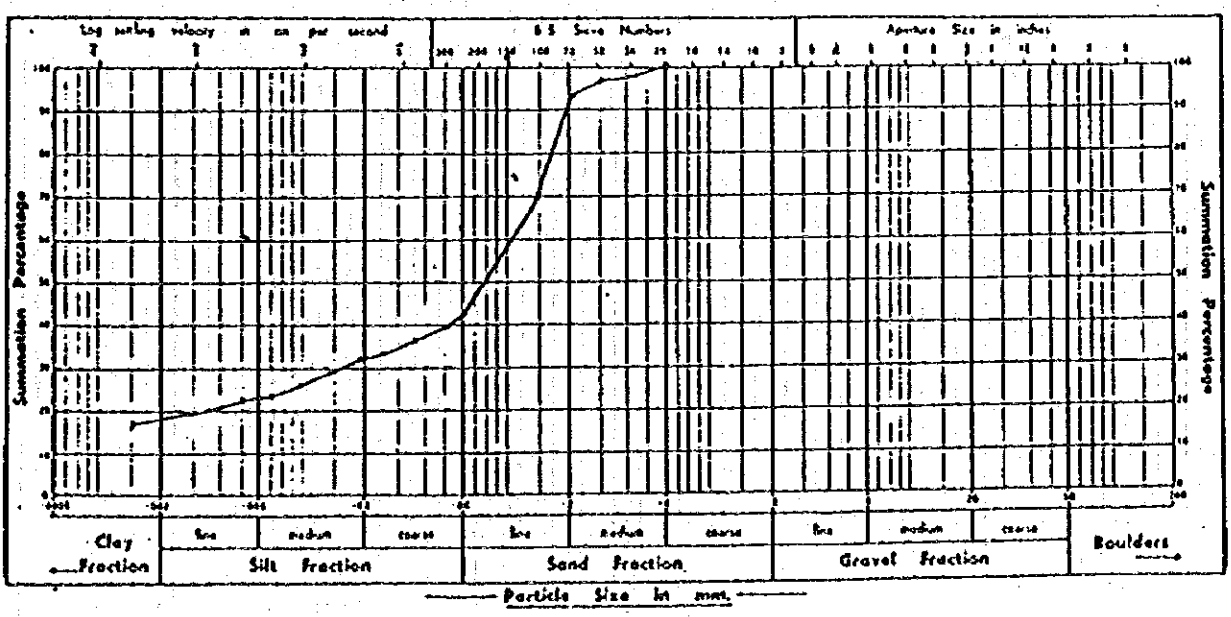


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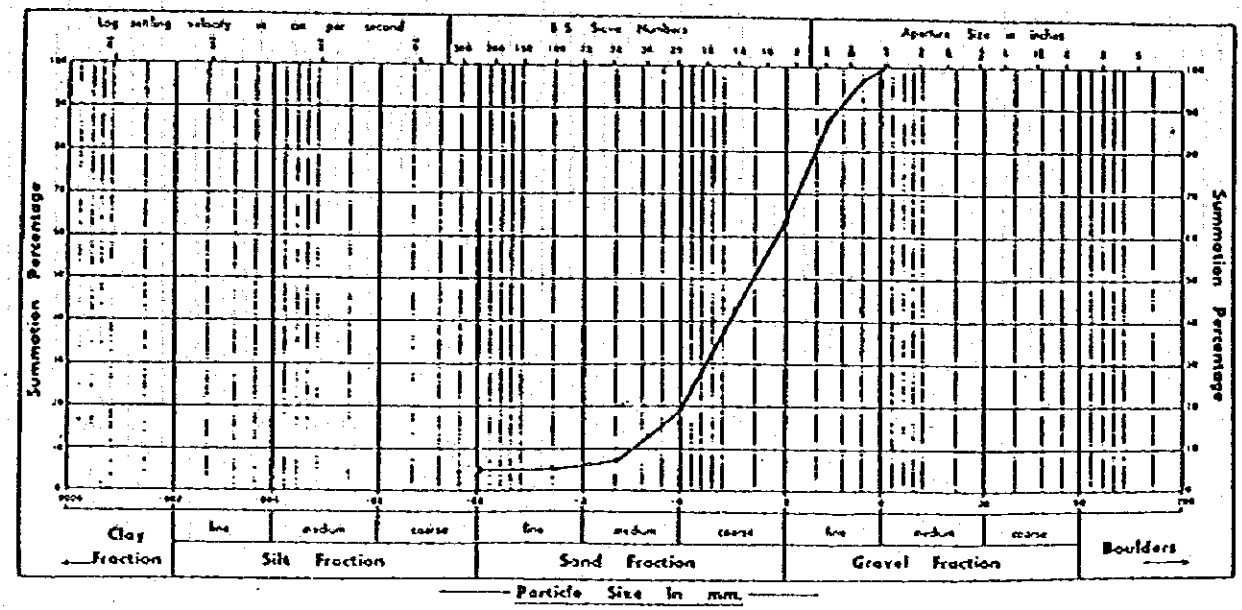
FIG.....

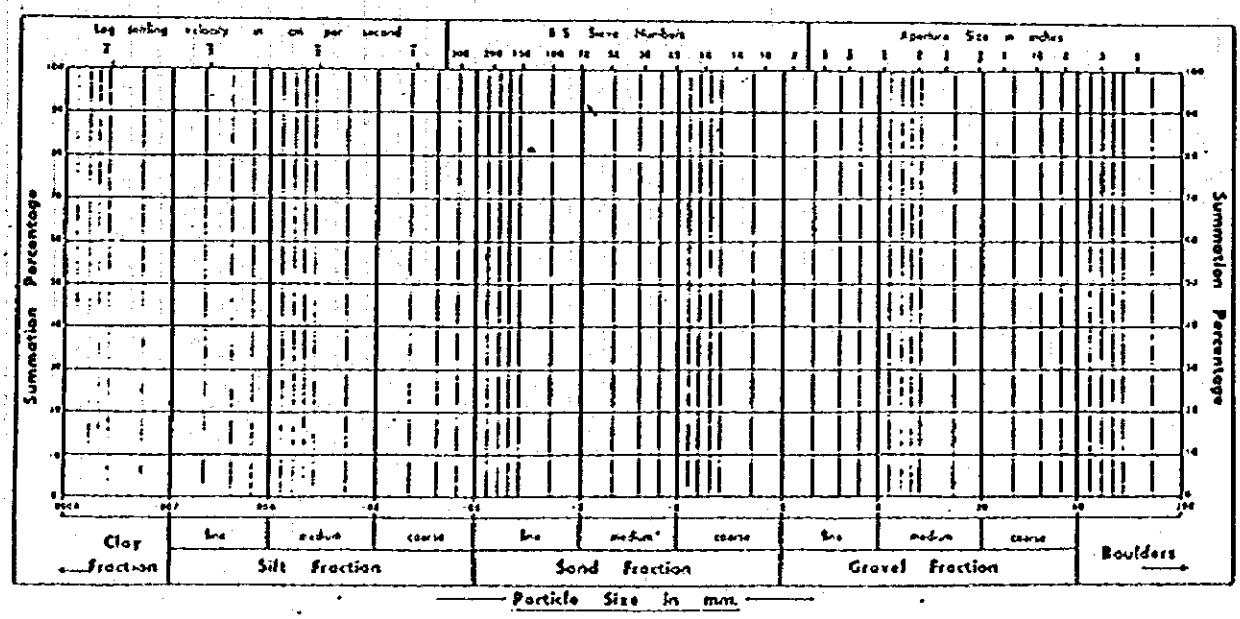
PARTICLE SIZE DISTRIBUTION

LOCATION. PROPOSED NEW OCEAN TERMINAL OPOBO. DATE OF TEST. MAY 1981

SAMPLE No. 0 - 2/43 DEPTH. 31·50 m



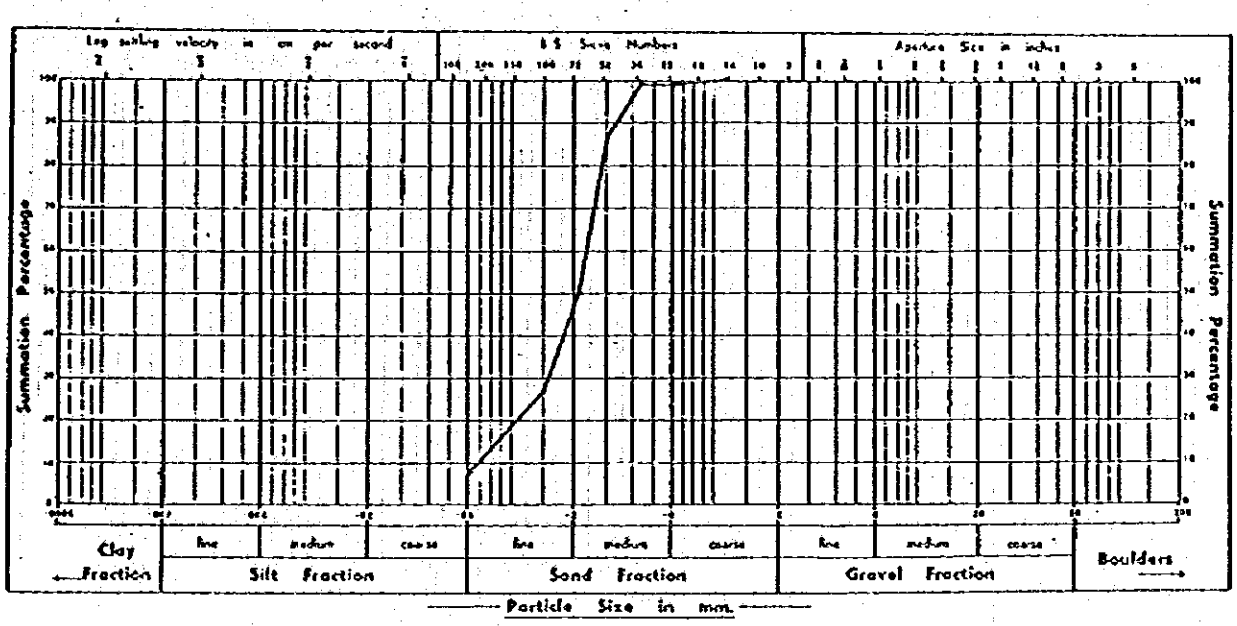
SAMPLE No. - DEPTH.



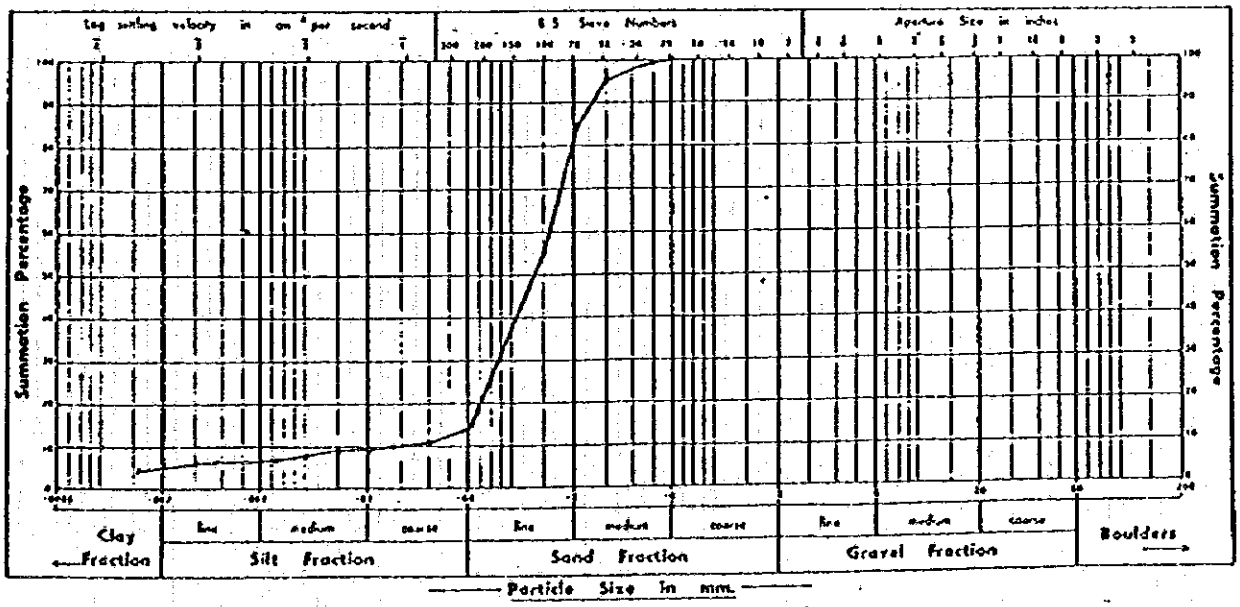
PARTICLE SIZE DISTRIBUTION

LOCATION. PROPOSED NEW OCEAN TERMINAL, IBENO. DATE OF TEST. MAY 1961

SAMPLE No. 1 - 1/3 DEPTH. 2.25m



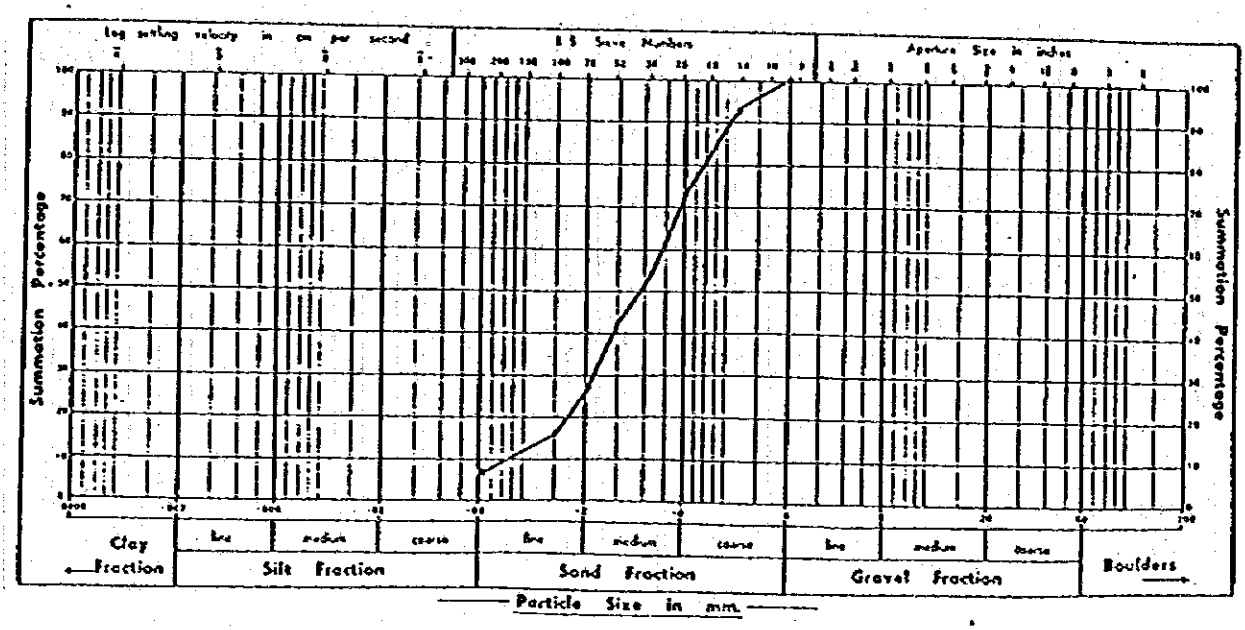
SAMPLE No. 1 - 1/8 DEPTH. 6.00m



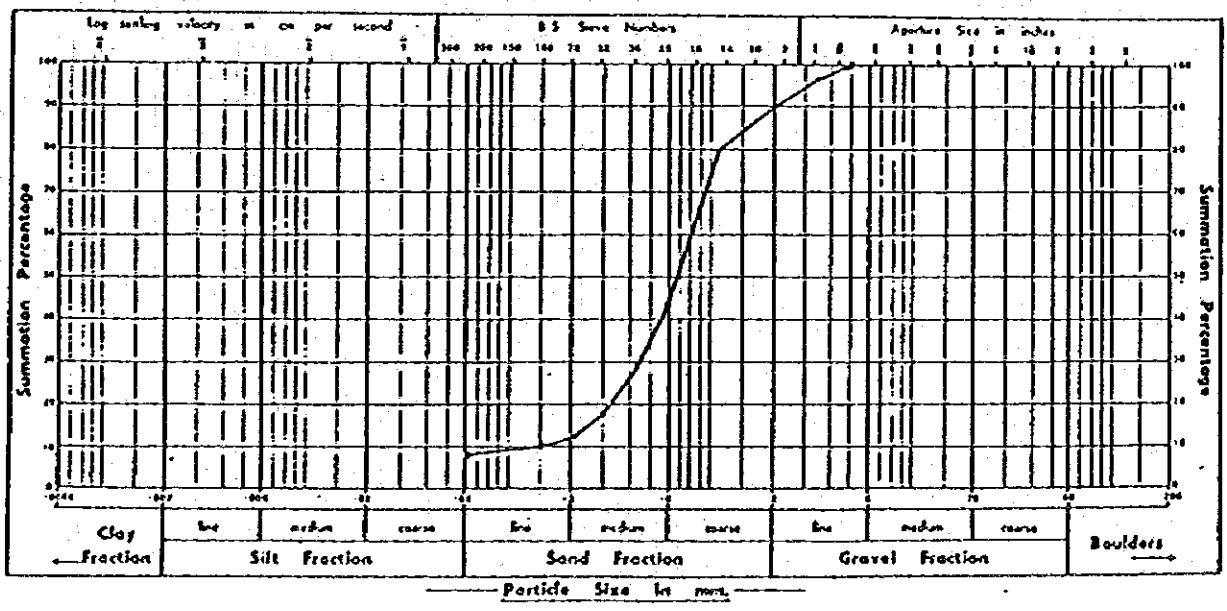
PARTICLE SIZE DISTRIBUTION

LOCATION. PROPOSED NEW OCEAN TERMINAL, IBENO. **DATE OF TEST.** MAY 1981

SAMPLE No. I - 1 / 13 **DEPTH.** 9.75m



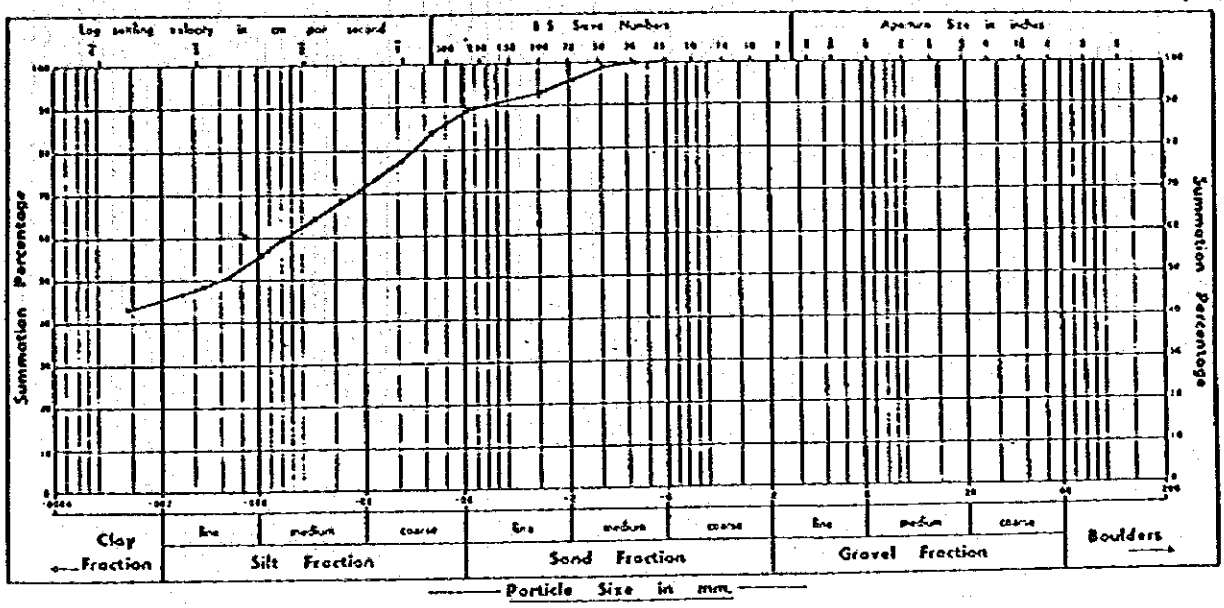
SAMPLE No. I - 1 / 48 **DEPTH.** 36.00m



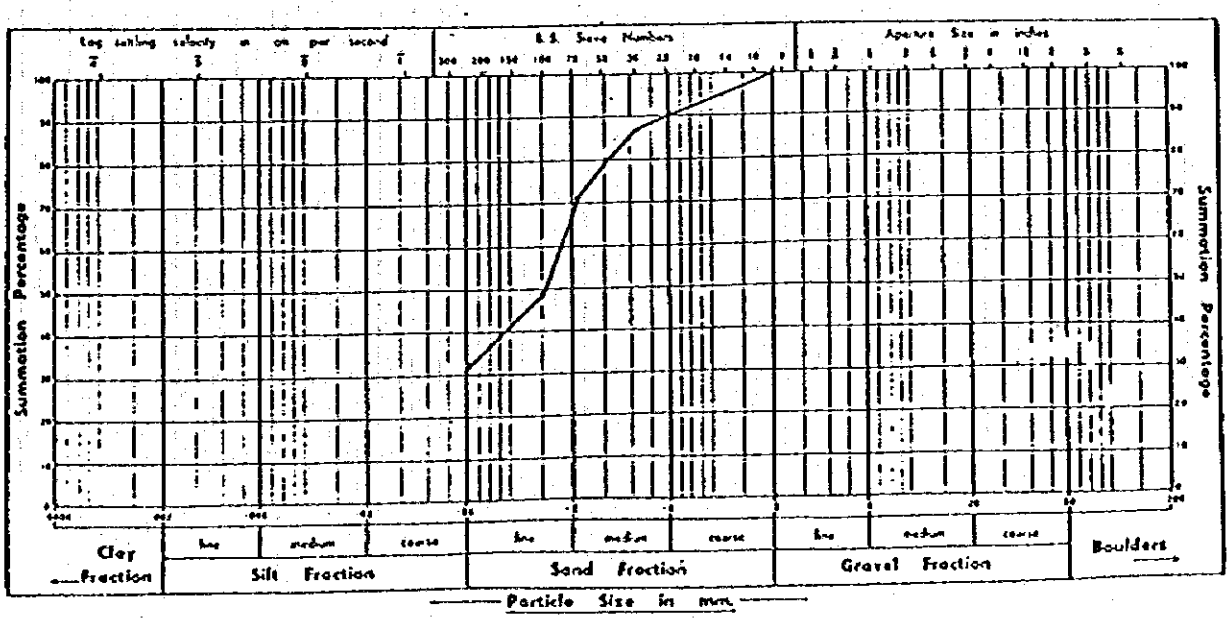
PARTICLE SIZE DISTRIBUTION

LOCATION. PROPOSED NEW OCEAN TERMINAL, IBENO **DATE OF TEST.** MAY 1981

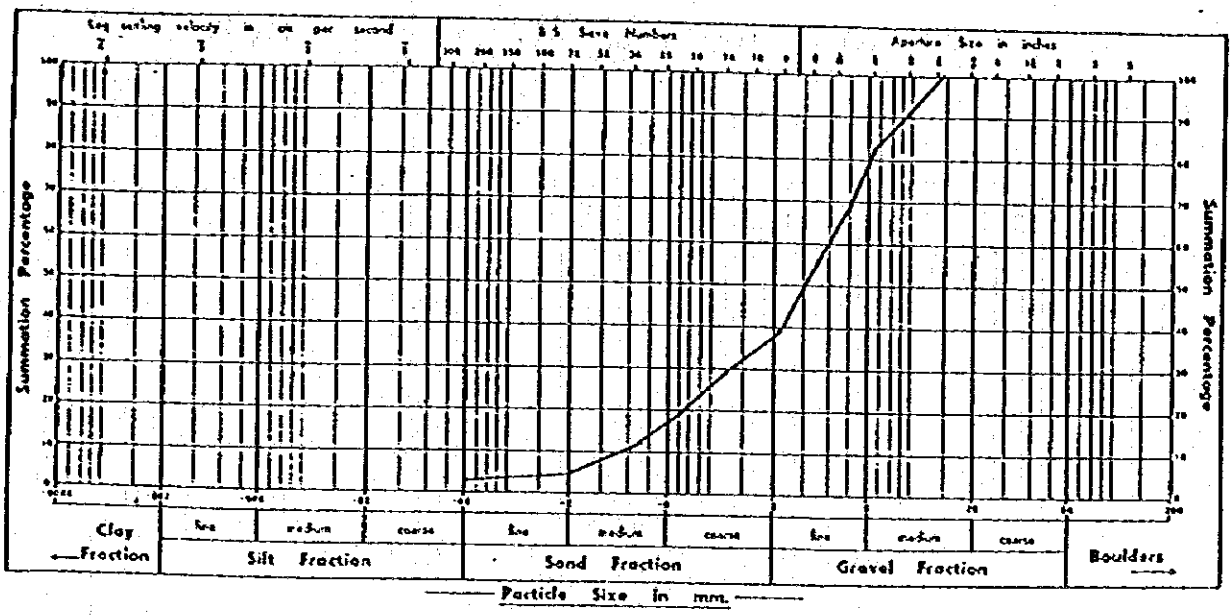
SAMPLE No. 1 - 2 / 17 **DEPTH.** 10.50m



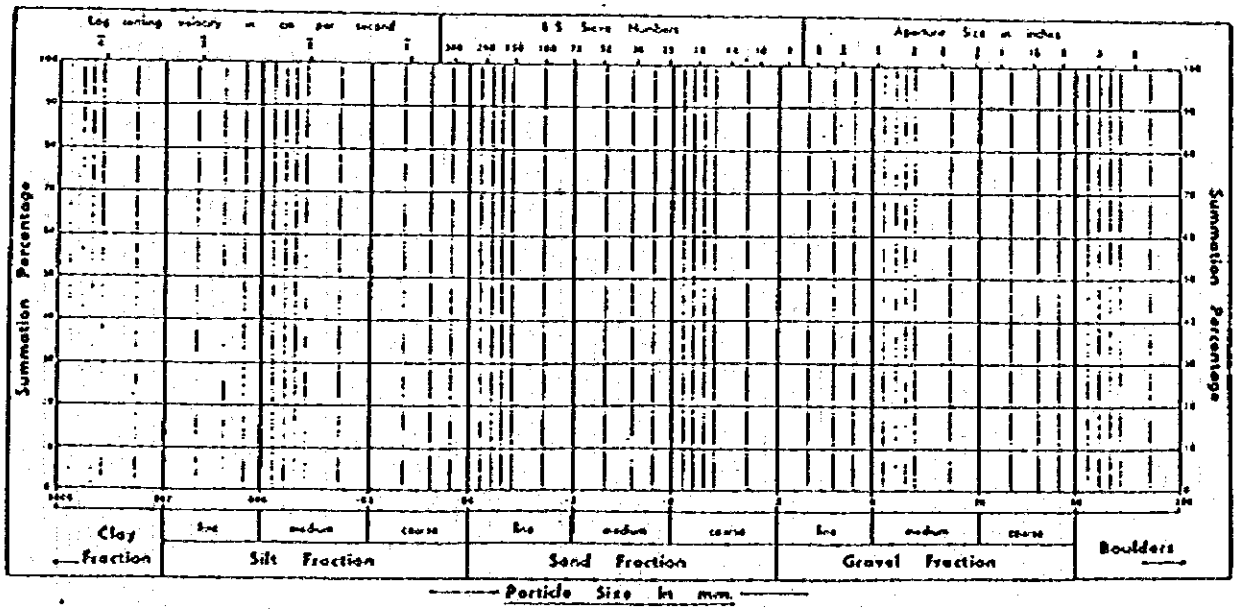
SAMPLE No. 1 - 2 / 30 **DEPTH.** 20.25



SAMPLE No. 1-2/56 DEPTH. 39.00m



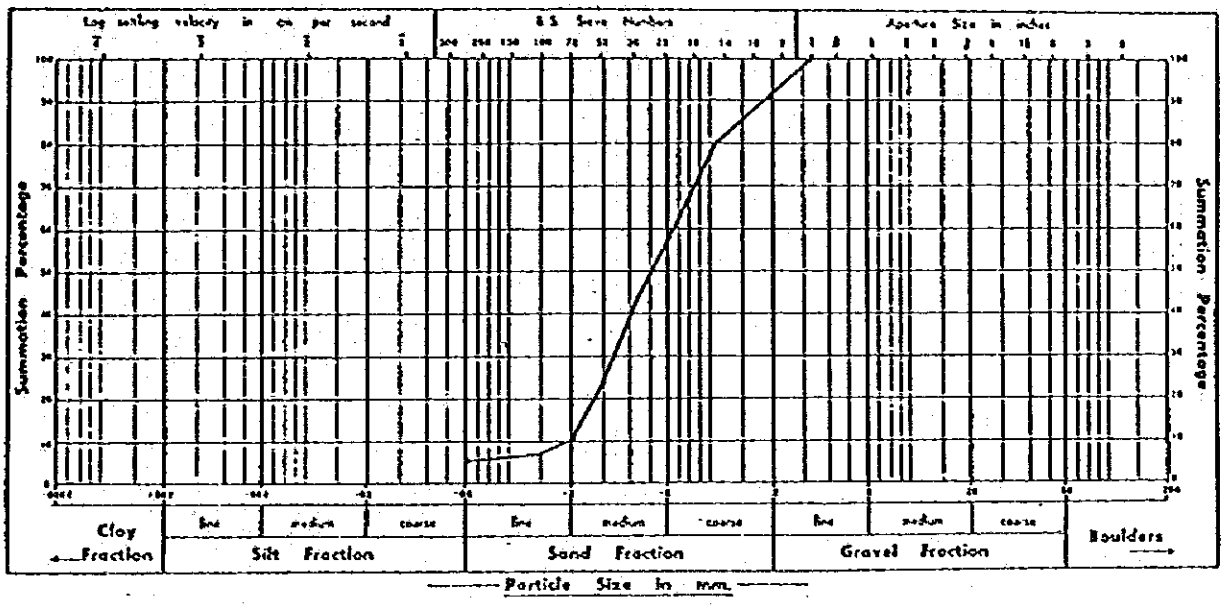
SAMPLE No. DEPTH.



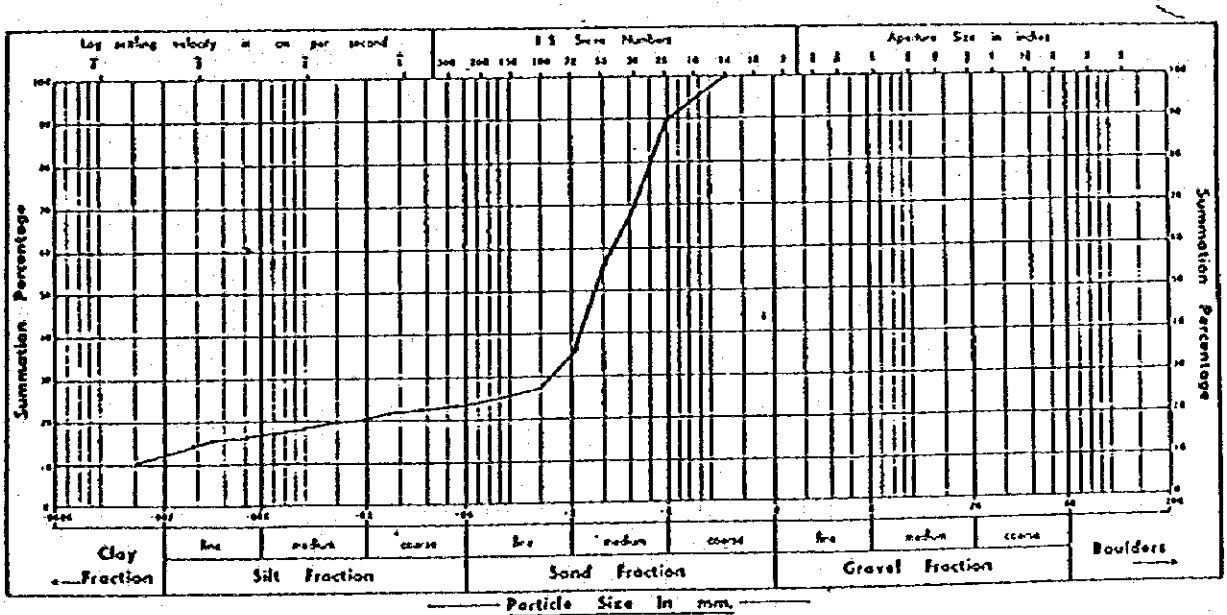
PARTICLE SIZE DISTRIBUTION

LOCATION. PROPOSED NEW OCEAN TERMINAL JAMES TOWN **DATE OF TEST.** MAY 1981

SAMPLE No. J - 1 / 4 **DEPTH.** 2 . 25m



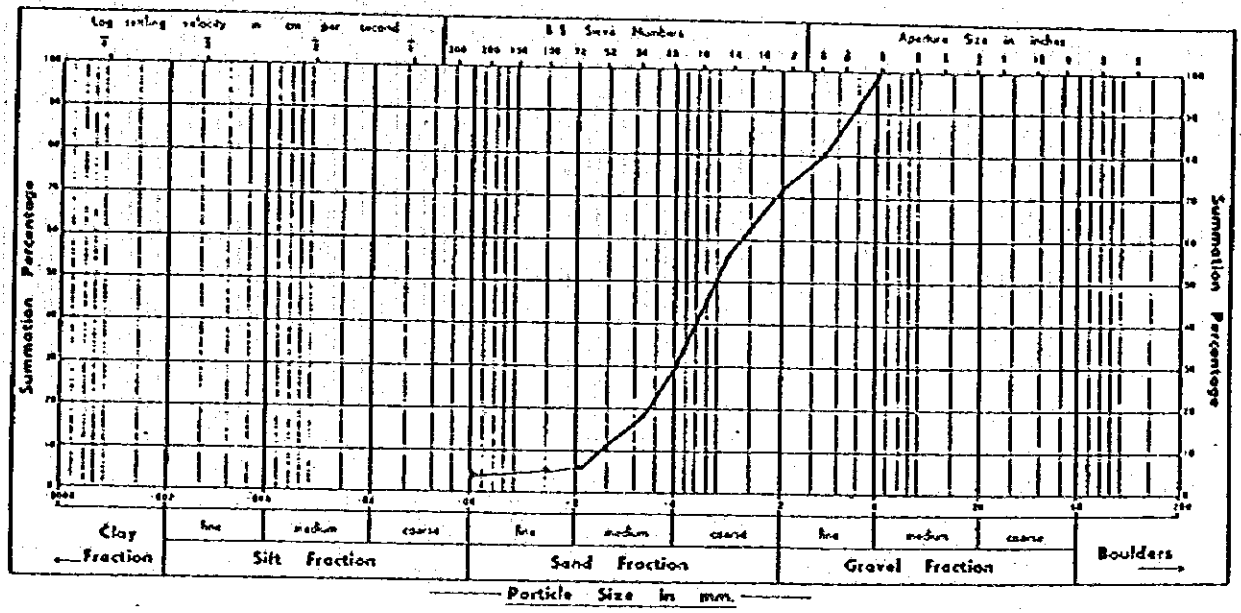
SAMPLE No. J - 1 / 16 **DEPTH.** 10 . 50m



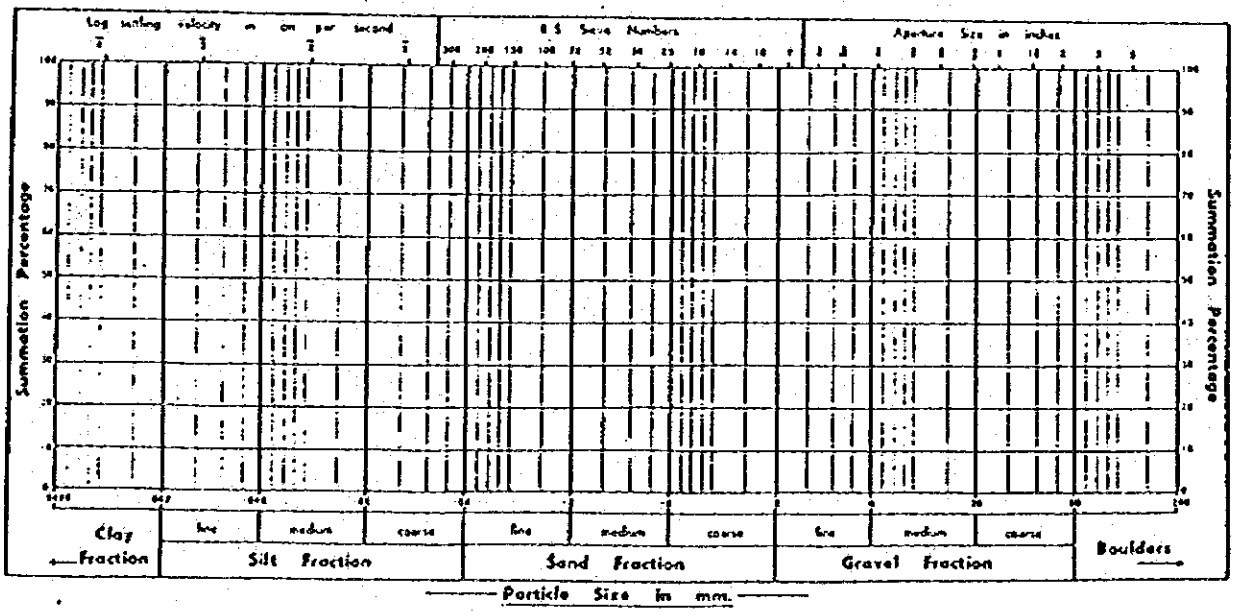
PARTICLE SIZE DISTRIBUTION

LOCATION. PROPOSED NEW OCEAN TERMINAL, JAMES TOWN DATE OF TEST. MAY 1981

SAMPLE No. J-1129 DEPTH. 20.25m



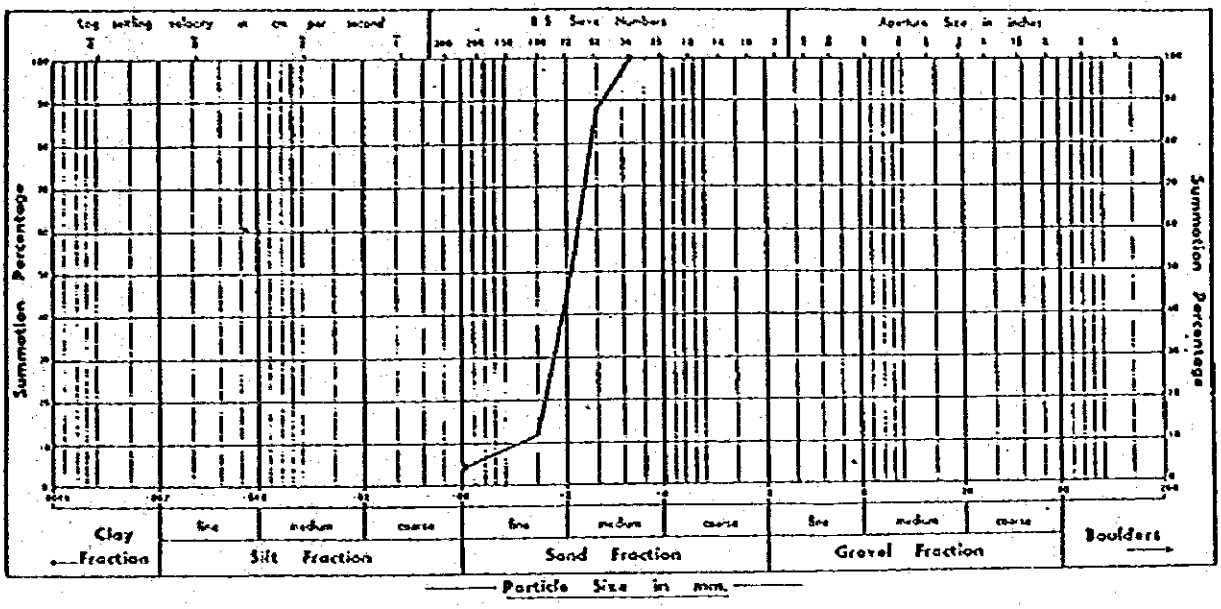
SAMPLE No. DEPTH.



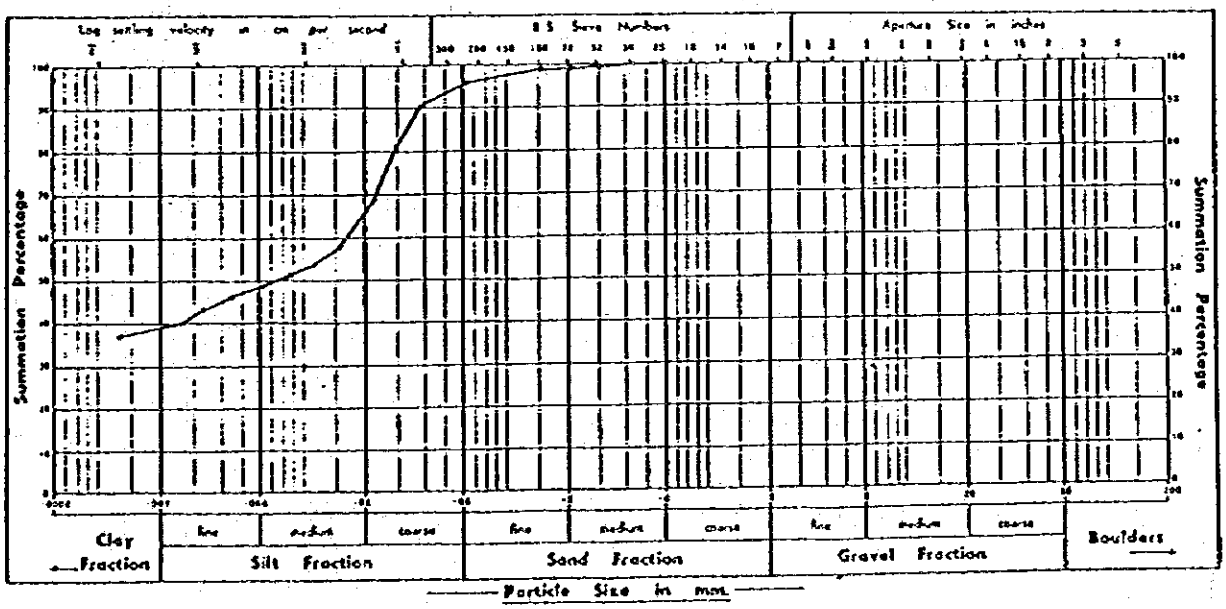
PARTICLE SIZE DISTRIBUTION

LOCATION. PROPOSED NEW OCEAN TERMINAL, JAMES TOWN **DATE OF TEST.** MAY 1981

SAMPLE No. J - 2/7 **DEPTH.** 4.00m



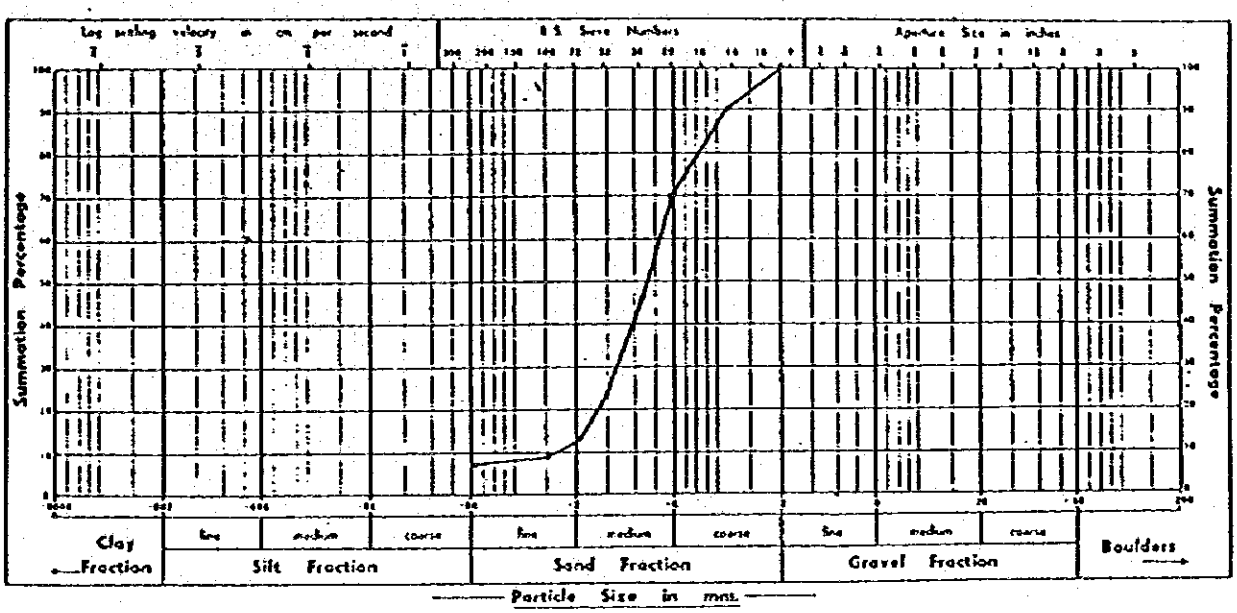
SAMPLE No. J - 2/36 **DEPTH.** 25.50m



PARTICLE SIZE DISTRIBUTION

LOCATION. PROPOSED NEW OCEAN TERMINAL, IBENO. **DATE OF TEST.** MAY 1981

SAMPLE No. J / 2 - 50 **DEPTH.** 36.00m



SAMPLE No. 1 - 2 / 56 **DEPTH.** 39.00m