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SOIL TESTING LABORATORY  
893 E. de los SANTOS AVENUE  
QUEZON CITY, PHILIPPINES

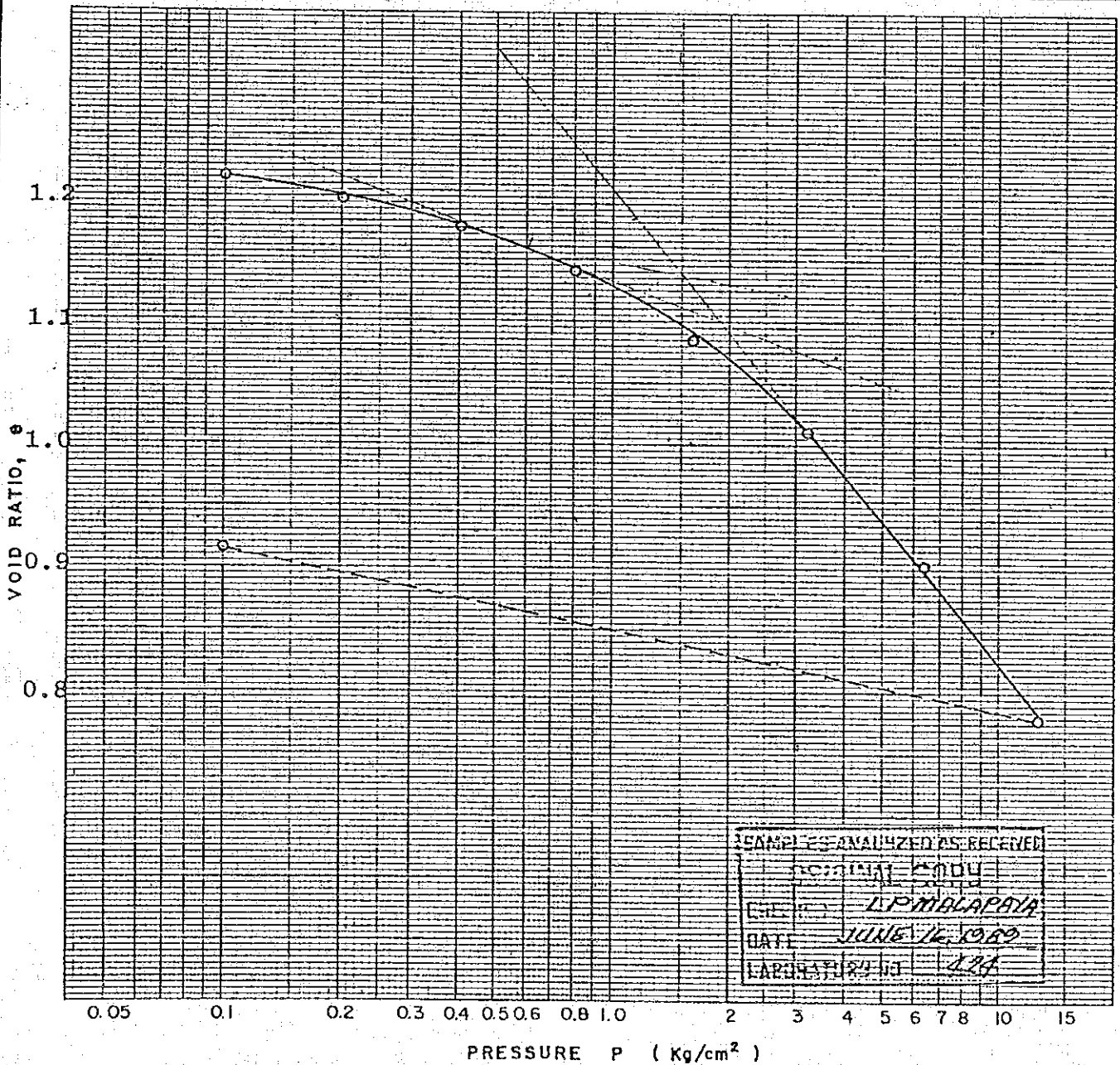
I-10

### CONSOLIDATION TEST e-log p CURVES

PROJECT: Flood Control and Drainage Project DATE: 6-15-89  
BOREHOLE No: JB-8 (TP) DEPTH: 0.5-1.00 m TESTED BY: L. SANTIAGO

DRY DENSITY g/cc	WET DENSITY γt g/cm <sup>3</sup>	SPECIFIC GRAVITY G <sub>s</sub>	MOISTURE CONTENT W <sub>o</sub> %	INITIAL DEGREE of SATURATION S <sub>o</sub> %	INITIAL VOID RATIO e <sub>o</sub>	COMPRESSION INDEX C <sub>c</sub>	PRECONSOLIDATION PRESSURE P <sub>c</sub> Kg/cm <sup>2</sup>
1.16	1.69	2.61	45.86	95.99	1.247	0.383	1.102

REMARKS:





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I-101

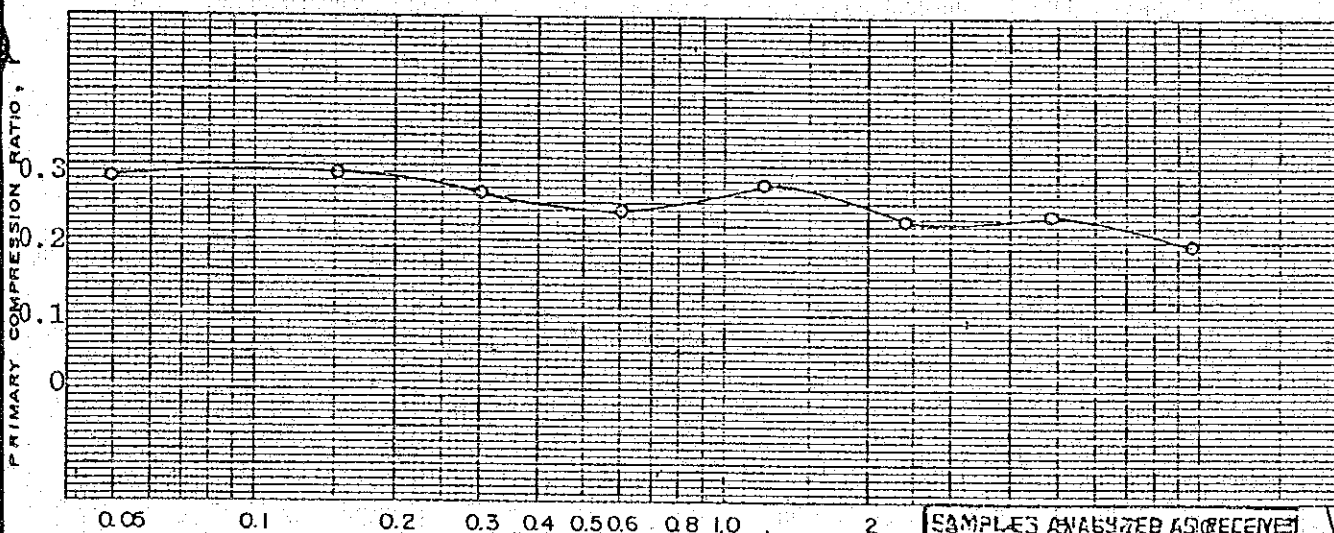
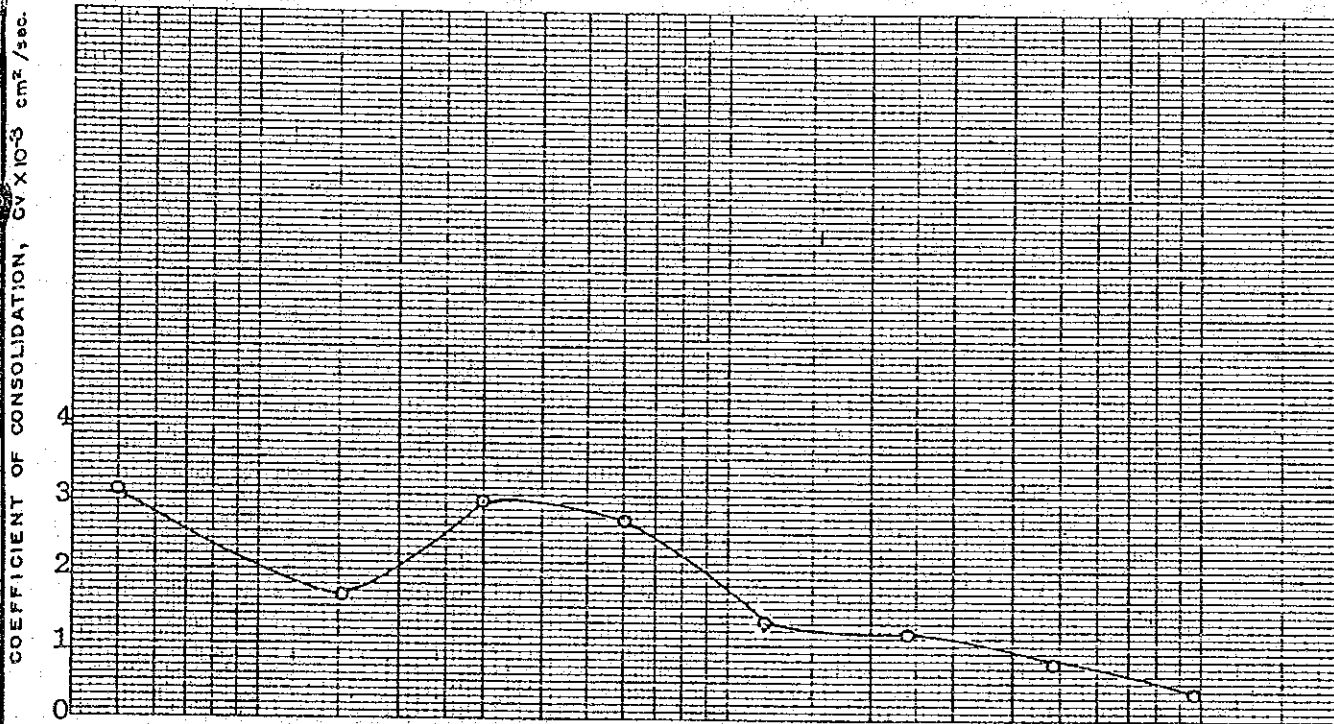
**CONSOLIDATION TEST  $C_v, r \sim \log \bar{P}$  CURVES**

PROJECT: Flood Control and Drainage Project

BOREHOLE No: JB-8 (TP)

DEPTH: 0.5-1.00 m

DATE: 6-15-89



PRESSURE  $\bar{P} = \frac{1}{2} (P_{n-1} + P_n)$

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REMARKS:

CHECKED BY: LPM

DATE: 6-16-89

LABORATORY NO: 424



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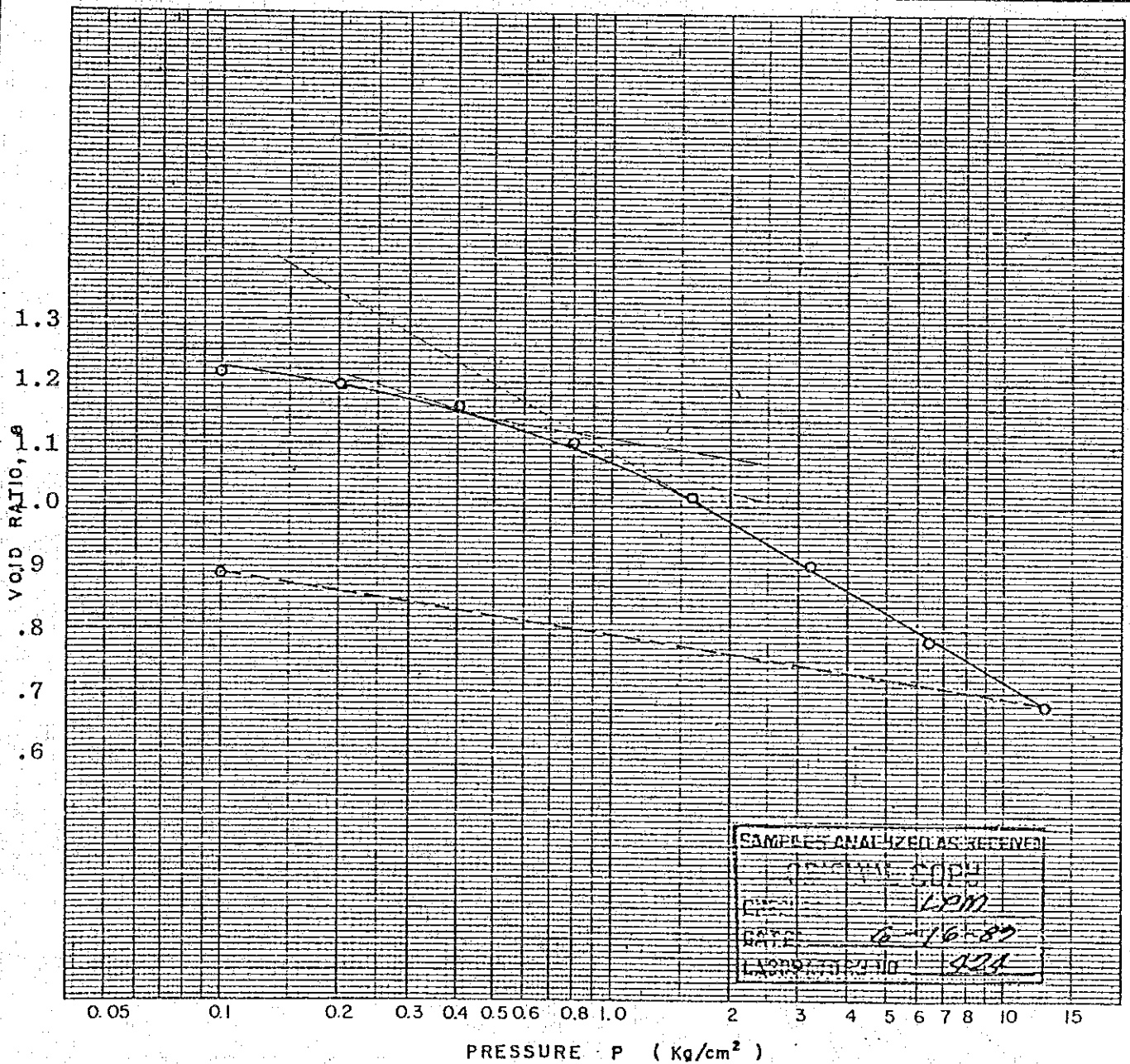
I-110

**CONSOLIDATION TEST e-log p CURVES**

PROJECT: Flood Control and Drainage Project DATE: 6-15-89  
 BOREHOLE No: JB-9 (TP) DEPTH: 0.5-1.00 m TESTED BY: L. SANTIAGO

DRY DENSITY g/cc	WET DENSITY $\gamma_t$ g/cm <sup>3</sup>	SPECIFIC GRAVITY G <sub>s</sub>	MOISTURE CONTENT W <sub>o</sub> %	INITIAL DEGREE of SATURATION s <sub>o</sub> %	INITIAL VOID RATIO e <sub>o</sub>	COMPRESSION INDEX C <sub>c</sub>	PRECONSOLIDATION PRESSURE P <sub>c</sub> Kg/cm <sup>2</sup>
1.17	1.72	2.62	47.30	99.38	1.247	0.368	0.83

REMARKS:





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I-111

### CONSOLIDATION TEST $C_v, r \sim \log \bar{P}$ CURVES

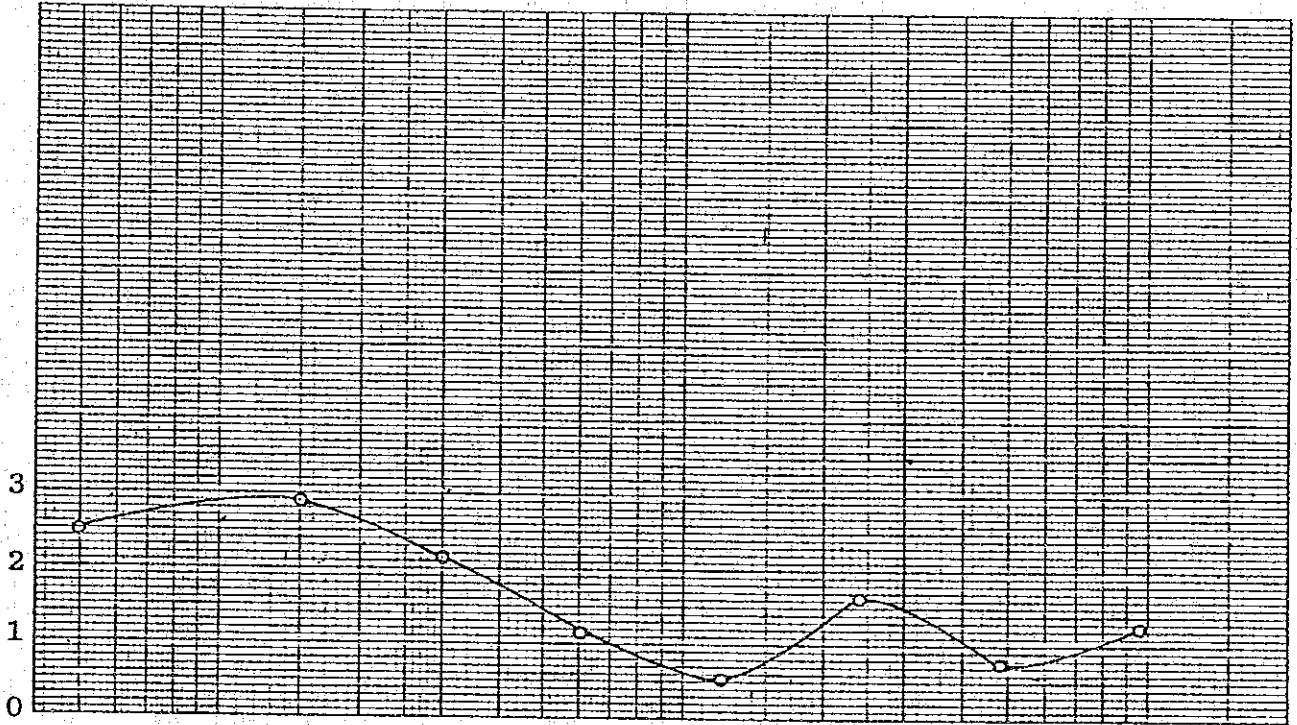
PROJECT: Flood Control and Drainage Project

BOREHOLE No: JB-9 (TP)

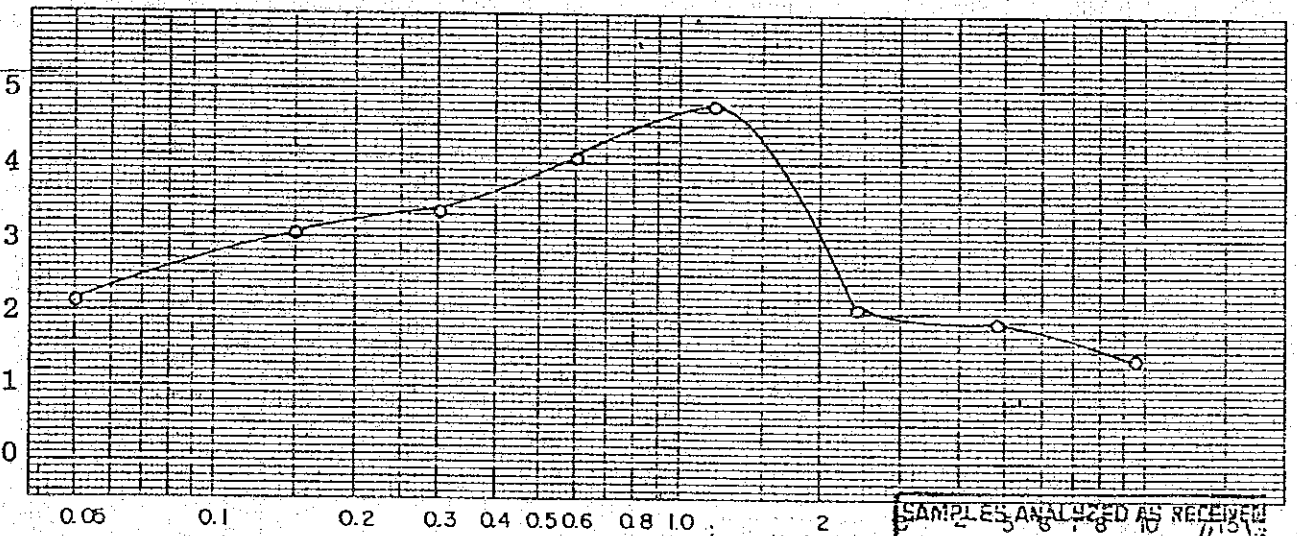
DEPTH: 0.5-1.00m

DATE: 6-15-89

COEFFICIENT OF CONSOLIDATION,  $C_v \times 10^{-3} \text{ cm}^2/\text{sec}$



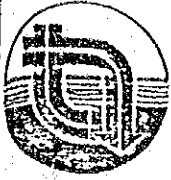
PRIMARY COMPRESSION RATIO,  $r$



PRESSURE  $\bar{P} = \frac{1}{2} (P_{n-1} + P_n)$

REMARKS:

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J-1

Standard  
 Volume=926 cc

**PROCTOR COMPACTION TEST**

PROJECT: Flood Control and Drainage Project

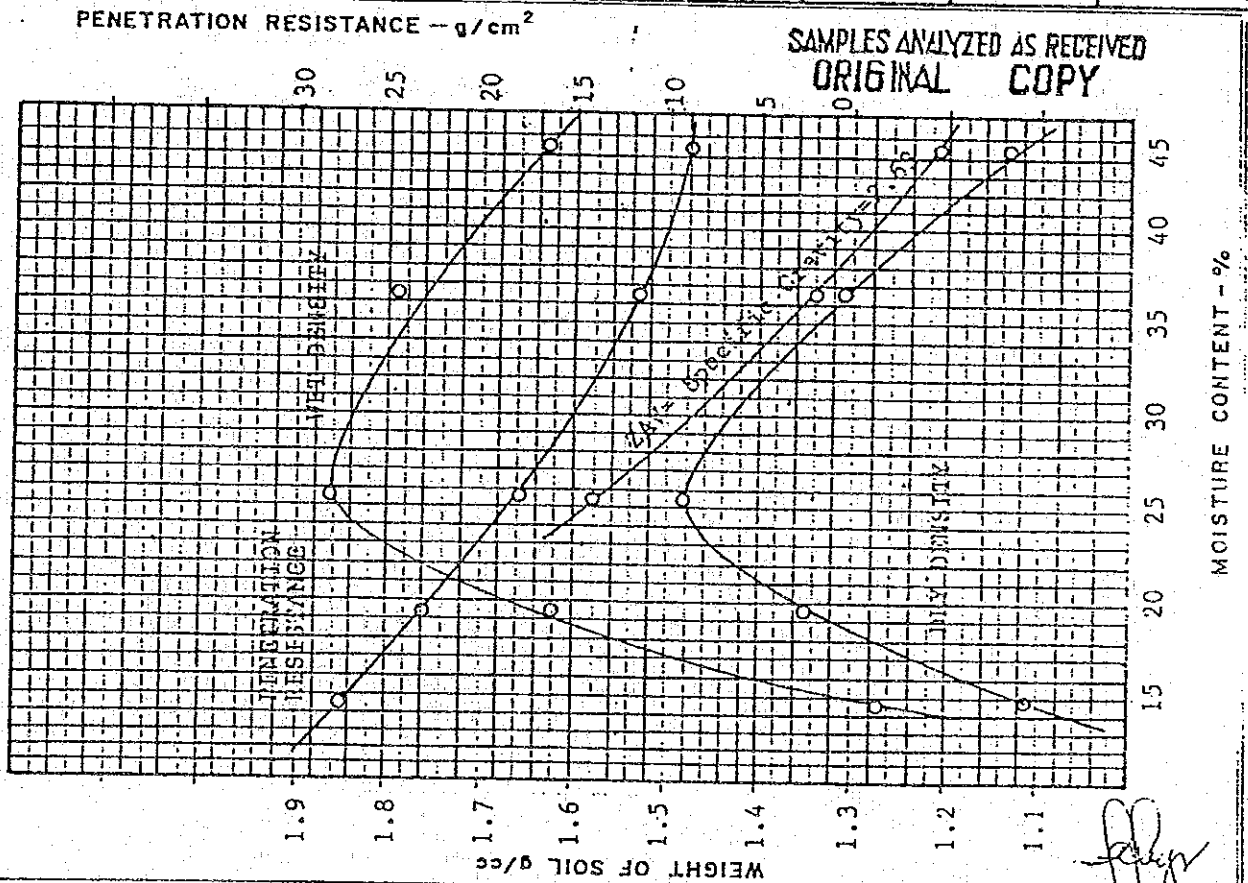
TYPE OF MATERIAL:

SAMPLE No. JB-3 (TP) DEPTH (m): DATE: 6-30-89

DETERMINATIONS		RUN NUMBER						
		1	2	3	4	5		
DENSITY	WATER ADDED	cc	400	500	600	700	800	
	WT. CYLINDER+W SOIL	g	5114	5438	5660	5595	5447	
	WT. OF CYLINDER	g	3938	3938	3938	3938	3938	
	WT. OF W SOIL	g	1176	1500	1722	1657	1509	
	WET DENSITY	g/cc	1.27	1.62	1.86	1.79	1.63	
WATER CONTENT	CONTAINER NUMBER		1	2	3	4	5	
	WT. DISH + W SOIL	g	134.52	142.73	152.65	163.23	167.52	
	WT. DISH + D SOIL	g	119.24	121.97	125.09	123.97	121.14	
	WT. OF DISH	g	16.41	16.56	16.75	16.32	16.60	
	WT. OF WATER	g	15.28	20.76	27.56	39.26	46.38	
	WT. OF D SOIL	g	102.83	105.41	108.34	107.65	104.54	
	WATER CONTENT/D SOIL	%	14.86	19.69	25.44	36.47	44.37	
	DRY DENSITY	g/cc	1.11	1.35	1.48	1.31	1.13	
	PENETRATION RESISTANCE	NEEDLE NUMBER		1	2	3	4	5
		NEEDLE AREA, sq. in.		1/20	1/20	1/20	1/20	1/20
AVERAGE READING, lbs.			96.45	80.80	62.00	42.80	31.64	
RESISTANCE		psi	1929	1616	1240	817	632.80	
(psi / 70.3)		g/cm <sup>2</sup>	27.44	23.00	17.64	11.63	9.00	

DENSITY/PENETRATION RESISTANCE CURVE

MAXIMUM DRY DENSITY, g/cc = 1.48  
 OPTIMUM MOISTURE CONTENT, % = 25.44  
 NATURAL MOISTURE CONTENT, % =





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J-2

Standard

Volume=926 cc

**PROCTOR COMPACTION TEST**

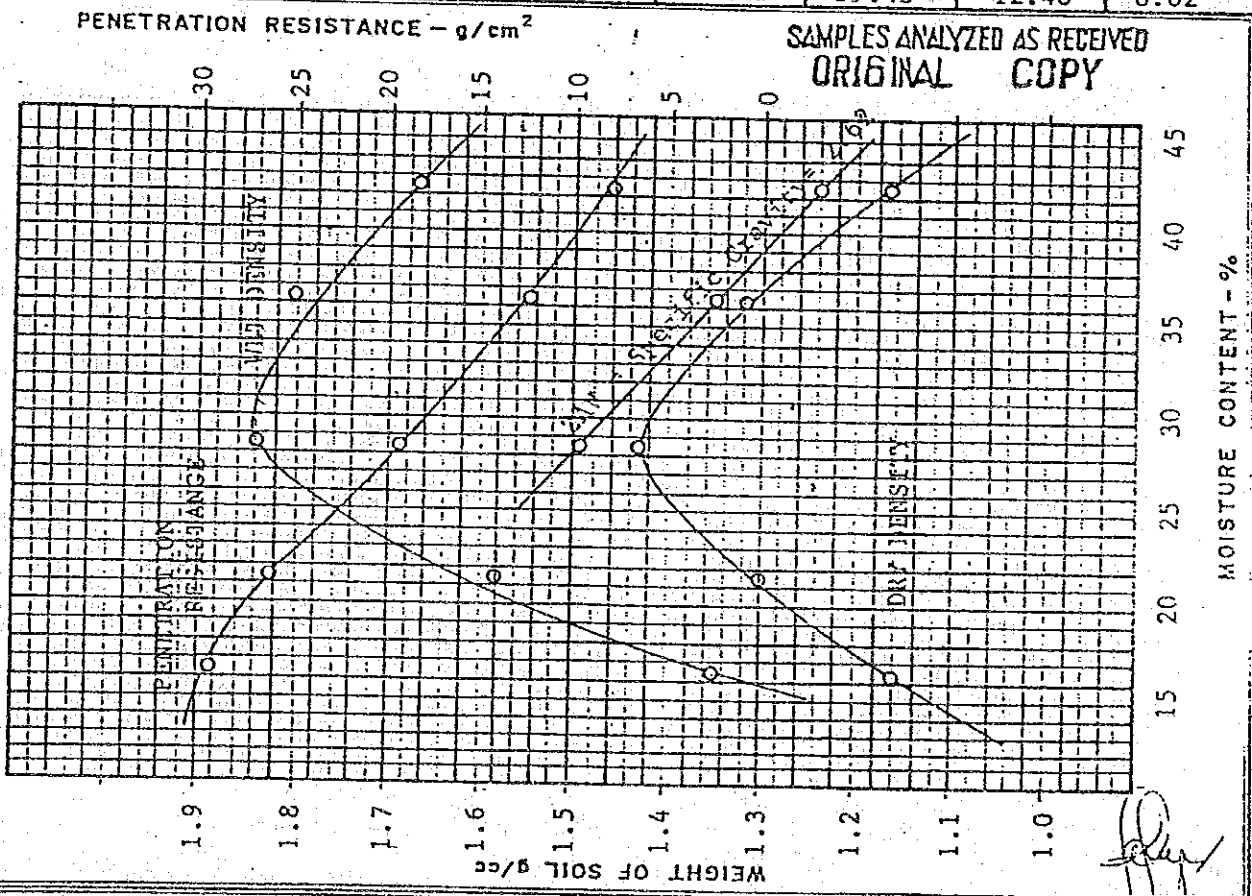
PROJECT: Flood Control and Drainage Project

TYPE OF MATERIAL:

SAMPLE No. JB-4 (TP) DEPTH (m): DATE: 6-30-89

DETERMINATIONS	DENSITY	RUN NUMBER						
		1	2	3	4	5		
		WATER ADDED	cc	400	500	600	700	800
		WT. CYLINDER+W SOIL	g	5188	5401	5641	5604	5484
		WT. OF CYLINDER	g	3938	3938	3938	3938	3938
		WT. OF W SOIL	g	1250	1463	1703	1666	1546
		WET DENSITY	g/cc	1.35	1.58	1.84	1.80	1.67
WATER CONTENT		CONTAINER NUMBER		1	2	3	4	5
		WT. DISH + W SOIL	g	138.74	152.56	168.39	207.98	257.07
		WT. DISH + D SOIL	g	121.54	128.55	134.37	157.17	185.02
		WT. OF DISH	g	16.78	16.37	15.11	16.22	15.61
		WT. OF WATER	g	17.20	43.88	34.02	50.81	72.05
		WT. OF D SOIL	g	104.76	112.18	119.26	140.95	169.41
		WATER CONTENT/D SOIL	%	16.42	21.40	28.53	36.05	42.53
	DRY DENSITY	g/cc	1.16	1.30	1.43	1.32	1.17	
PENETRATION RESISTANCE		NEEDLE NUMBER		1	2	3	4	5
		NEEDLE AREA, sq. in.		0.05	0.05	0.05	0.05	0.05
		AVERAGE READING, lbs.		102.60	92.15	68.25	43.55	28.15
		RESISTANCE	psl	2052	1843	1365	871	563
		(psl / 70.3)	g/cm <sup>2</sup>	29.19	26.22	19.43	12.40	8.02

DENSITY/PENETRATION RESISTANCE CURVE  
 MAXIMUM DRY DENSITY, g/cc = 1.43  
 OPTIMUM MOISTURE CONTENT, % = 28.53  
 NATURAL MOISTURE CONTENT, % =







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J-3

**PROCTOR COMPACTION TEST**

Standard  
 Volume = 926 cc

PROJECT: Flood Control and Drainage Project

TYPE OF MATERIAL:

SAMPLE No. JB-7 (TP)

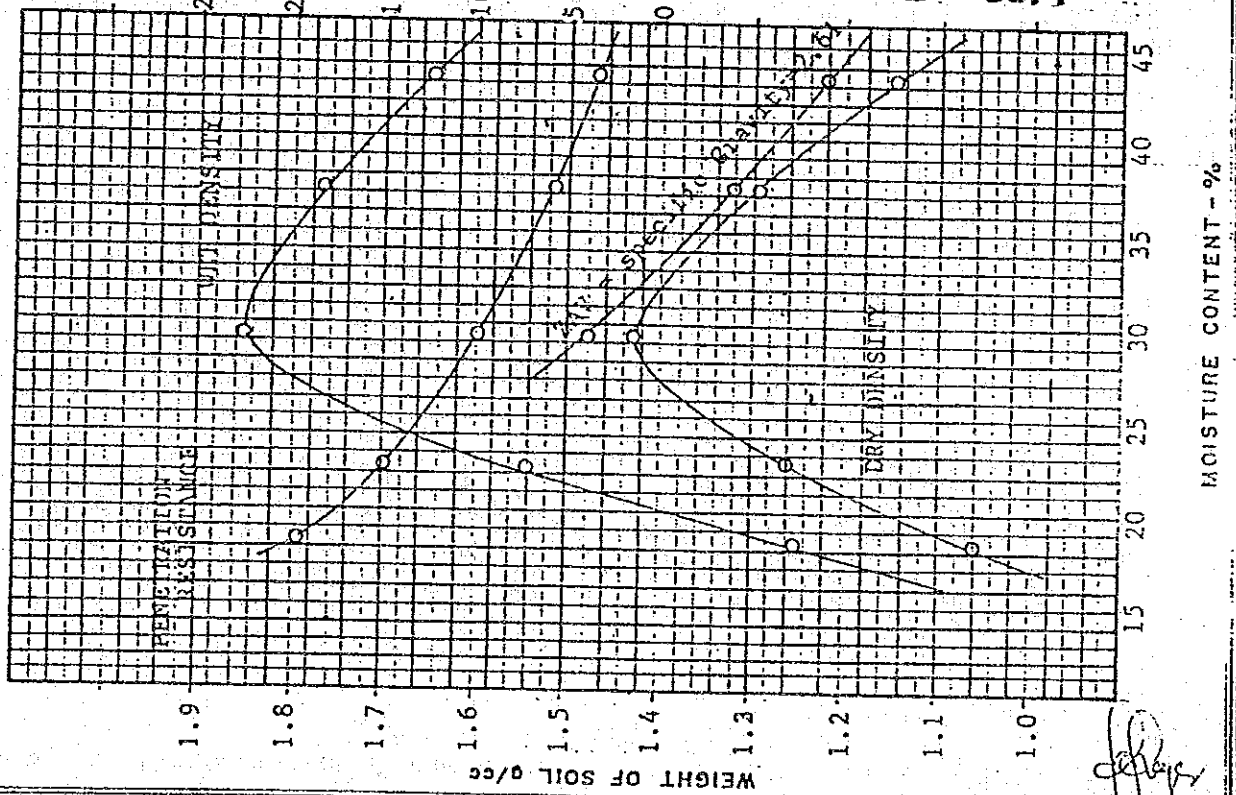
DEPTH (m):

DATE: 6-29-89

DENSITY	RUN NUMBER		DEPTH (m)				
	1	2	3	4	5		
WATER ADDED	cc	400	500	600	700	800	
WT. CYLINDER + W SOIL	g	5095	5364	5651	5577	5465	
WT. OF CYLINDER	g	3938	3938	3938	3938	3938	
WT. OF W SOIL	g	1157	1426	1713	1639	1527	
WET DENSITY	g/cc	1.25	1.54	1.85	1.77	1.65	
WATER CONTENT	CONTAINER NUMBER		DEPTH (m)				
	1	2	3	4	5		
WT. DISH + W SOIL	g	136.16	142.87	132.32	168.37	188.50	
WT. DISH + D SOIL	g	117.36	119.57	105.84	126.71	135.88	
WT. OF DISH	g	14.60	16.11	15.21	15.40	14.55	
WT. OF WATER	g	18.80	23.30	26.48	41.66	52.62	
WT. OF D SOIL	g	102.76	103.46	90.63	111.31	121.33	
WATER CONTENT/D SOIL	%	18.30	22.52	29.22	37.43	43.37	
DRY DENSITY	g/cc	1.06	1.26	1.43	1.29	1.15	
PENETRATION RESISTANCE	NEEDLE NUMBER		DEPTH (m)				
	1	2	3	4	5		
NEEDLE AREA, sq. in.		1/20	1/20	1/20	1/20	1/20	
AVERAGE READING, lbs.		69.00	52.50	36.00	20.45	12.70	
RESISTANCE	psi	1380	1050	720	409	254	
(psi / 70.3)	g/cm <sup>2</sup>	19.63	14.95	10.24	5.83	3.62	

PENETRATION RESISTANCE - g/cm<sup>2</sup>

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J-4

**PROCTOR COMPACTION TEST**

Standard  
 Volume=926 cc

PROJECT: Flood Control and Drainage Project

TYPE OF MATERIAL:

SAMPLE No. JB-8 (TP) DEPTH (m): 0.5-1.00 m DATE: 6-30-89

DENSITY		1	2	3	4	5
RUN NUMBER						
WATER ADDED	cc	400	500	600	700	800
WT. CYLINDER+W SOIL	g	5178	5438	5632	5632	5604
WT. OF CYLINDER	g	3938	3938	3938	3938	3938
WT. OF W SOIL	g	1240	1500	1694	1694	1666
WET DENSITY	g/cc	1.34	1.62	1.83	1.83	1.80

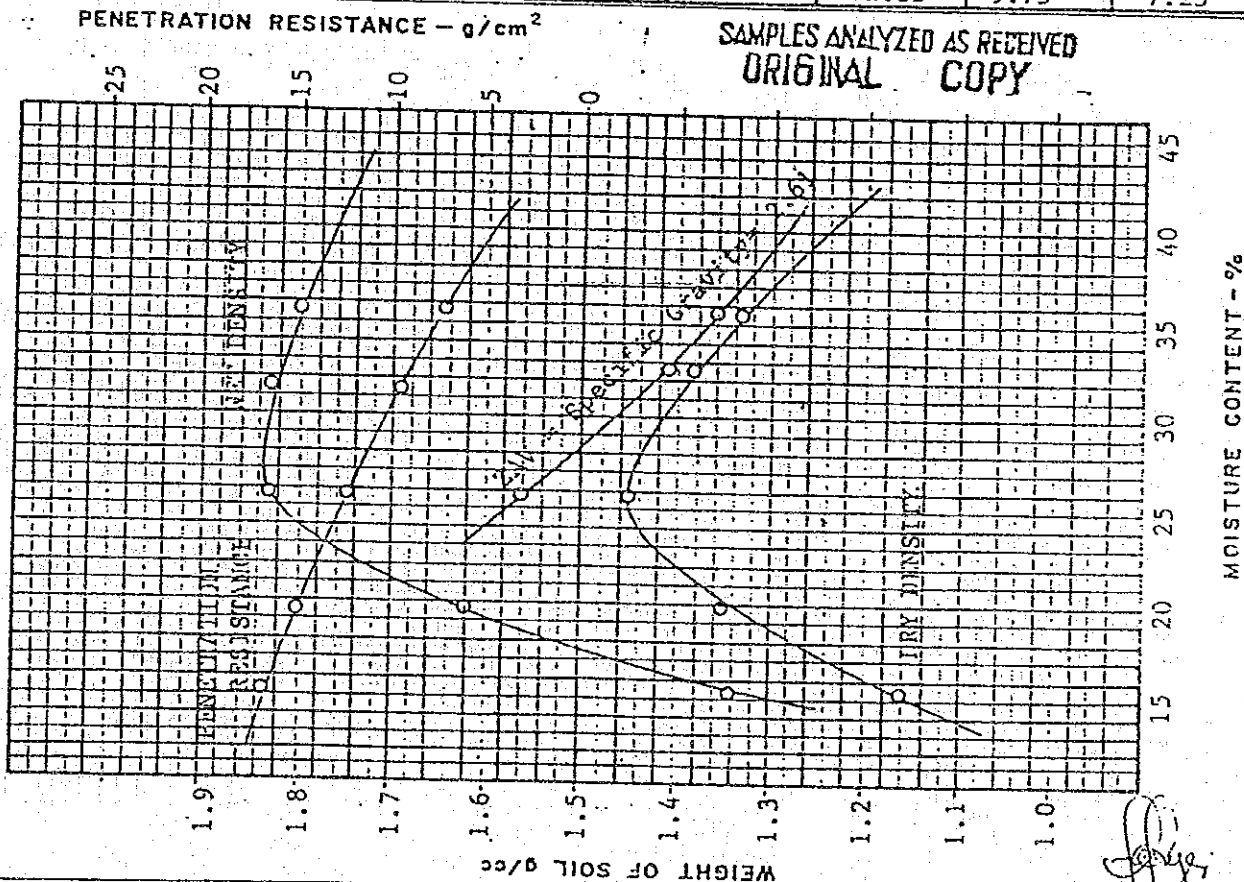
WATER CONTENT		1	2	3	4	5
CONTAINER NUMBER						
WT. DISH + W SOIL	g	94.74	154.50	123.99	147.75	149.03
WT. DISH + D SOIL	g	84.27	131.24	101.92	115.59	113.89
WT. OF DISH	g	16.85	14.64	16.87	16.62	14.71
WT. OF WATER	g	10.47	23.26	22.07	32.16	35.14
WT. OF D SOIL	g	67.62	116.60	85.05	98.97	99.18
WATER CONTENT/D SOIL	%	15.48	19.95	25.95	32.49	35.43
DRY DENSITY	g/cc	1.16	1.35	1.45	1.38	1.33

PENETRATION RESISTANCE		1	2	3	4	5
NEEDLE NUMBER						
NEEDLE AREA, sq. in.		0.05	0.05	0.05	0.05	0.05
AVERAGE READING, lbs.		58.95	52.75	43.40	34.25	25.40
RESISTANCE	psi	1179	1055	868	685	508
(psi / 70.3)	g/cm <sup>2</sup>	16.78	15.00	12.35	9.75	7.23

DENSITY/PENETRATION RESISTANCE CURVE

MAXIMUM DRY DENSITY, g/cc = 1.45  
 OPTIMUM MOISTURE CONTENT, % = 25.95  
 NATURAL MOISTURE CONTENT, % =



*[Handwritten signature]*

GENELL ANTONIO R





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METRO MANILA, PHILIPPINES

J-5

## PROCTOR COMPACTION TEST

Standard

Volume = 926 cc

PROJECT: Flood Control and Drainage Project

TYPE OF MATERIAL:

SAMPLE No. JB-9 (TP)

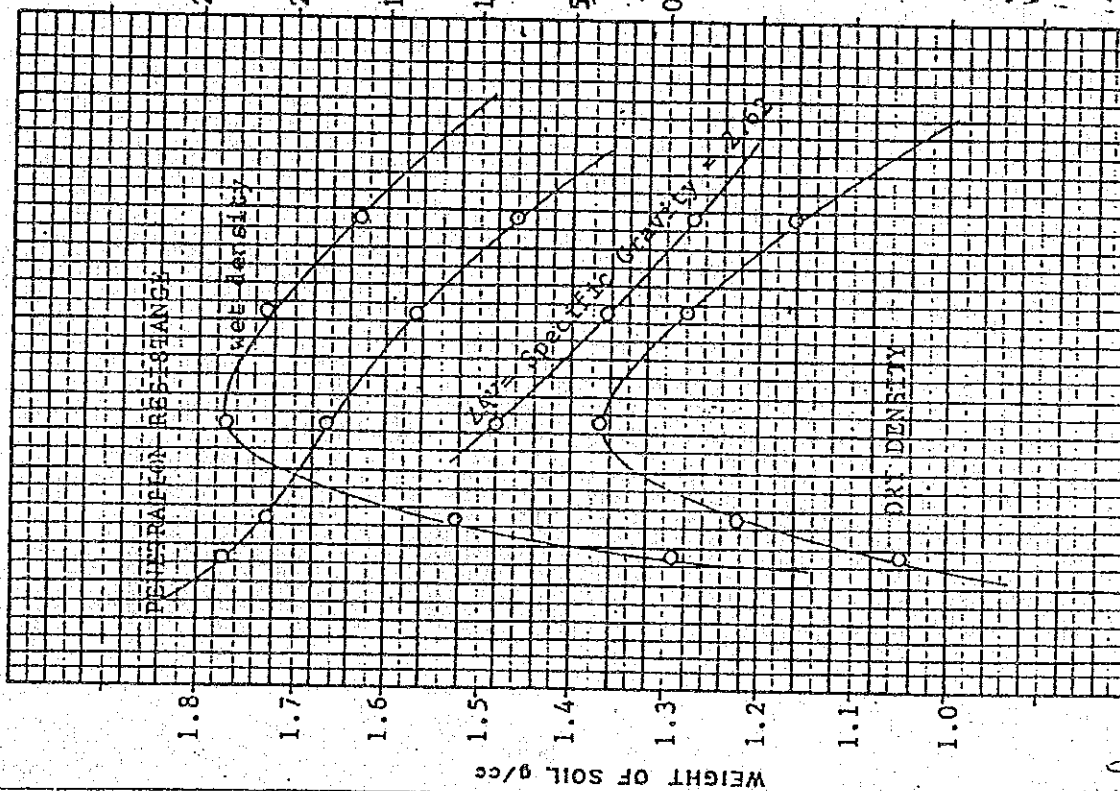
DEPTH (m): 0.5-1.00 m

DATE: 6-29-89

DENSITY		1	2	3	4	5
RUN NUMBER		1	2	3	4	5
WATER ADDED		400	500	600	700	800
WT. CYLINDER+W SOIL		5133	5346	5577	5539	5447
WT. OF CYLINDER		3938	3938	3938	3938	3938
WT. OF W SOIL		1195	1408	1639	1601	1509
WET DENSITY		1.29	1.52	1.77	1.73	1.63
CONTAINER NUMBER		1	2	3	4	5
WT. DISH + W SOIL		143.75	174.82	156.59	178.93	191.06
WT. DISH + D SOIL		120.29	143.85	124.79	135.95	140.86
WT. OF DISH		16.01	16.92	16.99	14.87	16.90
WT. OF WATER		23.46	30.97	31.80	42.98	50.20
WT. OF D SOIL		104.28	126.93	107.80	121.08	123.96
WATER CONTENT / D SOIL		22.50	24.40	29.50	35.50	40.50
DRY DENSITY		1.05	1.22	1.37	1.28	1.16
NEEDLE NUMBER		1	2	3	4	5
NEEDLE AREA, sq. in.		1/20	1/20	1/20	1/20	1/20
AVERAGE READING, lbs.		83.05	74.55	64.25	47.15	28.12
RESISTANCE		1661	1491	1285	943	562.4
(psi / 70.3)		23.63	21.21	18.29	13.42	8.00

PENETRATION RESISTANCE - g/cm<sup>2</sup>

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DETERMINATIONS

WATER CONTENT

PENETRATION RESISTANCE

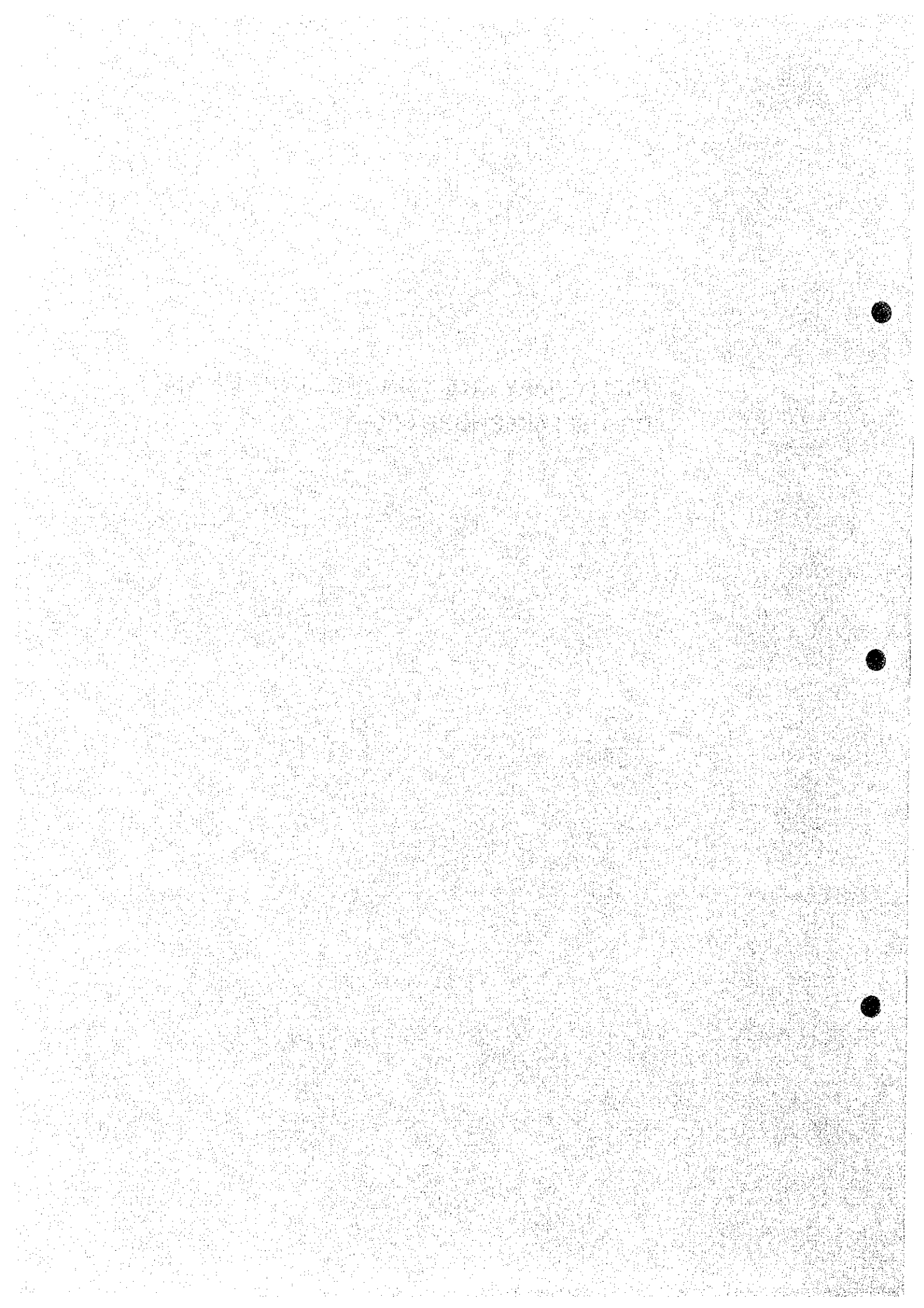
DENSITY

MAXIMUM DRY DENSITY, g/cc = 1.37

OPTIMUM MOISTURE CONTENT, % = 29.50

NATURAL MOISTURE CONTENT, % =

**C. PRELIMINARY STUDY ON THE OPTIMUM SHAPE  
FOR THE LAKESHORE DIKE**



**PRELIMINARY STUDY ON THE OPTIMUM SHAPE FOR THE LAKESHORE DIKE**

## Table of Contents

	Page
1. Top Elevation of the Lakeshore Dike . . . . .	1
2. Alternative Shape of the Lakeshore Dike . . . . .	3
3. Optimum Shape of the Lakeshore Dike . . . . .	6
4. Consolidation Settlement . . . . .	8

## List of Tables

Table 1	List of Wave length and Celerity for a given Wave Period and Water Depth
Table 2	Cost Comparison of Embankment Method of Lakeshore Dike

## List of Figures

Fig. 1	Relation between Wave Height, Wind Velocity and Fetch Length of Shallow Wave under Constant Water Depth (Bretchneider's Curve)
Fig. 2	Wind Wave Prediction Curves (corrected by Wilson's formula, 1956)
Fig. 3	Wave Setup to Tidal Dike (Saville's Curve)
Fig. 4	Stability Analysis of the Lakeshore Dike (1/2)-(2/2)
Fig. 5	Typical Section of the Lakeshore Dike for Alternatives
Fig. 6	Typical Model for Consolidation Settlement of Foundation of the Lakeshore Dike
Fig. 7	Consolidation-time Curve of Foundation of the Lakeshore Dike
Fig. 8	Volume of Extra-embankment of the Lakeshore Dike

## PRELIMINARY STUDY ON THE OPTIMUM SHAPE FOR THE LAKESHORE DIKE

Lakeshore dike is designed by the following procedure.

First step : To examine the wave effect of the Laguna lake to the top elevation of the dike varying its bank slope,

Second step: To examine the shape of the dike varying its embankment material and method,

Third step : To determine the optimum shape of the dike by construction cost comparison, and

Fourth step: Study the consolidation settlement of foundation.

### 1. Top Elevation of the Lakeshore Dike

Top elevation of the lakeshore dike is determined by the following equation.

$$\text{TOP EL.} = \text{HWL} + \Delta H + 0.50 \text{ m} \dots\dots\dots \textcircled{1}$$

where, TOP EL.; Top elevation of the lakeshore dike

HWL ; Design high water level of the Laguna lake  
(EL. 13.80 m)

$\Delta H$  ; Wave setup to the dike

(1) Shallow wave (Bretschneider's method)

The lakeshore dike is planned to be located at the north shoreline. The biggest wind wave to the dike is supposed to be



caused by the south wind of a typhoon. In this case, its fetch length is about 20 km and its wind speed is supposed to be 20 m/s.

The shallow wave can be calculated by Bretschneider's Method using Fig. 1, Fig. 2 and Table 1 for wave height, its period and length respectively.

Now,  $h=2.3$  m,  $U_{10}=20$  m/s and  $F=20,000$  m,

$$gh/U_{10}^2=0.056$$

$$gF/U_{10}^2=490$$

From Fig. 1,

$$gH_{1/3}/U_{10}^2=0.019$$

$$H_{1/3}=0.019 \times 20^2 / 9.8 = 0.78 \text{ m}$$

From Fig. 2,

$$T_{1/3}=2.7 \text{ sec}$$

$$t=1.0 \text{ hr}$$

From Table 1,

$$L_{1/3}=9.89 \text{ m}$$

where,  $h$ ; water depth of the Laguna lake (=2.3 m)

$U_{10}$ ; wind speed at 10 m above water surface (=20 m/s)

$F$ ; fetch length (=20 km)

$g$ ; acceleration of gravity (=9.8 m/s<sup>2</sup>)

$H_{1/3}$ ; wave height of one-third significant wave

$T_{1/3}$ ; wave period of one-third significant wave

$t$ ; required minimum wind duration

$L_{1/3}$ ; wave length of one-third significant wave

The design wave in front of the dike becomes as follows;

Wave height;  $H=0.78$  m

Wave length;  $L=9.89$  m

Wave period;  $T=2.7$  sec.

(2) Wave setup ( $\Delta H$ )

Wave setup to the dike can be calculated by Fig. 3 of Savielle's diagram which is a function of bank slope and H/L.

(3) Top elevation of the dike

Top elevation of the lakeshore dike is calculated by equation (1) as follows:

Bank slope	HWL	$\Delta H$	TOP. EL.
1:2	EL. 13.80 m	1.20 m	EL. 15.50 m
1:3	EL. 13.80 m	0.80 m	EL. 15.10 m
1:4	EL. 13.80 m	0.60 m	EL. 14.90 m
1:5	EL. 13.80 m	0.50 m	EL. 14.80 m
1:6	EL. 13.80 m	0.50 m	EL. 14.80 m
1:7	EL. 13.80 m	0.50 m	EL. 14.80 m
1:8	EL. 13.80 m	0.40 m	EL. 14.70 m
1:9	EL. 13.80 m	0.40 m	EL. 14.70 m
1:10	EL. 13.80 m	0.30 m	EL. 14.60 m

2. Alternative Shape of the Lakeshore Dike

Five alternative embankment methods are considered in relation to the embankment material and its method as follows;

Case 1: Embankment by dredged material from the bottom or lakeshore of the Laguna lake

Case 2: Embankment by mixed soil of dredged material with borrowed material

Case 3: Embankment by dredged material for the center part and borrowed material for the outer part

Case 4: Embankment by borrowed material

Case 5: Embankment by mixed soil of dredged material with cement or lime powder

As the soil along the lakeshore dike and the embankment material of the dike are generally soft, stability analysis of slip circle method is conducted to determine the dike's shape. The typical soil profile of the original ground is supposed to be as follows;

Depth	Soil Property	N-value
Ground surface to EL. 9.00m	: Clay $\gamma_t = \gamma_s = 1.64 \text{ t/m}^3$ $C' = 1.10 \text{ t/m}^2$ $\phi' = 22.0^\circ$	10
EL. 9.00 m to EL. 6.50 m	: Sand $\gamma_t = \gamma_s = 1.75 \text{ t/m}^3$ $C' = 1.80 \text{ t/m}^2$ $\phi' = 36.0^\circ$	5
EL. 6.50 m to EL. -5.50 m	: Clay $\gamma_t = \gamma_s = 1.50 \text{ t/m}^3$ $C' = 1.90 \text{ t/m}^2$ $\phi' = 20^\circ$	2
EL. -5.50 m to EL. -10.50 m	: Clay $\gamma_t = \gamma_s = 1.70 \text{ t/m}^3$ $C' = 3.20 \text{ t/m}^2$ $\phi' = 18.5^\circ$	20 - 50

where,  $\gamma_t$ ; wet unit weight ( $\text{t/m}^3$ )

$\gamma_s$ ; saturated unit weight ( $\text{t/m}^3$ )

$C'$ ; cohesion ( $\text{t/m}^2$ )

$\phi'$ ; angle of internal friction ( $^\circ$ )

Embankment materials are supposed to be as follows;

Case No.	Soil Property
Case 1 : dredged material	$\gamma_t = \gamma_s = 1.60 \text{ t/m}^3$ $C' = 0.90 \text{ t/m}^2$ $\phi' = 11.0^\circ$
Case 2 : mixed clay	$\gamma_t = \gamma_s = 1.60 \text{ t/m}^3$ $C' = 1.10 \text{ t/m}^2$ $\phi' = 22.0^\circ$
Case 3 : borrowed material	$\gamma_t = \gamma_s = 1.70 \text{ t/m}^3$ $C' = 3.00 \text{ t/m}^2$ $\phi' = 22.0^\circ$
dredged material	$\gamma_t = \gamma_s = 1.60 \text{ t/m}^3$ $C' = 0.90 \text{ t/m}^2$ $\phi' = 11.0^\circ$
Case 4 : borrowed material	$\gamma_t = \gamma_s = 1.70 \text{ t/m}^3$ $C' = 3.00 \text{ t/m}^2$ $\phi' = 22.0^\circ$
Case 5 : soil material	strongest in these 5 cases

In the stability analysis, coefficient of earthquake is set to be 0.2. The required safety factors for normal and seismic conditions are 1.5 and 1.2 respectively. The top width of the lakeshore dike is set to be 9.10 m from the requirement of maintenance road. The ground elevation is supposed to be EL. 12.00 m.

Stability analysis of Case 4, which will be the optimum case as shown in sub-section 3 is shown in Fig. 4.

From the stability analysis, typical shapes of the lakeshore dike for these 5 alternatives are determined as

follows (ref. to Fig. 5);

Case	Bank Slope	Top. EL.
1	1:10	EL. 14.60
2	1:3	EL. 15.10
3	1:4	EL. 14.90
4	1:2	EL. 15.50
5	1:2	EL. 15.50

### 3. Optimum Shape of the Lakeshore Dike

Optimum Shape of the lakeshore dike is determined by comparing the construction costs for these 5 alternatives.

#### (1) Construction method

Construction methods for these alternatives are supposed to be as follows;

Case 1: First step is excavating the soft soil around the lakeshore dike by dredger etc. Second step is pre-loading it to proceed consolidation of the foundation of the dike. Third step is embanking the dike with compaction.

Case 2: First and second steps are the same as Case 1. Third step is transporting the borrowed material from the borrowed area. Fourth step is mixing the soft soil and the borrowed material with a proportion of 60% and 40% respectively. Fifth step is embanking the dike with compaction by the mixed material.

Case 3: First, second and third steps are the same as Case 2. Fourth step is embanking the dike with

compaction using the soft soil for the center part and borrowed material for the outer part with a proportion of 60% and 40% respectively.

Case 4: First step is transporting the borrowed material from the borrowed area. Second step is embanking the dike with compaction.

Case 5: First and second steps are the same as Case 1. Third step is embanking the dike with compaction by the soil cement which is made by mixing the soft soil with cement or lime powder during embankment. In the case of cement powder, the mixing ratio is supposed to be about 5% of weight of the soil that is  $0.08 \text{ t/m}^3$  from the economical view point.

## (2) Cost comparison

Cost comparison of the construction cost of the lakeshore dike per unit length is made considering the above embankment method. The embankment volume is set to be 1.2 times of the design volume considering the consolidation settlement of the foundation as shown in subsection 4. The summary of the construction costs becomes as follows (ref. to Table 2);

Case No.	Construction Cost (P/m)
1	34,880
2	21,910
3	20,980
4	17,590
5	29,210



### (3) Optimum shape of the dike

From the above result, it is shown that the Case 4 is the most economical. This reason is that the Case 4 can avoid double handling of excavated material and become the simplest construction method.

Costs of Case 2 and 3 are high because of this double handling. Cost of Case 1 is the highest because of its high revetment cost. Cost of Case 5 is high because of its cement cost.

As a result, Case 4 of embankment by the borrowed material is the optimum embankment method.

### 4. Consolidation Settlement

Consolidation settlement of the foundation of the lakeshore dike for the Case 4 is calculated using the model shown in Fig. 6. In this calculation, it is supposed that consolidation settlement does not occur for the dike itself because compaction is provided.

(1) Total quantity of settlement

Total quantity of settlement of the foundation is 0.70 m as shown in the following table:

Layer	H (m)	$P_E$ (t/m <sup>2</sup> )	$P_F$ (t/m <sup>2</sup> )	$P_E+P_F$ (t/m <sup>2</sup> )	e	$C_c$	$\Delta H$ (m)
1	-	-	-	-	-	-	-
2	3.00	2.46	6.08	8.54	1.19	0.37	0.27
3	-	-	-	-	-	-	-
4	12.00	18.30	4.38	22.68	1.34	0.80	0.38
5	5.00	31.55	3.54	35.09	1.30	0.48	0.05
6	-	-	-	-	-	-	-
Total							0.70

Notes:

H : Height of a layer

$P_E$ : Earth pressure acting at the center part of a layer

$P_F$ : Load acting at the center part of a layer by the weight of the embankment

e : Void ratio of a layer

$C_c$ : Compression index of a layer

$\Delta H$ : Consolidation settlement

$$\Delta H = H \cdot C_c / (1+e) \cdot \log_{10}((P_E+P_F)/P_E)$$

(2) Consolidation-time curve

Consolidation-time curve of the foundation is calculated as shown in Fig. 7 by summing up those of clay layers as shown in the following table.

U (%)	Tv	Layer 2		Layer 4		Layer 5	
		$\Delta H$ (m)	t (day)	$\Delta H$ (m)	t (day)	$\Delta H$ (m)	t (day)
10	0.008	0.03	1.0	0.04	19.6	0.01	2.9
20	0.031	0.05	3.8	0.08	76.0	0.01	11.2
30	0.071	0.08	8.8	0.11	174.0	0.02	25.7
40	0.126	0.11	15.6	0.15	308.8	0.02	45.6
50	0.197	0.14	24.4	0.19	482.8	0.03	71.3
60	0.287	0.16	35.6	0.23	703.4	0.03	103.8
70	0.403	0.19	50.0	0.27	987.7	0.04	145.8
80	0.567	0.22	70.3	0.30	1,389.7	0.04	205.1
90	0.848	0.24	105.2	0.34	2,078.4	0.05	306.7
100		0.27		0.38		0.05	

Notes: U; degree of consolidation

Tv; time factor

$\Delta H$ ; consolidation settlement

t; consolidation time

$$t = Tv - (H/2)^2 / Cv$$

H; height of a clay layer

Cv; coefficient of consolidation

As a result, consolidation times of 70% and 80% of the foundation are about 1.5 years and 2.8 years respectively.

### (3) Extra-embankment

Percentage of the extra-embankment due to consolidation settlement is 20% as shown in Fig. 8.

### 5. Remarks

As the lakeshore dike is designed based on the data collected in the investigation conducted in this study, there are some inadequate data which are used by estimation as

follows;

- Wave and wind data of the Laguna lake
- Water depth data of the Laguna lake
- Geotechnical data of the disturbed sample of the soil along the lakeshore dike and the borrowed material

It is necessary to collect these data in the detailed design stage.

Table 1

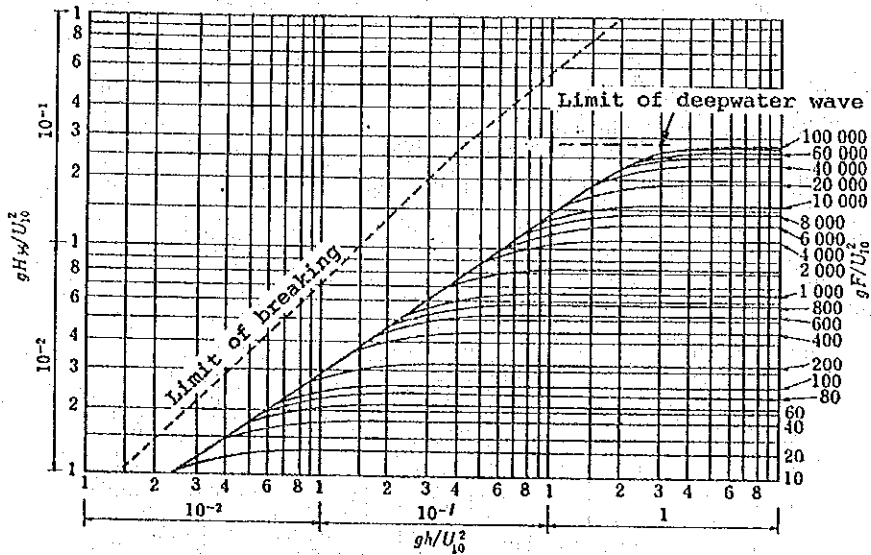
List of wavelength and celerity for a given wave period and water depth ( $g = 9.8\text{m/s}^2$ ).

Wave period (s)	2.0		2.5		3.0		4.0		5.0	
	Wave-length (m)	Cel-erity (m/s)	Wave-length (m)	Cel-erity (m/s)	Wave-length (m)	Cel-erity (m/s)	Wave-length (m)	Cel-erity (m/s)	Wave-length (m)	Cel-erity (m/s)
0.1	1.95	0.97	2.45	0.98	2.95	0.98	3.94	0.99	4.94	0.99
0.2	2.71	1.35	3.42	1.37	4.14	1.38	5.55	1.39	6.96	1.39
0.3	3.26	1.63	4.15	1.66	5.03	1.68	6.77	1.69	8.50	1.70
0.4	3.69	1.85	4.74	1.89	5.76	1.92	7.79	1.95	9.79	1.96
0.5	4.05	2.03	5.24	2.09	6.39	2.13	8.67	2.17	10.92	2.18
0.6	4.36	2.18	5.67	2.27	6.95	2.32	9.45	2.36	11.93	2.39
0.7	4.62	2.31	6.05	2.42	7.45	2.48	10.17	2.54	12.85	2.57
0.8	4.85	2.42	6.40	2.56	7.90	2.63	10.82	2.71	13.70	2.74
0.9	5.04	2.52	6.70	2.68	8.31	2.77	11.43	2.86	14.49	2.90
1.0	5.21	2.61	6.98	2.79	8.69	2.90	11.99	3.00	15.23	3.05
1.1	5.36	2.68	7.23	2.89	9.04	3.01	12.52	3.13	15.93	3.19
1.2	5.49	2.74	7.46	2.99	9.36	3.12	13.02	3.26	16.59	3.32
1.3	5.60	2.80	7.67	3.07	9.66	3.22	13.50	3.37	17.22	3.44
1.4	5.70	2.85	7.87	3.15	9.95	3.32	13.94	3.49	17.82	3.56
1.5	5.78	2.89	8.04	3.22	10.21	3.40	14.37	3.59	18.40	3.68
1.6	5.85	2.93	8.20	3.28	10.46	3.49	14.77	3.69	18.95	3.79
1.8	5.96	2.98	8.48	3.39	10.90	3.63	15.53	3.88	19.98	4.00
2.0	6.05	3.02	8.72	3.49	11.30	3.77	16.22	4.05	20.94	4.19
2.2	6.11	3.05	8.91	3.56	11.65	3.88	16.85	4.21	21.84	4.37
2.5	6.16	3.08	9.14	3.66	12.09	4.03	17.71	4.43	23.08	4.62
3.0	6.21	3.11	9.40	3.76	12.67	4.22	18.95	4.74	24.92	4.98
3.5	6.23	3.11	9.55	3.82	13.09	4.36	19.98	5.00	26.52	5.30
4.0	6.23	3.12	9.64	3.86	13.39	4.46	20.85	5.21	27.93	5.59
4.5	6.24	3.12	9.69	3.88	13.60	4.53	21.57	5.39	29.18	5.84
5.0	6.24	3.12	9.72	3.89	13.75	4.58	22.18	5.55	30.29	6.06
6.0	6.24	3.12	9.74	3.90	13.91	4.64	23.11	5.78	32.17	6.43
7.0	6.24	3.12	9.75	3.90	13.99	4.66	23.75	5.94	33.67	6.73
8.0	6.24	3.12	9.75	3.90	14.02	4.67	24.19	6.05	34.86	6.97
9.0	6.24	3.12	9.75	3.90	14.03	4.68	24.47	6.12	35.81	7.16
10.0	6.24	3.12	9.75	3.90	14.03	4.68	24.65	6.16	36.56	7.31
11.0	6.24	3.12	9.75	3.90	14.04	4.68	24.77	6.19	37.15	7.43
12.0	6.24	3.12	9.75	3.90	14.04	4.68	24.84	6.21	37.60	7.52
13.0	6.24	3.12	9.75	3.90	14.04	4.68	24.89	6.22	37.95	7.59
14.0	6.24	3.12	9.75	3.90	14.04	4.68	24.91	6.23	38.22	7.64
15.0	6.24	3.12	9.75	3.90	14.04	4.68	24.93	6.23	38.42	7.68
16.0	6.24	3.12	9.75	3.90	14.04	4.68	24.94	6.23	38.57	7.71
17.0	6.24	3.12	9.75	3.90	14.04	4.68	24.95	6.24	38.68	7.74
18.0	6.24	3.12	9.75	3.90	14.04	4.68	24.95	6.24	38.77	7.75
19.0	6.24	3.12	9.75	3.90	14.04	4.68	24.95	6.24	38.83	7.77
20.0	6.24	3.12	9.75	3.90	14.04	4.68	24.95	6.24	38.87	7.77
Deepwater waves	6.24	3.12	9.75	3.90	14.04	4.68	24.96	6.24	38.99	7.80

Table 2 Cost Comparison of Embankment Method of Lakeshore Dike (Per Unit Length)

Work Item	Unit Cost (P)	Case 1		Case 2		Case 3		Case 4		Case 5		
		Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	
1. Excavation, dredger	m <sup>3</sup>	50	149	7,450	57	2,850	61	3,050	-	-	91	4,550
2. Excavation, dredged material incl. loading hauling & spreading	m <sup>3</sup>	30	-	-	57	1,710	-	-	-	-	-	-
3. Excavation, borrowed material incl. loading hauling & spreading	m <sup>3</sup>	100	-	-	37	3,700	41	4,100	91	9,100	-	-
4. Embankment, dredged material	m <sup>3</sup>	40	149	5,960	-	-	61	2,440	-	-	-	-
5. Compacting, borrowed material	m <sup>3</sup>	5	-	-	-	-	41	210	91	460	-	-
6. Embankment, mixed soil with dredged material & borrowed material incl. mixing	m <sup>3</sup>	40	-	-	94	3,760	-	-	-	-	-	-
7. Embankment, soil cement incl. mixing	m <sup>3</sup>	45	-	-	-	-	-	-	-	-	91	4,100
8. Cement (0.08 t/m <sup>3</sup> )	ton	1,450	-	-	-	-	-	-	-	-	7.3	10,590
9. Revetment	m <sup>2</sup>	600	26.1	15,660	10.4	6,240	12.8	7,680	8.5	5,100	8.5	5,100
10. Preparatory works (20%)	L.S.	-	-	5,810	-	3,650	-	3,500	-	2,930	-	4,870
Total				34,880		21,910		20,980		17,590		29,210





$H_{1/3}$ : wave height of one-third significant wave  
 $U_{10}$ : wind velocity (10 m above water surface)  
 $F$ : fetch length  
 $h$ : water depth  
 Coefficient of roughness  $f$  is 0.01.

Fig. 1 Relation between Wave Height, Wind Velocity, and Fetch Length of Shallow Wave under Constant Water Depth (Bretschneider's Curve)

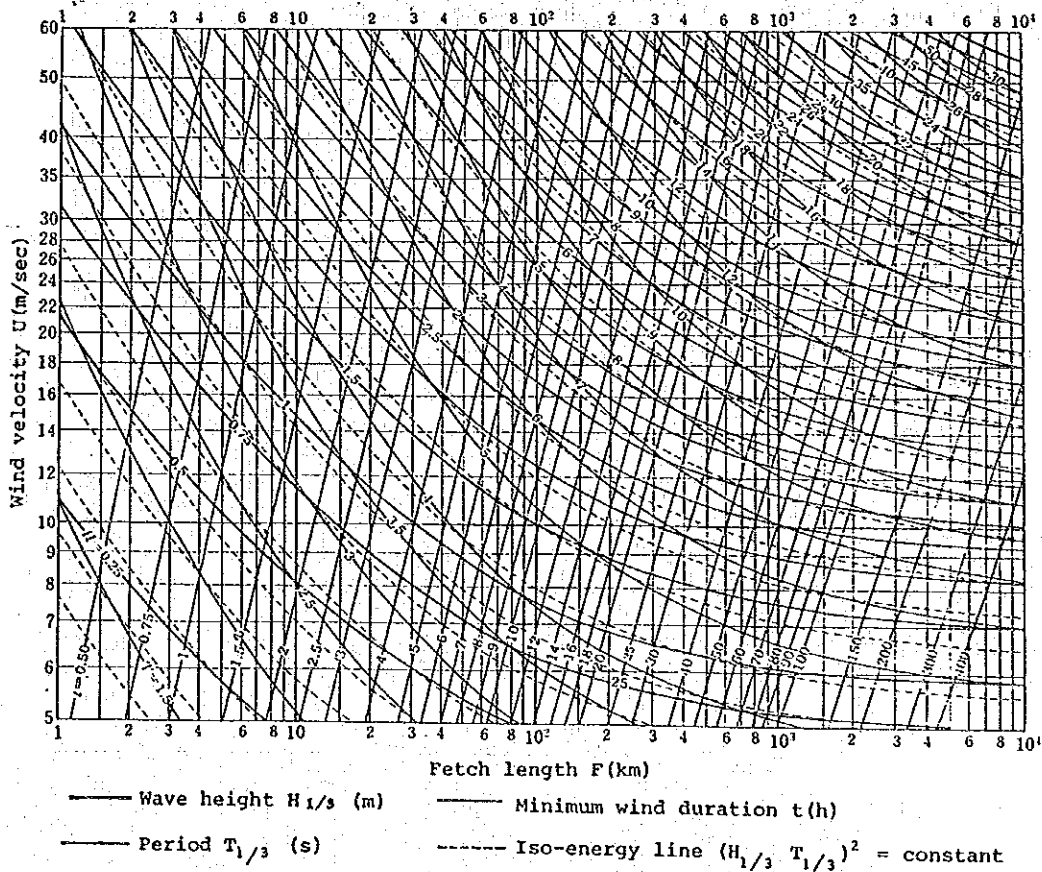
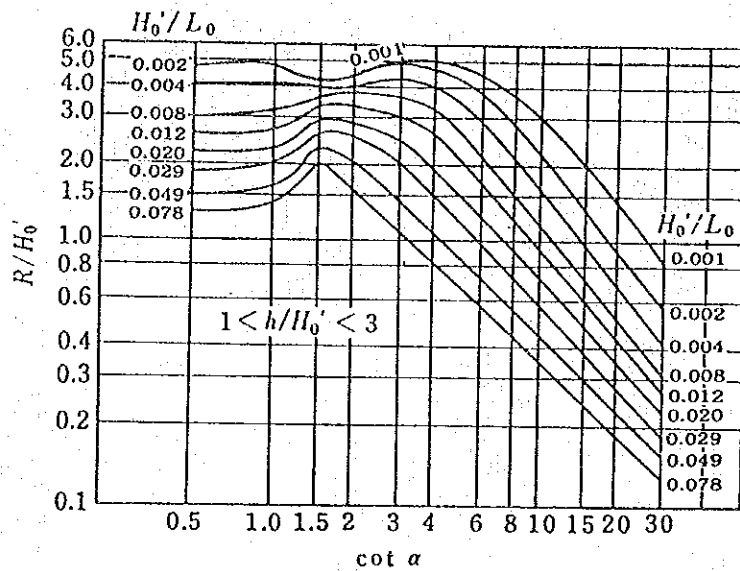


Fig. 2 Wind Wave Prediction Curves (corrected by Wilson's formula, 1956)



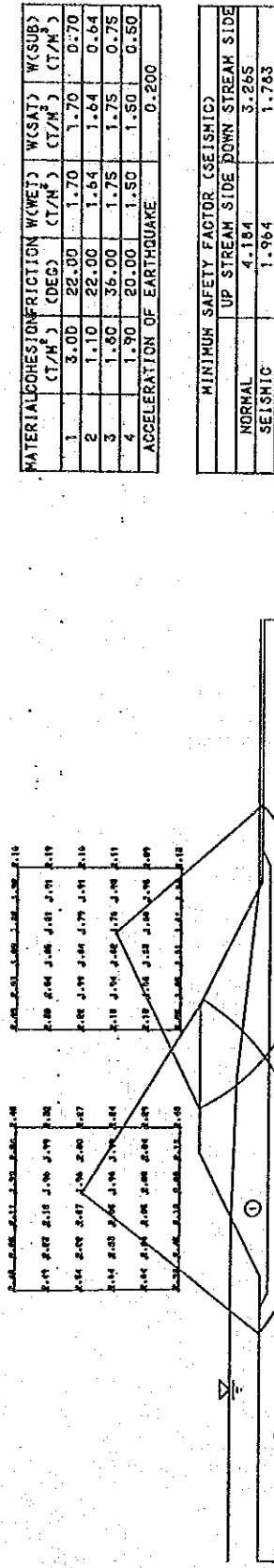
- $\alpha$  : angle of slope between horizontal plane
- $H_0'$  : height of wave
- $L_0$  : length of wave
- $h$  : water depth
- $R$  : wave setup

Fig. 3 Wave Setup to Tidal Dike  
(Saville's Curve)

LAKESHORE DIKE .CASE 4-1 (SLOPE=1:2,C=3.0,PAI=22.0,HWL.B=9.10)  
 S T A B I L I T Y A N A L Y S I S

2.18	2.19	2.20	2.21	2.22	2.23	2.24	2.25	2.26	2.27	2.28	2.29	2.30	2.31	2.32	2.33	2.34	2.35	2.36	2.37	2.38	2.39	2.40	2.41	2.42	2.43	2.44	2.45	2.46	2.47	2.48	2.49	2.50	2.51	2.52	2.53	2.54	2.55	2.56	2.57	2.58	2.59	2.60	2.61	2.62	2.63	2.64	2.65	2.66	2.67	2.68	2.69	2.70	2.71	2.72	2.73	2.74	2.75	2.76	2.77	2.78	2.79	2.80	2.81	2.82	2.83	2.84	2.85	2.86	2.87	2.88	2.89	2.90	2.91	2.92	2.93	2.94	2.95	2.96	2.97	2.98	2.99	3.00	3.01	3.02	3.03	3.04	3.05	3.06	3.07	3.08	3.09	3.10	3.11	3.12	3.13	3.14	3.15	3.16	3.17	3.18	3.19	3.20	3.21	3.22	3.23	3.24	3.25	3.26	3.27	3.28	3.29	3.30	3.31	3.32	3.33	3.34	3.35	3.36	3.37	3.38	3.39	3.40	3.41	3.42	3.43	3.44	3.45	3.46	3.47	3.48	3.49	3.50	3.51	3.52	3.53	3.54	3.55	3.56	3.57	3.58	3.59	3.60	3.61	3.62	3.63	3.64	3.65	3.66	3.67	3.68	3.69	3.70	3.71	3.72	3.73	3.74	3.75	3.76	3.77	3.78	3.79	3.80	3.81	3.82	3.83	3.84	3.85	3.86	3.87	3.88	3.89	3.90	3.91	3.92	3.93	3.94	3.95	3.96	3.97	3.98	3.99	4.00	4.01	4.02	4.03	4.04	4.05	4.06	4.07	4.08	4.09	4.10	4.11	4.12	4.13	4.14	4.15	4.16	4.17	4.18	4.19	4.20	4.21	4.22	4.23	4.24	4.25	4.26	4.27	4.28	4.29	4.30	4.31	4.32	4.33	4.34	4.35	4.36	4.37	4.38	4.39	4.40	4.41	4.42	4.43	4.44	4.45	4.46	4.47	4.48	4.49	4.50	4.51	4.52	4.53	4.54	4.55	4.56	4.57	4.58	4.59	4.60	4.61	4.62	4.63	4.64	4.65	4.66	4.67	4.68	4.69	4.70	4.71	4.72	4.73	4.74	4.75	4.76	4.77	4.78	4.79	4.80	4.81	4.82	4.83	4.84	4.85	4.86	4.87	4.88	4.89	4.90	4.91	4.92	4.93	4.94	4.95	4.96	4.97	4.98	4.99	5.00	5.01	5.02	5.03	5.04	5.05	5.06	5.07	5.08	5.09	5.10	5.11	5.12	5.13	5.14	5.15	5.16	5.17	5.18	5.19	5.20	5.21	5.22	5.23	5.24	5.25	5.26	5.27	5.28	5.29	5.30	5.31	5.32	5.33	5.34	5.35	5.36	5.37	5.38	5.39	5.40	5.41	5.42	5.43	5.44	5.45	5.46	5.47	5.48	5.49	5.50	5.51	5.52	5.53	5.54	5.55	5.56	5.57	5.58	5.59	5.60	5.61	5.62	5.63	5.64	5.65	5.66	5.67	5.68	5.69	5.70	5.71	5.72	5.73	5.74	5.75	5.76	5.77	5.78	5.79	5.80	5.81	5.82	5.83	5.84	5.85	5.86	5.87	5.88	5.89	5.90	5.91	5.92	5.93	5.94	5.95	5.96	5.97	5.98	5.99	6.00	6.01	6.02	6.03	6.04	6.05	6.06	6.07	6.08	6.09	6.10	6.11	6.12	6.13	6.14	6.15	6.16	6.17	6.18	6.19	6.20	6.21	6.22	6.23	6.24	6.25	6.26	6.27	6.28	6.29	6.30	6.31	6.32	6.33	6.34	6.35	6.36	6.37	6.38	6.39	6.40	6.41	6.42	6.43	6.44	6.45	6.46	6.47	6.48	6.49	6.50	6.51	6.52	6.53	6.54	6.55	6.56	6.57	6.58	6.59	6.60	6.61	6.62	6.63	6.64	6.65	6.66	6.67	6.68	6.69	6.70	6.71	6.72	6.73	6.74	6.75	6.76	6.77	6.78	6.79	6.80	6.81	6.82	6.83	6.84	6.85	6.86	6.87	6.88	6.89	6.90	6.91	6.92	6.93	6.94	6.95	6.96	6.97	6.98	6.99	7.00	7.01	7.02	7.03	7.04	7.05	7.06	7.07	7.08	7.09	7.10	7.11	7.12	7.13	7.14	7.15	7.16	7.17	7.18	7.19	7.20	7.21	7.22	7.23	7.24	7.25	7.26	7.27	7.28	7.29	7.30	7.31	7.32	7.33	7.34	7.35	7.36	7.37	7.38	7.39	7.40	7.41	7.42	7.43	7.44	7.45	7.46	7.47	7.48	7.49	7.50	7.51	7.52	7.53	7.54	7.55	7.56	7.57	7.58	7.59	7.60	7.61	7.62	7.63	7.64	7.65	7.66	7.67	7.68	7.69	7.70	7.71	7.72	7.73	7.74	7.75	7.76	7.77	7.78	7.79	7.80	7.81	7.82	7.83	7.84	7.85	7.86	7.87	7.88	7.89	7.90	7.91	7.92	7.93	7.94	7.95	7.96	7.97	7.98	7.99	8.00	8.01	8.02	8.03	8.04	8.05	8.06	8.07	8.08	8.09	8.10	8.11	8.12	8.13	8.14	8.15	8.16	8.17	8.18	8.19	8.20	8.21	8.22	8.23	8.24	8.25	8.26	8.27	8.28	8.29	8.30	8.31	8.32	8.33	8.34	8.35	8.36	8.37	8.38	8.39	8.40	8.41	8.42	8.43	8.44	8.45	8.46	8.47	8.48	8.49	8.50	8.51	8.52	8.53	8.54	8.55	8.56	8.57	8.58	8.59	8.60	8.61	8.62	8.63	8.64	8.65	8.66	8.67	8.68	8.69	8.70	8.71	8.72	8.73	8.74	8.75	8.76	8.77	8.78	8.79	8.80	8.81	8.82	8.83	8.84	8.85	8.86	8.87	8.88	8.89	8.90	8.91	8.92	8.93	8.94	8.95	8.96	8.97	8.98	8.99	9.00	9.01	9.02	9.03	9.04	9.05	9.06	9.07	9.08	9.09	9.10	9.11	9.12	9.13	9.14	9.15	9.16	9.17	9.18	9.19	9.20	9.21	9.22	9.23	9.24	9.25	9.26	9.27	9.28	9.29	9.30	9.31	9.32	9.33	9.34	9.35	9.36	9.37	9.38	9.39	9.40	9.41	9.42	9.43	9.44	9.45	9.46	9.47	9.48	9.49	9.50	9.51	9.52	9.53	9.54	9.55	9.56	9.57	9.58	9.59	9.60	9.61	9.62	9.63	9.64	9.65	9.66	9.67	9.68	9.69	9.70	9.71	9.72	9.73	9.74	9.75	9.76	9.77	9.78	9.79	9.80	9.81	9.82	9.83	9.84	9.85	9.86	9.87	9.88	9.89	9.90	9.91	9.92	9.93	9.94	9.95	9.96	9.97	9.98	9.99	10.00	10.01	10.02	10.03	10.04	10.05	10.06	10.07	10.08	10.09	10.10	10.11	10.12	10.13	10.14	10.15	10.16	10.17	10.18	10.19	10.20	10.21	10.22	10.23	10.24	10.25	10.26	10.27	10.28	10.29	10.30	10.31	10.32	10.33	10.34	10.35	10.36	10.37	10.38	10.39	10.40	10.41	10.42	10.43	10.44	10.45	10.46	10.47	10.48	10.49	10.50	10.51	10.52	10.53	10.54	10.55	10.56	10.57	10.58	10.59	10.60	10.61	10.62	10.63	10.64	10.65	10.66	10.67	10.68	10.69	10.70	10.71	10.72	10.73	10.74	10.75	10.76	10.77	10.78	10.79	10.80	10.81	10.82	10.83	10.84	10.85	10.86	10.87	10.88	10.89	10.90	10.91	10.92	10.93	10.94	10.95	10.96	10.97	10.98	10.99	11.00	11.01	11.02	11.03	11.04	11.05	11.06	11.07	11.08	11.09	11.10	11.11	11.12	11.13	11.14	11.15	11.16	11.17	11.18	11.19	11.20	11.21	11.22	11.23	11.24	11.25	11.26	11.27	11.28	11.29	11.30	11.31	11.32	11.33	11.34	11.35	11.36	11.37	11.38	11.39	11.40	11.41	11.42	11.43	11.44	11.45	11.46	11.47	11.48	11.49	11.50	11.51	11.52	11.53	11.54	11.55	11.56	11.57	11.58	11.59	11.60	11.61	11.62	11.63	11.64	11.65	11.66	11.67	11.68	11.69	11.70	11.71	11.72	11.73	11.74	11.75	11.76	11.77	11.78	11.79	11.80	11.81	11.82	11.83	11.84	11.85	11.86	11.87	11.88	11.89	11.90	11.91	11.92	11.93	11.94	11.95	11.96	11.97	11.98	11.99	12.00	12.01	12.02	12.03	12.04	12.05	12.06	12.07	12.08	12.09	12.10	12.11	12.12	12.13	12.14	12.15	12.16	12.17	12.18	12.19	12.20	12.21	12.22	12.23	12.24	12.25	12.26	12.27	12.28	12.29	12.30	12.31	12.32	12.33	12.34	12.35	12.36	12.37	12.38	12.39	12.40	12.41	12.42	12.43	12.44	12.45	12.46	12.47	12.48	12.49	12.50	12.51	12.52	12.53	12.54	12.55	12.56	12.57	12.58	12.59	12.60	12.61	12.62	12.63	12.64	12.65	12.66	12.67	12.68	12.69	12.70	12.71	12.72	12.73	12.74	12.75	12.76	12.77	12.78	12.79	12.80	12.81	12.82	12.83	12.84	12.85	12.86	12.87	12.88	12.89	12.90	12.91	12.92	12.93	12.94	12.95	12.96	12.97	12.98	12.99	13.00	13.01	13.02	13.03	13.04	13.05	13.06	13.07	13.08	13.09	13.10	13.11	13.12	13.13	13.14	13.15	13.16	13.17	13.18	13.19	13.20	13.21	13.22	13.23	13.24	13.25	13.26	13.27	13.28	13.29	13.30	13.31	13.32	13.33	13.34	13.35	13.36	13.37	13.38	13.39	13.40	13.41	13.42	13.43	13.44	13.45	13.46	13.47	13.48	13.49	13.50	13.51	13.52	13.53	13.54	13.55	13.56	13.57	13.58	13.59	13.60	13.61	13.62	13.63	13.64	13.65	13.66	13.67	13.68	13.69	13.70	13.71	13.72	13.73	13.74	13.75	13.76	13.77	13.78	13.79	13.80	13.81	13.82	13.83	13.84	13.85	13.86	13.87	13.88	13.89	13.90	13.91	13.92	13.93	13.94	13.95	13.96	13.97	13.98	13.99	14.00	14.01	14.02	14.03	14.04	14.05	14.06	14.07	14.08	14.09	14.10	14.11	14.12	14.13	14.14	14.15	14.16	14.17	14.18	14.19	14.20	14.21	14.22	14.23	14.24	14.25	14.26	14.27	14.28	14.29	14.30	14.31	14.32	14.33	14.34	14.35	14.36	14.37	14.38	14.39	14.40	14.41	14.42	14.43	14.44	14.45	14.46	14.47	14.48	14.49	14.50	14.51	14.52	14.53	14.54	14.55	14.56	14.57	14.58	14.59	14.60	14.61	14.62	14.63	14.64	14.65	14.66	14.67	14.68	14.69	14.70	14.71	14.72	14.73	14.74	14.75	14.76	14.77	14.78	14.79	14.80	14.81	14.82	14.83	14.84	14.85	14.86	14.87	14.88	14.89	14.90	14.91	14.92	14.93	14.94	14.95	14.96	14.97	14.98	14.99	15.00	15.01	15.02	15.03	15.04	15.05	15.06	15.07	15.08	15.09	15.10	15.11	15.12	15.13	15.14	15.15	15.16	15.17	15.18	15.19	15.
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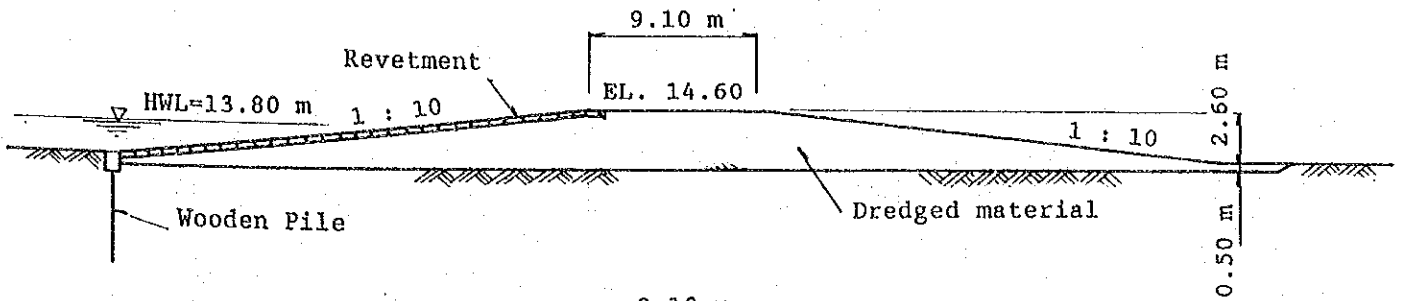
LAKESHORE DIKE, CASE 4 (SLOPE=1:2, C=3.0, PAI=22.0, HWL.B=9.10)  
 STABILITY ANALYSIS



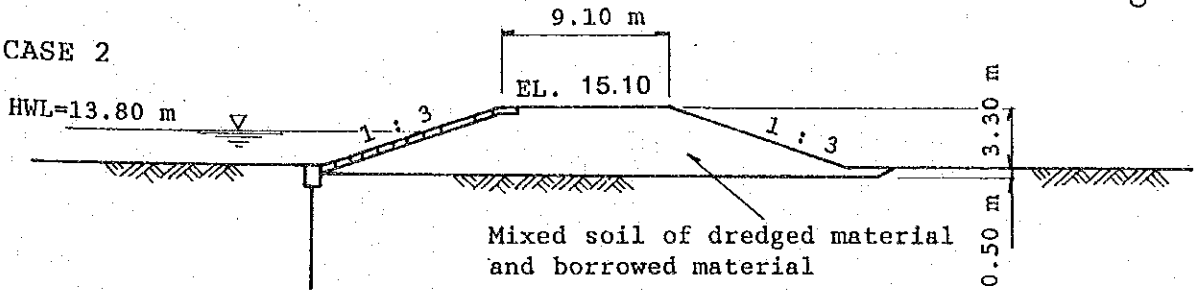
0 15.0 M  
 SCALE=1/300

Fig.4 Stability Analysis of the Lakeshore Dike (2/2)  
 (Case 4, Seismic Condition)

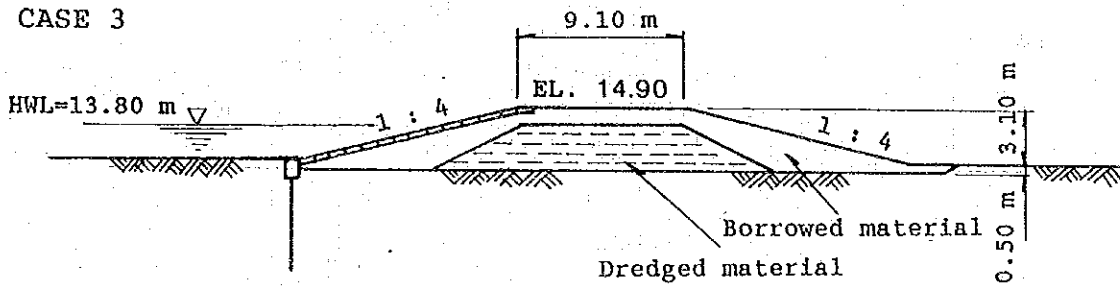
CASE 1



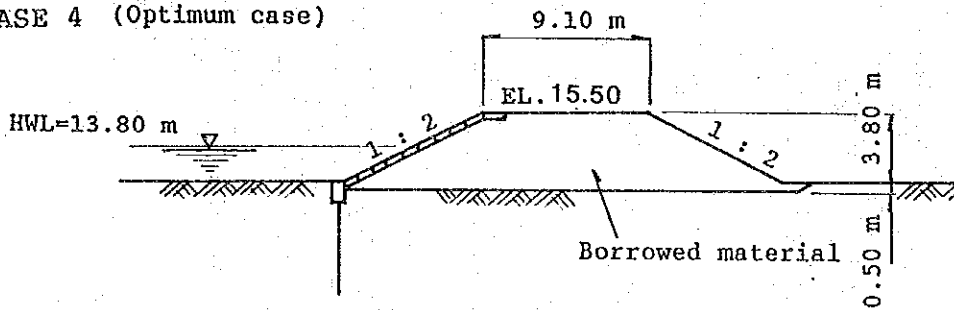
CASE 2



CASE 3



CASE 4 (Optimum case)



CASE 5

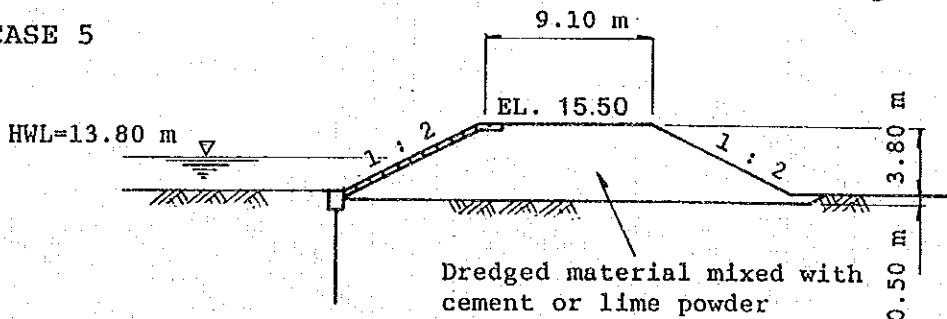
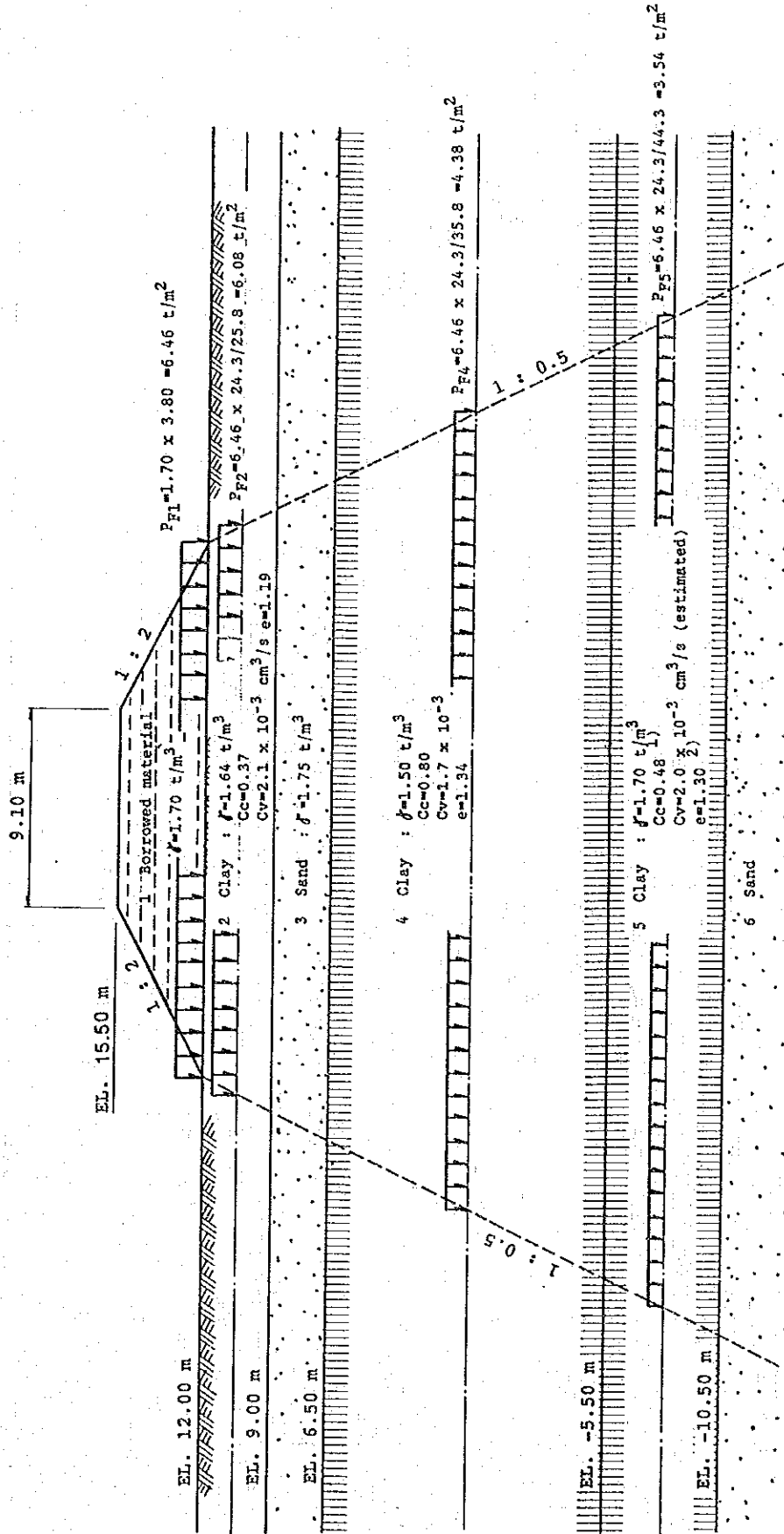


Fig. 5 Typical Sections for the Lakeshore Dike for Alternatives

- Notes;
- $f$  : unit weight ( $t/m^3$ )
  - $C_c$  : compression index
  - $C_v$  : Coefficient of consolidation ( $cm^2/s$ )
  - $e$  : void-ratio
  - $LL$  : liquid limit (%)
  - $G_s$  : specific gravity of soil substance
  - $G$  : specific gravity of soil



- Remarks :
- 1)  $C_c=0.009(LL-10)$   
 $=0.009 \times (63-10)$   
 $=0.48$
  - 2)  $e=(G_s-G)/(G-1)$   
 $= (2.61-1.70)/(1.70-1)$   
 $= 1.30$

Fig.6 Typical Model for Consolidation Settlement of Foundation of the Lakeshore Dike



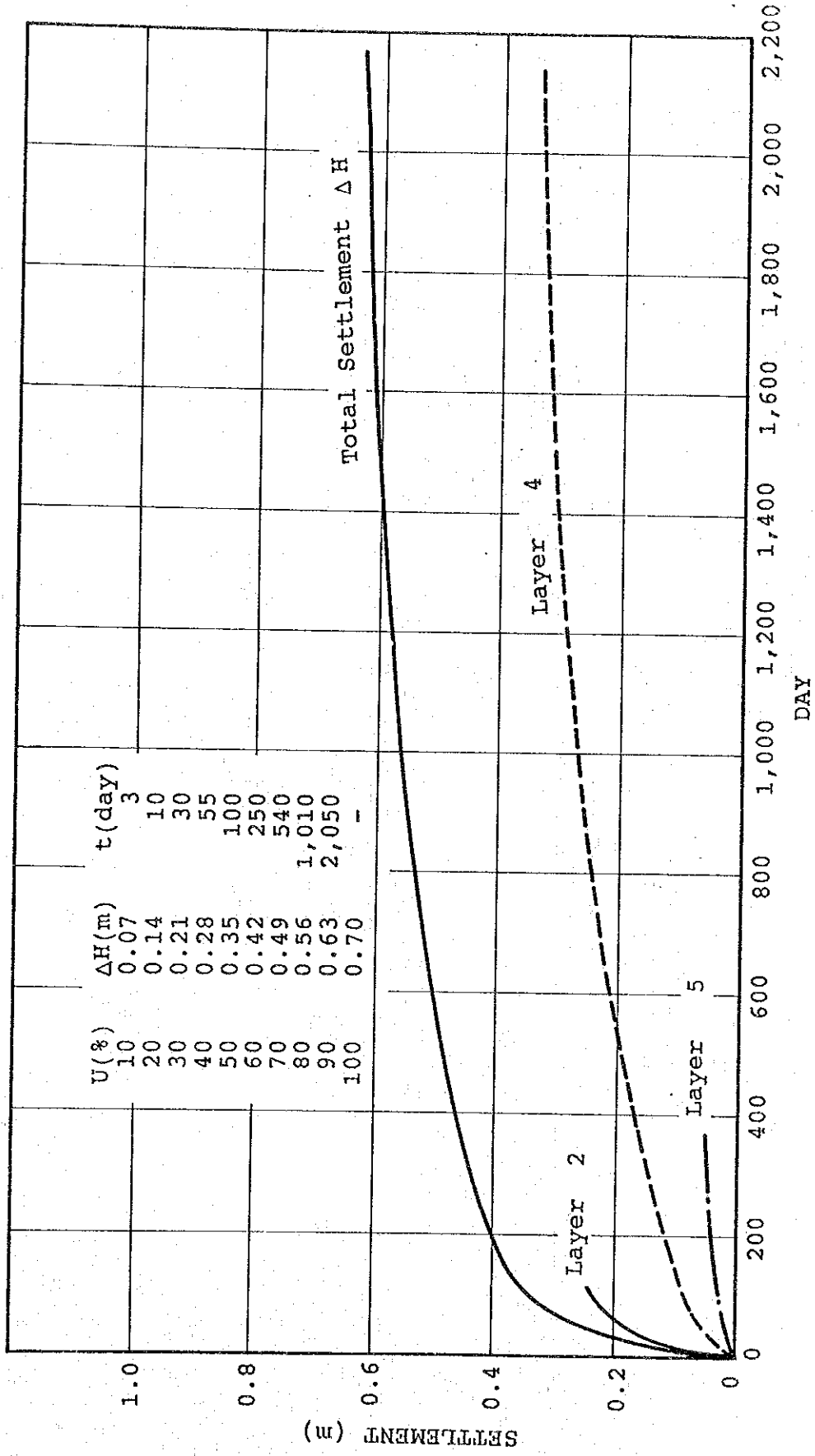
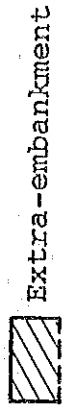
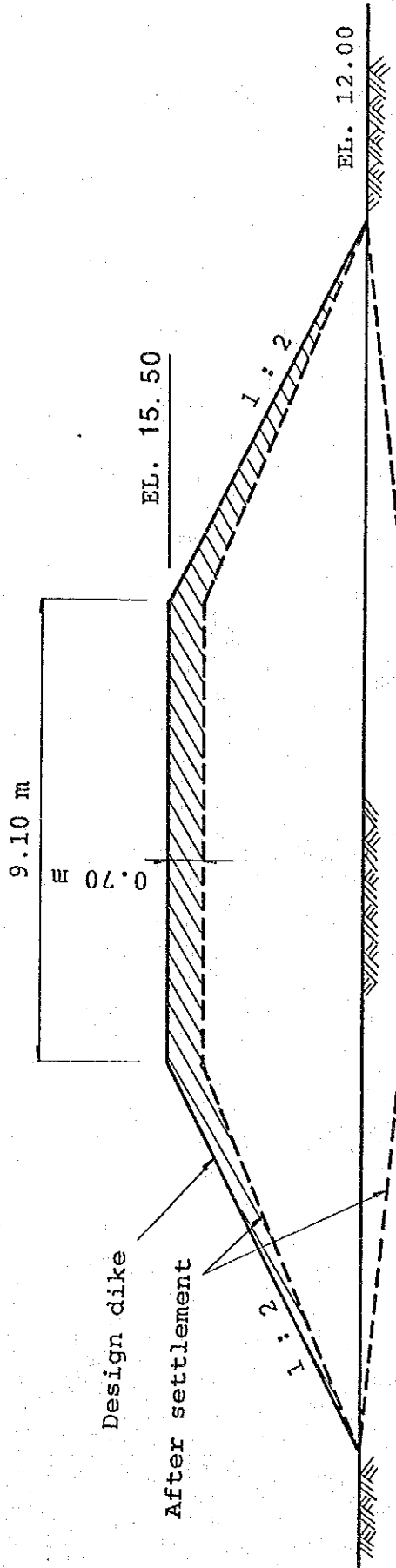


Fig. 7 Consolidation -Time Curve of Foundation of the Lakeshore Dike

LEGEND :



Extra-embankment



- 1). Design embankment :  $63.5 \text{ m}^2$
  - 2). Extra-embankment :  $11.7 \text{ m}^2$
- $11.7/63.5=18.4 \%$  — 20 %

Fig.8 Volume of Extra-Embankment of the Lakeshore Dike

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