(3) Permeability and groundwater in welded tuff: Permeability of welded tuff ranges from Lu = 8 to 18 ($k = 1 \times 10^{-4}$ to 2.7×10^{-4} cm/sec) proving a necessity of grout curtain in the foundation. Remarkable fact is that the groundwater table in welded tuff was very low as measured in B.K1-1 at the depth of 59 m and in B.K1-2 at the depth of 50 m. This fact may be caused on the low permeability of argillized volcanic ash covering welded tuff on the surface and on the rather high permeability of welded tuff. The complete foundation treatment will be required to cutt-off the seepage.

(4) Fault may rarely exist in the welded tuff which sedimented in relatively new geological period, namely, late-Pleistocene and did not suffer any vigorous tectonic disturbance.

3.4 Komering No.2 Damsite

3.4.1 Topography

The site is located at about 21 km southwestward of Muaradua, also 21 km northward of the Lake Ranau, and situated near the border between the hilly mountain land and the undulating hilly land. Topographical condition is very similar to Komering No.1 damsite. In the surroundings of the site, flat and wide terrace in a width of 300 m or more spreads over both banks at altitude of EL. 240 m - 270 m with gentle undulation.

The Selabung river dissects the terrace until EL. 173 m forming a very narrow gorge with a width of about 30 m and depth of about 50 m.

3.4.2 Geology

Welded tuff forms steep cliff along the gorge and is covered with terrace deposit in the flat and wide terrace. At about 300 m upstream and about 500 m downstream, the sandstone and marl of Telisa formation (Tertiary) crop out in the riverbed and are covered with welded tuff. Therefore, welded tuff may only distribute in the subsurface of flat terrace area so as to fill the old Selabung valley dissected in the Tertiary bedrock.

Welded tuff is greyish white coloured, more highly compacted and hard comparing to the Komering No.1 damsite, and composed of phenocryst of feldspar, quartz and mica and glassy but granule groundmass, containing large amount of pumices in the maximum diameter of 10 cm. Welded tuff has also a joint system consisting of joint of N15°W.80°S, namely, vertical joint extending to the direction of the Selabung at interval of 0.5 m - 2 m, and of joint of N70°E15°S, namely, horizontal joint slightly inclined toward upstream at interval of 1.5 m - 3 m.

The boundary between welded tuff and Tertiary sedimentary rocks is well compacted and interbeding a non-welded volcanic ash of yellowish white colored accompanied by pumices of small diameter of less than 2 cm. Any gravelly materials were not found during the observation of out-crops so far made.

Terrace deposit covers the welded tuff in the flat and wide terrace, and consists of yellow coloured sandy clay with semi-rounded gravel of sandstone and marl of Tertiary sedimentary rocks with the maximum diameter of 3 cm. Terrace deposit is rather soft and highly moistened according to the result of hand auger boring carried out in alternative dam site which is located at about 500 m upstream from the proposed damsite.

3.4.3 Dam Foundation

The geological condition in this damsite is very similar to the Komering No.1 damsite, so that the items to be discussed will be essentially same with that of Komering No.1 damsite, namely;

(1) Height of bedrock surface in the terrace is estimated as to be higher than EL. 255.00 m, the proposed crest of dam, based on the results of vertical electric sounding carried out in both of the bank, as shown in Fig. III-5.

(2) Bearing capacity of welded tuff; The degree of welding of the tuff in this damsite seems to be so high as to hardly allow a breaking by hand-hammer, and the bearing capacity, namely, shearing strength, of welded tuff may be much higher than that of Komering No.1 damsite.

However, the shearing strength of welded tuff in this damsite might not exceed $\tau_o = 15$ kg/cm^2 in any case. In consideration of higher shearing strength and lower height of dam comparing to Komering No.1 damsite, a concrete-gravity type may be applied to this site.

As for the following items, discussion will be omitted due to the quite same condition with Komering No.1 damsite, and reference will be made to paragraph 3.3.3.

(3) Permeability of welded tuff.

(4) Fault

Adding to the above items, this damsite has an essential problem on geological structure as follows;

(5) Location and condition of boundary between welded tuff and underlying sedimentary rocks of Telisa formation: Very hard and well compacted calcarious sandstone and marl layers of Telisa formation were seen in the river-bed of the Selabung in places within a distance of 500 m. At the dam site, the side walls of steep valley are composed of welded tuff so far observed, but the river-bed could not seen due to covers of flowing water. If the boundary runs at the considerable shallow depth below the river-bed, boundary condition especially existence of interbeding layer such as loose volcanic ash and old terrace or old river-bed deposits may affect the safety and construction cost of dam, even though both welded tuff and Telisa formation bounding on each other are sound enough as a dam foundation. This matter will be clarified by the proposed two (2) bore-holes to be drilled in this study.

3.5 Geology of Power Station Sites

3.5.1 Ranau Power Station

The Ranau power station is located in the margin of hills bounding on the high and wide terrace of the Selabung river, at about 9 km northwestward of the Lake Ranau.

The hills are composed of andestic volcanic products, chiefly of andesite lava and tuff, tuff-breccia in well consolidated condition.

The high terrace extends along the Selabung river with width of about 200 m, and is covered by sand and gravel in the maximum thickness of 14 m according to the results of vertical electric sounding. Sub-surface of terrace consists of welded tuff flowed down from the Ranau volcano in the past, under laid with andestic volcanic products at depth of 30 m to 40 m.

Ranau power station will be located in the subsurface of margin of hills, perhaps in the andestic volcanic products. The tail-race will penetrate the boundary between welded tuff and underlying andestic volcanic products, where old talus pile and/or old river-bed deposits might exist forming loose and pervious intercalation. This condition will be revealed by the proposed one bore-hole to be drilled up to depth of 100 m from the terrace in this study.

3.5.2 Komering No.1 Power Station

The site is located at about 5.5 km northeastward of the Komering No.1 damsite, and situated in the flat and wide terrace at the altitude ranging from 300 m to 400 m spreading over the left bank of the Selabung.

The terrace has a relative height of about 90 m above river-bed of Selabung and the power station will be constructed in the subsurface of the terrace.

Geology of the site consists of the welded tuff underlain by the Tertiary sedimentary rocks and also covered with acid volcanic ash at the ground surface. Rock condition in the site is essentially same with the Komering No.1 damsite, and the welded tuff might be sound enough to allow the construction of underground power station provided that the rock bolting in dense pattern be executed for underground excavation due to well developed joint system in the welded tuff.

3.5.3 Komering No.2 Power Station

The site is located in the right bank of the Selabung at about 2.5 km downstream of the Komering No.2 damsite and situated at the top of high terrace rising for about 90 m from the river-bed of the Selabung.

Geology of the site consists of welded tuff and underlying sedimentary rocks of Tertiary. The sedimentary rocks distribute in the lower part of terrace scarp below EL. 250 m, and the welded tuff forms the higher terrace scarp. Therefore, the proposed facilities may be founded on the sedimentary rocks consisting of well compacted calcarious sandstone and mudstone.

The headrace tunnel will penetrate the welded tuff in its upper reach and the sedimentary rocks in its lower reach.

Those rocks are essentially sound enough for the foundation of proposed facilities but the boundary between the sedimentary rocks and welded tuff should carefully be investigated for the detailed design.

3.6 Quarry Site

The possible quarry sites will be situated in the area of andestic volcanic products which distribute in the Ranau depression forming foreland of the Barisan mountains.

It is difficult to fix the sites at present due to thick covers of volcanic ash and inaccessibility of gorges dissected in the foreland. However, for example in Komering No.1 damsite a large amount of angular to semi-rounded andesite boulders spreads over the river-bed of the Selabung river, proving the distribution of andestic lava or dyke close to the damsite.

Further study be required for this matter.

Fig. III -- 1 GEOLOGICAL SKETCH MAP OF UPPER KOMERING BASIN

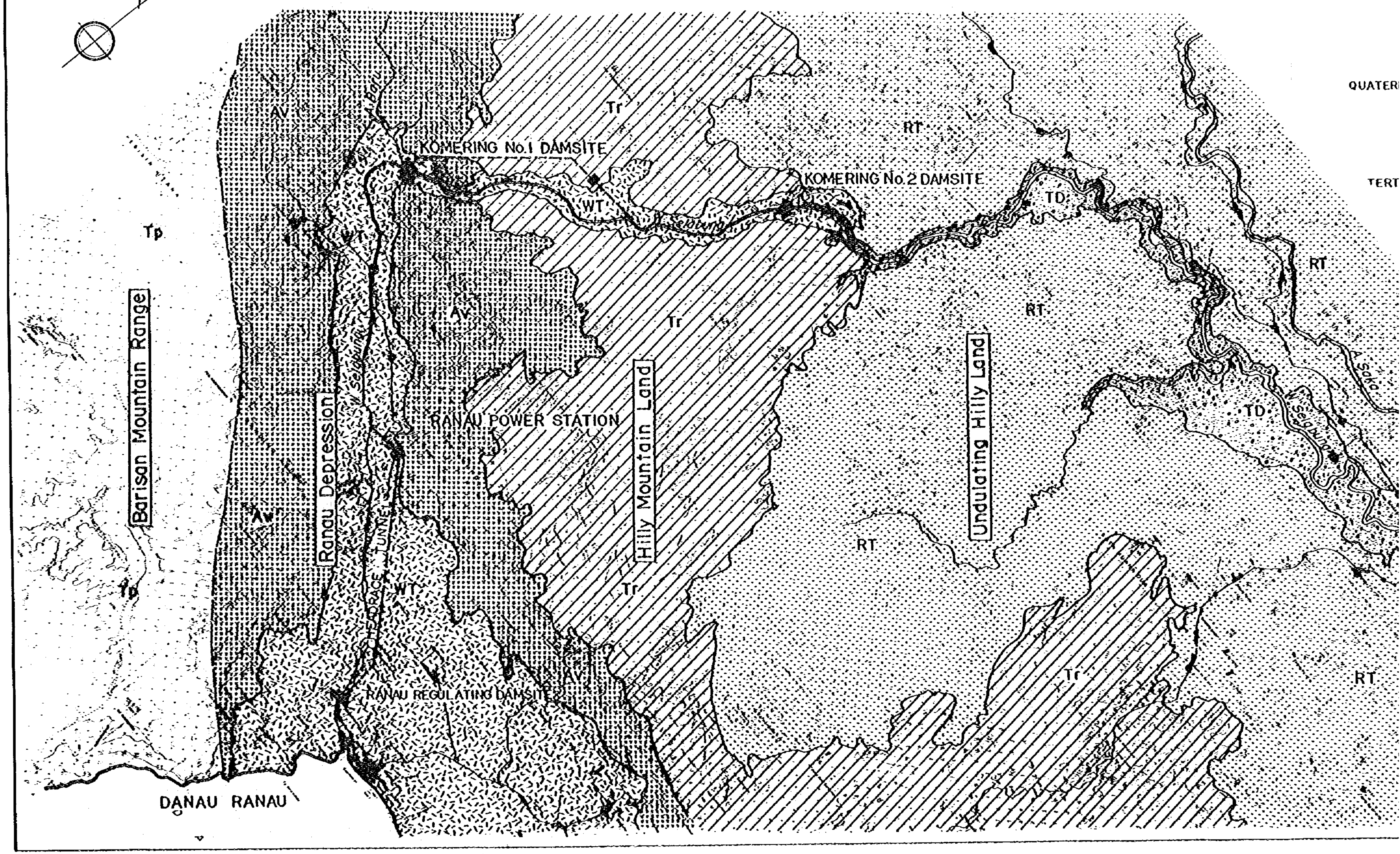
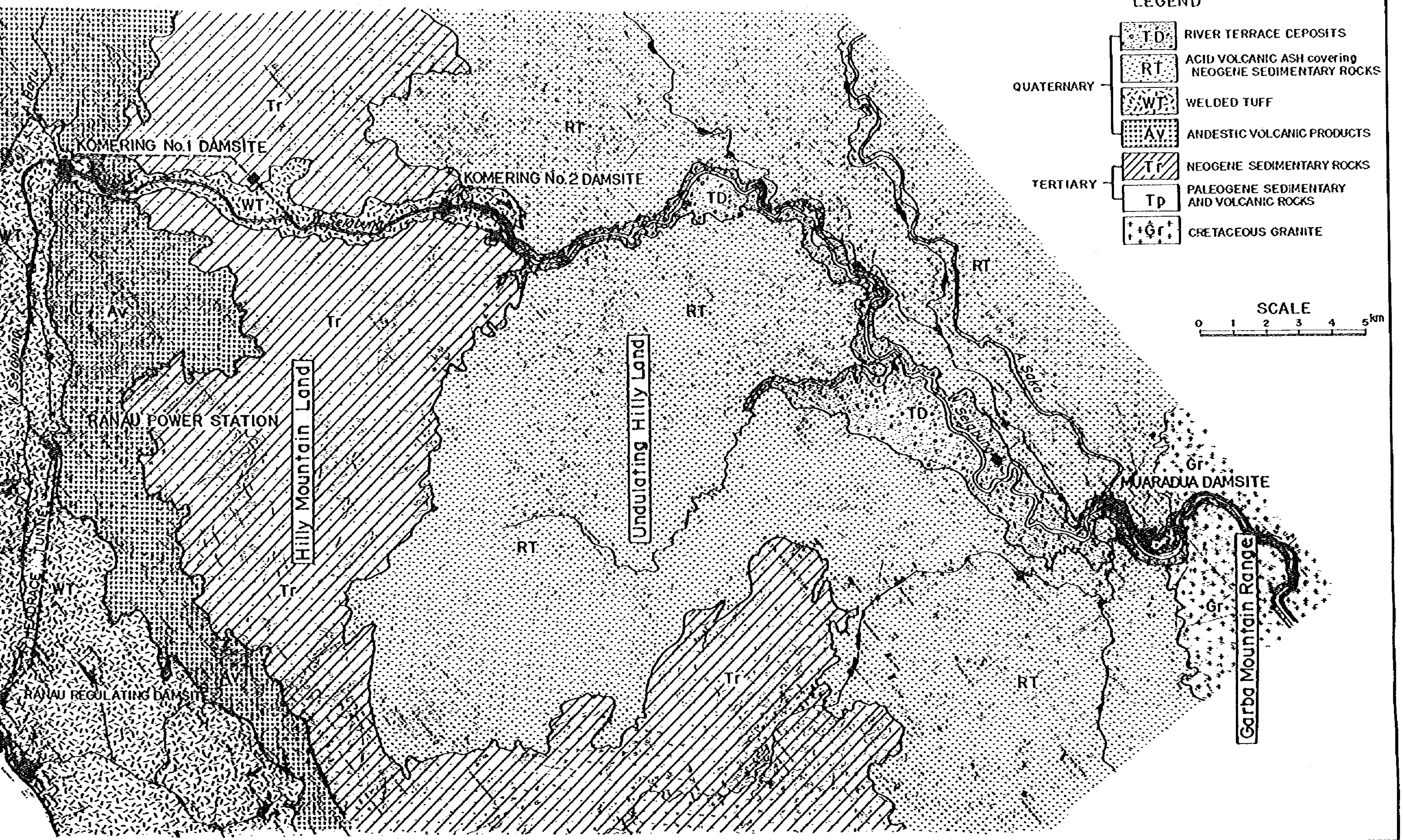


Fig. III - 1 GEOLOGICAL SKETCH MAP OF UPPER KOMERING BASIN



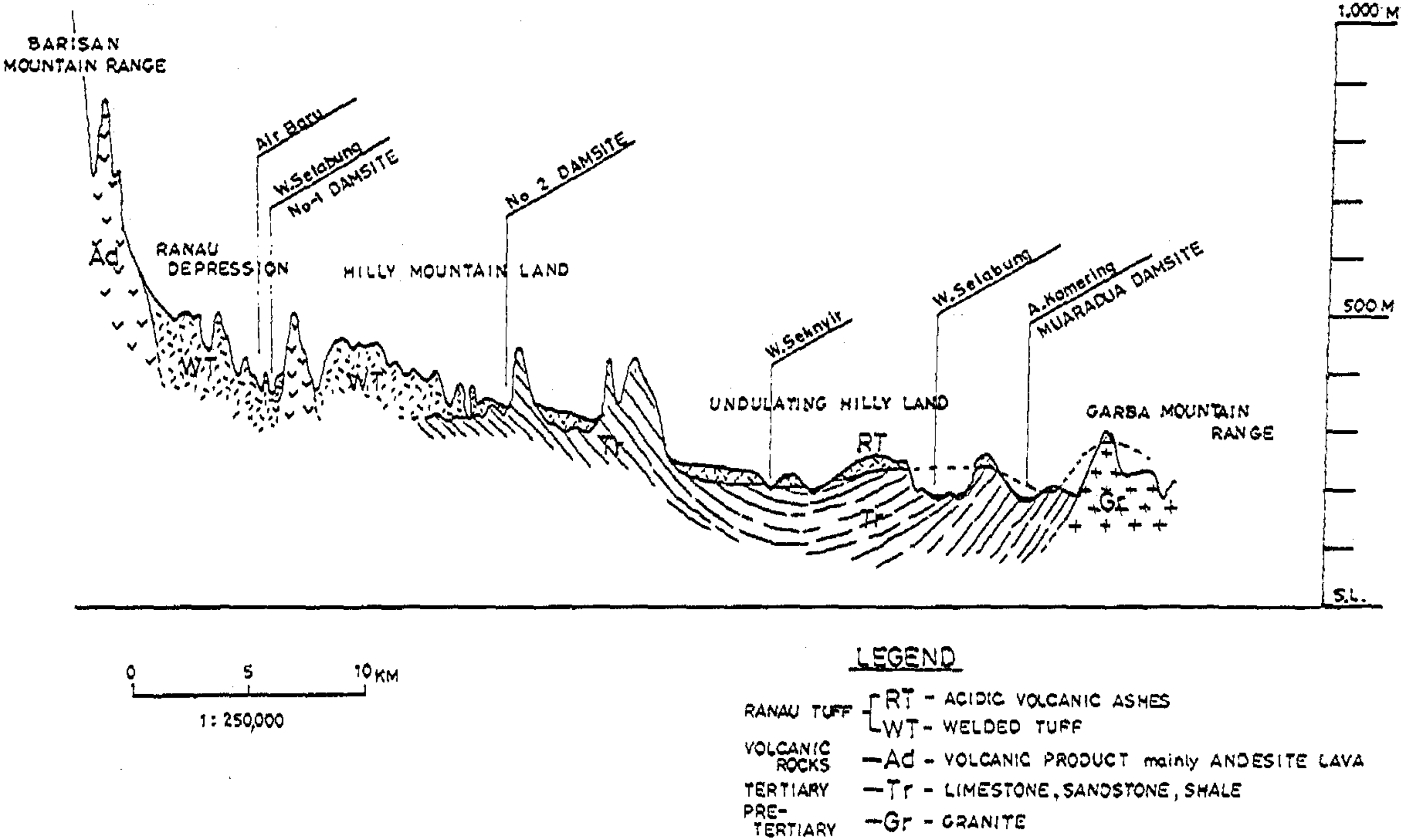
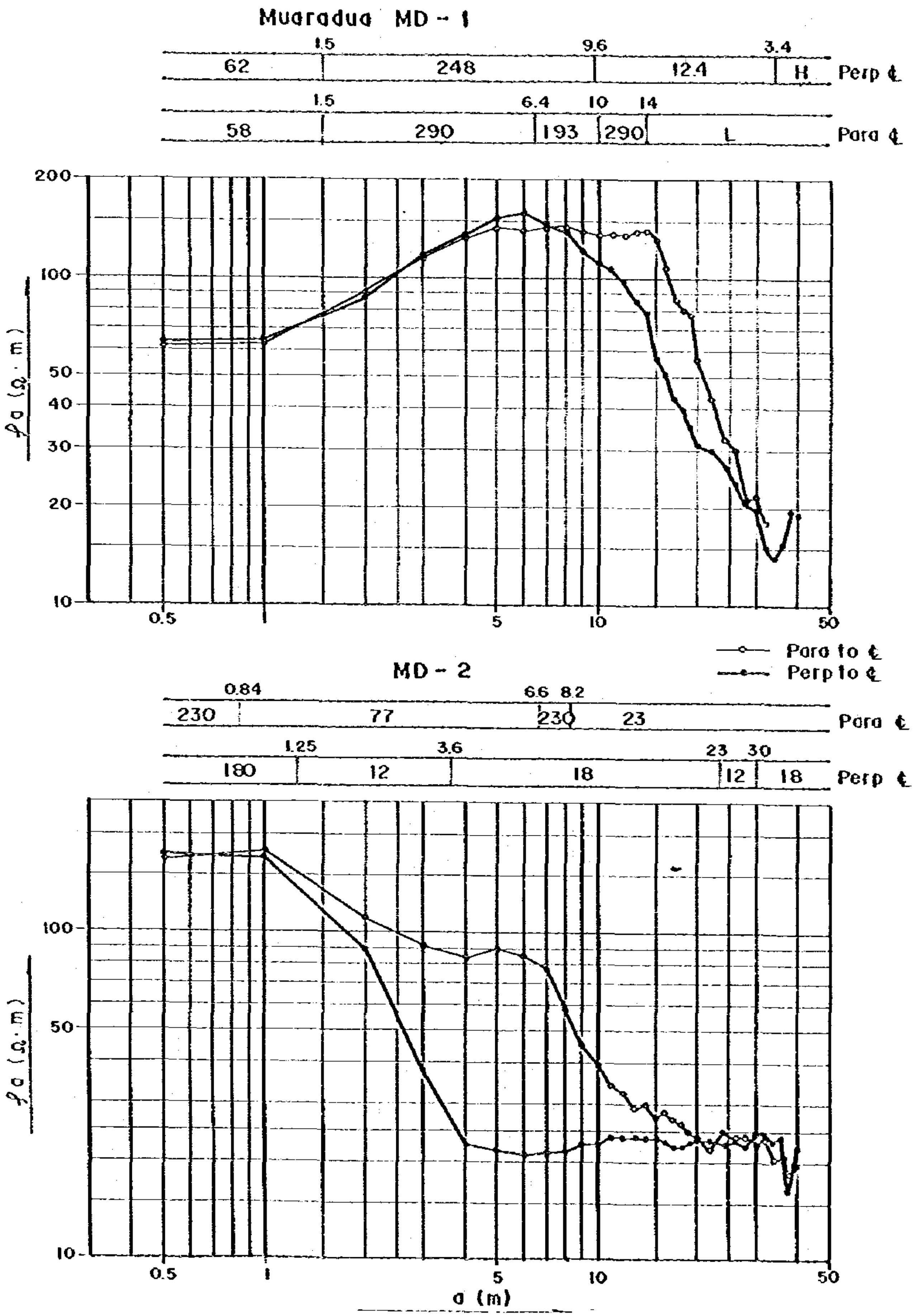
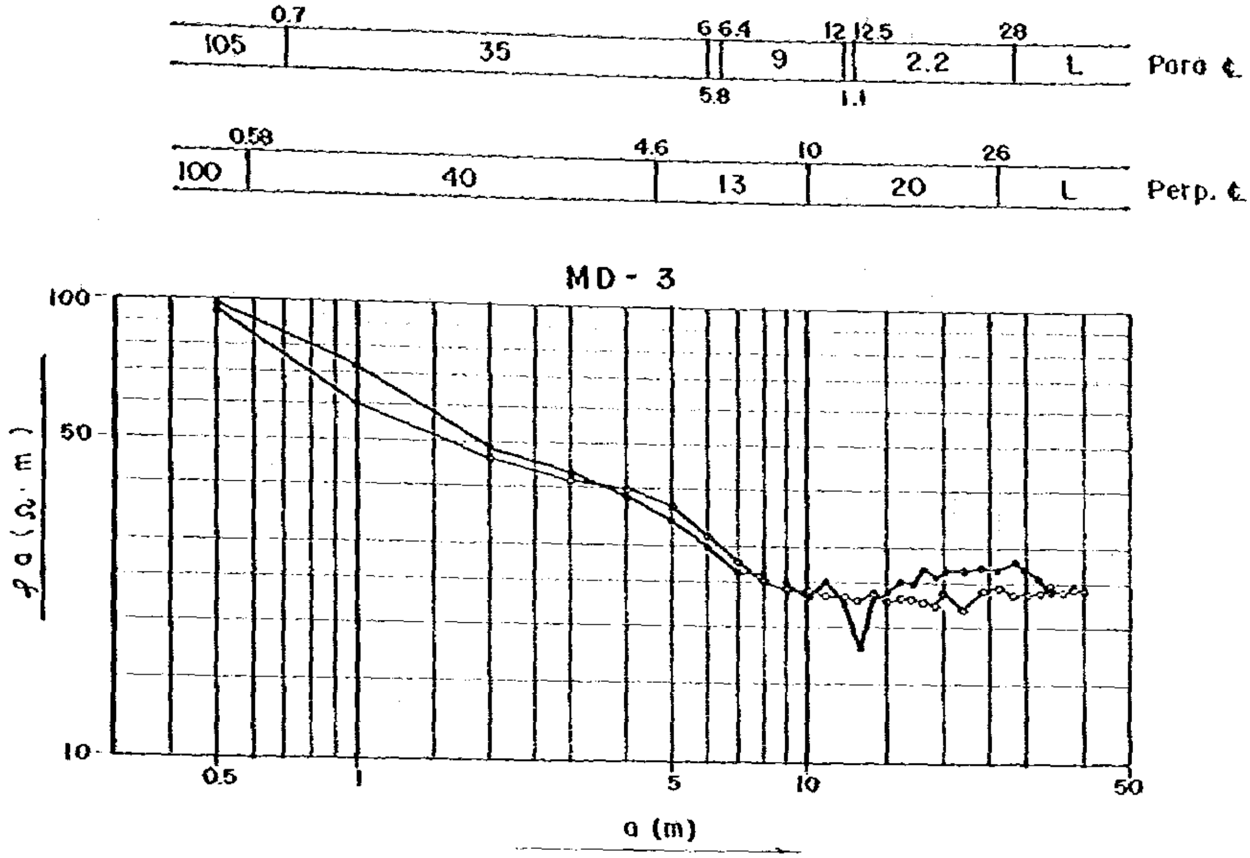
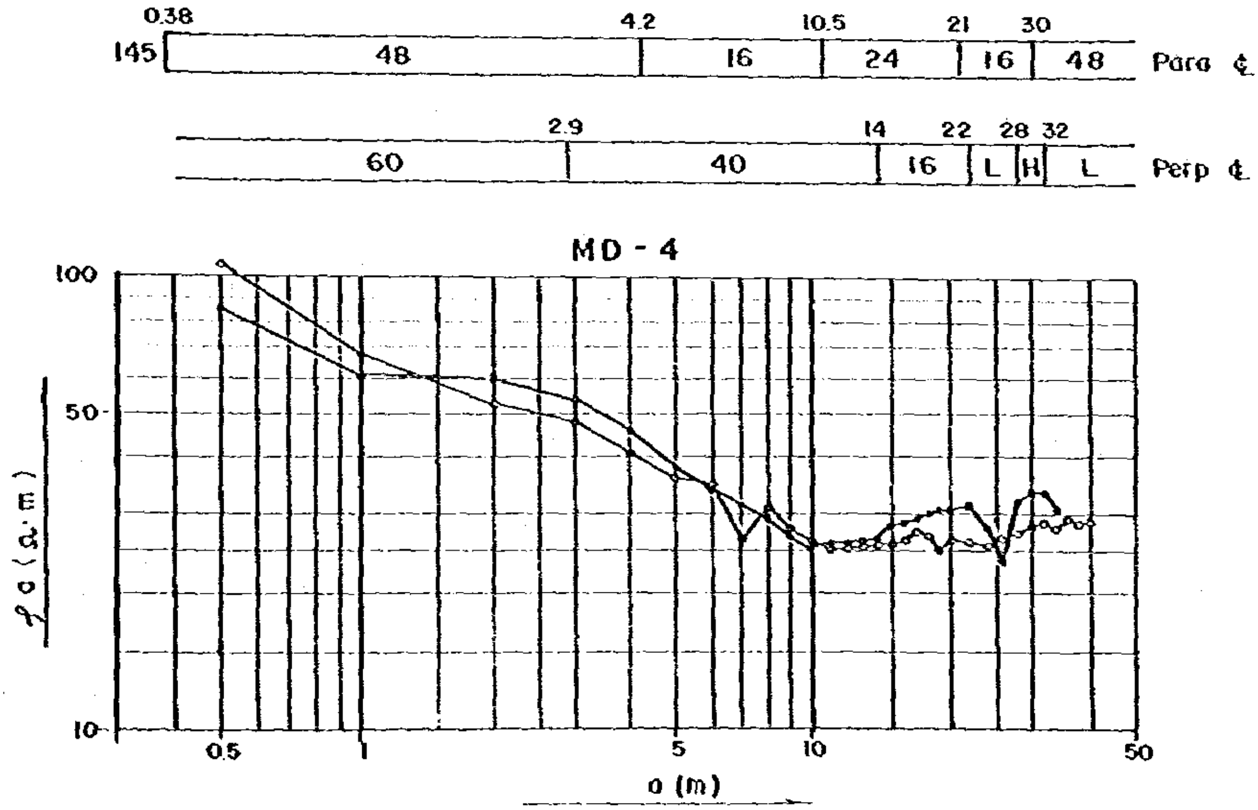


Fig III.2 SCHEMATIC GEOLOGICAL PROFILE of UPPER REACH of KOMERING

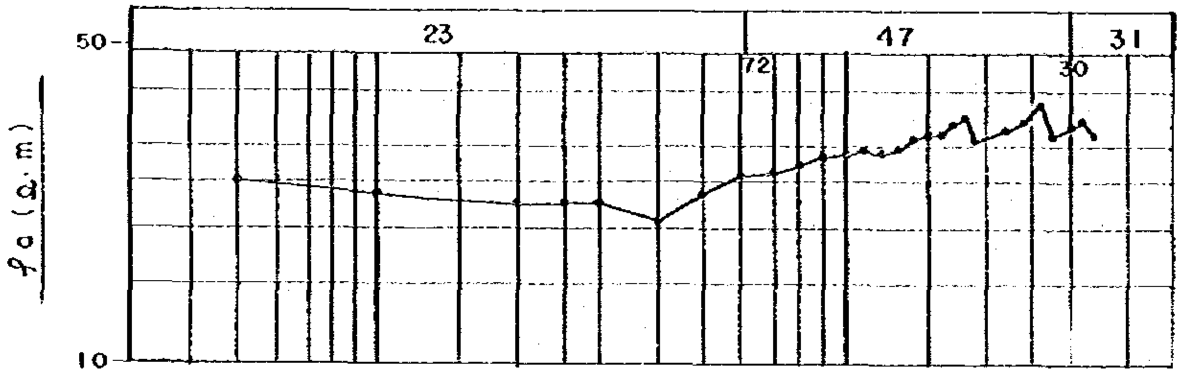
Fig. III - 3 Result of VES (ρ - a curve)




0.7
6 6.4
12 12.5
28
105
35
9
2.2
L
Para ¢
5.8
1.1
0.58
4.6
10
26
100
40
13
20
L
Perp. ¢
MD - 3
100
50
10
ρa (Ω·m)
0.5
1
5
10
50
a (m)

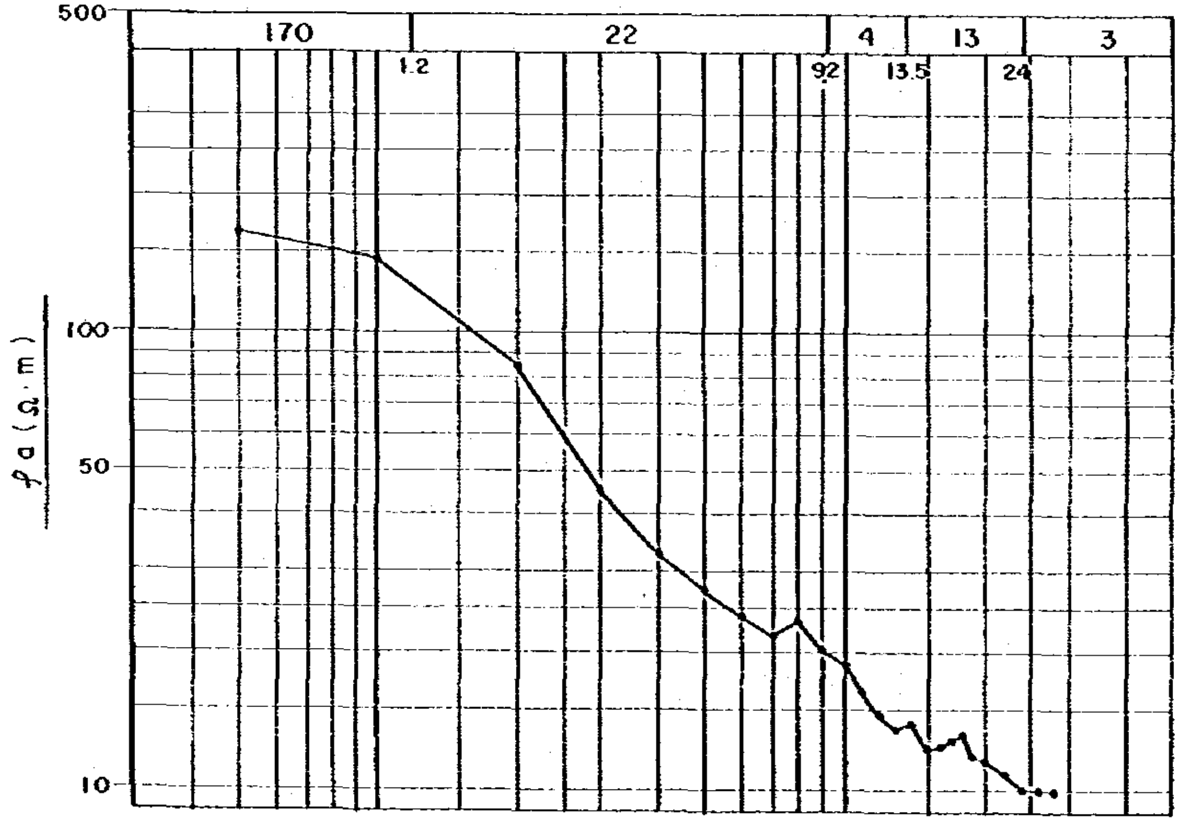

0.38
4.2
10.5
21
30
145
48
16
24
16
48
Para ¢
2.9
14
22
28
32
60
40
16
L
H
L
Perp ¢
MD - 4
100
50
10
ρa (Ω·m)
0.5
1
5
10
50
a (m)

MD - 5



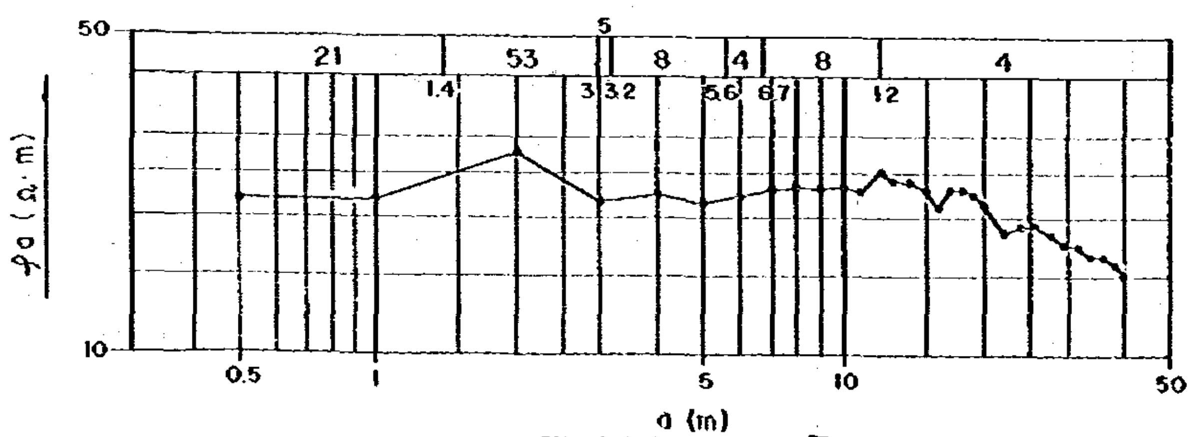
23
47
31
72
30
50
10
ρa (Ω·m)

MD - 6



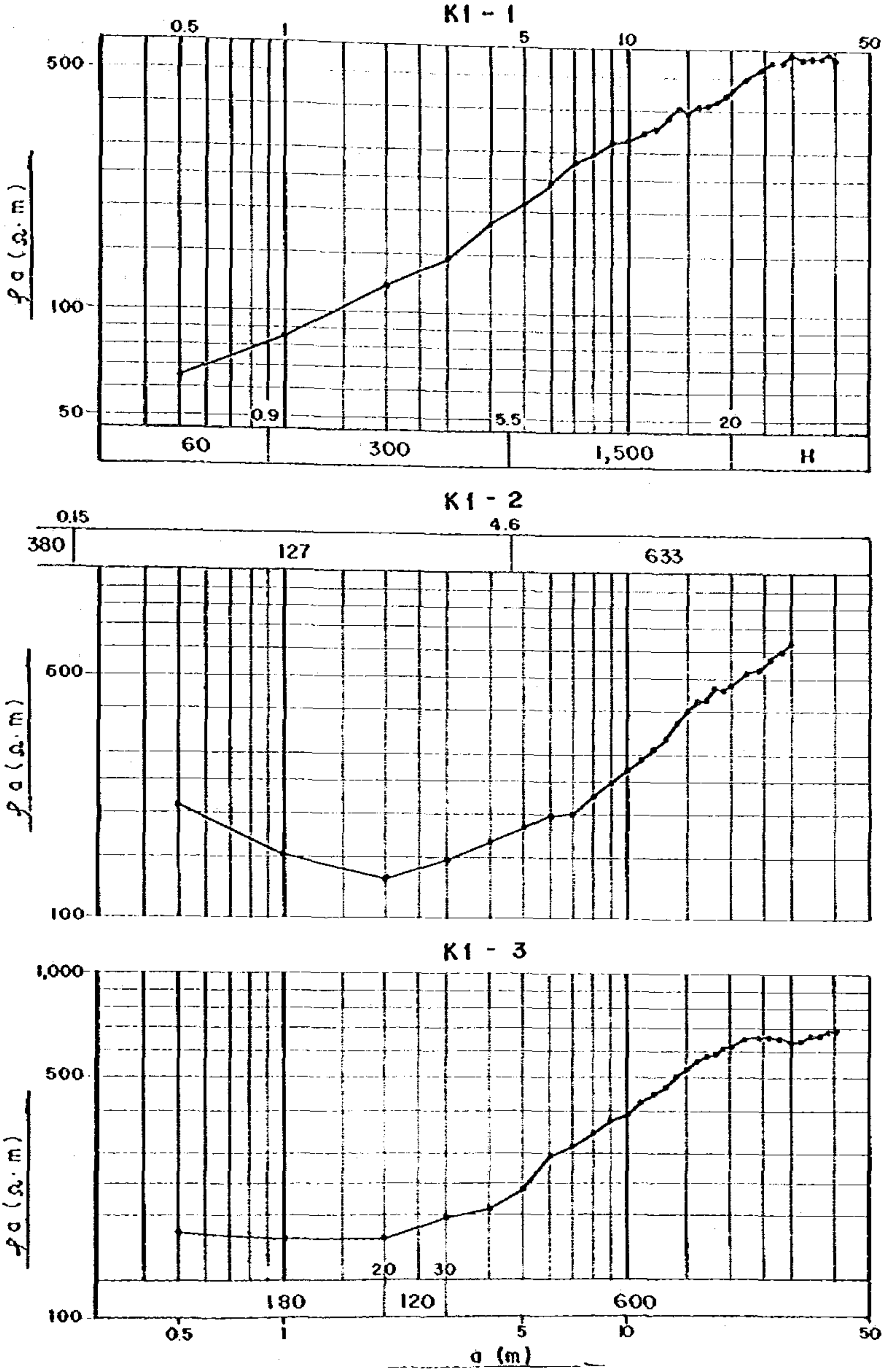
170
22
4
13
3
1.2
9.2
13.5
24
500
100
50
10
ρa (Ω·m)

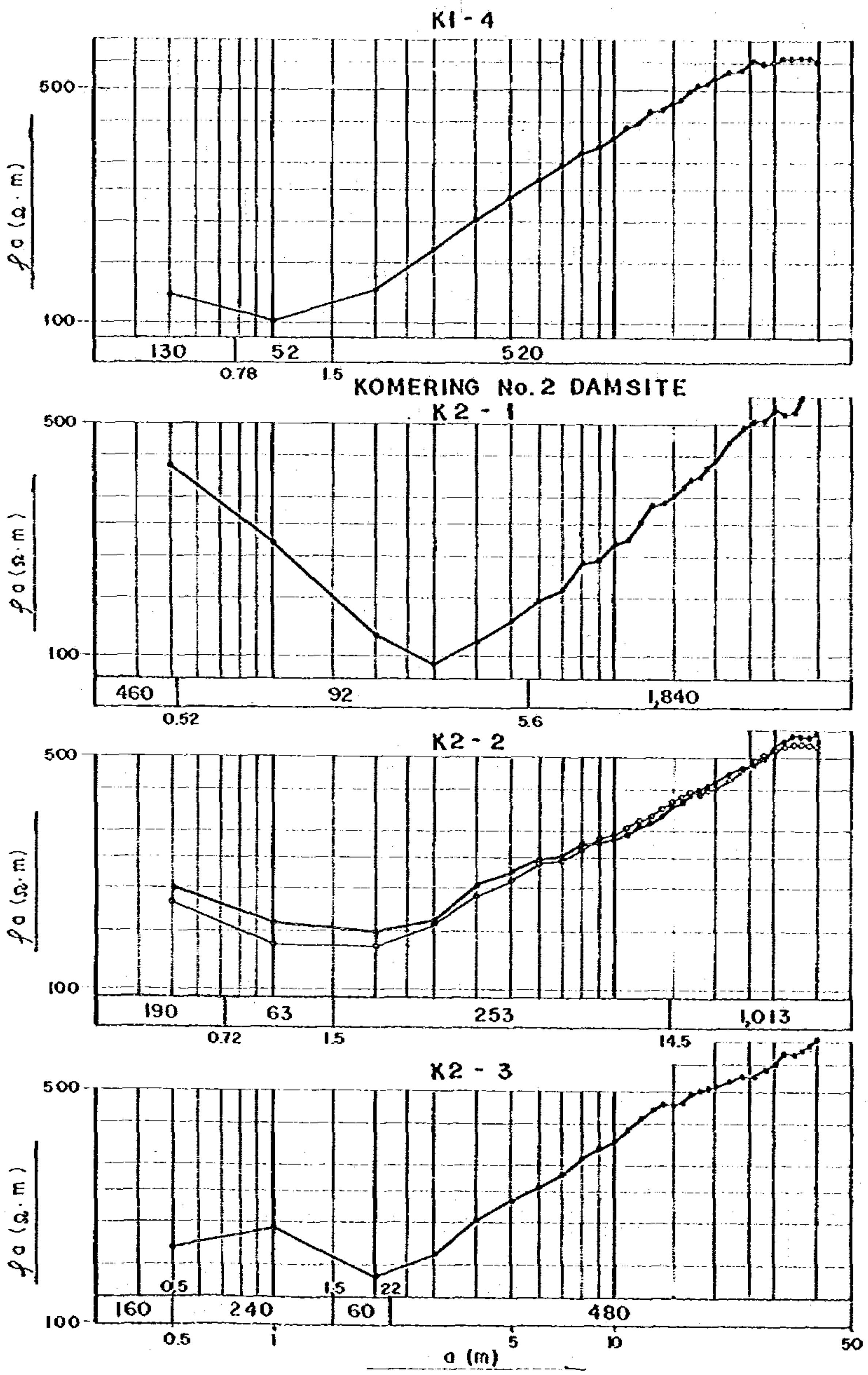
MD - 7



21
53
5
8
4
8
4
1.4
3
3.2
5.6
6.7
12
50
10
ρa (Ω·m)
0.5
1
5
10
50
a (m)

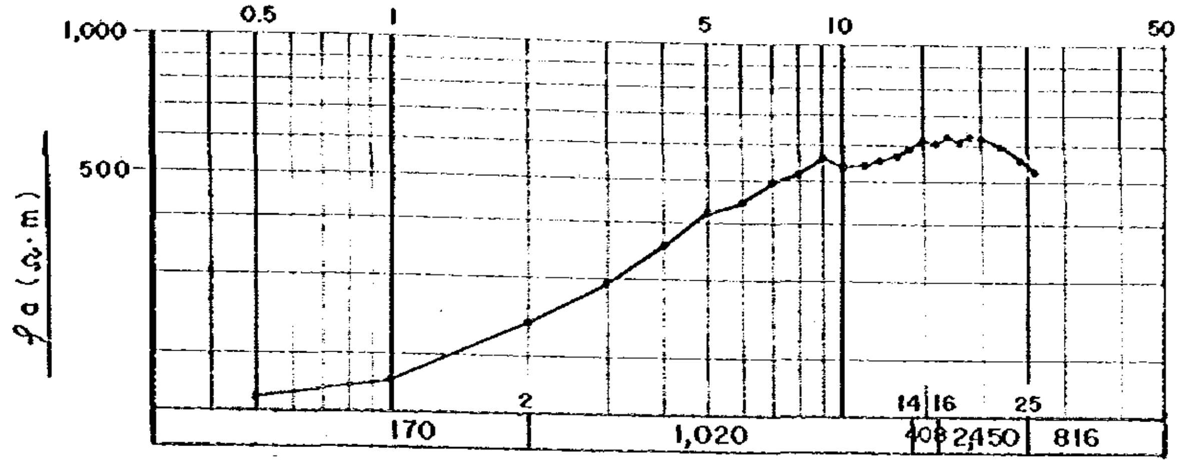
KOMERING No. 1, DAMSITE





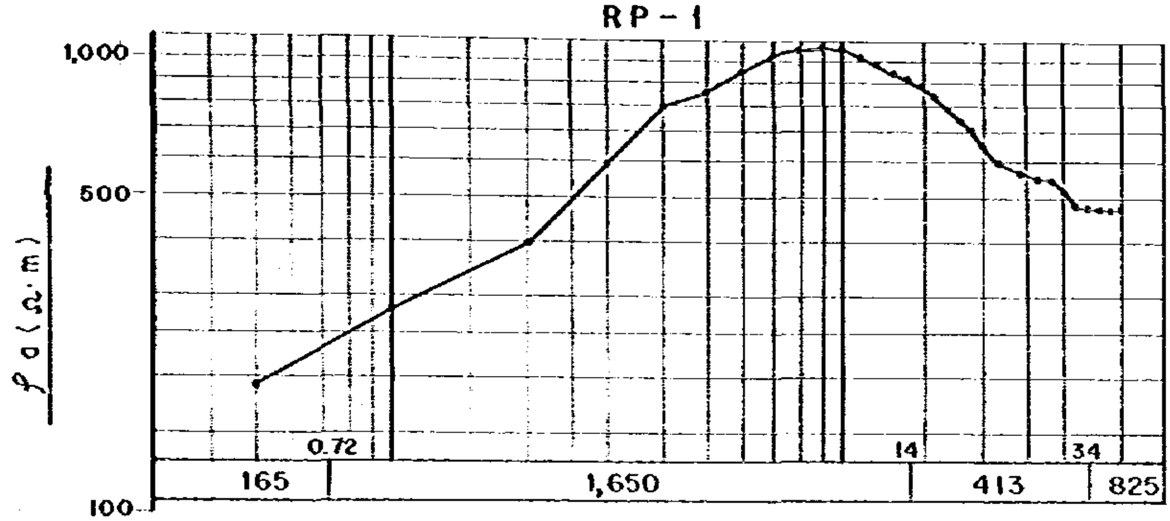
K1 - 4
500
100
ρa (Ω·m)
130
52
520
0.78
1.5
KOMERING No. 2 DAMSITE
K2 - 1
500
100
ρa (Ω·m)
460
92
1,840
0.52
5.6
K2 - 2
500
100
ρa (Ω·m)
190
63
253
1,013
0.72
1.5
14.5
K2 - 3
500
100
ρa (Ω·m)
0.5
1.5
22
160
240
60
480
0.5
1
5
10
50
a (m)

K2-4



RANAU POWER STATION

RP - 1



RP - 2

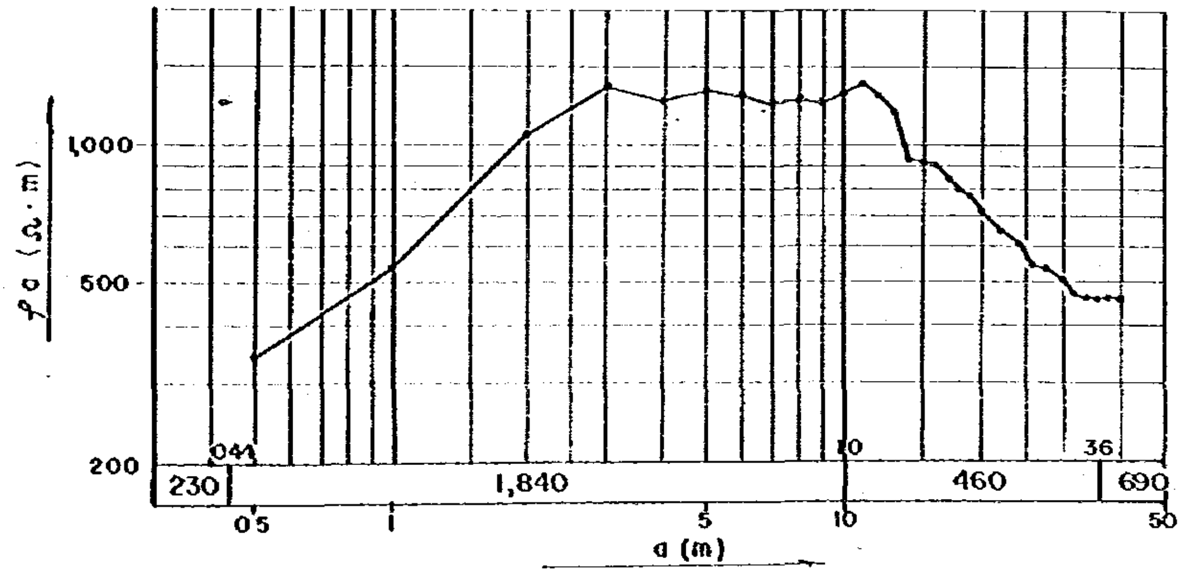


Fig III-4 GEOLOGICAL PROFILE OF KOMERING No-1 DAMSITE

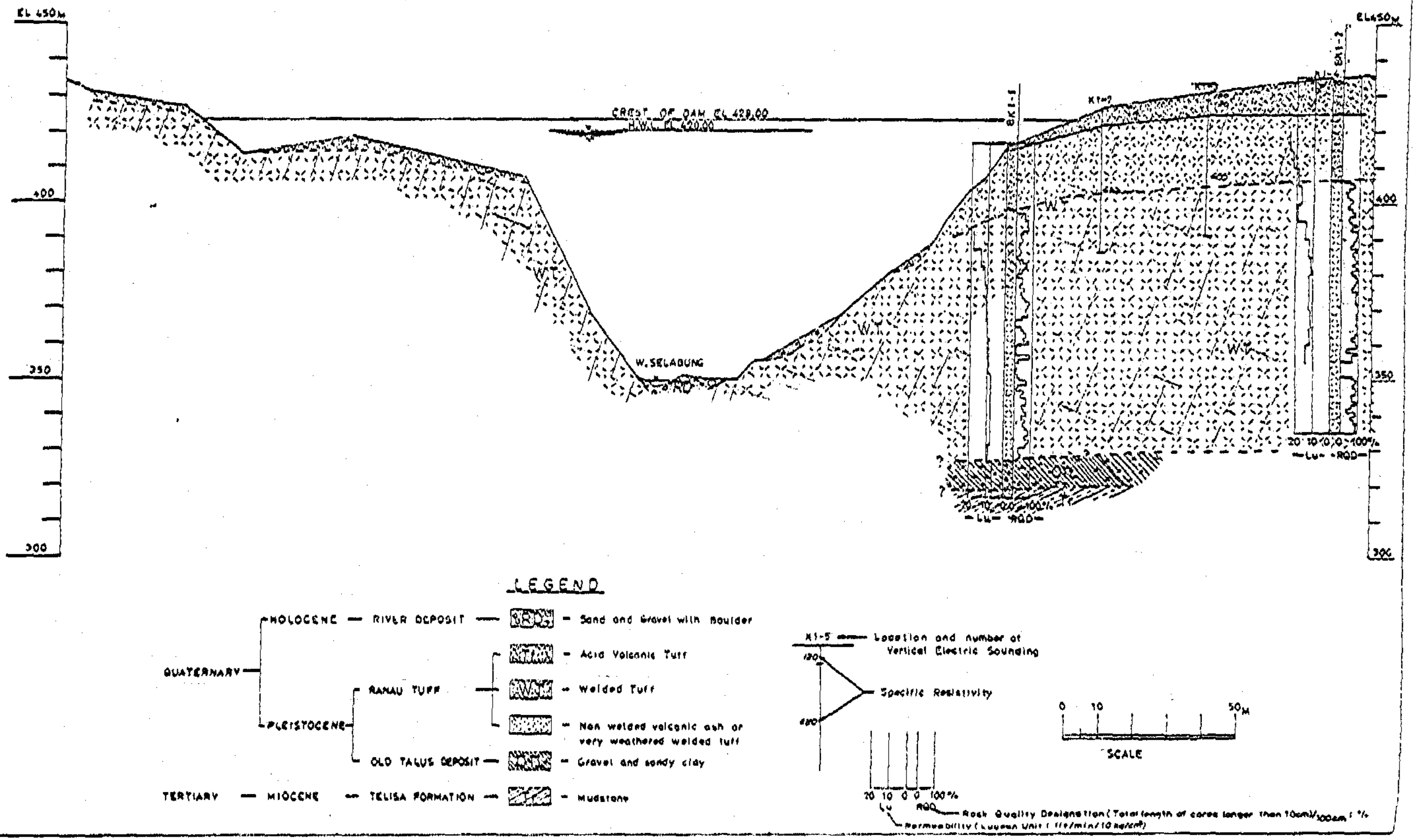


Fig.III-5 GEOLOGICAL PROFILE OF KOMERING No-2 DAMSITE

Note : TENTATIVE ANALYSIS

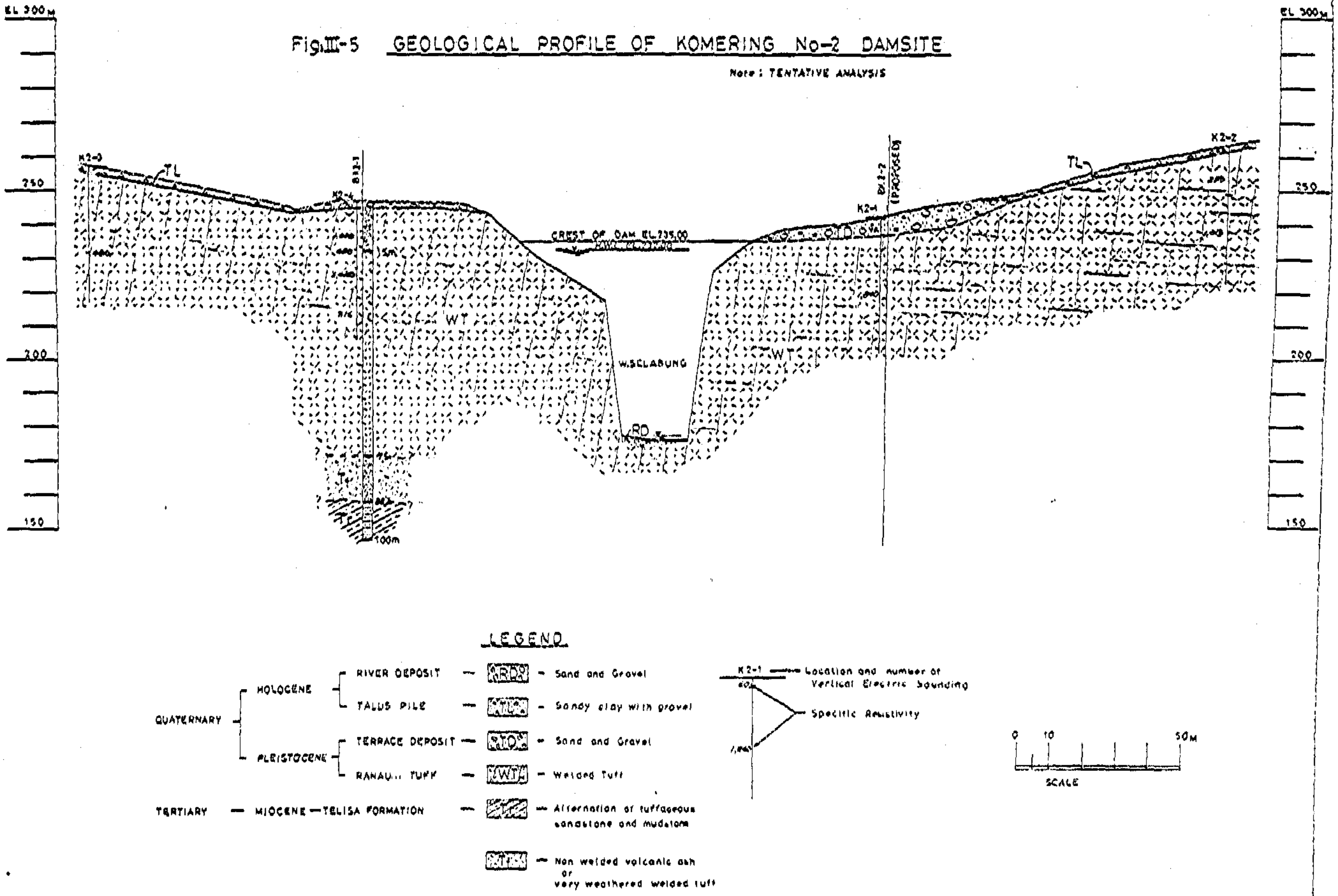


Fig III.6 GEOLOGICAL PROFILE OF MUARADUA DAMSITE

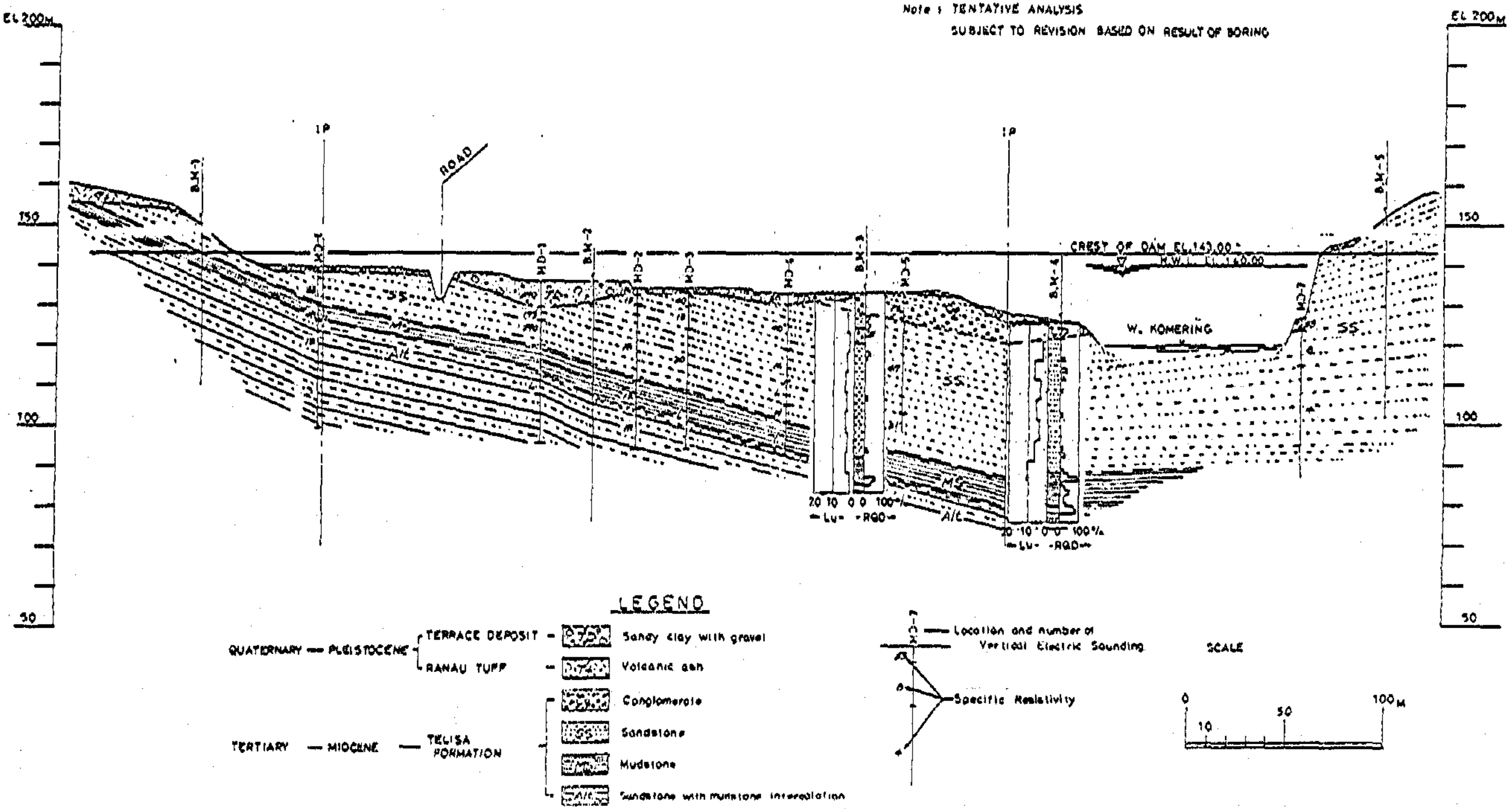


Fig III-7 GEOLOGICAL MAP OF MUARADUA DAMSITE

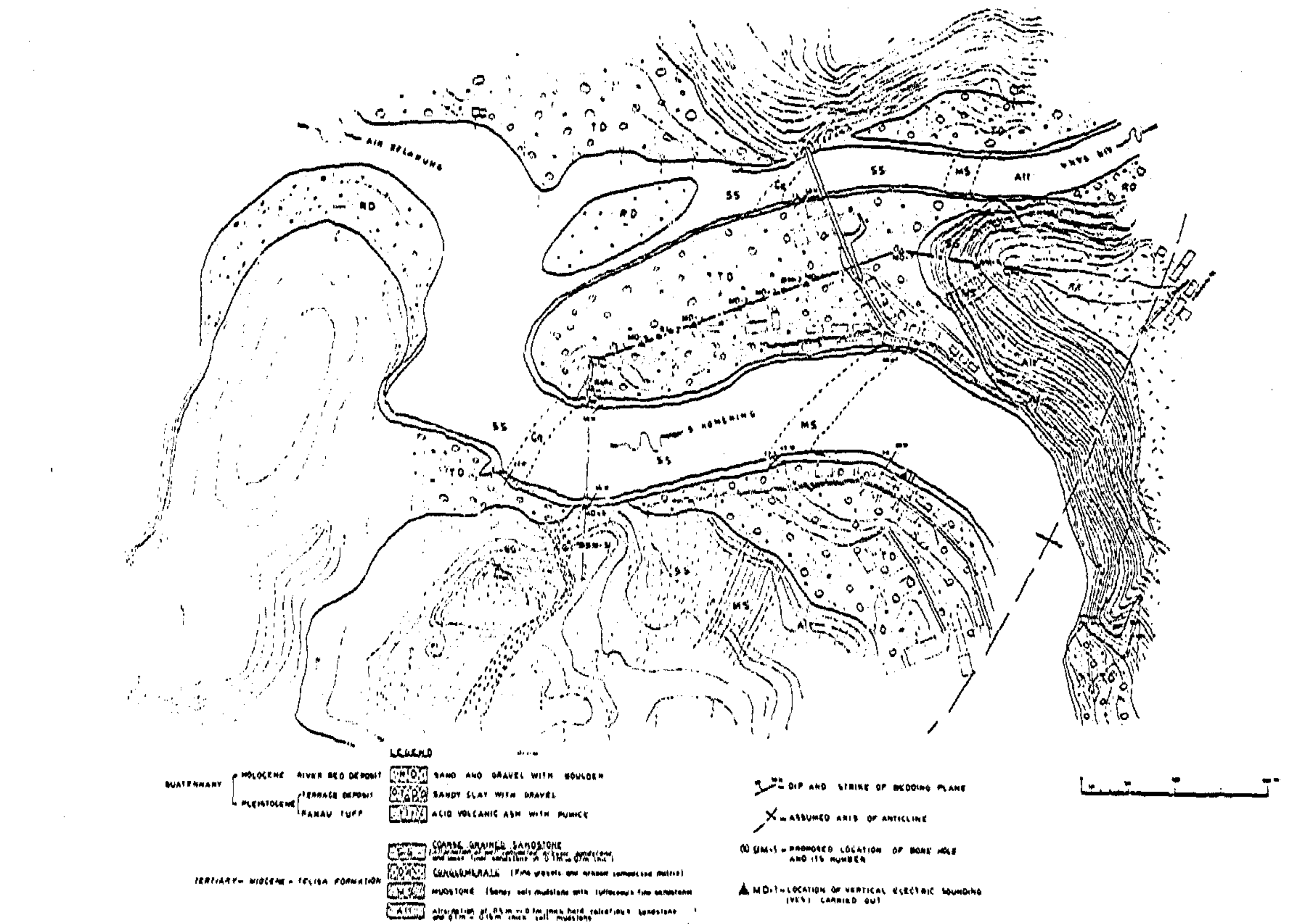


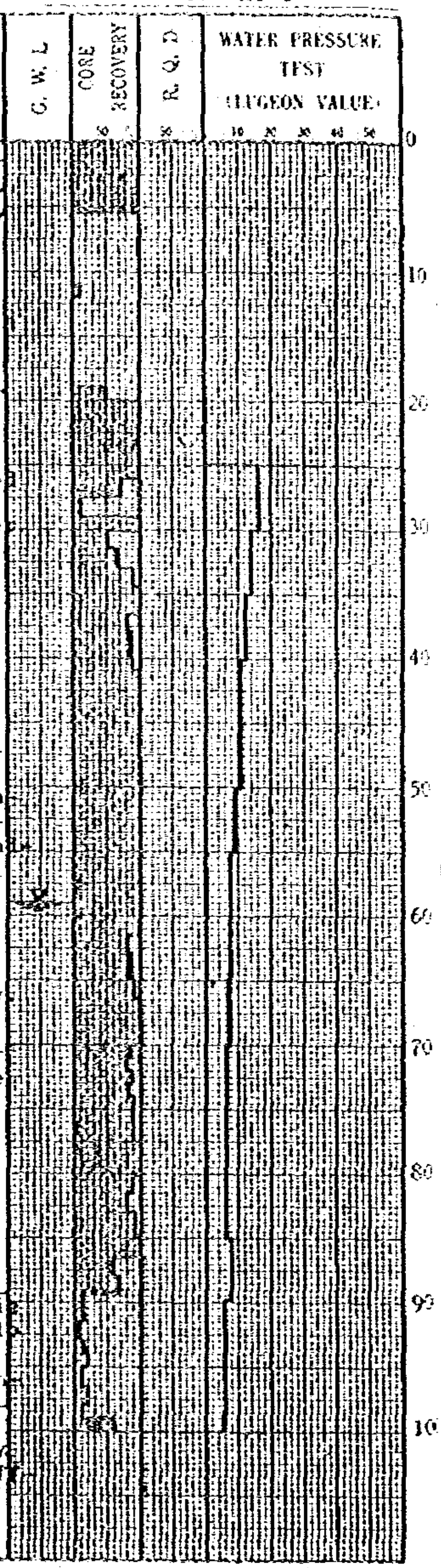
Fig. III. 8. 1

SUMMARY OF DRILL LOG

PROJECT Komering

HOLE NO. KI-1

DEPTH	ELEVATION	THICKNESS	COLUMN SECTION	ROCK TYPE OR FORMATION	DESCRIPTION
				TOP SOIL	
				TERRACE DEPOSITE	
				VOLCANIC ASH	
18.8		13.8		WEATHERED WELDED TUFF	low core recovery, almost granular (1-2mm) slime of quartz and feldspar same wit welded tuff-grey white-brown grey
89.3		70.5		WELDED TUFF	18.8 - 27.4 medium hard, well welded pumice tuff with 2-3 nos. incline (30°-50°)open crack oxidized per one mete brownish grey 27.4 - 29.0 cuttings, due to low welding. 29.0 - 89.3 medium hard, well welded pumice tuff, coarsely(1-2mm)crystalized quartz, feldspar and small and less mica. almost consists of those phenocrysts and less groundmass. Crack interval generally 0.3m-0.5m, occasionally 0.05m-0.15m. Open cracks but not oxidized. greyish white to grey 85.0-89.3 soft but fresh, weakly welded. disk-shope or crushed cores.
98.0		8.7		OLD TALUS DEPOSIT	mainly ø1-5cm andesti gravel semi-rounded to angular, with brown sandy clay matrix consolidated.
100				WEATHERED MUDSTONE	hardly determine due to poor core recovery consists of brown tuff mud stone. Tertiary sedimentary rock



LOG FORM-A

Fig. III.8.2

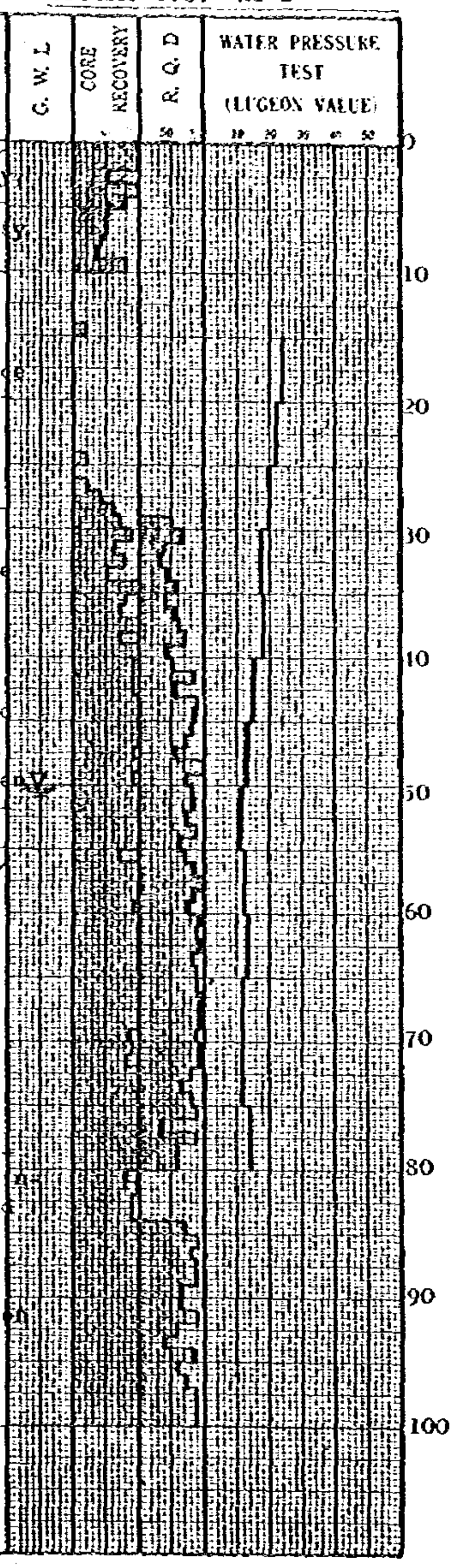
SUMMARY OF DRILL LOG

PROJECT Komering

HOLE NO. K1-2

DEPTH	ELEVATION	THICKNESS	ROCK TYPE OR FORMATION	DESCRIPTION
0.6		0.6	TOP SOIL	sandy silt, brown
3.4		2.8	TALUS	tuffaceous sandy clay brown
10.0		6.6	VOLCANIC ASH	white fine ash without gravel. glassy little argilized
28.4		18.4	WEATHERED WELDED TUFF	only slime cores. coarse(ø1-2mm)quartz feldspar and mica. with 1-2 pcs of pumice and/or andestic fragment per one meter. greyish-white.
40.0		11.6	WELDED TUFF	28.4-40.0 semi-weathered or loosely welded pumice tuff. breakable by hand. coarse grained crystals. greyish-white.
55.0		15.0		40.0-55.0 medium hard compacted welded tuff. crack 30°-45° inclined, 30 cm-50cm interval, open and stained. greyish-white.
55.2		0.2	CLAY	Reddish brown clay old top soil
100.0			WELDED TUFF	very welded coarse grained crystaline tuff with scattered pumice ø1-3cm and andestic fragments ø0.5-2 cm. occasionally tabluar or disk shape cores, cracks 30°-50° inclined, 50-150 cm interval, open and stained. Medium-hard, hand imbreakable, hammer breakable greyish-white rather homogeneous rock condition to 100 m.

Depth scale (m): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100



LOG FORM-A

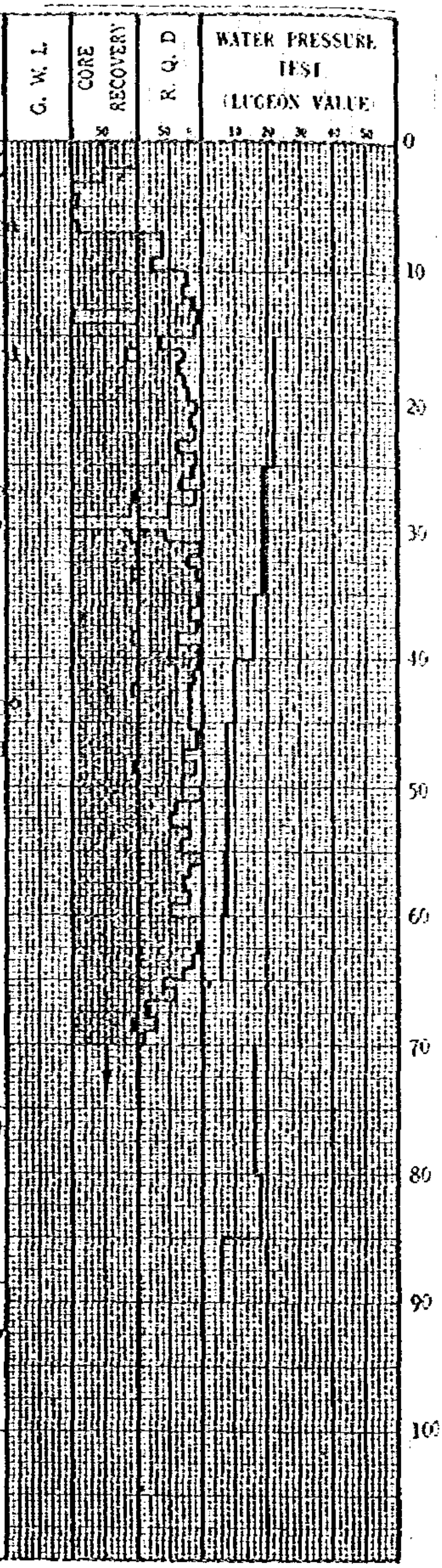
Fig. III.8.3

SUMMARY OF DRILL LOG

PROJECT Komering

HOLE NO. K2-1

DEPTH	ELEVATION	THICKNESS	COLUMN SECTION	ROCK TYPE OR FORMATION	DESCRIPTION
0.5		0.5		TOP SOIL	sandy clay brown
2.0		1.5		VOLCANIC ASH	clayey sand with ash
7.0		5.0		VERY WEATH'D WELDED TUFF	almost cuttings of quartz, feldspar, mic
15.0		8.0		WEATHERED WELDED TUFF	slightly weathered welded tuff, soft but less cracks. greyish white.
75		60.0		WELDED TUFF	15.0-29.0 Medium hard fresh welded tuff, with cracks interval 0.3-0.5m, open, inclined 40°-50°, 29.0-29.9 No core due to soft ash or cave?, not weathered. 29.9-30.4 Brecciated core 30.4-33.0 Fresh medium hard welded tuff with cracks of interval 0.3-0.5m, open, inclined 60°-70° 33.0-67.0 Fresh, hard welded tuff with cracks of interval 0.3-0.5m, tight, inclined 60°-70°. 67.0- Fresh or slightly weathered,
88.5		13.5		VOLCANIC ASH	grey colored ash with pumice.
100.0				ALTERNATION OF TUFFACEOUS SANDSTONE AND MUDSTONE	Medium hard sedimentary rocks. Generally fresh. Thickness of unit layer is 2 m to 4 m.



LOG FORM-A

Fig. III.8.4

SUMMARY OF DRILL LOG

PROJECT Komering

HOLE NO. M-1

DEPTH	ELEVATION	THICKNESS	COLUMN SECTION	ROCK TYPE OR FORMATION	DESCRIPTION	G. W. L	CORE RECOVERY	R. Q. D	WATER PRESSURE TEST (LUGEON VALUE)
1.0		1.0		TOP SOIL	contain Mica and root				
5.0		4.0		VOLCANIC ASH	brown, argilized. sandy clay with pumic				
12.0		7.0		SANDSTONE	Alternation of fine t medium grained hard sandstone and loose sandstone. weathered.				
(15)				MUDSTONE	Tuffaceous mudstone				

As of Dec.20, 1981

Proposed depth

Depth scale: 0, 10, 20, 30, 40

LOG FORM-A

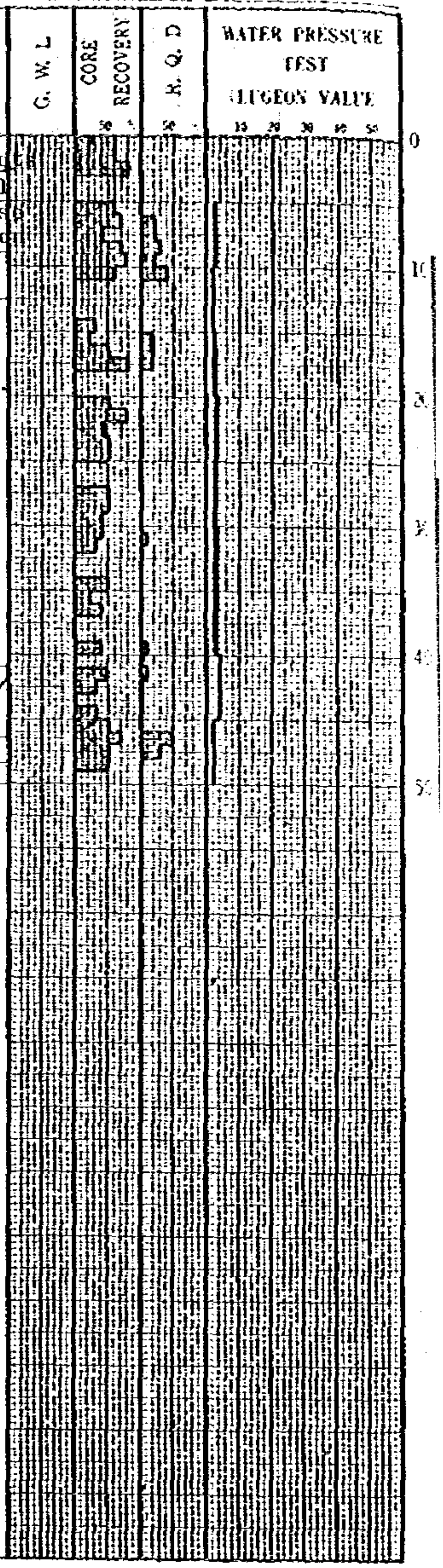
Fig. III. 8.5

SUMMARY OF DRILL LOG

PROJECT Komering

HOLE NO. M-3

DEPTH	ELEVATION	THICKNESS	COLUMN SECTION	ROCK TYPE OR FORMATION	DESCRIPTION
2.0		2.0		TOP SOIL	soft brown clay with wood
5.0		3.0		TERRACE DEPOSIT	coarse sand with gravel
9.0		4.0		SANDSTONE	Hard arkosic and loose taffaceous alternation
12.5		3.5		CONGLOMELATE	Fine gravel and calcarious sandy matrix
41.0		28.5		SANDSTONE	Alternation of hard arkosic and loose tuffaceous sandstone. Interbedding fine conglomerate.
41.5		0.5		MUDSTONE	sandy
46.5		5.0		SANDSTONE	Alternation as 12.5-41.0
48.4		1.9		MUDSTONE	silty ~ sandy hard
50.0				SANDSTONE	Alternation



LOG FORM—A

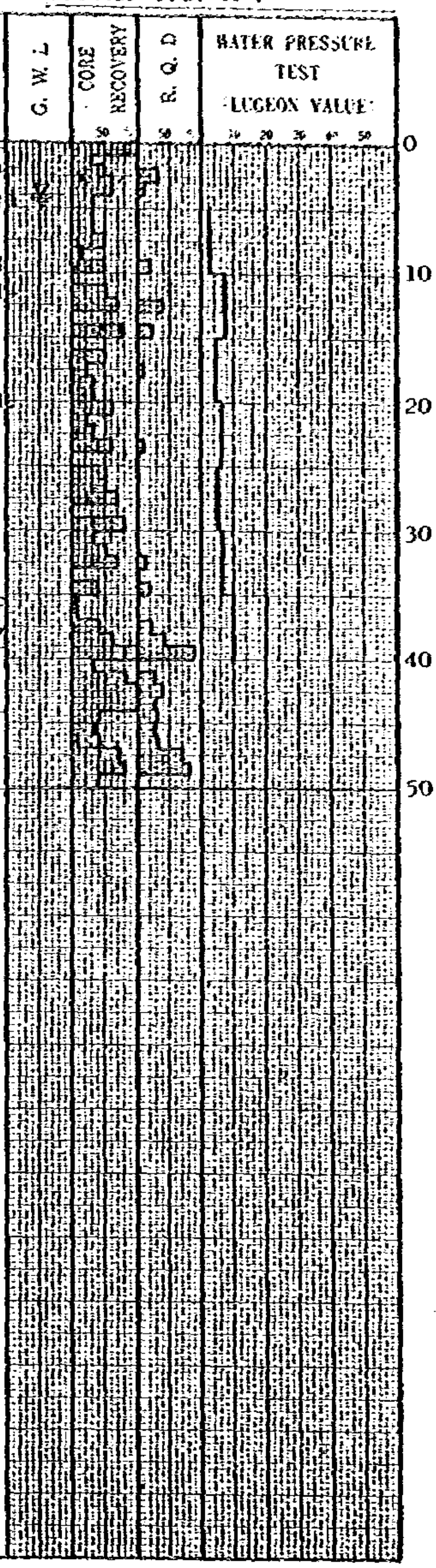
Fig. Ⅲ.8.6

SUMMARY OF DRILL LOG

PROJECT Komering

HOLE NO. M-4

DEPTH	ELEVATION	THICKNESS	COLUMN SECTION	ROCK TYPE OR FORMATION	DESCRIPTION
0.2		0.2		TOP SOIL	
4.0		3.8		CONGLOMERATE	Fine gravel and calcarious sandy matrix weathered
35.4		31.4		SANDSTONE	Alternation of hard alkosic sandstone and loose tuffaceous sand stone. Thickness of unit layer is 0.6 m to 1.7 m. Greyish white colored
37.0		1.6		CONGLOMELATE	Fine gravel and sandy matrix
39.0		2.0		SANDSTONE	Tuffaceous.
44.0		5.0		MUDSTONE	silty clay stone. medium hard,
50.0				SANDSTONE	Alternation of hard arkosic and loose tuffaceous sanstone



LOG FORM-A

ANNEX IV

SOIL MECHANICS

ANNEX - IV

SOIL MECHANICS

1. INTRODUCTION

1.1 Purpose

The present soil survey consists of two parts; one for soil mechanical survey along the main canal routes and the other for construction material survey particularly for the construction of three dams, i.e. *The Komering No.1 and No.2* dams and the Muaradua dam. The main purpose of the soil mechanical survey along the main canal routes are:

(1) to know the physical and mechanical properties of soils along the canal routes,

(2) to know the foundation conditions at the proposed major structure sites such as intake structure, syphones, aqueducts, culverts, etc.

(3) to know the depth of groundwater table which should be considered in preparing the construction plan and in estimating the construction costs, and

(4) to know the availability and suitability for construction materials such as sand, gravel and canal embankment materials.

On the other hand, the main purposes of the construction material survey for the dam construction are:

(1) to select the quarry sites for rock-fill materials, sand and gravel for concrete,

(2) to select the borrow pit sites for dam core and filter materials, and

(3) to judge the suitability of the materials through laboratory tests.

1.2 Method of Investigation

The field surveys and tests on the soil mechanics and construction materials were carried out during the period from July 22 to August 19, 1981. The item and quantity of the field survey are shown in the following table.

Surveyed Area	Item	Quantity
Muncak Kabau Main Canal	Hand auger & test pit	6 sites
	Cone-penetration test	3 sites
	Soil sampling	27 samples
Lempuing Main Canal	Hand auger & test pit	5 sites
	Cone-penetration test	2 sites
	Soil sampling	23 samples
Tulangbawang Main Canal	Hand auger & test pit	5 sites
	Cone-penetration test	2 sites
	Soil sampling	18 samples
Muaradua Dam	Hand auger & test pit	5 sites
	Soil sampling	19 samples
Komering No. 1 Dam	Hand auger	2 sites
	Sampling	
	- Soil	4 samples
	- Gravel and Sand	2 samples
Komering No. 2 Dam	Hand auger	2 sites
	Soil sampling	5 samples

The hole number, depth and location are shown in Table IV - 1.

The soil, sand and gravel samples collected were sent to the laboratory in Bandung for the physical and mechanical tests which were carried out following the ASTM Standard. Particulary for the soil mechanical tests, the remarks were given as follows:

(1) <u>Compaction test</u>

(a) The test shall be made using the non-dry and non-repeat method.

(b) Compaction shall be done with standard energy.

(c) Cone-penetration test shall be made on the compacted specimen after weighing the specimen.

(2) <u>Triaxial compression test</u>

(a) The lateral pressures (σ_3) of the test shall be 1.0, 2.0 and 3.0 kg/cm^2.

(b) The pore water pressure shall also be measured during the compression time.

(c) The pre-consolidation pressure for the CU-test shall be same as the lateral pressure on the specimen.

(3) <u>Permeability test</u>

(a) The test shall be made according to the falling head method.

(b) Vertical confined pressure on the specimen shall be 3 kg/cm^2.

(4) <u>Consolidation test</u>

(a) The specimen shall be saturated under the surcharged condition of 0.1 kg/cm^2.

(5) Soil mechanical tests such as triaxial compression test, consolidation test and permeability test shall be carried out for the respective specimen to be prepared for the following two conditions:

(a) γdmax and Wopt

(b) γdmax x 0.95 and W 95

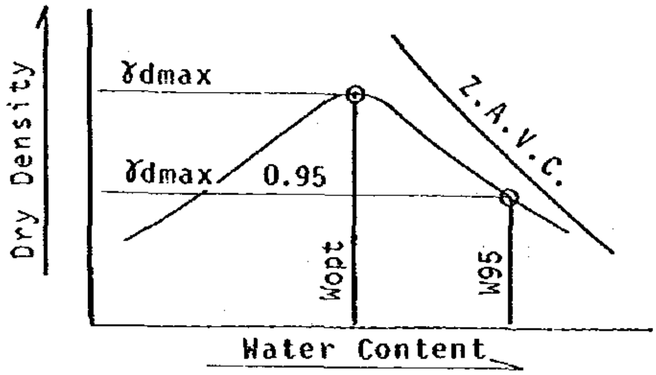


Table IV-2 shows the item and quantity for the soil physical and mechanical tests and aggregate tests.

2. SOIL MECHANICS ALONG THE MAIN CANALS

2.1 General Soil Condition

(1) Muncak Kabau Area

The area along the main canal route is roughly classified into two main parts: one is hilly area with gentle slope and 20 to 30 meter higher than the paddy field, and the other is paddy field area. The hilly area lies scatteredly along the upper reach of the East Main Canal, but continuously along the lower reach of the canal.

The geology of the hilly area is of diluvial deposit. In every hilly area along the East Main Canal, almost the same geological formation is observed as explained below:

First stratum : This stratum consists of cohesive soil of reddish brown color and its thickness is less than 2 m. This stratum contains round-shaped gravel with a grain size of less than 1 cm and its content is less than 5%. The natural moisture content of the soil is almost same as the optimum moisture content. This stratum is not well consolidated and its N-value is less than 10.

Second stratum : This stratum consists of light gray soil spotted with red soil. The light gray soil is highly plastic and cohesive. The red soil is composed of extremely weathered gravel being rich in ferric component partially reserving original structure. The gravel content of this stratum is less than 5% and its natural moisture content is higher than the optimum moisture content. This stratum is rather solidified and its N-value is within a range from 15 to 20, but its mechanical strength will be loosened by remolding. The sensitivity ratio of this soil is 3 - 4.

Third stratum : This stratum consists of secondary deposits of volcanic ashes of pale orange color. The plasticity and cohesion are lower than those of the second stratum. The natural moisture content is higher than the optimum moisture content. The N-value of the stratum is less than 15. This stratum does not contain gravels.

Fourth stratum : This stratum consists of light gray colored soil, and are well consolidated. The plasticity and cohesion are the highest of all the strata in the hilly area. This stratum does not contain any gravel. The sensitivity ratio is rather big.

On the other hand, most parts of the Headreach and the West Main Canal run through the paddy field area having its ground height of within 10 m above the Komering water stage. The geology of the paddy field area is of alluvial deposit consisting of well-graded sand to fat clay. These soils are broadly classified into three groups: (1) SW, SP, (2) SM, SC and (3) CH, CL, MH, ML, according to the Unified Classification Method.

The geological formation in the paddy field area is different from test pit to test pit. Around 7% of total depth of the test pits, 21.5 m for 5 pits, are classified into the group - (1), 43% are into the group-(2) and 50% are into the group - (3). The followings are brief descriptions about the soil property of each group mentioned above.

Group - (1) : SW, SP. The stratum in this group consists of rounded gravels and sands originated from andesite, sandstone or granite and its maximum grain size is around 1 cm. The above sands contain rounded quartz and mica. The soil of this group is well compacted and its N-value is more than 30.

Group - (2) : SM, SC. The stratum in this group consists of fine sand and silt, and its color is brownish gray. The above fine sand contains volcanic ashes and mica. The soil of this group is not so well compacted and its N-value is within the range from 15 to 20.

Group - (3) : CH, CL, MH, ML. The stratum in this group consists of brownish light gray colored clay and does not contain any gravel. The natural moisture content of this soil is higher than the optimum moisture content. The consistency of this stratum is soft to medium showing the cone index (qc) of 10 kg/cm^2 in the most soft stratum and the estimated N-value of 25 in the hardest stratum. The sensitivity ratio is in the order of 2 - 3, and its remolding loss is rather big.

(2) Lempuing Area

In this area also, the main canal route will pass through two main parts: hilly area and paddy field area. The soil properties in this area are almost same as those of the Muncak Kabau area. However, the extent of the group - (3) in this area is bigger, and the solidness of the alluvial deposit is lower than those of the Muncak Kabau. Around 65% of the main canal reach will pass through the hilly area and remaining reach pass through the paddy field area.

(3) Tulangbawang Area

The geological formation of this area is basically same as that of the Muncak Kabau area, except the thickness of the third stratum, mainly along the upper reach from the beginning point to 4.0 km point of the Tulangbawang Main Canal. This third stratum is well consolidated and stable. More than 80% of the main canal reach is planned to pass through the hilly area, and the remaining canal reach will pass through the paddy field area.

2.2 Results of Laboratory Tests

2.2.1 Index Properties of Soils

The results of index property tests on the soils in every irrigation area are shown in Table IV-3. Each index property of soil can be summarized according to the soil classification.

(1) Specific gravity (Gs)

Summary of Specific Gravity

Stratum	Highest	Lowest	Mean
1st stratum	2.93	2.64	2.71
2nd stratum	2.73	2.63	2.67
3rd stratum	2.70	2.61	2.65
4th stratum	2.79	2.62	2.70
Group (1)	2.90	2.64	2.72
Group (2)	2.70	2.49	2.57
Group (3)	2.70	2.50	2.60

The values in the above table are generally accepted within the reasonable range. The mean value of Group (2) shows smaller value than the others, because of pumiceous particle of volcanic ash contained in the stratum.

(2) Gradation

The results of grain size analyses are shown in Fig. IV-1. The value of Rp (percent finer than No. 200 sieve) is summarized for each soil as follows:

Percent Finer than No. 200 Sieve (74μ)

Stratum	Highest	Lowest	Mean
1st stratum	79	5	29
2nd stratum	79	10	51
3rd stratum	95	15	57
4th stratum	79	58	68
Group (1)	6	1	4
Group (2)	52	11	38
Group (3)	93	47	67

The value of Rp is one of the indications for judging appropriateness of soil materials for the impervious zone of embankment. In general, the materials with Rp of over 20% are judged to be appropriate, but cracking will occur on the materials which have extremely high value of Rp.

According to the USBR standards, it is noted that the critical range of Rp should be 55 to 90%. Fig. IV-2 shows the critical zone of cracking and average gradation of the soil in each stratum or group mentioned above.

Taking into account the above-mentioned conditions, the soils in the 1st stratum and in the Group (2) are judged to be suitable as the impervious materilas. Moreover, from the gradation curves, the soils in Group (1) are judged to be suitable as the materials for compacted soil-cement.

(3) Consistency

The results of Atterberg limit tests are shown in the plasticity chart in Fig. IV-3 and summarized below:

Summary of Consistency

Stratum	Liquid Limit (%)			Plasticity Index		
	Highest	Lowest	Mean	Highest	Lowest	Mean
1st stratum	107	47	76	59	27	43
				(N.P. 1 sample)		
2nd stratum	115	66	86	58	31	45
				(N.P. 1 sample)		
3rd stratum	139	50	84	86	27	48
4th stratum	122	65	94	66	34	50
Group (2)	98	38	61	56	22	34
				(N.P. 1 sample)		
Group (3)	107	47	75	74	18	43

(N.P. : Non plastic)

It is generally known that the soils with plasticity index of over 15% have high resistance against piping phenomena. Almost all the soils in the project area satisfy this condition.

(4) Field moisture (Wf)

Summary of Field Moisture Content (%)

Stratum	Highest	Lowest	Mean
1st stratum	40.6	13.5	24.9
2nd stratum	37.2	20.9	27.9
3rd stratum	70.2	28.7	44.0
4th stratum	42.6	42.1	42.4
Group (1)	16.2	12.0	14.1
Group (2)	66.6	24.2	36.3
Group (3)	51.3	28.1	39.6

2.2.2 Classification

Based upon the results of the grain size analyses and the consistency tests, the soils distributed in the project area can be classified as follows according to the Unified Classification Method:

(1) Classification of soils in hilly area

1st stratum : Soils in this stratum are classified into "SM", "SC" and "MH", and these are distributed in almost the same extent.

2nd stratum : Soils are classified into "SM", "SC", "MH" and "CH", among which "MH" dominates over the project area.

3rd stratum : Soils in this stratum can be classified into "MH", if the ASTM designation is applied. However, since this stratum consists of volcanic ashes, the soils can be well-defined, if the group symbol of "DH" of Japanese method is introduced for the classification.

4th stratum : Major parts of this stratum are composed of "CH" soil and partly "MH".

(2) Classification of soils in paddy field

Soils in paddy field are classified as shown in the following table according to the Unified Classification in gradation.

Soil Group	Gradation Classification
Group (1)	SP, SW
Group (2)	SC, SM

About 70% of soils in Group (2) can be classified into "SC". "MH", "CL" and "CH" in Group (3) are distributed at almost the same ratio.

Relative desirability for various uses is shown in Table IV-4 in accordance with each soil classification. From this table, it is judged that most of the soils distributed in the project area are usable as the embankment materials for the canal construction.

2.2.3 Mechanical Properties of Soils

Mechanical property tests are carried out on the impervious materials, i.e. diluvium selected in the hilly area and alluvium of Group (3) in the paddy field area.

(1) *Compaction characteristics*

The results of standard proctor compaction tests are summarized in the following table.

Summary of Compaction Test

Stratum	Sample Name	γd_{max} (t/m^3)	Wopt (%)	Wf minus Wopt (%)	Wf minus W95 (%)	γdf (t/m^3)	Df (%)
Diluvium from 2nd stratum in hilly area	L.No2 Z=2.5m	1.32	37.3	-5.1	-8.4	1.24	94
Alluvium from Group (3) in paddy field	M.No2 Z=1.5m	1.51	23.1	5.9	1.4	1.41	93

The relation between Wf and Wopt is as explained follows:

- For diluvium soil, Wf is 5.1% drier than Wopt.
- For alluvium soil, Wf is 5.9% wetter than Wopt.

The above relation was already estimated through the field investigation. The diluvium soil is generally dry and Wf will be in several percent dry side from Wopt, but the alluvium soil is generally on wet side and Wf will be in about 5 to 10% wet side from the Wopt.

The diluvium soil will be desirable material for sound compaction. On the contrary, the alluvium soil may give low traficability and may require the drying procedure before compaction.

(2) Triaxial compression tests

Results of triaxial compression tests on remolded samples are summarized in Table IV-5, and the results of additional tests on undisturbed samples are summarized below:

Stratum	Sample Name	C' (t/m^2)	P' (deg)
Diluvium from 2nd stratum in hilly area	L.No2U	1.2	27.5
Alluvium from Group (2) in paddy field	M.No5U	2.0	33.0

The results of the tests on remolded samples are utilized for the determination of shearing strength parameter for embankment, and the undisturbed samples are tested to determine the shearing strength parameter for foundation.

(3) Permeability tests

The results of permeability tests on remolded samples are also summarized in Table IV-5. Permeability coefficients of the samples are in the order of 1×10^{-7} cm/sec.

(4) Consolidation tests

Results of consolidation tests on remolded samples are summarized in Table IV-5, and Fig. IV-4 shows the relation between consolidation pressure and settlement percentage.

2.3 Foundation along the Main Canals

2.3.1 Soil Sounding

Soil sounding investigation was conducted using cone-penetrometer. The results are shown in Fig. IV-5. The cone index tests in all the test holes except some give higher value than the upper limit value of qc = 15 kg/cm^2 of cone-penetrometer, and the foundations along all the main canal are judged to be stable. In the holes shown in Fig. IV-5, qc does not increase according to the soil depth.

The approximate N-values can be estimated by visual checking of the excavated conditions in the test holes.

The results of soil sounding are summalized below:

District	Stratum	Minimum	Average
Muncak Kabau	Diluvium	N ≒ 10	N ≒ 20
	Alluvium		
	Group (1)	N ≒ 15	N ≒ 30
	Group (2), (3)	qc = 12	qc ≒ 15
Lempuing	Diluvium	qc = 11	N ≒ 15
	Alluvium		
	Group (1)	N ≒ 15	N ≒ 30
	Group (2), (3)	qc = 8	qc ≒ 13
Tulangbawang	Diluvium	qc = 10	N ≒ 20
	Alluvium		
	Group (1)	N ≒ 15	N ≒ 30
	Group (2), (3)	N ≒ 5	N ≒ 10

(Unit of qc : kg/cm^2)

Following relations are generally known between Cu, ϕu and qc, N-value.

- For clayey soil ($\phi u = 0$)

$$Cu \fallingdotseq qc/20 \quad (\because qu \fallingdotseq qc/10, \ qu = 2 \cdot Cu)$$

$$Cu \fallingdotseq N/16 \quad (\because qu \fallingdotseq N/8, \quad qu = 2 \cdot Cu)$$

(Unit of qu, qc, Cu ; kg/cm^2)

- For sandy soil ($Cu = 0$)

$$\phi u = \sqrt{12 \cdot N} + 20$$

(Unit of ϕu ; degree)

2.3.2 Groundwater Table

The groundwater tables in the test holes dug along the main canal routes are shown in Table IV-6. It is noted that these data are obtained during the dry season, and that according to the villagers, the groundwater table in the paddy field rises up to the ground surface during the rainy season.

The groundwater table in the hilly area stays below the 2nd stratum in the most cases. This means that the groundwater table stays 3 m to 7 m below the ground surface, where sand strata lie in general case. Clay strata in paddy field are completely impervious, and accordingly perched water is observed in some areas. In some holes dug in the Lempuing and Tulangbawang areas, confined aquifers are observed also.

2.3.3 Shearing Strength

The shearing strength parameters obtained from the soil sounding results are shown in the following table.

District	Stratum	Shearing Strength Parameter			
		Minimum		Average	
		Cu (t/m^2)	ϕu (deg.)	Cu (t/m^2)	ϕu (deg.)
Muncak Kabau	Diluvium	6.3	-	12.5	-
	Alluvium				
	Group (1)	-	33	-	39
	Group (2), (3)	6.0	-	7.5	-
Lempuing	Diluvium	6.9	-	9.4	-
	Alluvium				
	Group (1)	-	33	-	39
	Group (2), (3)	4.0	-	6.5	-
Tulangbawang	Diluvium	5.0	-	12.5	-
	Alluvium				
	Group (1)	-	33	-	39
	Group (2), (3)	3.1	-	6.3	-

Based on the figures mentioned in the above table and the results of triaxial tests on undisturbed samples, the following shearing strength parameters (Cu, ϕu) for the design of canal foundation are recommended:

- For Diluvium soil Cu = 5 t/m^2 ϕu = 10 degree
- For Alluvium soil
  - Group (1) Cu = 0 ϕu = 33 degree
  - Group (2), (3) Cu = 3 t/m^2 ϕu = 10 degree

2.3.4 Permeability

The coefficient of permeability (k) of foundation soil is estimated based on the grain size and groundwater discharge into the test pits. Table IV-7 and IV-8 show the procedure to obtain k values from the grain size.

The following table shows the estimated result of the coefficient of permeability.

Stratum	k(cm/sec)	Unified Classification
Diluvium		
1st and 2nd stratum	5×10^{-6}	MH, SM, SC
3rd stratum	1×10^{-5}	MH, SC
4th stratum	1×10^{-7}	CH, MH
Alluvium		
Group (1)	3×10^{-2}	SW, SP
Group (2)	$3 \times 10^{-4} \sim 4 \times 10^{-5}$	SM, SC
Group (3)	1×10^{-7}	CH, CL, MH ,ML

Based on the distribution of the permeability coefficient and the fact that the confined aquifer was found through the investigation in the alluvium soil, it may be concluded that the stratum of Group (3) acts as complete impervious layer against Group (1) and Group (2), and the Group (3) stratum will have sufficient impervious characteristics for the irrigation canal.

2.3.5 Bearing Capacity

Judging from the value of $\phi u = 33$ degree, the bearing capacities of the foundations at the proposed major structure sites will be sufficient.

In case of the alluvium foundation of Group (2) or (3), in other words silty or clayey soil foundation, pile foundation may be necessary, though it should be confirmed through the detailed survey. In order to estimate the bearing capacity, a sample calculation is made applying Terzaghi formula as follows:

Equation

$$qf = \frac{2}{3} \cdot \alpha \cdot Cu \cdot Nc + \gamma_1 \cdot Df \cdot Nq + \beta \cdot \gamma_2 \cdot Nr$$

where,

q^f : Ultimate bearing capacity

Cu : Average cohesion of the soil in the foundation layer

$\gamma 1$: Unit weight above the bottom level of foundation structure

$\gamma 2$: Unit weight under the bottom level of foundation structure

Df : Depth of overburden (from ground surface to the bottom level of foundation structure)

Nc, Nq, Nr : Bearing capacity factor (refer to Table IV-9)

α, β : Shape factor (refer to Table IV-10)

For the unit weight of layer, "γsub" below groundwater surface or seepage surface and "γt" above them should be used for γ1 and γ 2 mentioned above. The foundation depth from the ground surface should be more than 2 times of the width of structure foundation in adopting the above Terzaghi formula.

Conditions

$Cu = 3\ t/m^2$,

$\phi u = 10$ degree,

$\gamma 1 = \gamma 2 = \gamma t = 1.5\ t/m^3$

Bearing capacity factor

Nc = 8.0,

Nq = 1.9,

Nr = 0

Shape of foundation structure

Square B x B meter,

Shape factor

$\alpha = 1,3,$
$\beta = 0.4$ B

Ultimate bearing capacity (qf)

Df (m)	qf (t/m^2)
1	23.7
2	26.5
3	29.4

2.3.6 Stability of Cut Slope

It is better to analize separately the stability of cut slope of canals to be constructed in the hilly area and the paddy field area, because the unsolidified sand layer with high groundwater level is expected in the paddy field, but clayey soils are dominated mostly in hilly area.

The height of cut slope in the paddy field area is expected to be less than 5 m, and the stability of sand layer sandwiched by the clay layer will be safe enough against large scaled base failure. On the other hand, the protection work will be required for the small surface failure or erosion expected after construction. In the hilly area, the high cut slope will be expected, and accordingly a careful stability analysis will be required in future.

For the stability analysis on preliminary basis, the Taylor's method is adopted, of which stability chart is shown in Fig. IV-6. The analysis is made for the following conditions.

Conditions : $\gamma t = 1.5\ t/m^3$,
$Cu = 3\ t/m^2$,
$\phi u = 10$ degree,
Safety factor (Fs) = 1.5

The results of analyses are summarized in the following table.

Cutting Height (m)		2	4	6	8	10
Angle of cut slope	(degree)	90	90	90	72	57
	(= 1/tanβ)	Vertical			0.32	0.65

2.4 Embankment Materials for Canal

2.4.1 Suitability of Excavated Material for Embankment

Excavated soil in canal construction should fully be utilized as the embankment material, if the soil is suitable for embankment.

Table IV-4 shows the suitability of soil judged by the Unified Classification Method.

The degree of suitability of the soil as the impervious material is judged as follows:

- Most suitable group : GC, GM, SC
- 2nd suitable group : CL, SM, ML
- 3rd suitable group : CH, MH, VH

The degree of suitability of the soil as non-impervious material is judged based on the shearing strength of compacted soil.

- Most suitable group : GW, SP
- 2nd suitable group : SW, SP
- 3rd suitable group : Other classes

The soil of the project area is then classified according to the degree of suitability for embankment material.

- Impervious material

  1st stratum → Group (2) → 2nd stratum → Group (3) → 4th stratum → 3rd stratum

- Non-impervious material

  Group (1) → Group (2) → 1st stratum → Others

2.4.2 Available Ratio of Excavated Soil for Canal Embankment

Judging from the above-mentioned analyses and studies it may be concluded that about 70% to 80% of excavated materials in the project area are suitable as the embankment materials, among which the impervious soil ratio will be 80 to 90% for diluvium and 40 to 70% for alluvium. The Lempuing area will give greater ratio of impervious soil than the Muncak Kabau and the Tulangbawang areas.

2.4.3 Shearing Strength of Impervious Material

The results of triaxial tests on the remolded sample of SC-Cl materials are shown in Table IV-5. Generally, the values of C' and ϕ' obtained by the $\overline{C\text{-}U}$ tests are greater than the values of Cu and ϕu obtained by the U-U tests, though some results of the above-mentioned triaxial tests show the relation of $C' < Cu$. However, considering that the value of C' is unreliable, the value of C' is deemed to be the same as that of C in this study.

Assuming that the tests results represent the average characteristics of the impervious materials, the design values of impervious materials are recommended as follows:

$$Cu = 5\ t/m^2,\ \phi u = 5\ \text{degree} \quad (\text{U-U test})$$

$$C' = 5\ t/m^2,\ \phi' = 25\ \text{degree} \quad (\overline{\text{C-U}}\ \text{test})$$

In slope stability analysis of embankment, it is judged that the results of U-U tests are applicable against a short-term stability (end of construction) and the results of $\overline{C\text{-}U}$ tests are against a long-term stability respectively.

2.4.4 Permeability

The results of permeability tests under the initial conditions of $\gamma dmax$ with Wopt, $\gamma dmax \times 0.95$ with W95 and both with $Sr > 85\%$ are shown in Table IV-5. Permeability coefficients obtained through the tests are approximately in the order of 1×10^{-7} cm/sec. These permeability coefficients are low enough for the required imperviousness for the canal embankment. Then, the following deisgn value is recommended for the study: $k = 5 \times 10^{-6}$ cm/sec.

2.4.5 Settlement Characteristics

The results of consolidation tests and the initial conditions of specimen are shown in Table IV-5. These tests give the coefficients of consolidation (Cv) ranging from 2×10^{-3} to 4×10^{-3} cm^2/sec. Judging from these values of Cv a fairly long lapse of time would be expected before getting 90% degree of consolidation on the embankment.

The final percentage of settlement(s) of each soil relating to the consolidation stress (σc) is shown in Fig. IV-4. In order to calculate the final settlement for the arbitrary heights of embankment, the following equation is available:

$$\Delta S = \frac{1}{2 \cdot Es} \cdot \gamma t \cdot h^2 \cdot A$$

where, ΔS : settlement on crest of embankment
ES : coefficient of deformation
γt : unit weight of embankment
h : height of embankment
A : constant, generally A equal to 0.35

The coefficient of deformation can be obtained from S-σc curve under the expected stress and assuming linear relation.

3. CONSTRUCTION MATERIALS FOR DAMS

3.1 Geological Conditions around the Dam Sites

The descriptions of geological formations at each dam site are briefly given below:

(1) Muaradua dam site

The bed rock at this dam site consists of neogene sedimentary rock (Tr), and acid volcanic ash (RT) widely cover the bed rock. River terrace deposits (Td) and RT are distributed on both banks of the Selabung river and the Saka river respectively. Cretaceous granite (Gr) is observed at several kilometers downstream from the dam sites.

(2) Komering No. 2 dam site

Quaternary welded tuff (WT) is distributed along the Selabung river. Neogene sedimentary rock (Tr) is observed at the right bank hill of the river. On the other hand, the left bank hill is composed of RT and Tr.

(3) Komering No. 1 dam site

WT is distributed on the both banks of the Selabung river, and hills on both banks of the river are covered with Tertiary andesitic volcanic products (Av). Tr is found at downstream of dam site.

3.2 Results of Laboratory Tests

3.2.1 Samples

Fig. IV-7 shows the selected borrow pit sites, test pit sites, auger boring sites and other soil sampling sites. Samples collected for laboratory tests are classified geologically into following four groups:

- Gr (T) : Talus deposit derived from cretaceous granite
- Gr (R) : Residual deposit of cretaceous granite
- Td : Talus deposit derived from neogene sedimentary rock, and
- RT : Volcanic ash of quaternary

3.2.2 Index Properties

The results of the index property tests are shown in Table IV-11, and are summarized in accordance with the geological classification as follows:

(a) Specific Gravity (Gs)

Class	Highest	Lowest	Mean
Gr (T)	2.750	2.624	2.659
Gr (R)	2.672	2.628	2.652
Td	2.706	2.616	2.659
RT	2.743	2.466	2.656

(b) Gradation

The results of gradation analyses are shown Fig. IV-8, and further summarized as follows:

Percent Finer than No. 200 Sieve (74μ)			
Class	Highest	Lowest	Mean
Gr (T)	16.2	1.5	9.5
Gr (R)	14.5	6.5	44.5
Td	23.2	11.3	16.3
RT	99.0	13.0	56.6

Fig. IV-9 shows the relation between the average gradation curve and the critical zone of gradation for the cracking.

(c) Consistency

The results of Atterberg Limit tests are summarized in plasticity chart in Fig. IV-10, and further summarized below:

	Liquid Limit (%)			Plasticity Index		
	Highest	Lowest	Mean	Highest	Lowest	Mean
Gr (T)	70.6	23.8	38.4	41.2	8.6	19.1
				(N.P. 2 samples)		
Gr (R)	53.7	45.4	50.0	29.4	23.3	26.4
Td	51.5	34.3	47.1	29.8	16.0	26.0
RT	167.8	54.7	108.6	135.8	29.4	65.7

(N.P. : Non Plastic)

(d) Field Moisture Content (Wf)

Class	Highest	Lowest	Mean
Gr (T)	14.9	5.3	9.8
Gr (R)	24.2	11.7	17.3
Td	29.6	21.8	25.2
RT	71.1	20.7	49.9

3.2.3 Classification

Based upon the results of the grain size analyses and the consistency tests, the samples are classified as follows according to the Unified Classification Method.

Sample	Classification
Gr (T)	SC, GC, SM, SW, SW
Gr (R)	SC
Td	SC
RT	VH, SC, SM

3.2.4 Mechanical Properties

Some representative samples were selected from Gr(T), Td, RT groups to assess the mechanical properties of the soils at the borrow pit sites.

Results of triaxial compression tests, permeability tests and consolidation tests are shown in Table IV-12.

(1) Compaction characteristics

The results of standard procter compaction tests are summarized in the following table.

Results of Procter Compaction Tests

Geological Class	Sample Name	γ dmax (t/m^3)	Wopt (%)	Wf Minus Wopt (%)	Wf Minus W95 (%)	γdf (t/m^3)	Df (%)
RT	D.No4 Z = 1.0 m	1.02	58.6	7.7	3.1	0.94	92
Gr(T)	D.No5 Z = 1.0 m	2.02	10.8	-5.5	-8.0	1.83	90
RT	D.No12Z = 2.4 m	1.26	39.2	5.9	2.2	1.16	91
Td	D.No13Z = 3.0 m	1.64	22.0	-0.2	-4.0	1.64	100

The relation between field moisture content (Wf) and optimum moisture content (Wopt) is as follows:

-Gr(T) : The value of Wf of representative sample is 5.5% dry. For the generalization of the test results and field conditions, it is defined that Wf will be within the range between Wopt and Wopt minus 5%. The maximum density obtained by the compaction test is fairly high and suitable as the embankment material of large-scale dam.

-Td : The value of Wf of representative sample is almost equal to the value of Wopt. The number of samples is not sufficient to generalize the characteristics, but it will be defined that the value of Wf will exceed Wopt minus 5% except for such materials deposited in swampy area. The maximum density of the compaction tests is in the medium range.

-RT : The values of Wf of representative samples range from 5.9 to 7.7% wet side from Wopt. The soil classified in RT has a wide range of Wf value because of wide texture variation. The relation between Wf and Wopt is not estimated. The maximum density of the compaction test is very low and is not suitable for embankment use of large-scale dam.

(2) Triaxial compression test

The shearing strength parameters (C, ϕ) depend on the initial conditions of the soil. Taking the several construction conditions, the following design values are generally recommended.

Class	U-U Test Cu (t/m^2)	U-U Test ϕu (deg.)	$\overline{\text{C-U}}$ Test C' (t/m^2)	$\overline{\text{C-U}}$ Test ϕ' (deg.)
Gr(T)	1.5	30	1.5	35
Td	1.0	10	1.0	30
RT	2.0	5	2.0	10

(3) Permeability Test

The permeability coefficients of most of the samples show the values on the order of 10^{-7} cm/sec except one sample of RT soil showing 10^{-6} cm/sec. The design values of the permeability coefficients (k) are recommended as follows under the condition that the degree of saturation (Sr) is more than 90%.

Class	k (cm/sec)
Gr (T)	5×10^{-5}
Td	1×10^{-6}
RT	5×10^{-6}

(4) Settlement Characteristics

(4-a) Coefficient of Consolidation (Cv)

Class	Cv (cm^2/sec)
Gr (T)	1×10^{-2}
Td	5×10^{-3}
RT	1×10^{-3}

The value of Cv indicates the speed of consolidation. The larger value of Cv will give a small consolidation settlement after embankment.

(4-b) Compression Index (Cc)

Class	Cc
Gr (T)	0.05 to 0.1
Td	0.2
RT	0.3 to 0.7

From view point of deformation of dam embankment, the material showing the value of Cc less than 0.3 is judged suitable for the dam embankment.

(4-c) Yield Pressure of Consolidation (Py)

Class	Py (kg/cm2)
Gr (T)	12.8 over
Td	4.0
RT	1.5

(4-d) Settlement Percentage (S)

Fig. IV-4, shows relation between the consolidation pressure and the settlement percent. The RT material will give excessive settlement when it is used as the material for the embankment which receive a large load on it. Single use of the RT material is not recommended; the RT material should be mixed with coarse material for embankment use. Settlement yield from the single use of the Gr(T) or the Td material for embankment will be in the acceptable range.

3.3 Impervious Materials

3.3.1 Suitability

Based on the laboratory tests and field reconnaissance, the suitability of each material as the impervious material of dam is summarized as follows:

- Gr(T) material: This material shows good characteristics on shearing strength and settlement. The mixing of this material with other impervious one may be necessary when this material is used as the core zone material of dam, because its permeability is slightly low. Necessary measurement in the dam design will be required against piping because of low plasticity index of this material. High plasticity clay (contact clay) of 50-cm thickness will be required on the whole joint surface between foundation rock and core zone.

- Td material : This material is suitable as impervious material, showing good performance in every characteristics in soil mechanics.

- RT material : This material shows poor characteristics, and use of this materials as the embankment material is not recommended. This can be utilized after mixing this material with coarse materials.

3.3.2 Available Amount of Impervious Material

(1) Gr(T) and Gr(R) Materials

The Gr(T) and clayey or silty Gr(R) can be utilized for the construction of fill-type dam. The geological condition of borrow pit selected at the nearest place to the dam site is summarized below.

The formation of the hillock up to the height of 40 m from the foot of hillock consists of weathered granite, and in the height of more than 40 m tuffous sandy rock crops out. the Gr(T) is found for 1.5 m to 3.0 m in depth on especially south side slope of the hillock. The Gr(R) lies under the Gr(T) on every side of slope. The available amount of the material is estimated to be around 400,000 m^3 for the Gr(T), and to be over 500,000 m^3 for the Gr(R).

(2) Td Material

Td material can be utilized as the core material of Komering No.1 dam. The distribution of this material is up to the Komering No.2 dam site from several kilometer downstream of Komering No.1 dam site having a width of 1 to 2 km. Sufficient amount of the material can be expected from the left bank area of the Selabung river.

(3) RT Material

This material can be obtained in every dam site, but usable depth may be 1 to 2 m from the ground surface. The available amount from the borrow pit area will be about 5,000 m^3 to 10,000 m^3.

3.4 Sand and Gravel Materials

(1) Muaradua Site

Sand material is available along every reach of the Komering river and its quantity will be enough for the construction use.

Gravel material is available at the curves and shoals of the Komering river and particularly the maximum gravel diameter of 100 mm is available 10-km upstream from the dam site. The available quantity of gravel would be 40,000 m^3 per 1 km of the river.

(2) Komering No. 2 Site

There found sand and gravel deposits in the Selabung river, particularly in the reach from 4 km to 2 km downstream from the dam site. The available quantity of sand-gravel mixed material would be 40,000 m^3. The mix ratio of sand and gravel is estimated to be 2:1 in volume. Other than this river reach, around 5,000 m^3 of sand-gravel mixed material would be available for every 1 km in the upstream from the dam site. Since these amounts will be not enough for the construction of the gravity dam, another quarry site should be exploited after detailed investigation.

(3) Komering No. 1 Site

Very limited amount of sand and gravel materials is only available in the Selabung river near the dam site. Therefore, it is necessary to carry the materials from the downstream of the river or to exploit the quarry site near the dam site. For this, further detailed investigation is required.

Table IV - 1 HOLE NUMBER, DEPTH AND ITS LOCATION

Survey district	Hole Number	Depth (m)	Location
Muncak Kabau Main Canal	M.N01	a 4.0	proposed Intake site
	M.N02	a 5.0	1 km to North from Proposed Intake site
	M.N03	t 3.0	1 km to North - east from Simpang Sirimiryo
	M.N04	a 5.0	2.5 km to East from D.Jatimuryo
	M.N05	a 5.0	proposed Biturcation site D. Anyer
	M.N06	a 4.3	D. Riang bandung.
Lempuing Main Canal	L.N01	t 2.0	4 km to South from D. Burnaimulia
	L.N02	a, t 6.0	2 km to North from D. Siriwangi
	L.N03	a 5.0	D. Bumi Agung
	L.N04	a 5.0	D. Karang Nongko
	L.N05	a 5.0	D. Sidorjo
Tulangbawang Main Canal	T.N01	t 2.5	3 km To North from D. Mesir
	T.N02	a 5.0	3 km from proposed Bifurcation site
	T.N03	a 5.0	proposed Bifurcation site
	T.N04	a 3.0	
	T.N05	a 3.0	
	T.N06	a 2.5	D. Karang Sari
Muaradua Dam	D.N01)	sampled	refer to Fig. IV- 7
	D.N02)	from	
	D.N03)	outcrop	
	D.N04	t 2.5	
	D.N05	t 3.0	
	D.N06	t 2.0	
	D.N07	t 3.0	
	D.N08	t 3.0	
Komering No. 1 Dam	D.N011	a 1.5	"
	D.N012	a 3.0	
Komering No. 2 Dam	D.N013	a 3.1	"
	D.N014	a 3.0	

Remark ; "a" and "t" indicate auger borehole and test pit respectively.

Table IV -2 LABORATORY TEST ITEM AND ITS QUANTITY

Test Item	Number of samples tested for canals	for dams	Total
1) Water content	37	23	60
2) Specific gravity	63	28	91
3) Gradation /1	63	30	93
4) Liquid Limit	63	28	91
5) Plastic Limit	63	28	91
6) Absorption	-	1	1
7) Unit weight	2	-	2
8) Compaction	2	4	6
9) Triaxial compression /2			
(U - U) /3	2	-	2
(U - U) /4	4	8	12
(C - U) /4	4	8	12
10) Permeability	4	8	12
11) Consolidation	4	8	12

Note: /1 ; This test was carried out using both hydrometer and sieve.

/2 ; " UU " and " CU " indicate the tests made under unconsolidated and undrained conditions, and under consolidated and undrained conditions respectively.

/3 ; This test was made using the undisturbed sample.

/4 ; This test was made using the remolded specimen.

Table IV-3(1) RESULT OF INDEX PROPERTY TEST FOR THE CANAL

(Muncak Kabau Main Canal)

HOLE NUMBER	DEPTH (m)	GEOLOGICAL CLASSIFI-CATION	UNIFIED CLASSIFI-CATION	FIELD MOISTURE CONTENT Wf (%)	SPECIFIC GRAVITY Gs	CONSISTENCY L.L. (%)	P.L. (%)	P.I	GRADATION Passed Percentage (%) 4.76 mm	2.00 mm	0.42 mm	0.074 mm	0.005 mm	Particle Size (mm) D_{60}	D_{30}	D_{10}	Cu	Cc	REMARKS
M. No.1	1.0	Al. G(2)	SC	22.6	2.509	40.6	18.0	22.6	—	100.0	87.8	40.0	5.3	0.12	0.059	0.016	7.5	0.55	
	2.0	Al. G(2)	CL	42.1	2.607	46.0	24.4	21.6	—	100.0	99.0	52.0	7.0	0.089	0.036	0.0076	12	0.52	
	3.0	Al. G(1)	SP	—	2.641		N.P.		99.5	95.5	38.5	5.5	under 2.0	0.58	0.36	0.12	4.8	0.57	
	4.0	Al. G(1)	SP	12.0	2.699		N.P.		80.0	66.5	18.5	0.5	0	1.45	0.56	0.33	4.4	1.52	
M. No.2	1.0	Al. G(2)	SC	—	2.499	—	—	—	—	100.0	99.0	42.5	10.2	0.11	0.046	0.0045	24	0.23	
	1.5	Al. G(2)	CL	—	2.571	37.9	15.7	22.2	—	—	100.0	51.4	16.1	0.091	0.030	0.0010	91	0.10	
	2.0	Al. G(2)	SC	33.4	2.495	—	—	—	—	—	100.0	31.5	6.0	0.093	0.072	0.016	5.8	0.29	
	3.0	Al. G(3)	CL	38.8	2.558	46.5	19.9	26.6	—	—	100.0	55.5	15.0	0.087	0.019	0.0018	48	0.43	
	4.0	Al. G(3)	CH	—	2.629	97.0	23.5	73.5	—	—	100.0	90.0	51.5	0.0098	—	—	—	—	
	5.0	Al. G(3)	SC - CH	44.5	2.639	90.4	31.5	58.9	—	100.0	98.5	47.0	23.0	0.13	0.012	0.0010	130	0.90	
M. No.3	1.0	Dl. 1st	SM	31.3	2.670	95.7	44.2	51.5	—	100.0	78.5	25.8	5.0	0.26	0.094	0.025	10	0.74	
	2.0	Dl. 2nd	SM - SW	27.3	2.643		N.P.		100.0	94.0	35.0	9.5	under 0	1.02	0.34	0.079	13	0.70	
	3.0	Dl. 3rd	VH	43.0	2.703	87.9	43.7	44.2	—	—	100.0	95.0	25.0	0.023	0.0072	0.00079	29	0.35	
M. No.4	1.0	Al. G(3)	CH	37.8	2.577	53.6	23.8	29.8	—	—	100.0	63.0	12.0	0.069	0.023	0.0034	20	0.44	
	2.0	Al. G(3)	SM - CH	39.4	2.630	69.6	38.0	31.6	—	100.0	99.0	47.5	13.0	0.115	0.030	0.0030	38	0.38	
	3.0	Al. G(3)	CH	50.8	2.607	60.3	25.8	34.5	—	100.0	97.5	59.0	28.0	0.079	0.0066	0.00045	176	0.82	
	4.0	Al. G(3)	MH	43.7	2.703	90.3	40.6	49.7	—	100.0	99.0	56.5	19.0	0.090	0.013	0.0015	60	0.80	
	5.0	Al. G(3)	MH	40.0	2.646	93.6	41.0	52.6	—	—	100.0	93.0	53.0	0.0079	0.0014	—	—	—	
M. No.5	1.0	Al. G(2)	CL - SC	29.6	2.552	49.0	19.2	29.8	—	—	98.0	50.0	10.0	0.093	0.035	0.0047	20	0.36	
	2.0	Al. G(2)	SC	—	2.518	52.6	23.2	29.4	—	—	100.0	45.0	9.0	0.102	0.042	0.0060	17	0.35	
	3.0	Al. G(3)	CL	—	2.502	45.7	21.6	24.1	—	—	100.0	71.0	14.0	0.052	0.017	0.0021	25	0.38	
	4.0	Al. G(3)	MH	—	2.496	67.8	36.0	31.8	—	—	100.0	74.0	13.0	0.050	0.018	0.0017	29	0.26	
	5.0	Al. G(3)	SC	—	2.652	44.6	23.1	21.5	—	—	98.0	31.0	5.0	0.115	0.072	0.015	7.7	0.33	
M. No.6	1.0	Al. G(3)	CH	39.7	2.525	52.7	25.9	26.8	—	—	100.0	55.0	11.0	0.091	0.023	0.0042	22	0.72	
	2.0	Al. G(3)	CL - CH	37.6	2.502	—	—	—	—	—	100.0	55.0	7.0	0.083	0.040	0.0107	7.8	0.56	
	3.0	Al. G(2)	SM	43.8	2.488		N.P.		—	100.0	99.0	28.5	under 5	0.125	0.079	0.043	2.9	0.86	
M. No.5 U (undisturbed)	1.0	Al. G(2)		—	2.539	—	—	—											

Table IV-3(2) RESULT OF INDEX PROPERTY TEST FOR THE CANAL

(Lempuing Main Canal)

HOLE NUMBER	DEPTH (m)	GEOLOGICAL CLASSIFI-CATION	UNIFIED CLASSIFI-CATION	FIELD MOISTURE CONTENT Wf (%)	SPECIFIC GRAVITY Gs	CONSISTENCY L.L. (%)	CONSISTENCY P.L. (%)	CONSISTENCY P.I	GRADATION Passed Percentage (%) 4.76 mm	2.00 mm	0.42 mm	0.074 mm	0.005 mm	Particle Size (mm) D_{60}	D_{30}	D_{10}	Cu	Cc	REMARKS
L. No.1	2.0	D1, 1st	GM	15.5	2.932		N.P.		72.5	37.0	18.0	5.0	1.0	2.85	1.29	0.15	26	0.35	
L. No.2	1.0	D1, 1st	SM	40.6	2.699	83.3	38.4	44.9	100.0	96.0	84.5	34.0	12.6	0.17	0.052	0.0025	68	0.16	
	2.0	D1, 2nd	MH	28.3	2.726	102.1	47.4	54.7	100.0	98.5	93.5	78.5	42.0	0.022	0.0013	—	—	—	
	2.5	D1, 2nd	SC	—	2.731	—	—	—	—	100.0	97.5	48.0	24.0	0.12	0.0107	—	—	—	
	4.0	D1, 2nd	SM	32.2	2.629	66.3	35.5	30.8	—	—	100.0	41.5	17.5	0.102	0.038	0.00063	162	0.045	
	5.0	D1, 3rd	SC	36.5	2.621	69.9	25.2	44.7	—	100.0	99.0	49.5	19.0	0.091	0.026	0.00075	122	0.10	
	5.0	D1, 3rd	SC	34.6	2.638	63.8	27.8	36.0	100.0	98.5	87.0	23.0	7.0	0.209	0.105	0.0115	18	0.22	
L. No.3	1.0	A1, G(2)	SC	32.3	2.516	—	—	—	—	98.0	90.5	37.0	4.5	0.110	0.062	0.0102	11	0.29	
	2.0	A1, G(3)	CL	24.0	2.650	33.6	15.3	18.3	—	100.0	93.0	51.5	11.0	0.100	0.029	0.0038	26	0.45	
	3.0	A1, G(3)	CH	42.4	2.622	105.1	31.2	73.9	—	—	100.0	90.5	52.5	0.0105	—	—	—	—	
	4.0	A1, G(3)	MH	51.3	2.648	107.0	44.3	62.7	—	—	100.0	76.0	32.0	0.055	0.0038	—	—	—	
	5.0	A1, G(2)	SM	66.6	2.549	79.6	37.9	41.7	—	—	100.0	42.0	9.0	0.117	0.043	0.0058	20	0.37	
L. No.4	0.5	A1, G(1)	MH	28.1	2.642	95.9	42.5	53.4	—	100.0	96.0	79.0	42.0	0.017	0.0024	—	—	—	
	2.0	A1, G(2)	SC	32.7	2.613	68.4	32.7	35.7	—	100.0	88.5	46.5	19.0	0.18	0.017	0.0015	120	0.93	
	3.0	A1, G(3)	MH	36.0	2.621	82.4	40.2	42.2	—	100.0	99.0	68.0	26.0	0.056	0.0079	0.00075	75	0.67	
	4.0	A1, G(2)	SM	—	2.612	97.8	41.8	56.0	—	100.0	99.0	41.5	15.0	0.14	0.030	0.0021	67	0.33	
	5.0	A1, G(2)	SC	—	2.703	71.3	30.1	41.2	—	100.0	99.0	40.8	10.6	0.123	0.043	0.0042	29	0.28	
L. No.5	1.0	D1, 1st	SC	13.6	2.654	47.4	20.2	27.2	100.0	99.5	74.0	18.5	4.0	0.30	0.126	0.033	9.1	0.62	
	2.0	D1, 2nd	MH	21.4	2.671	100.7	46.4	54.3	—	100.0	90.0	66.5	33.5	0.046	0.0035	0.0016	29	0.60	
	3.0	D1, 3rd	VH	28.7	2.671	97.5	46.1	51.4	—	100.0	94.0	68.0	29.5	0.055	0.0052	0.00063	87	1.28	
	4.0	D1, 3rd	SC	43.7	2.657	60.7	27.2	33.5	—	—	100.0	46.5	21.0	0.112	0.0145	0.0005	224	0.27	
	5.0	D1, 4th	CH	42.1	2.616	65.0	30.6	34.4	—	—	100.0	57.5	28.0	0.083	0.0069	0.00104	80	1.81	
L. No.2 U (undisturbed)	2.5	D1, 2nd		—	2.692	—	—	—											

Table IV-4(3) RESULT OF INDEX PROPERTY TEST FOR THE CANAL

(Tulangbawang Main Canal)

HOLE NUMBER	DEPTH (m)	GEOLOGICAL CLASSIFI-CATION	UNIFIED CLASSIFI-CATION	FIELD MOISTURE CONTENT Wf (%)	SPECIFIC GRAVITY Gs	CONSISTENCY L.L. (%)	P.L. (%)	P.I.	GRADATION Passed Percentage (%) 4.76 mm	2.00 mm	0.42 mm	0.074 mm	0.005 mm	Particle Size (mm) D_{60}	D_{30}	D_{10}	Cu	Cc
T. No.1	1.0	Dl, 1st	SC	18.5	2.635	50.5	20.2	30.3	100.0	99.0	60.0	15.5	under 1.0	0.42	0.16	0.055	7.6	0.90
	2.2	Dl, 2nd	SC	20.9	2.648	66.8	28.1	38.7	—	100.0	84.0	22.0	"	0.24	0.105	0.035	6.9	0.76
T. No.2	1.0	Dl, 1st	MH	30.8	2.637	106.6	47.8	58.8	100.0	96.0	88.5	78.5	40.0	0.022	0.0013	—	—	—
	2.0	Dl, 3rd	VH	46.2	2.614	101.5	45.1	56.4	100.0	99.0	97.0	95.0	55.0	0.0076	0.00083	—	—	—
	3.0	Dl, 3rd	VH	49.2	2.663	139.2	53.7	85.5	100.0	99.5	98.5	77.0	44.5	0.028	0.0012	—	—	—
	4.0	Dl, 3rd	VH	70.2	2.661	108.1	51.0	57.1	—	—	100.0	82.0	40.0	0.028	0.0016	—	—	—
	5.0	Dl, 4th	CH	42.6	2.785	122.1	55.8	66.3	—	—	100.0	78.5	34.0	0.033	0.0042	0.00063	52	1.18
T. No.3	1.0	Dl, 1st	SC	23.9	2.733	69.5	24.6	44.9	97.5	89.0	65.5	27.0	7.0	0.316	0.087	0.0110	29	0.46
	2.0	Dl, 2nd	MH	37.2	2.652	114.7	57.1	57.6	100.0	98.0	91.0	73.5	39.5	0.024	0.0016	—	—	—
	3.0	Dl, 2nd	CH	—	2.643	66.5	31.5	35.0	95.5	94.5	88.0	68.5	37.0	0.036	0.0021	—	—	—
	4.0	Dl, 3rd	SC	—	2.641	63.1	23.7	39.4	99.5	97.5	70.6	21.5	under 5.0	0.316	0.123	0.032	9.9	0.67
	5.0	Dl, 3rd	SC	—	2.644	49.6	22.8	26.8	100.0	93.0	42.5	14.5	"	0.69	0.25	0.035	20	0.39
T. No.4	1.0	Al, G(2)	SC	—	2.659	60.7	30.9	29.8	100.0	99.0	90.0	33.5	10.5	0.166	0.061	0.0040	42	0.18
	2.0	Al, G(2)	SC	—	2.491	76.1	28.7	47.4	—	100.0	83.5	27.5	under 5.0	0.23	0.084	0.022	10	0.72
	2.5	Al, G(1)	SP	—	2.645		N.P.		98.0	91.0	35.0	3.5	under 1.0	0.69	0.39	0.166	4.2	0.75
T. No.5	0.5	Al, G(1)	SW	16.2	2.898		N.P.		48.5	38.5	24.5	5.0	"	6.0	0.71	0.13	46	1.55
	1.5	Al, G(2)	SC	25.8	—	79.3	33.0	46.3	99.0	96.0	81.0	23.0	under 5.0	0.25	0.10	0.030	8.3	0.75
	3.0	Al, G(2)	SC	24.2	2.655	49.7	23.9	25.8	98.0	91.7	39.0	11.0	"	0.69	0.30	0.060	12	0.46

REMARKS

Dl : Diluvium
Al : Alluvium
1st: First stratum on hilly area
2nd: Second stratum on hilly area
3rd: Third stratum on hilly area
4th: Fourth stratum on hilly area

G(1) : Group (1) on paddy field
G(2) : Group (2) on paddy field
G(3) : Group (3) on paddy field

Table IV-4(1) SOIL TYPE - MECHANICAL PROPERTIES

(a) Important Mechanical Properties

Group Symbols	Permeability when compacted	Shear strength when compacted and saturated	Compressibility when compacted and saturated	Workability as a construction material
GW	Pervious	Excellent	Negligible	Excellent
GP	Very pervious	Good	Negligible	Good
GM	Semi-pervious to impervious	Good	Negligible	Good
GC	Impervious	Good to fair	Very low	Good
SW	Pervious	Excellent	Negligible	Excellent
SP	Pervious	Good	Very low	Fair
SM	Semi-pervious to impervious	Good	low	Fair
SC	Impervious	Good to fair	low	Good
ML	Semi-pervious to impervious	Fair	Medium	Fair
CL	Impervious	Fair	Medium	Good to fair
OL	Semi-pervious to impervious	Poor	Medium	Fair
MH	Semi-pervious to impervious	Fair to poor	High	Poor
CH	Impervious	Poor	High	Poor
VH	Semi-impervious	Poor	High	Poor

Table IV-4(2) SOIL TYPE - MECHANICAL PROPERTIES

(b) Relative Desirability for Various Uses (No.1 is considered the best)

Group Symbols	Rolled Earthfill Dams			Canal Sections		Foundations		Roadways	
	Homogeneous Embankment	Core	Shell	Erosion Resistance	Compacted Earth Lining	Seepage Important	Seepage Not Important	Fills	Surfacing
GW	-	-	1	1	-	-	1	1	3
GP	-	-	2	2	-	-	3	3	-
GM	2	4	-	4	8	1	4	9	5
GC	1	1	-	3	1	2	6	5	1
SW	-	-	3/a	6	-	-	2	2	4
SP	-	-	4/a	7/a	-	-	5	4	-
SM	4	5	-	8/a	9/b	3	7	10	6
SC	3	2	-	5	2	4	8	6	2
ML	6	6	-	11	4/b	6	9	11	-
CL	5	3	-	9	3	5	10	7	7
MH	8	8	-	12	6	8	12	13	-
CH	7	7	-	10	5/c	9	13	8	-
VH	9	9	-	13	7/b	10	14	12	-
OL		Unsuitable				7	15	-	-
OH		"				11	11	-	-
PT		"				-	-	-	-

/a = if gravelly

/b = erosion critical

/c = volume change critical

Table IV-5 RESULTS OF MECHANICAL PROPERTY TESTS FOR THE CANAL

Stratum	Sample Name	Initial Condition of Specimen	Triaxial Compression Test				Permeability	Consolidation Test					
			U-U Test △1		C-U Test △2		Coefficient of Permeability	Coefficient of Consolidation Cv (cm²/sec) × 10^{-3}			Cc	Py	S △3
			Cu (t/m²)	φu (deg.)	C' (t/m²)	φ' (deg.)	k (cm/sec)	lowest	highest	mean		(kg/cm²)	(%)
2nd stratum on hilly area (Diluvium)	L. No.2 Z = 2.5m	1	5.5	5.5	0	29.0	3.3×10^{-7}	1.2	3.5	2.1	0.35	1.3	7.2
		2	3.7	5.0	0.8	29.5	1.6×10^{-7}	1.0	3.4	2.0	0.35	3.0	9.9
Group (3) on paddy field (Alluvium)	M. No.2 Z = 1.5m	3	10.8	11.5	2.5	36.0	3.3×10^{-7}	1.4	5.2	3.3	0.20	1.4	6.4
		4	7.3	7.0	—	—	3.0×10^{-7}	1.6	5.6	3.4	0.17	5.0	8.3

Initial Condition

Index / Number	D-value (%)	d (t/m³)	w (%)	t (t/m³)	e	Sr (%)
1	100	1.32	37.3	1.81	1.07	95
2	95	1.25	40.9	1.76	1.18	94
3	100	1.51	23.1	1.86	0.70	85
4	95	1.43	27.4	1.82	0.80	88

Remark

△1 : indicating with total stress

△2 : indicating with effective stress

△3 : settlement percent when consolidation pressure is 2.0kg/cm²

Table IV - 6 GROUNDWATER DEPTH IN TEST HOLE

Survey District	Hole Number	Depth below Ground Surface (m)
Muncak Kabau	M.No.1	2.0 m
	M.No.2	0.4 m
	M.No.3	3.0 m
	M.No.4	deeper than 5.0 m
	M.No.5	2.9 m
	M.No.6	4.2 m
Lempuing	L.No.1	deeper than 2.0 m
	L.No.2	deeper than 6.0 m
	L.No.3	1.2 m
	L.No.4	2.9 m
	L.No.5	deeper than 5.0 m
Tulangbawang	T.No.1	deeper than 2.5 m
	T.No.2	deeper than 5.0 m
	T.No.3	2.1 m
	T.No.4	deeper than 3.0 m
	T.No.5	deeper than 3.0 m
	T.No.6	0.5 m

Table IV - 7 EFFECTIVE GRAIN SIZE (D_{10}) OF SAND IN FOUNDATION ALONG THE CANAL ROUTES

(UNIT: mm)

Class	SC	SM	SW-SP
	0.0072	0.043	0.13
	0.0045	0.0058	0.12
	0.0010	0.002	0.31
	0.0170		0.16
	0.0046		
	0.0058		
	0.0170		
	0.0180		
	0.0015		
	0.0042		
	0.0040		
	0.0580		
	0.0220		
	0.0300		
	0.0170		
Average ($\overline{D_{10}}$)	0.0141	0.0169	0.18

Table IV - 8 COEFFICIENT OF PERMEABILITY FOR SAND IN FOUNDATION ALONG THE CANAL ROUTES

	SC	SM	SW-SP
$\overline{D_{10}}$(cm)	1.41×10^{-3}	1.69×10^{-3}	1.80×10^{-2}
$(\overline{D_{10}})^2$	1.99×10^{-6}	2.86×10^{-6}	3.24×10^{-4}
k (cm/sec)	2.0×10^{-4}	2.9×10^{-4}	3.2×10^{-2}

Utilized Hazan's Formula: $k = C.D_{10}$

C; constant
(adopt 100)

Table IV-9 BEARING CAPACITY FACTOR

ϕ_u	Nc	Nq	Nr
0	5.71	1.00	0
5	6.72	1.39	0
10	8.01	1.94	0
15	9.69	2.73	1.2
20	11.9	3.88	2.0
25	14.8	5.60	3.3
30	19.1	8.32	5.4
35	25.2	12.8	9.6
40	34.8	20.5	19.1

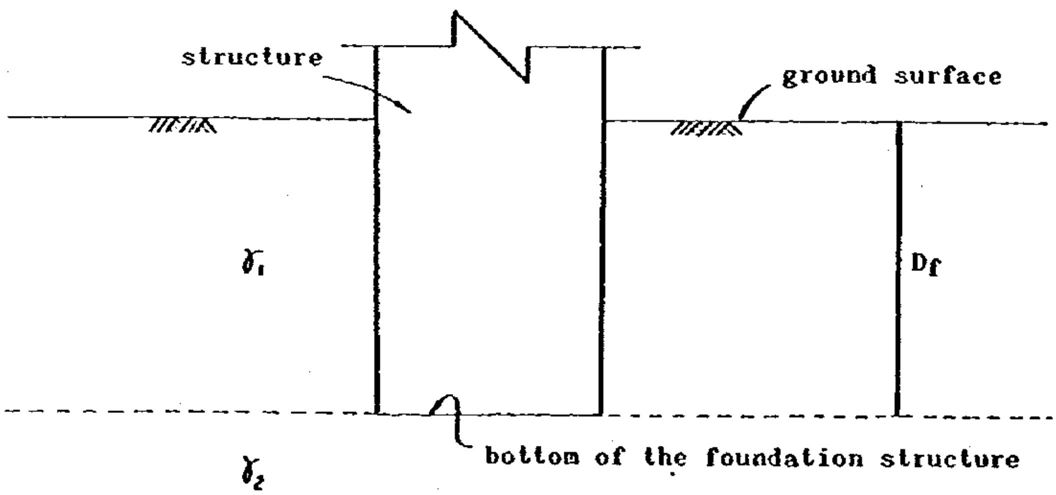


Table IV-10 SHAPE FACTOR OF BEARING CAPACITY

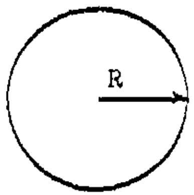
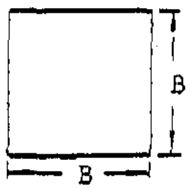
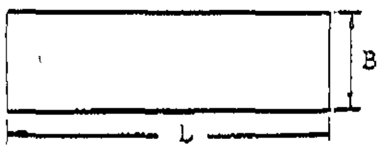
Shape of Foundation Load		Shape Factor	
		α	β
Continuous L B		1.0	0.5·B
Circular		1.3	0.6·R
Square		1.3	0.4·B
Rectangular		1 + B/3L	0.5·B(1-B/3L)

Table IV-11 RESULT OF INDEX PROPERTY TEST FOR THE DAMS

HOLE NUMBER	DEPTH (m)	GEOLOGICAL CLASSIFI-CATION	UNIFIED CLASSIFI-CATION	FIELD MOISTURE CONTENT Wf (%)	SPECIFIC GRAVITY Gs	CONSISTENCY L.L. (%)	P.L. (%)	P.I	GRADATION Passed Percentage (%) 4.76 mm	2.00 mm	0.42 mm	0.074 mm	0.005 mm	Particle Size (mm) D_{60}	D_{30}	D_{10}	Cu	Cc	REMARKS
D. No.1	out-crop	RT	SC	—	2.466	—	—	—	99.0	97.4	73.2	31.6	3.5	0.26	0.069	0.017	15	0.93	Gr(T) : Talus deposit originated from Cretaceous Granite Gr(R) : Residual deposit of Cretaceous Granite Td : Talus deposit originated from Neogene Sedimentary rock RT : Yocanic ash of Quaternary
D. No.2	out-crop	RT	SC	—	2.680	54.7	25.3	29.4	—	100.0	70.0	18.0	under 5.0	0.32	0.132	0.046	7.2	0.87	
D. No.4	0.5	RT	VH	71.1	2.712	167.8	32.0	135.8	—	100.0	99.8	96.0	60.0	0.016	0.0023	—	—	—	
	0.6	RT	VH	68.4	2.660	149.5	71.4	78.1	—	100.0	99.5	96.7	43.0	0.013	0.002	—	—	—	
	1.0	RT	VH	66.3	2.704	127.8	63.8	64.0	—	—	100.0	99.0	24.8	0.019	0.0069	0.001	19	0.40	
	2.0	RT	VH	54.5	2.742	123.5	40.6	82.9	—	—	100.0	97.3	29.5	0.022	0.0053	0.0007	31	0.55	
	2.5	RT	VH	53.3	2.723	130.5	46.8	83.7	—	100.0	99.5	95.0	22.0	0.047	0.0100	0.0014	34	0.66	
D. No.5	1.0	Gr(T)	SW	5.3	2.660		N.P.		92.0	60.5	15.3	4.0	under 2.0	1.91	0.91	0.23	8.3	0.53	
	2.0	Gr(T)	GW	5.9	2.624		N.P.		73.5	48.5	8.7	1.5	0	2.82	1.26	0.49	5.8	0.87	
	2.5	Gr(T)	SC	12.2	2.660	25.2	16.3	8.9	74.3	64.0	26.5	16.2	5.3	1.57	0.28	0.024	65	0.48	
D. No.6	1.0	Gr(T)	SC	9.7	2.651	23.8	15.2	8.6	92.0	83.0	39.5	11.0	0	0.93	0.26	0.081	12	1.11	
	1.5	Gr(T)	SW - SM	8.2	2.646	—	—	—	66.5	55.0	29.7	8.7	under 5.0	2.82	0.46	0.087	32	1.16	
D. No.7	1.0	Gr(T)	GC	12.3	2.750	33.9	16.2	17.7	54.0	48.0	38.0	10.0	"	9.12	0.25	0.076	120	11.1	
	2.0	Gr(R)	SC	41.5	2.672	—	—	—	100.0	99.8	83.2	14.5	under 5.0	0.31	0.19	0.022	14	0.19	
	3.0	Gr(R)	SC	11.7	2.659	—	—	—	—	100.0	68.0	6.5	under 2.0	0.41	0.29	0.105	3.9	0.51	
D. No.8	1.0	Gr(T)	SC	14.9	2.633	70.6	29.4	41.2	97.0	76.5	44.5	15.2	under 5.0	0.91	0.19	0.044	21	1.11	
	2.0	Gr(R)	SC	24.2	2.648	53.7	24.3	29.4	96.5	80.0	37.5	10.7	"	1.12	0.28	0.069	16	0.99	
	3.0	Gr(R)	SC	16.1	2.628	45.4	22.1	23.3	97.3	82.5	47.0	12.8	"	0.76	0.18	0.068	11	1.60	
D. No.11	1.0	RT	SM	44.6	2.642	76.4	39.3	37.1	—	100.0	78.5	48.0	24.3	0.16	0.013	—	—	—	
D. No.12	1.0	RT	SC	44.4	2.650	69.6	31.1	38.5	—	100.0	72.3	19.2	under 5.0	0.31	0.12	0.043	7.2	0.93	
	2.6	RT	SM	25.5	2.617	77.9	36.4	41.5	100.0	99.0	66.5	19.2	"	0.36	0.12	0.048	7.5	1.20	
	3.0	RT	SM	20.7	2.617	—	—	—	—	100.0	63.0	13.0	"	0.38	0.14	0.066	5.8	1.29	
D. No.13	1.0	Td	SC	23.6	2.616	50.8	23.2	27.6	100.0	98.0	70.0	17.3	"	0.33	0.13	0.046	7.2	0.90	
	2.0	Td	SC	25.2	2.653	51.5	21.7	29.8	92.5	87.2	57.3	23.2	5.0	0.48	0.12	0.018	27	0.60	
	3.0	Td	SC	21.8	2.706	34.3	18.3	16.0	61.5	54.0	29.3	11.3	under 5.0	4.07	0.46	0.063	65	1.21	
D. No.14	1.0	Td	SC	25.9	2.669	49.9	22.3	27.6	84.5	81.3	46.4	12.5	"	0.63	0.21	0.062	10	0.89	
	2.0	Td	SC	29.6	2.651	49.1	19.9	29.2	99.3	93.4	68.0	12.0	"	0.63	0.17	0.042	15	0.92	
K. No.1		Sand	SP	—	2.609	—	—	—	99.5	99.0	69.5	2.0	0	0.35	0.20	0.129	2.7	1.13	
K. No.2		Gravel	GW	—	2.726	—	—	—											

Table IV-12 RESULTS OF MECHANICAL PROPERTY TESTS FOR THE DAMS

Stratum	Sample Name	Initial Condition of Specimen	Triaxial Compression Tests: U-U Test ∠1 Cu (t/m²)	U-U Test ∠1 φu (deg.)	C-U Test ∠2 C' (t/m²)	C-U Test ∠2 φ' (deg.)	Permeability: Coefficient of Permeability k (cm/sec)	Consolidation Test: Coefficient of Consolidation Cv (cm²/sec) × 10^{-3} lowest	highest	mean	Cc	Py (kg/cm²)	∠3 S (%)
Volcanic ash	D. No.4 Z = 1.0m	1	4.2	6.0	1.8	21.5	1.6×10^{-6}	4.4	8.6	7.3	0.67	1.7	22.2
		2	2.3	7.0	2.0	20.0	3.4×10^{-6}	1.2	3.3	1.9	0.70	1.3	22.6
Talus deposit of Granite	D. No.5 Z = 1.0m	3	1.8	35.0	7.0	38.5	4.6×10^{-7}	2.9	19.0	12.0	0.049	>12.8	4.9
		4	2.0	38.0	0	39.0	1.8×10^{-7}	2.8	7.9	5.3	0.092	>12.8	8.1
Volcanic ash	D. No.12 Z = 2.4m	5	0.8	28.5	0	34.0	2.0×10^{-7}	1.4	2.6	1.8	0.30	2.5	12.7
		6	0.8	13.5	0.4	29.5	5.3×10^{-7}	2.0	7.0	4.0	0.32	1.8	16.4
Talus deposit of Sedimentary rock	D. No.13 Z = 3.0m	7	1.0	10.0	0.5	33.5	2.1×10^{-7}	1.2	4.2	3.1	0.18	4.0	9.9
		8	0.8	7.5	2.0	31.5	2.3×10^{-7}	2.2	5.6	3.5	0.19	3.0	11.6

Initial Condition

Index / Number	D-value (%)	γd (t/m³)	w (%)	γt (t/m³)	e	Sr (%)
1	100	1.02	58.6	1.62	1.65	96
2	95	0.97	63.1	1.58	1.79	95
3	100	2.02	10.8	2.24	0.32	91
4	95	1.92	13.8	2.18	0.39	95
5	100	1.26	39.2	1.75	1.08	95
6	95	1.20	42.8	1.71	1.18	95
7	100	1.64	22.0	2.00	0.65	92
8	95	1.56	25.6	1.96	0.73	94

Remarks

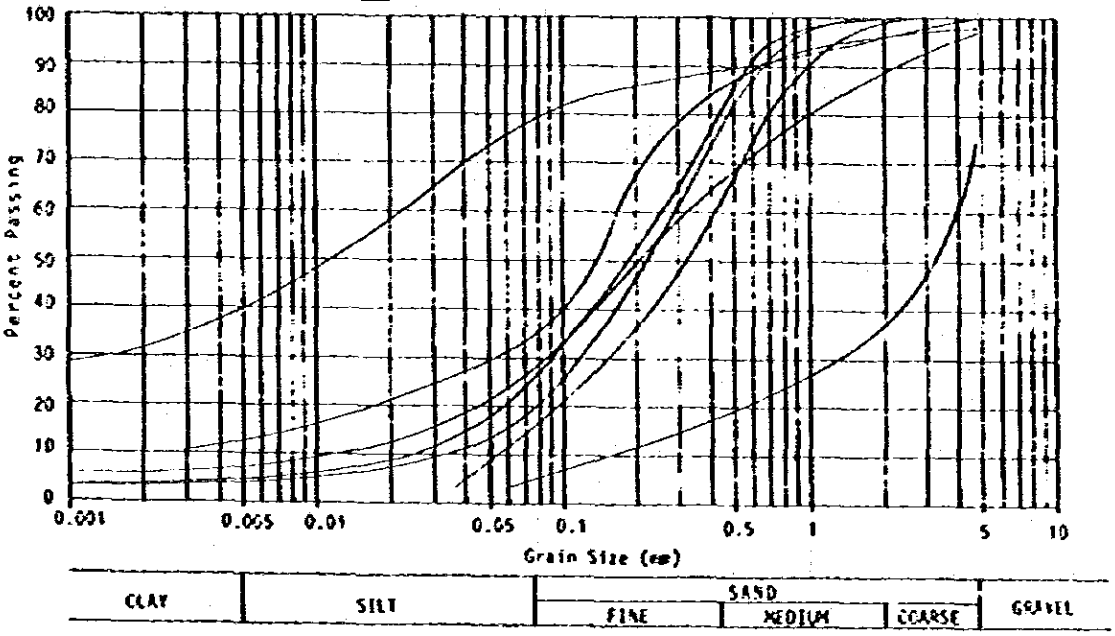
∠1 : indicating with total stress

∠2 : indicating with effective stress

∠3 : settlement percent when consolidation pressure is 6.4kg/cm³

Fig. IV-1(1) GRAIN SIZE ACCUMULATION CURVE
(materials along the canals)

1st stratum



2nd stratum

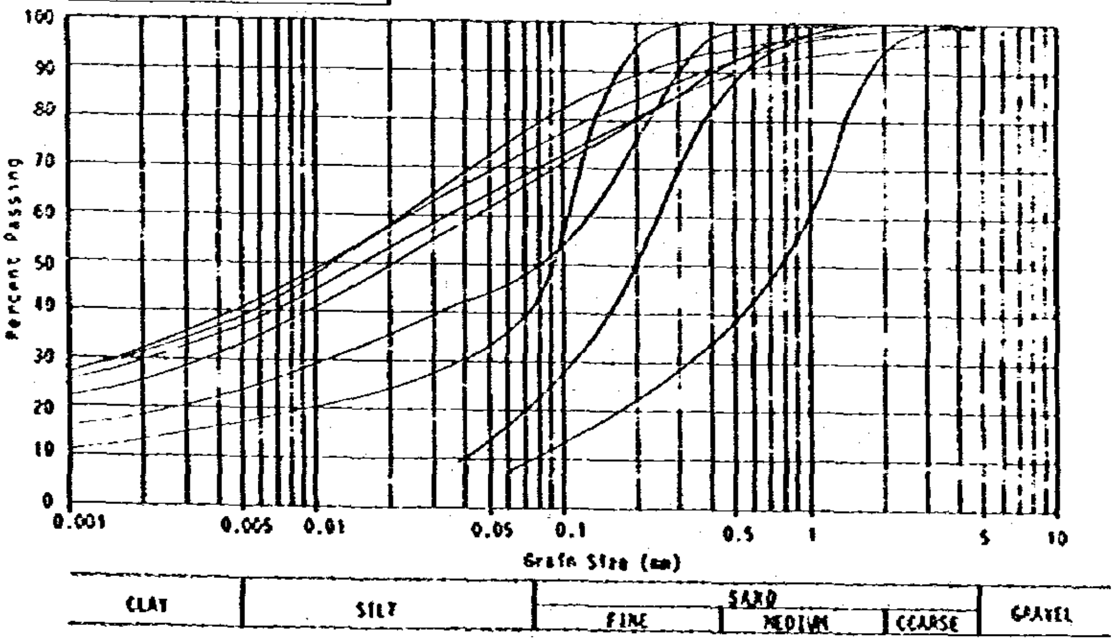
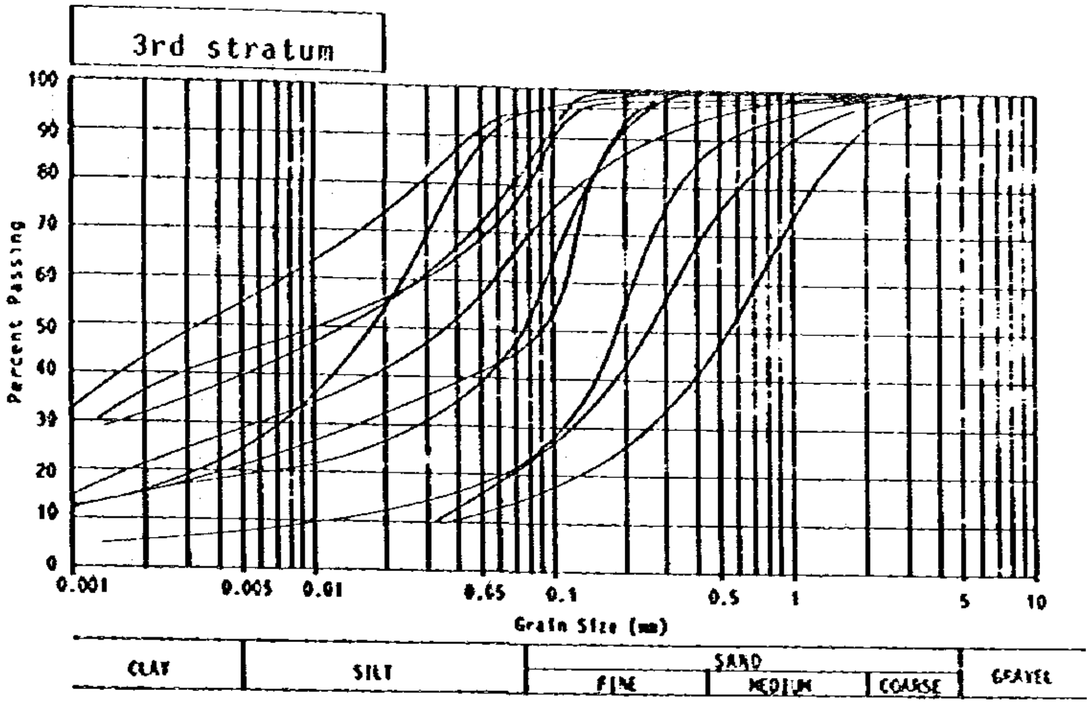


Fig. IV-1(2) GRAIN SIZE ACCUMULATION CURVE
(materials along the canals)



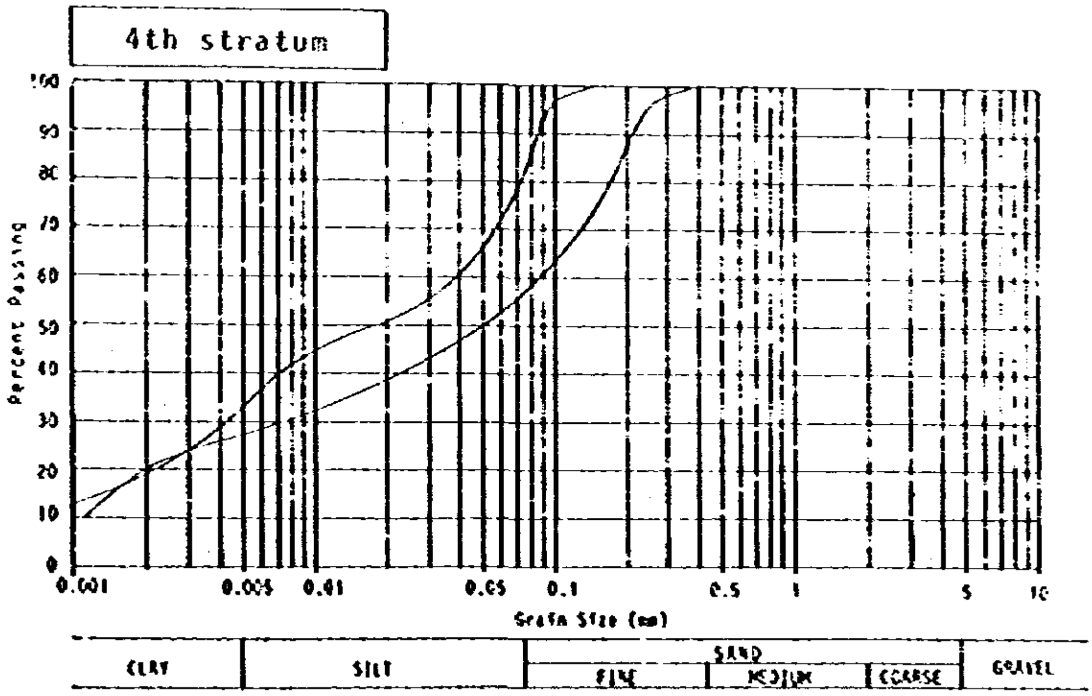
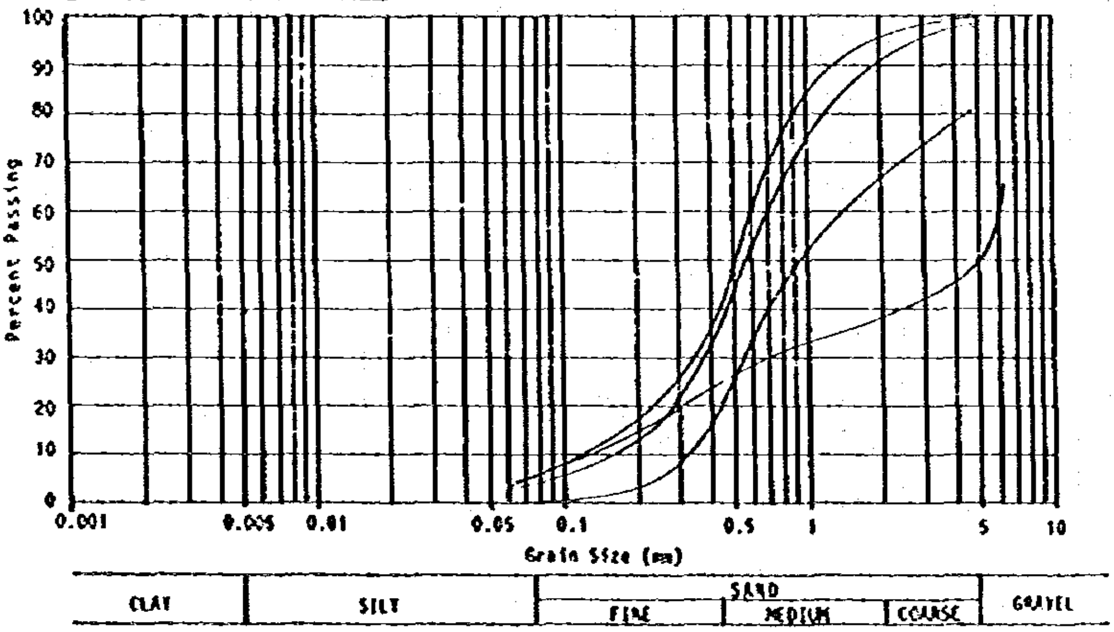


Fig. IV-1(3) GRAIN SIZE ACCUMULATION CURVE
(materials along the canals)

Group (1)



Group (2)

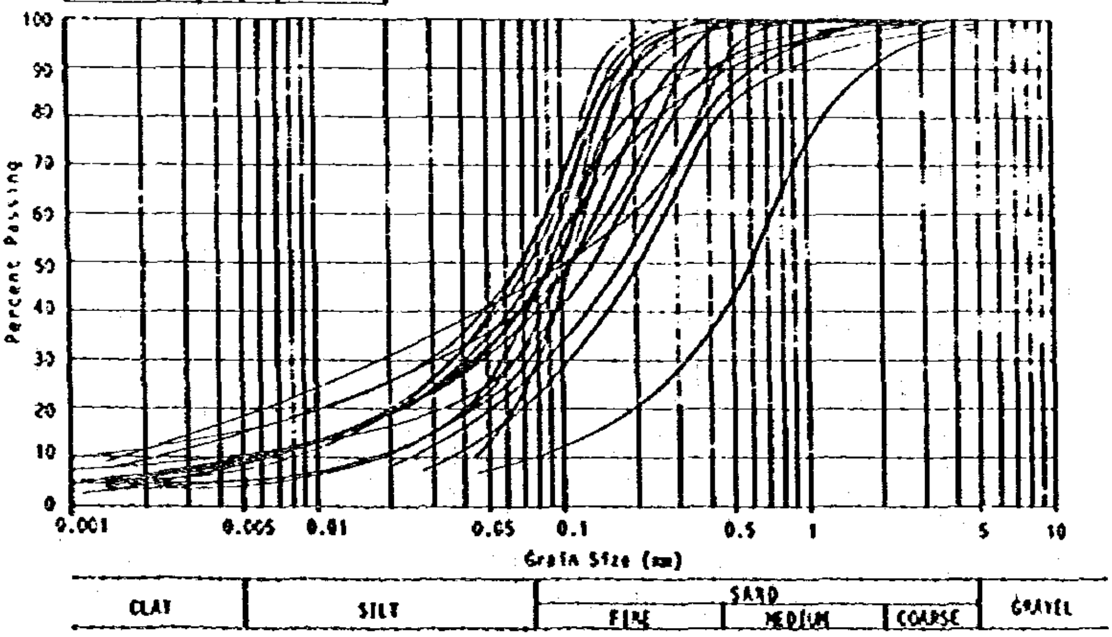


Fig. IV-1(4) GRAIN SIZE ACCUMULATION CURVE
(materials along the canals)

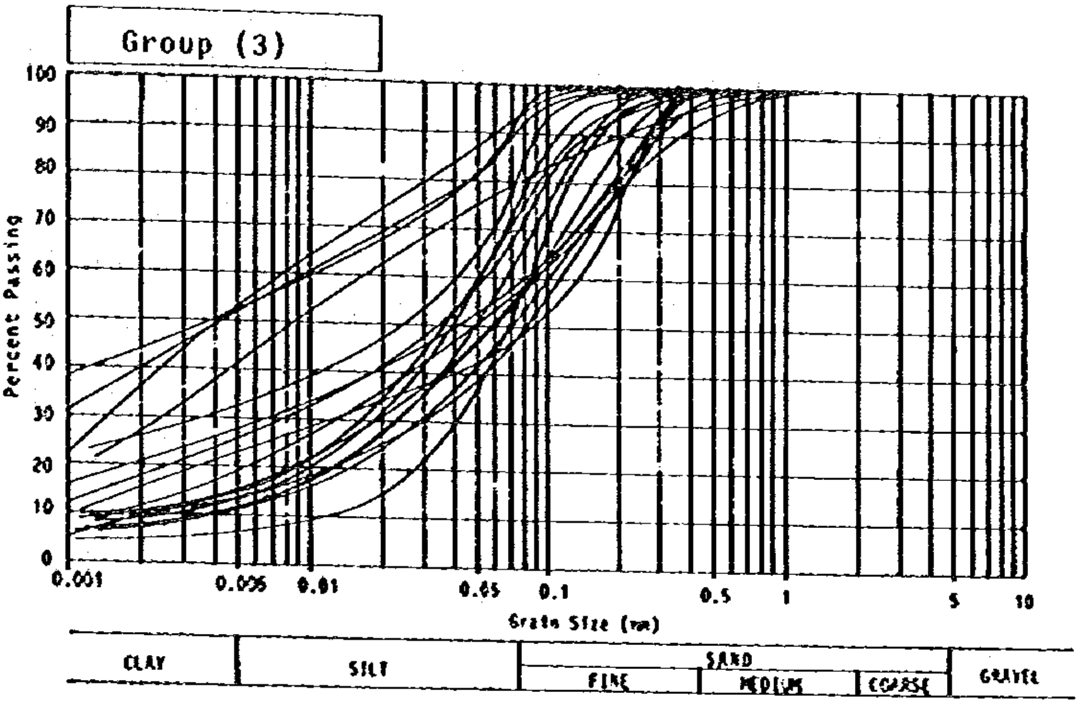


Fig.IV-2 AVERAGE GRAIN SIZE DISTRIBUTION OF EACH STRATUM AND CRITICAL ZONE FOR CRACKING (for the canals)

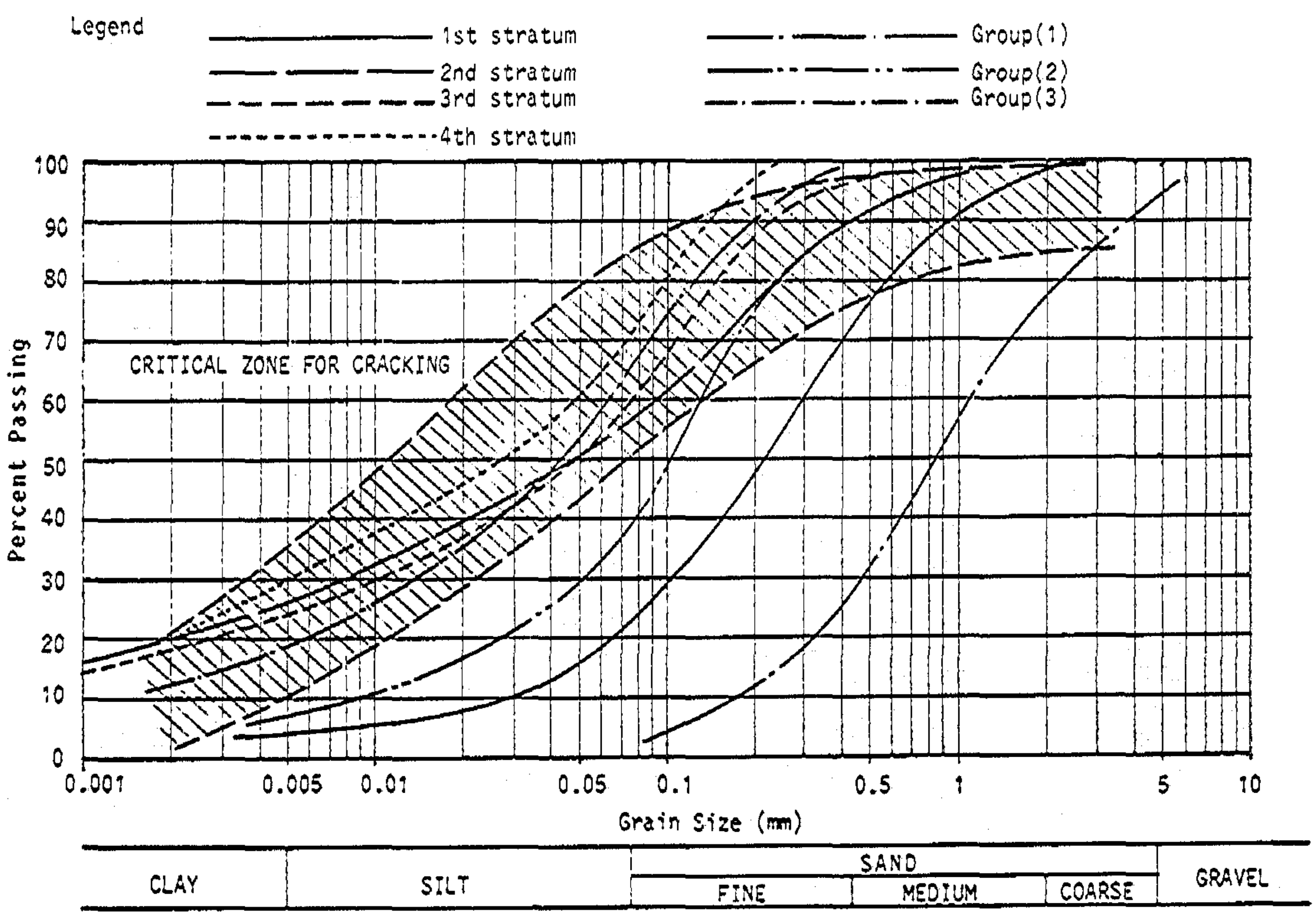


Fig. IV-3 PLASTICITY CHART OF SOILS ALONG THE MAIN CANALS

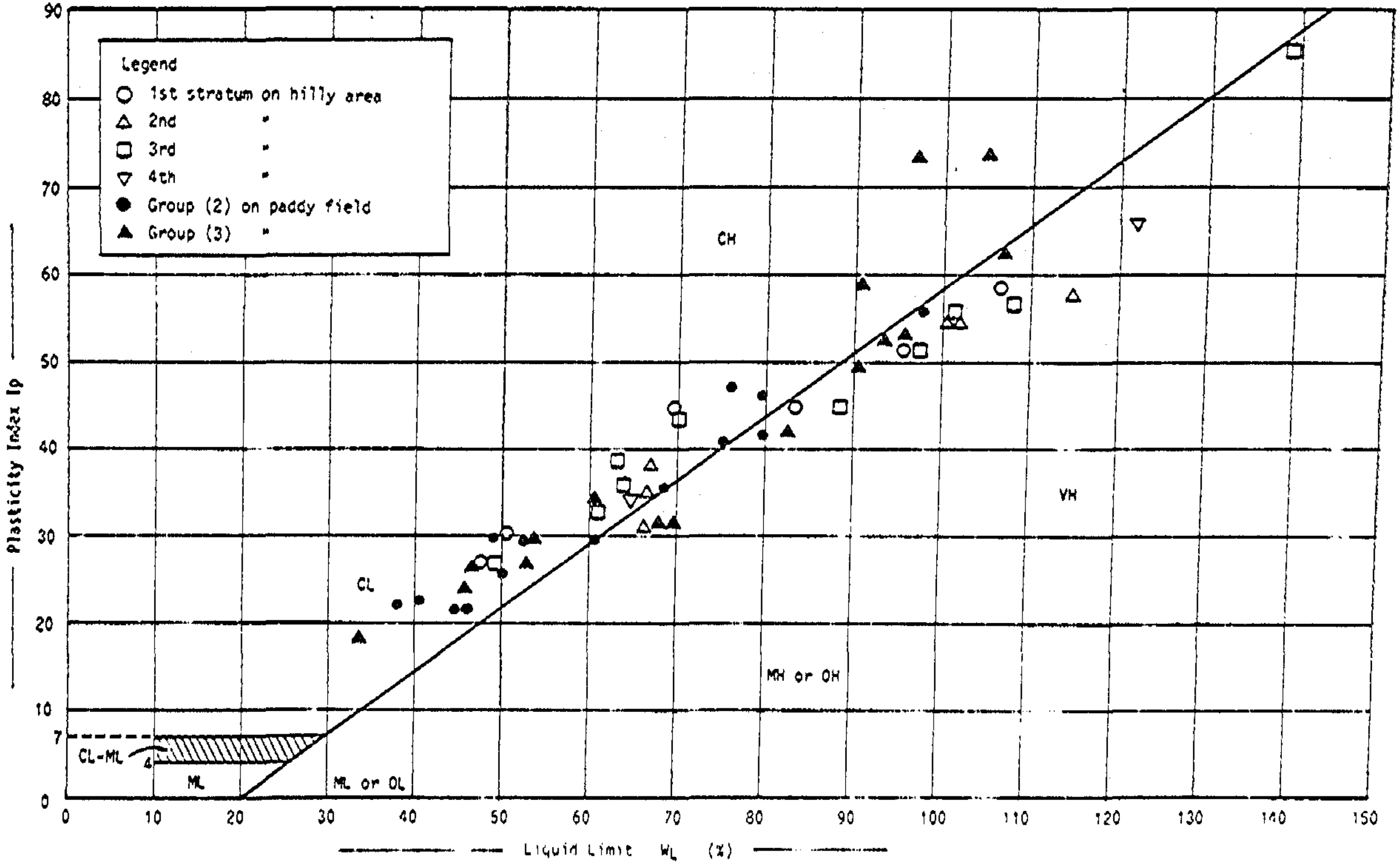


Fig. IV-4 SETTLEMENT CHARACTERISTICS

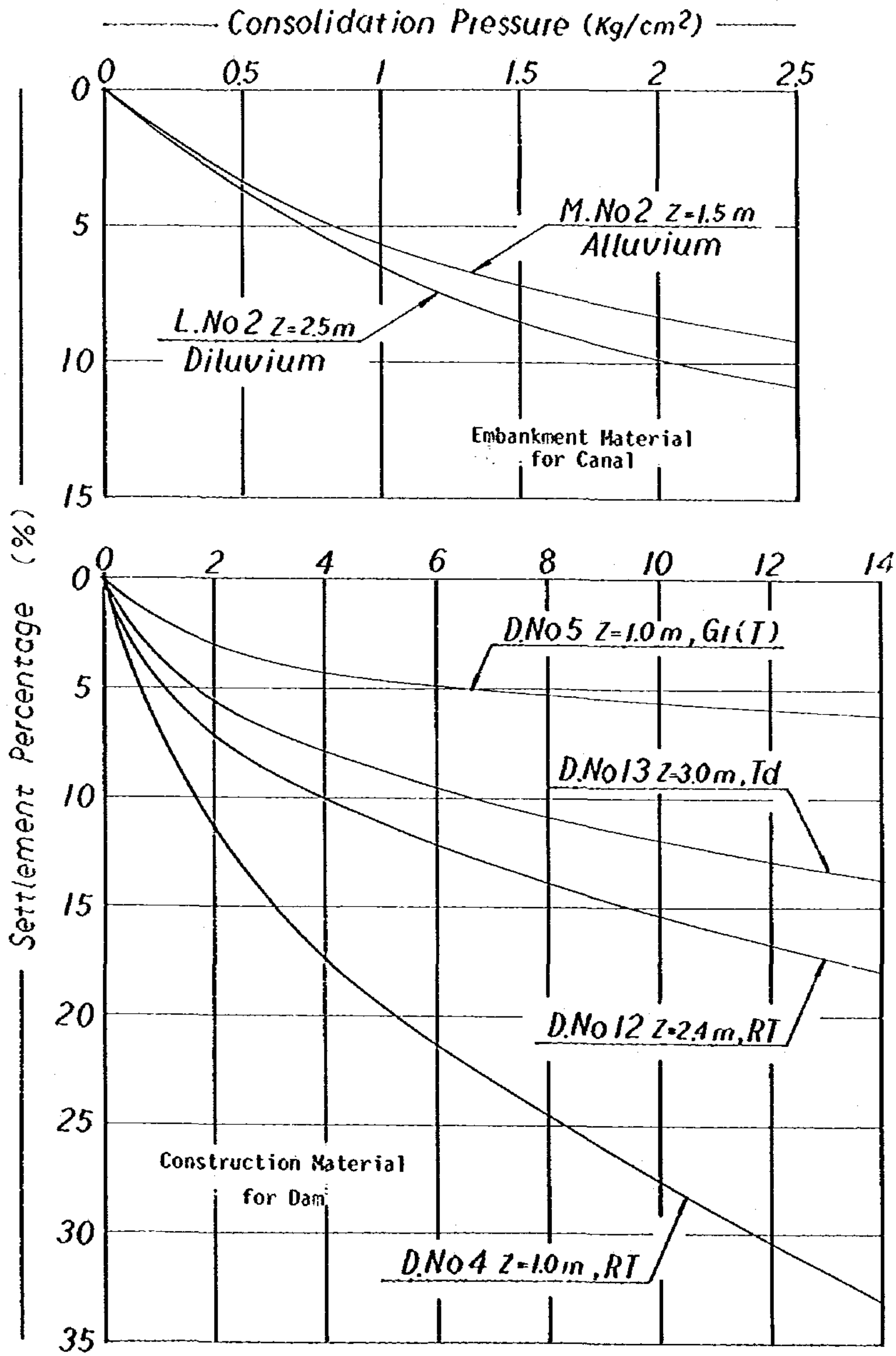
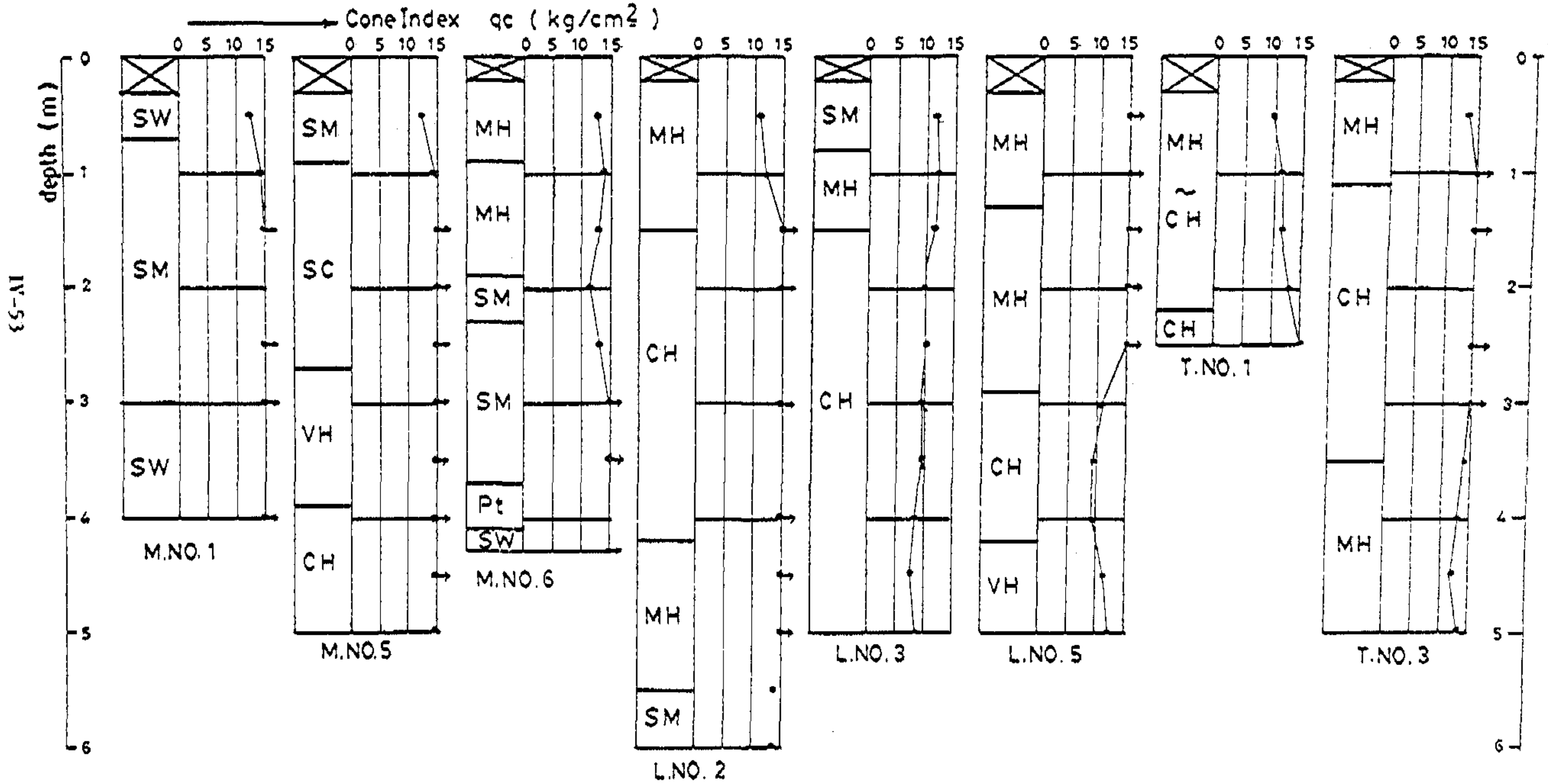
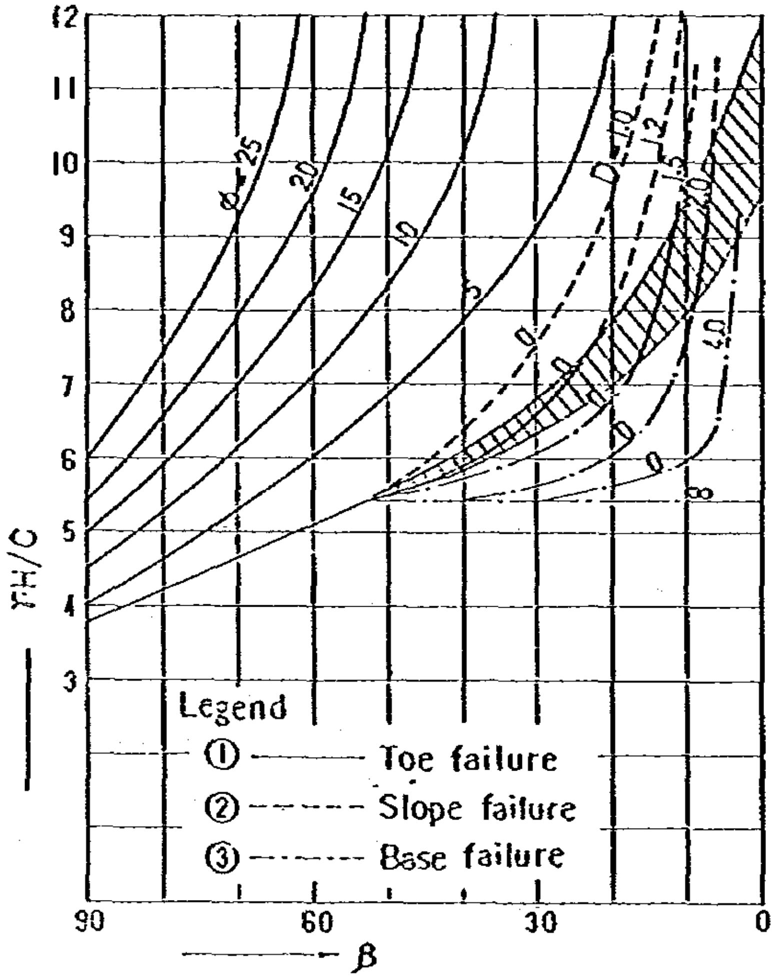


Fig. IV-5 RECORD OF CONE-PENETRATION TEST



: This symbol means that the cone index is more than 15 kg/cm²

Fig. IV-6 TAYLOR'S SLOPE STABILITY CHART



Example

Condition, $\gamma = \gamma t = 1.60\ t/m^3$

$C = Cu/Fs = 3.0/1.5 = 2.0\ t/m^2$

$\phi = \phi_u/Fs = 0/1.5 = 0$ degree

(Fs: safety factor)

$H = 6$ m

Result, $\gamma H/C = 1.60 \times 6/2.0 = 4.8$

from above chart

$\beta = 66$ degree

Fig. IV-7 LOCATION MAP OF SITE FOR BORROW PIT, TEST PIT, AUGER BORING AND SOIL SAMPLING

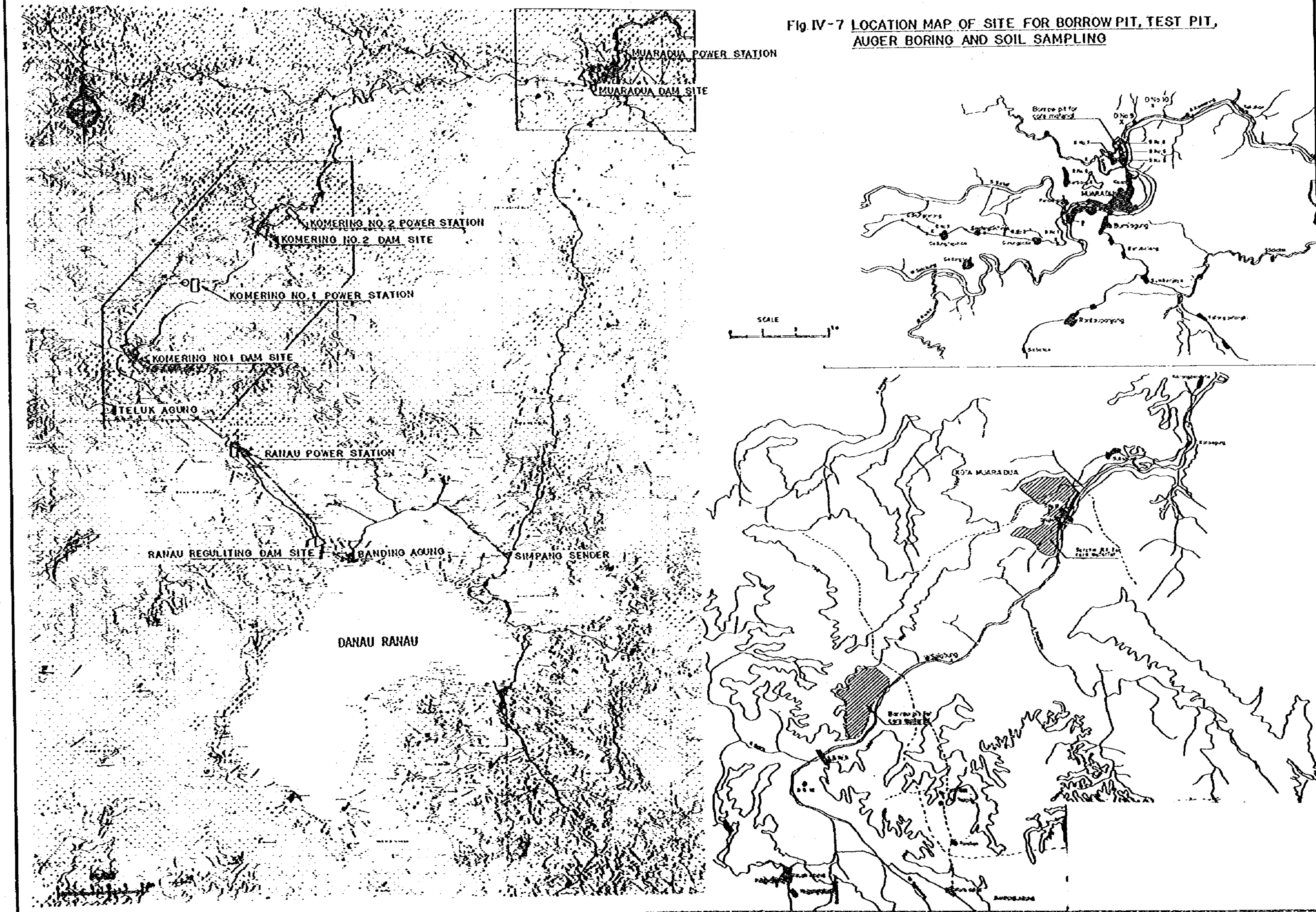
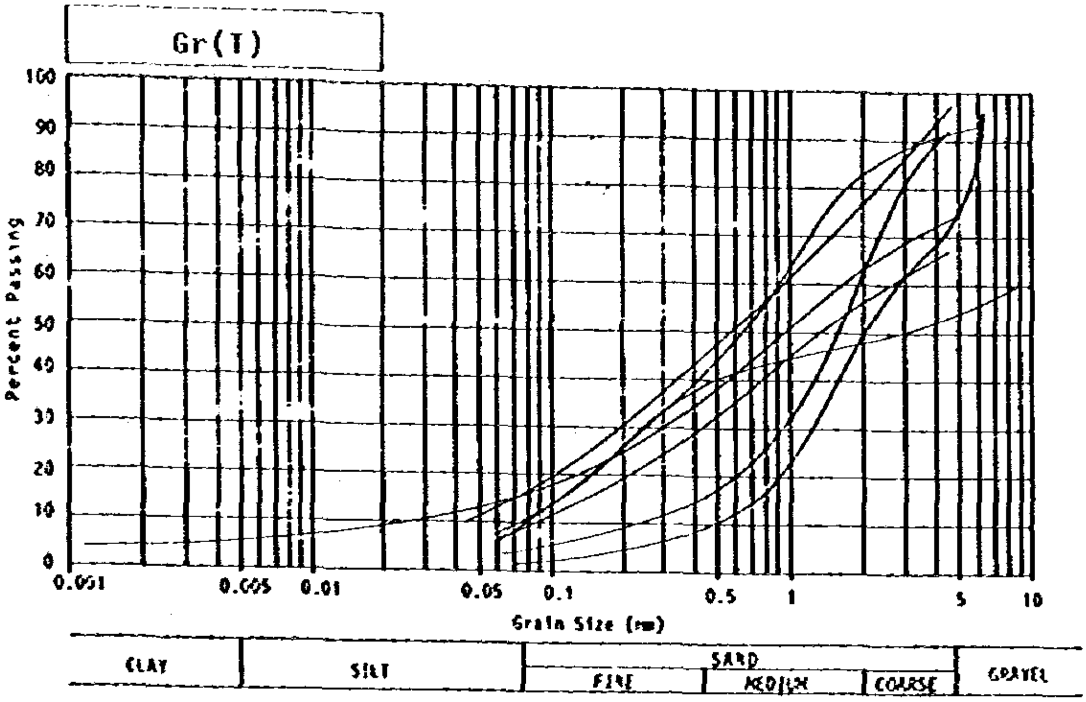


Fig. IV-8(1) GRAIN SIZE ACCUMULATION CURVE
(materials for the dams)



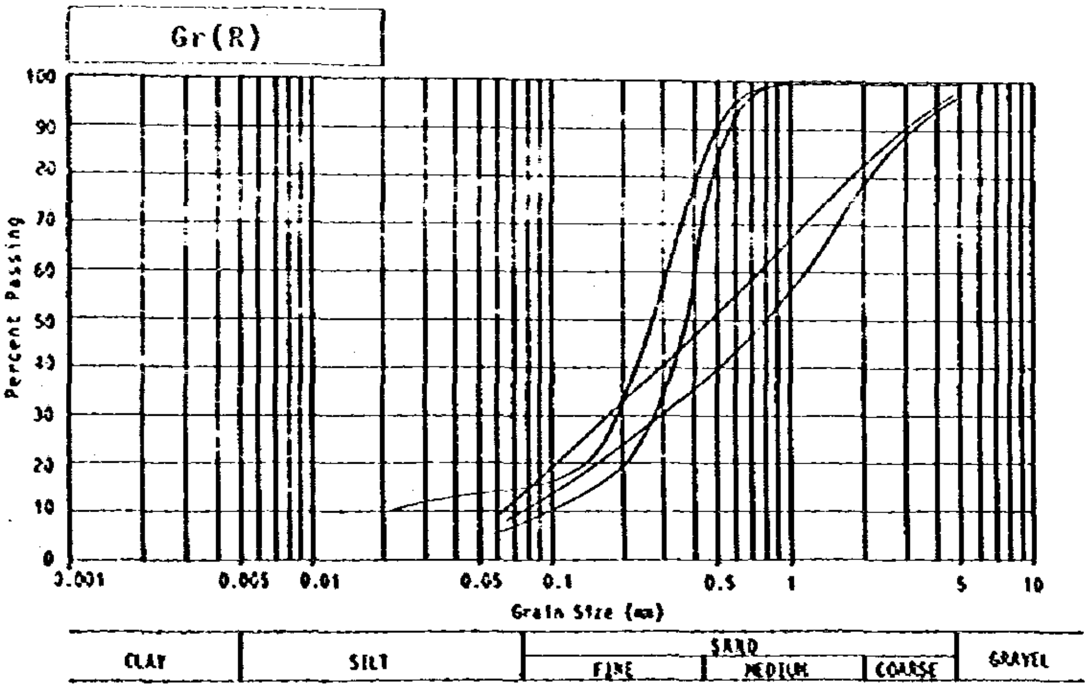
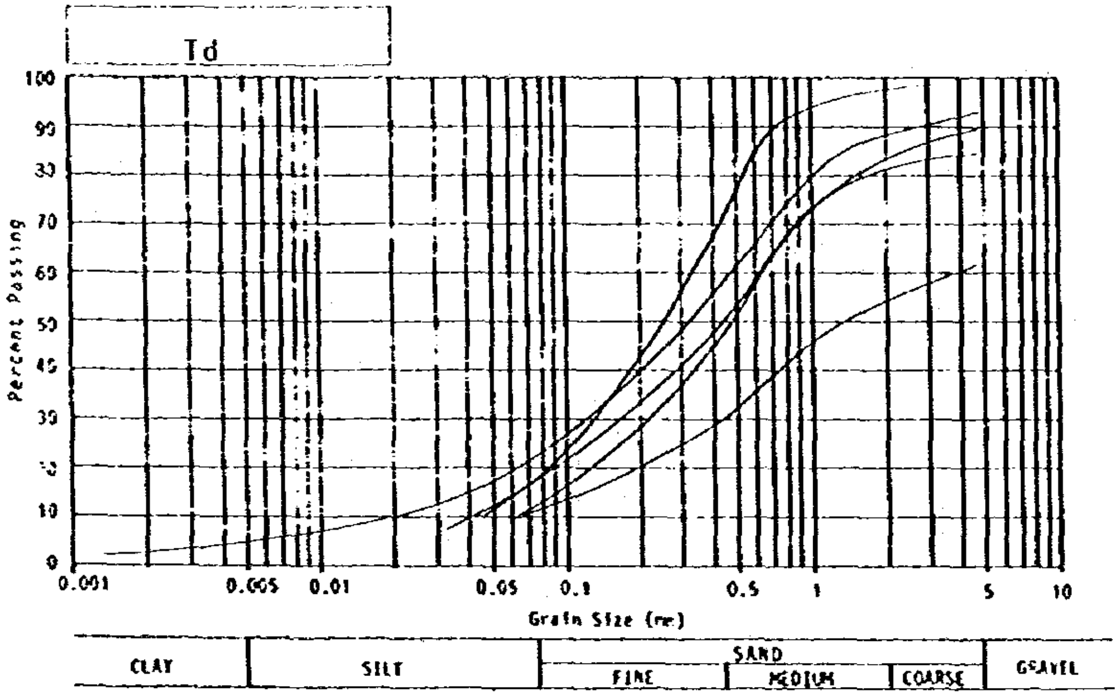


Fig. IV-8(2) GRAIN SIZE ACCUMULATION CURVE
(materials for the dams)



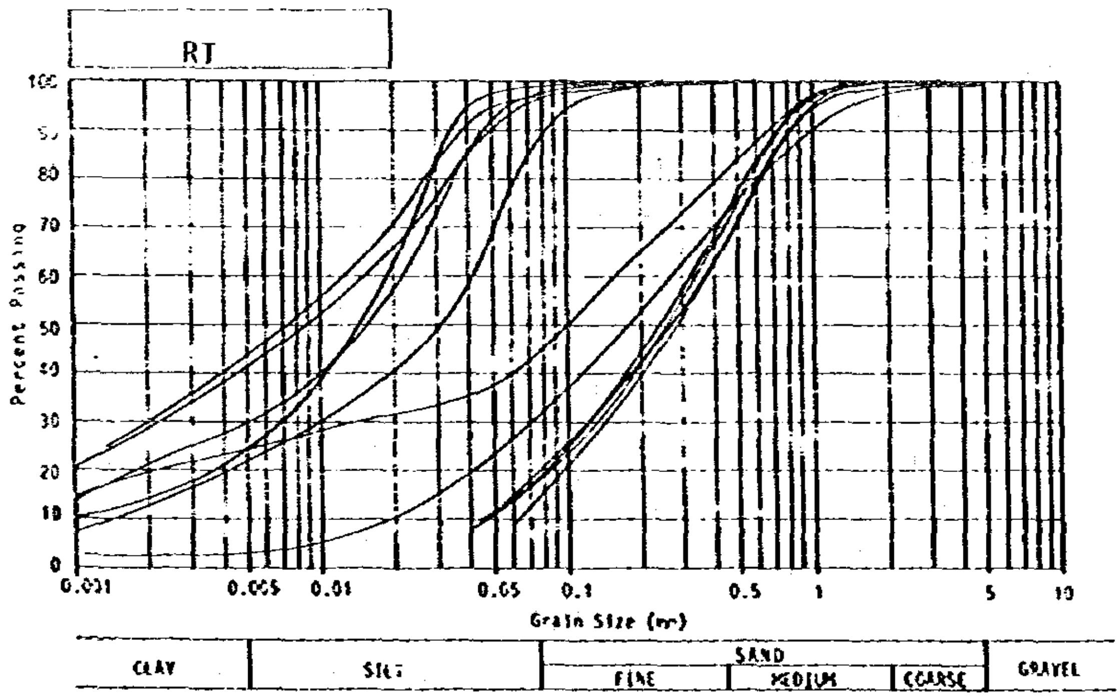


Fig. IV-9 AVERAGE GRAIN SIZE DISTRIBUTION OF EACH MATERIAL AND CRITICAL ZONE FOR CRACKING (for the dams)

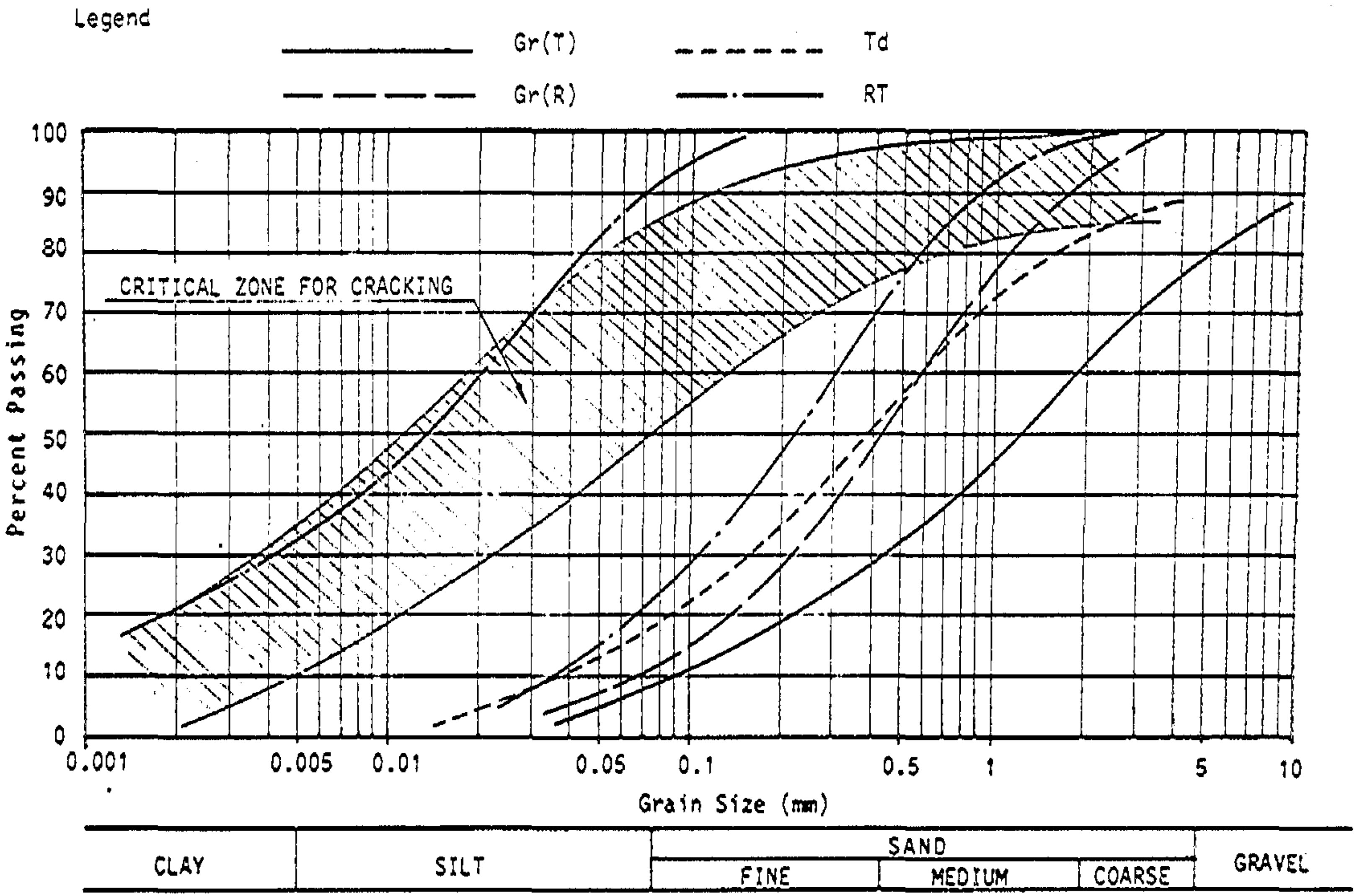
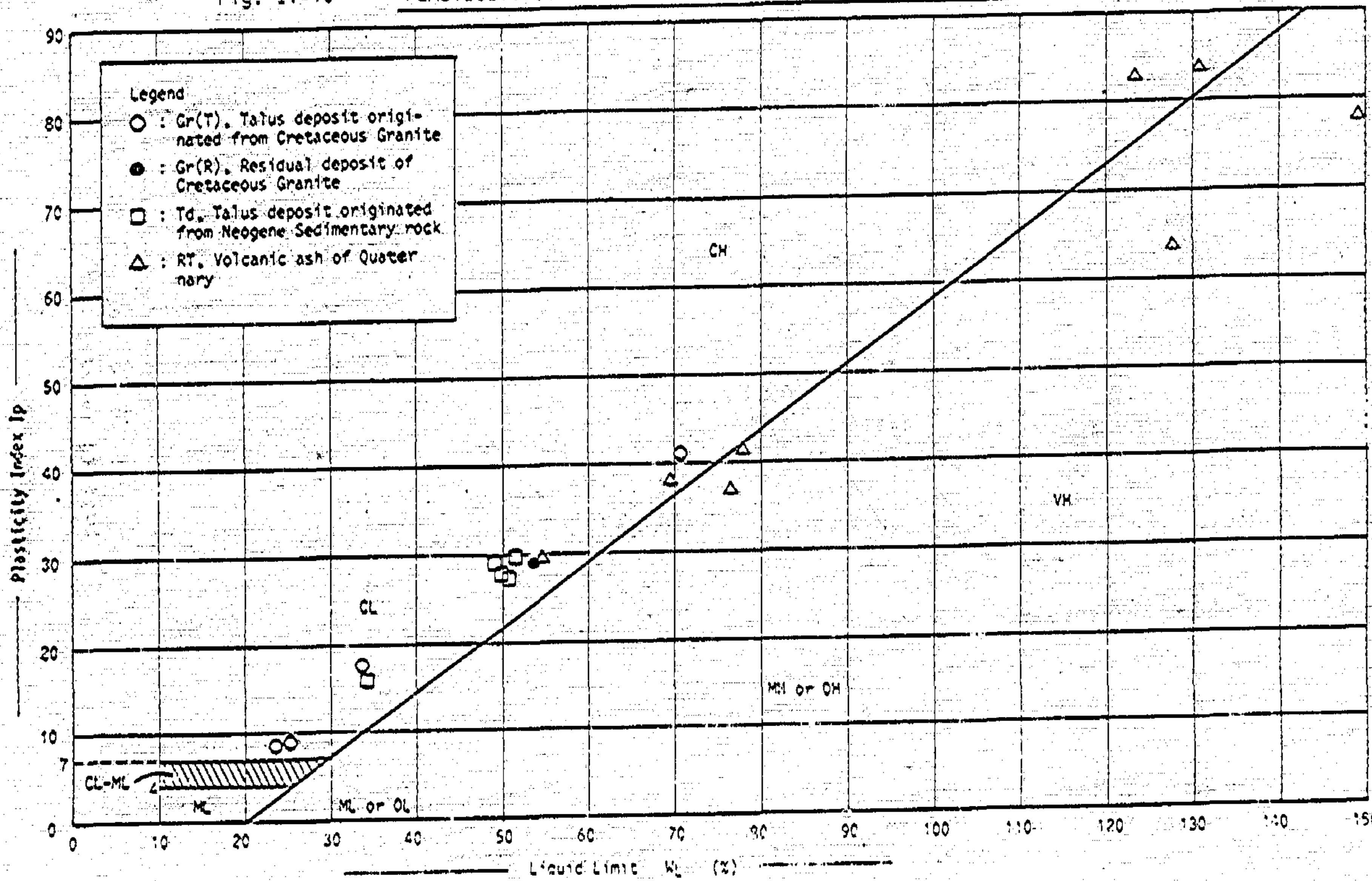


Fig. IV-10 PLASTICITY CHART OF EMBANKMENT MATERIAL FOR FILL DAMS



JICA