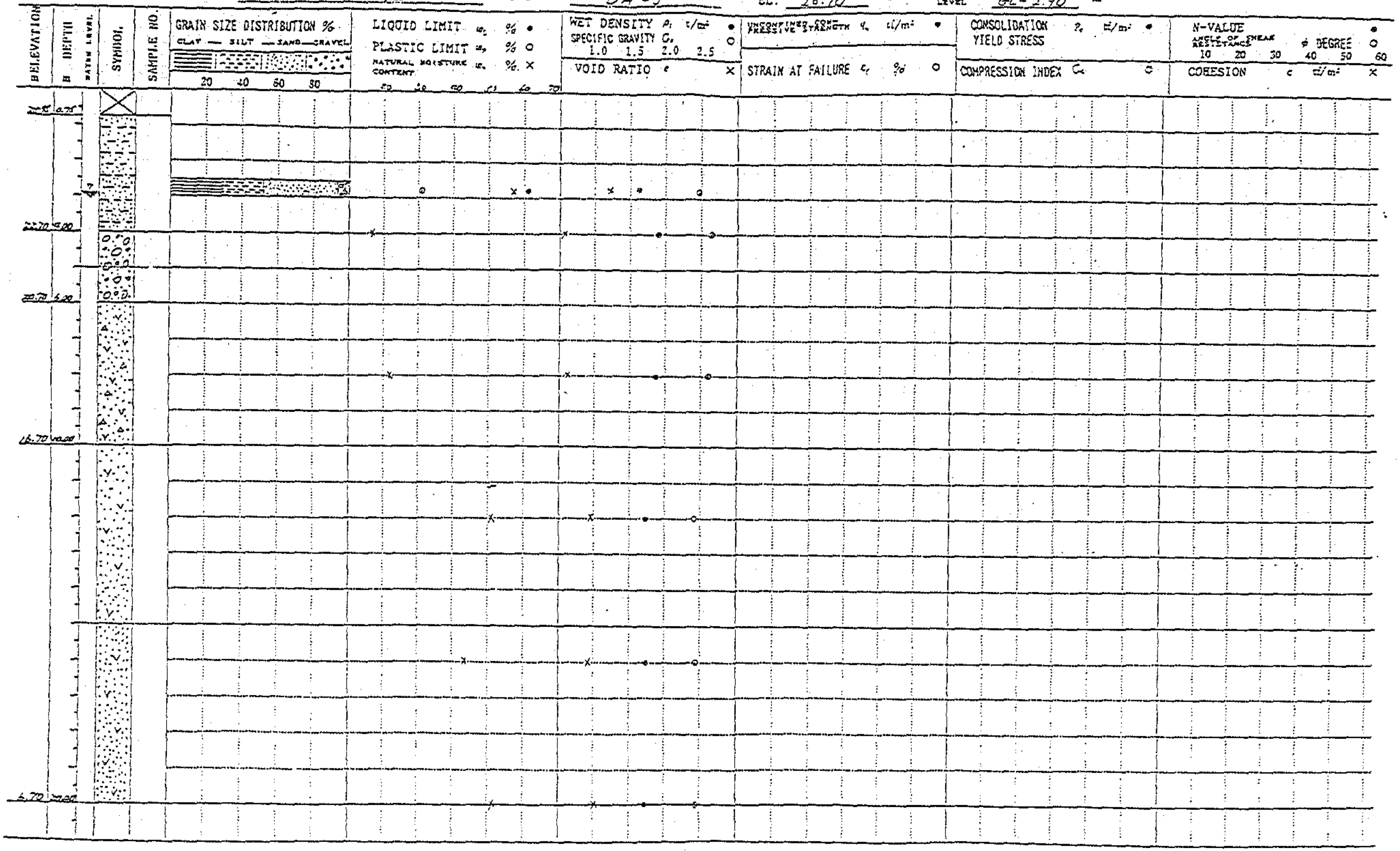
Fig.II-6 SOIL PROPERTY CHART (3/5)

LOCATION Wain side Right POINT : No. DH-3 EL. 26.70 m BOREHOLE WATER LEVEL GL-2.90 m



REMARKS

Fig.II-6 SOIL PROPERTY CHART (4/5)

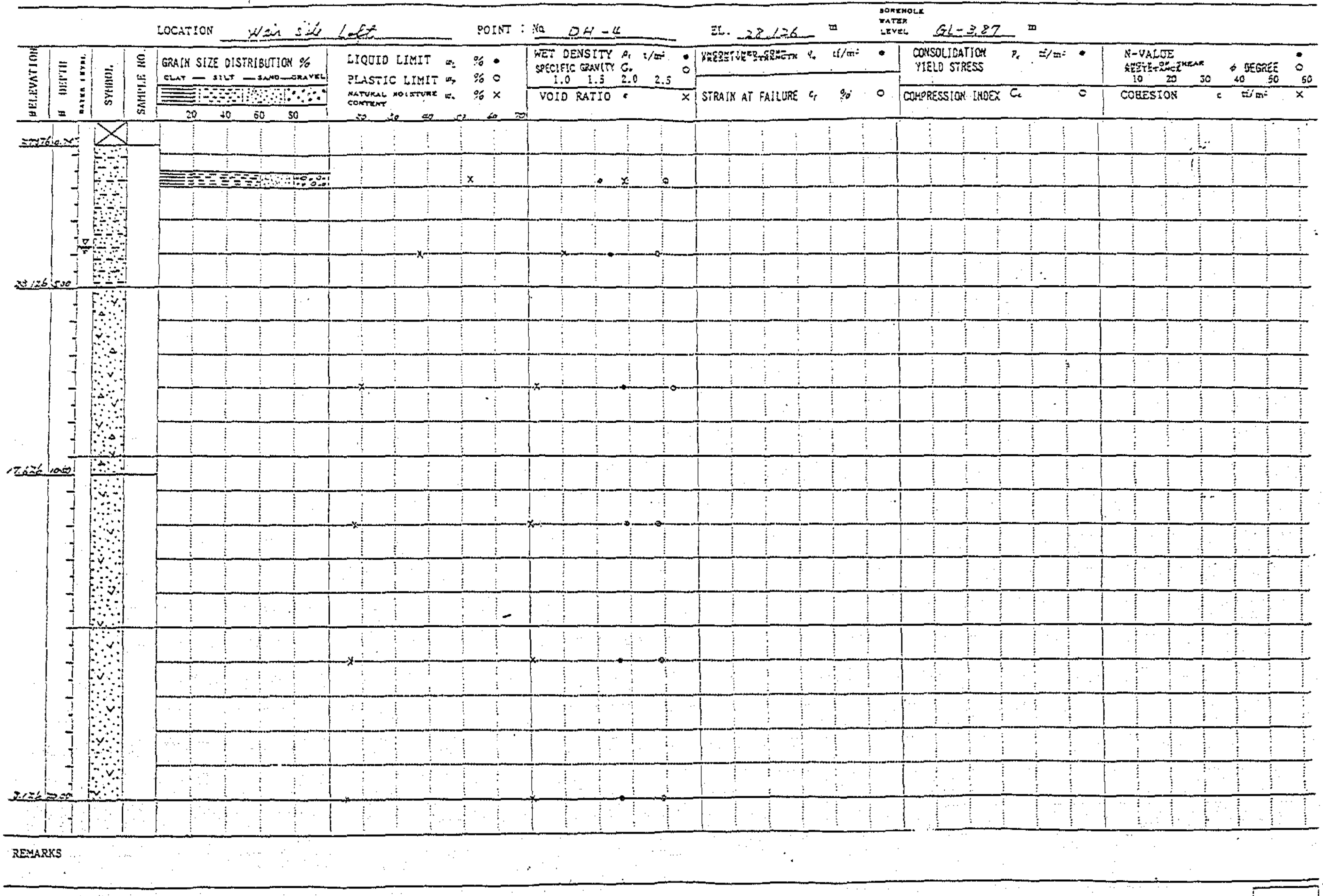


Fig.II-6 SOIL PROPERTY CHART (5/5)

LOCATION Hain sil right POINT : No. DH-5 EL. 27.436 m BOREHOLE WATER LEVEL GL-2.80 m

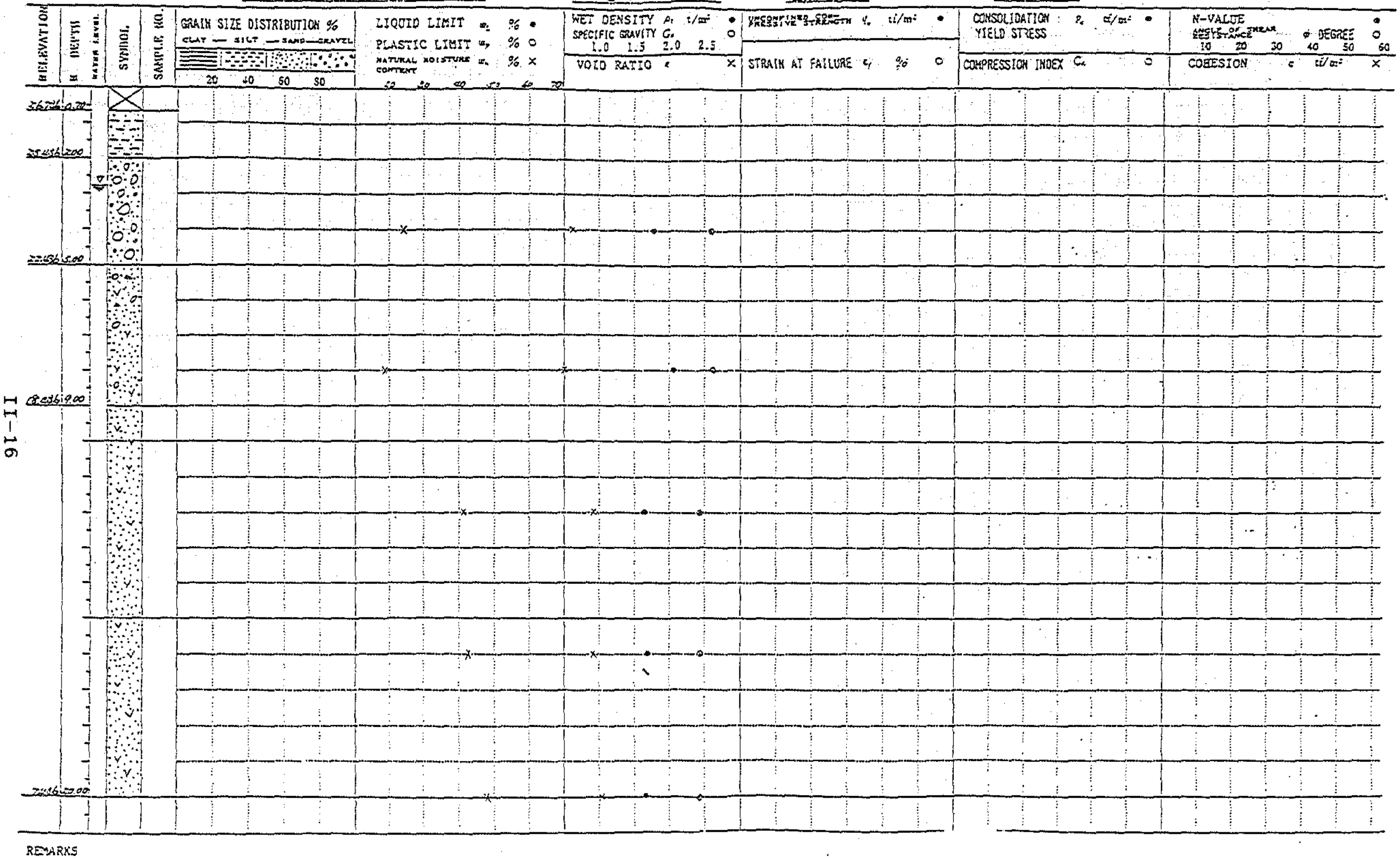
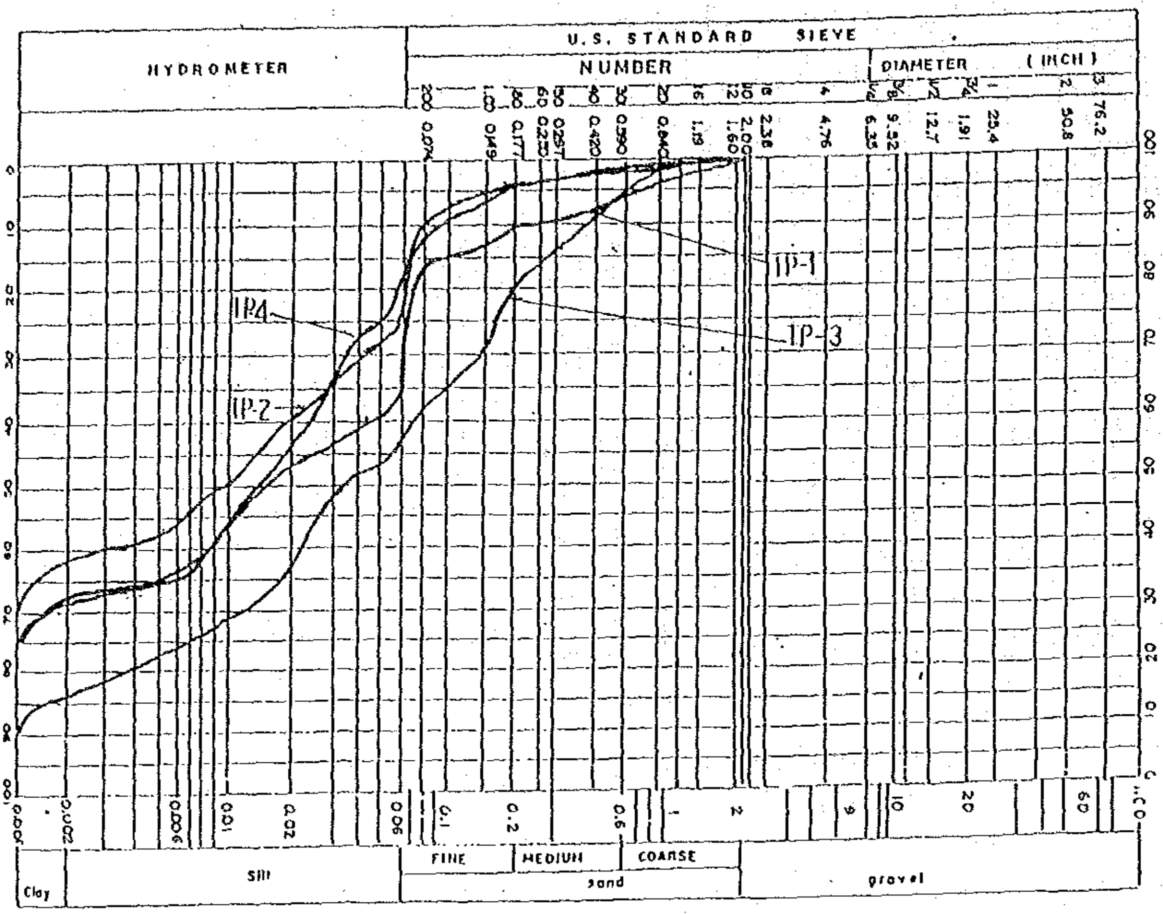


Fig.II-7 GRAIN SIZE DISTRIBUTION

WEIR SITE



CANAL

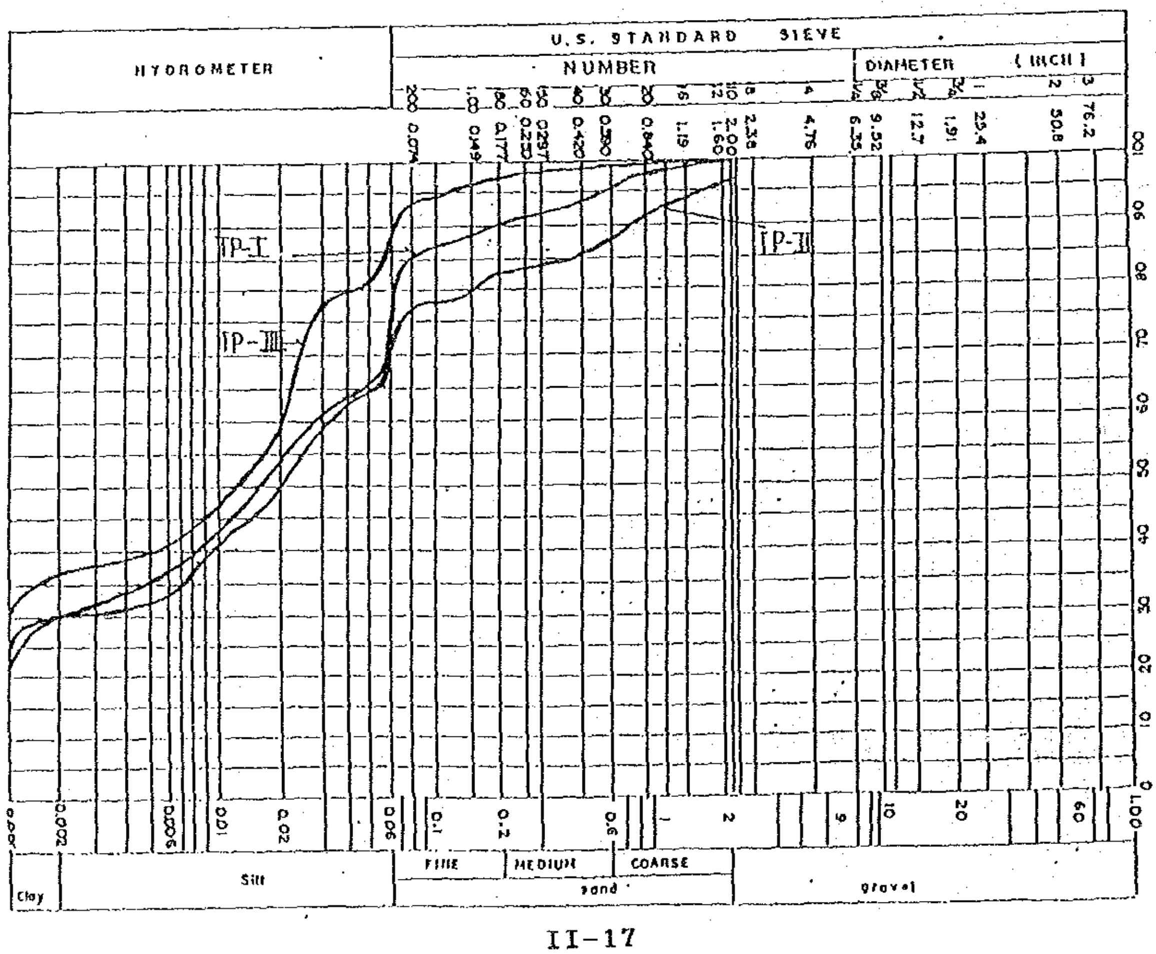
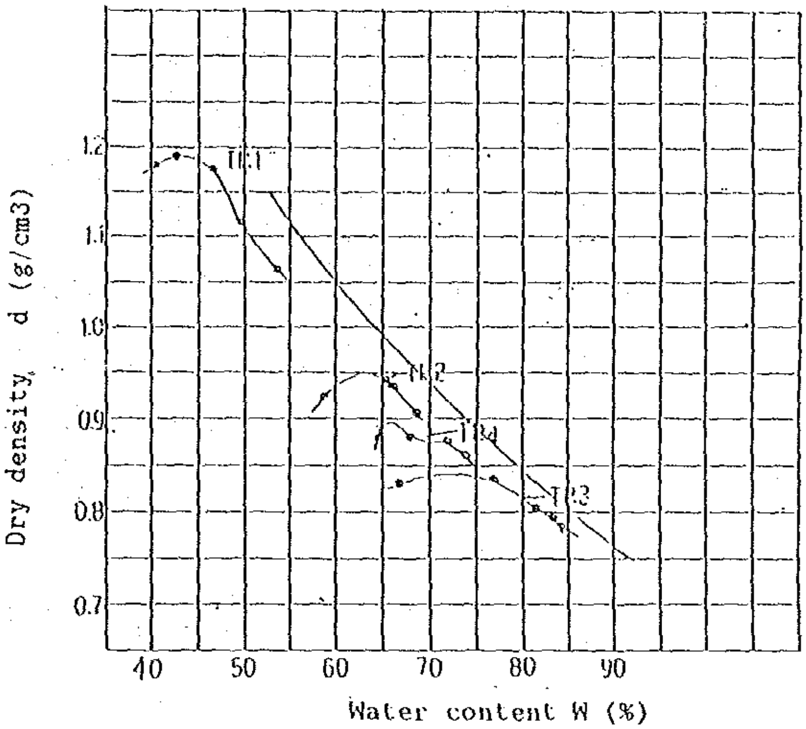


Fig.II-8 RESULTS OF COMPACTION TEST

Sample : WEIR SITE		TP1	TP2	TP3	TP4
Optimum water content W(%)	:	42.50	65.29	76.97	64.76
Max. dry density dmax (g/cm3)	:	1.190	0.943	0.836	0.889



Sample : CANAL SITE		TP1	TP2	TP3
Optimum water content W(%)	:	33.74	31.58	33.74
Max. dry density dmax (g/cm3)	:	1.373	1.406	1.373

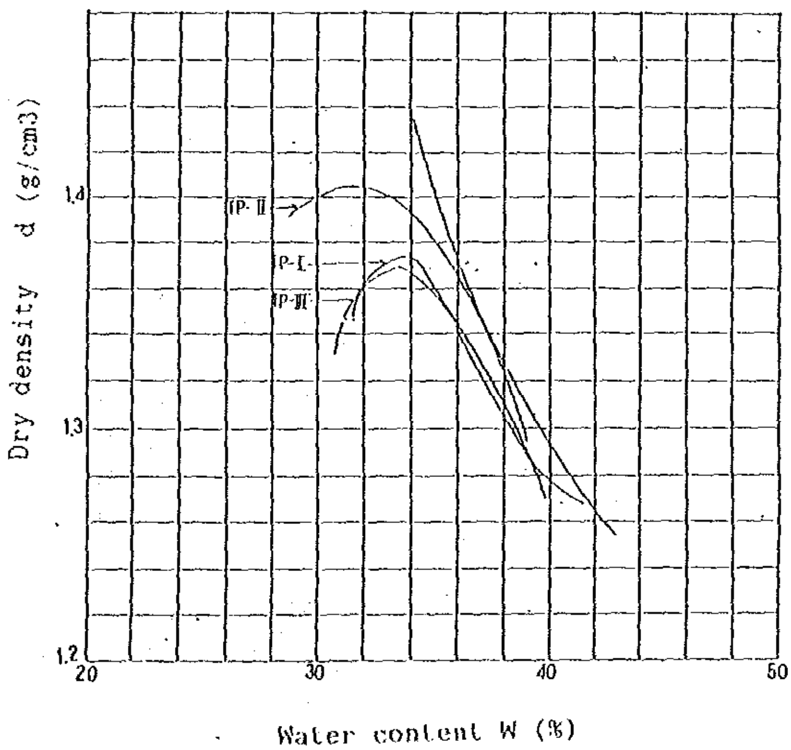


Table II-2 (1/3) RESULTS OF CONE-PENETRATION TEST

No.	Location	Depth	Humus Depth	Foundation Soil	Note
1	26km + 800m Kanan	2.55	-	Clay	Upstream
2	Bi 1	2.65	-	"	Dam Center Line
3	Middle point between Bi 1 and Bi 2	0.75	-	"	
4	Bi 5	2.35	-	Clay Graval	
5	TP 1	3.70	-	"	Not water
6	Bi 3	3.55	-	"	
7	Canal Kanan TP-1	4.70	-		
8	" Daun (RAWA)	2.35	1.50m (Self settlement: 0.75)	Clay	SAWA, Water 0.2m
9	Bi 2	3.30	-	Clay Cravel	Dam Center Line, D=2m-3m:soft
10	Bi 4 (To Sungai : 19m)	2.70	-	Clay	
11	" (To PT. To Rantiga : 12m)	2.10	-	"	
12	TP 4	2.65	-	"	Test Pit : Water : 1.4m
13	TP 2	5.00	-	"	" : 0.9m
14	TP 3	4.25	-	"	" : 1.2m
15	SP-2 Canal T.P	3.10	-	"	Man Canal T.P not water
16	SP-4 RAWA	4.15	GL - 2.50	Sand (D<4.15m under G.S.)	Water : 0.25m
17	" "	2.65	2.25	"	" : 0.80m
18	SP-4 TP 2 Main Canal (KIRI)	2.50	-	All clay	Clay with fine graval (D>2.40m from G.L.)
19	"	2.35	1.30m	Sand (D>1.85m under G.S.)	Wooden pieces: 1.00m-1.20m
20	SP-3 Timber Road Ki	2.95	2.00	" 2.95m	Water : 0.15m
21	" Ka	5.0m	2.45	From clay 2.45	" : 0.50m
22	" RAWA	1.85	-	Clay	Sawa
23	"	1.75	1.25	Clay 1.30	Water : 0.25m
24	"	5.00	1.25	" 1.30	" : 0.25m

Table II-2 (2/3)

No.	Location	Depth	Humus Depth	Foundation Soil	Note
25	Sawa (from Pon DOKKOPI->TRUJAM)	2.50	0.15	From Sand 2.35	Existing Paddy: 5ton/ha/yers/ no.
26	Sawa (SKPG: 50m from the road)	2.80	1.45	From Sand	Water : 0.20m
27	100m from BB5M (RAWA)	4.95	3.75	Sand (D>3.80m under G.S.)	Water : 0.70m, upto 1.25m:Wood
28	750m from BB5	3.90	2.40	Clay (D>2.40m under G.S.)	Secandry Canal RAWA Water 0.3m
29	Kiri 40m from BB5 canal	5.00	2.50	Clay (D>2.50m under G.S.)	2.00m (incl. wooden pieces)
30	300m from BB5 canal	5.00	1.00	Clay (D>1.00m under G.S.)	High Embankment: under settlement
31	SP-4 Road, 1km from E.P.	4.50	2.75	Sand (D>3.00m under G.S.)	Water : 0.70m
32	Air Sungai KP TANAH. REKAN	3.00	1.00	- ditto -	Kiri RAWA, WATER:0.25
33	"	3.50	1.00	Sand (D>2.50m under G.S.)	"
34	"	3.95	1.30	Sand (D>3.95m under G.S.)	Sludge : 0.15m
35	Road (Near Jumadja)	5.00	2.00	Clay (D>3.00m under G.S.)	Water:35cm, Wooden pieces: 2.35 - 2.60
36	"	5.00	2.75	- ditto -	Water:15cm, Wooden pieces: 2.00 - 2.35
37	"	5.00	2.30	- ditto -	Water:20cm, Wooden pieces: 2.60 - 2.80, 3.70 - 3.90
38	"	2.85	-	Clay (D>0.15m under G.S.)	Paddy (Upland nice)
39	"	1.50	1.00	Sand (D>1.20m under G.S.)	
40	Road 300m (RAWA)	0.70	0.35	Sand (D>0.35m under G.S.)	Water : 0.20m
41	" 1km	2.60	1.30	Sand (D>2.50m under G.S.)	Water : 0.20, Wooden pieces: 1.30 - 1.45

Table II-2 (3/3)

No.	Location	Depth	Humus Depth	Foundation Soil	Note
42	Road 1.5km	1.95	1.40	Sand (D>1.70m under G.S.)	Water : 0.20m
43	" 2.0	4.20	2.80	Sand (D>4.20m under G.S.)	" : 0.30m
44	" 2.5 Kanan	4.30	3.90	Sand (D>3.90m under G.S.)	Surface layer : Wooden pieces
45	" Kiri	4.10	3.90	- ditto -	Water : 0.20m
46	BB4 + 400m Kiri	5.00	5.00 <	---	Water : 0.10, Wooden pieces 1.75
47	" 1.6km Kiri	5.65	5.15	Clay (D>5.15 under G.S.)	Water : 0.20
48	" 1.65m	10.00	all 10.00	---	" : 0.50

Table II-3

SOIL TEST RESULTS IN TEST PIT

Site				Weir Site				CANAL (Depth 26.6 - 3.0m)		
Point No.				TP-1	TP-2	TP-3	TP-4	TP-1	TP-2	TP-3
WATER CONTENT			Wn (%)	47.27	54.47	124.38	80.0	42.63	33.46	50.94
UNIT-WEIGHT			rn (t/m3)	1.95	1.87	1.46	1.72	1.955	1.990	1.880
DRY DENSITY			rd (t/m3)	1.325	1.212	0.653	0.959	1.370	1.525	1.245
POROSITY			n (%)	47.78	51.87	53.02	62.67	46.35	40.15	50.98
VOID RATIO			e	0.915	1.078	1.129	1.679	0.864	0.671	1.04
DEGREE OF SATURATION			S (%)	131.097	127.27	108.387	122.476	126.197	127.058	124.396
SPECIFIC GRAVITY			s	2.54	2.52	2.61	2.57	2.56	2.55	2.54
LIQUID LIMIT			LL (%)	60.90	77.60 *	70.00 *	74.75 *	64.35	46.50	47.00 *
PLASTIC LIMIT			PL (%)	36.97	56.15	54.61	54.24	34.95	31.63	32.09
PLASTICITY INDEX			PI (%)	23.93	21.45	15.39	20.51	29.40	14.87	14.91
SIEVE ANALYSIS	FINER 1/4"		(%)					--	--	--
	FINER 40		(%)	92.03	97.63	90.83	98.45	93.62	85.01	99.10
	FINER NO:100		(%)	87.16	95.02	70.19	92.54	88.27	79.53	96.56
	FINER NO:200		(%)	84.45	91.20	62.17	88.19	86.00	77.16	93.30
HYDROMETER	> 50		(%)	39.50	27.50	47.00	25.00	35.00	35.00	19.00
	> 3W < 50W		(%)	27.50	32.50	34.50	4150	34.00	33.00	43.50
	> 2W < 5W		(%)	1.00	2.00	1.50	1.00	1.00	2.00	1.00
	< 2W		(%)	32.00	38.00	17.00	32.50	30.00	30.00	36.50
COMPACTION TEST			W opt (%)	42.50	65.29	76.97	64.76	33.74	31.58	33.74
			rd (t/m3)	1.190	0.943	0.836	0.889	1.373	1.406	1.374
TRIAXIAL	UU	C	kg/cm2	0.40	0.50	0.80	1.07	0.46	0.75	0.45
		ø	°	10°	8°	16°	12°	5°	2°	8°
	CU	C	kg/cm2	0.58	0.45	0.30	0.32	1.00	0.75	0.67
		ø		22°8'	22°8'	33°	30°9'	14°8'	14°2'	16°7'
CONSOLIDATION		Pc	kgf/cm2	0.97	1.00	0.9	1.2	1.6	1.2	1.9
		C2	--	--	--	--	--	--	--	--
		Cc	--	0.296	0.282	0.235	0.297	0.266	0.311	0.322
		Cv	cm2/sec	$6.8x10^{-3}$	$7.75x10^{-3}$	$8.05x10^{-3}$	$9.1x10^{-3}$	$8.10x10^{-3}$	$9.3x10^{-3}$	$7.9x10^{-3}$
		mv	cm2/sec	0.023	0.020	0.065	0.027	0.007	0.020	0.01
PERMEABILITY		K	c/sec	$5.73x10^{-6}$	$4.788x10^{-6}$	$2.924x10^{-5}$	$3.215x10^{-6}$	$3.723x10^{-6}$	$5.96x10^{-6}$	$1.747x10^{-6}$
UNIFIED CLASSIFICATION				OH-MH	OH-MH	OH-MH	OH-MH	OH-MH	OH-MH	OL-MLOL-ML

CHAPTER 3 GENERAL GEOLOGY

3.1 Regional Geology

Sumatra is an island with 1,650 km length extending from north west to southeast, and belongs to the India-Australian plate. It is located on part of the Great Sunda Land Plate which covers most of Southeast Area.

Ocean crust of Indian Ocean which is belonging to Indian-Australia plate is being subducted along the Sunda trench at the western margin of the Sunda land plate. Sumatra and its off-shore islands make form parallel and close to the Sunda trench. Magma generation is deeply and closely associating with subduction along the Sunda trench and has given rise to the Cenozoic Sumatra volcanic arc. This dominates Sumatra geology and forms the north west extension of Sunda volcanic arc. The oblique approach and subduction of the incoming ocean crust have been producing enormous stress. This stress has been released periodically by dextral fault movement parallel to the plate margin which resulted in the major Sumatra Fault System. The Subduction seems to have been taking place intermittently since the Late Permian.

East of Sumatra is back-arc basin behind volcanic arc where thick sequence of Tertiary sediments accumulated and swampy coastal plain and peneplain are widely spreading at present.

Bengkulu province is located in southwest of Sumatra bordering West Sumatra province on the northeast, Lampung province on the southeast, and South Sumatra province on the northeast, and is a long and narrow province with a length of 380 km. The province, in which about 60% is occupied by the ridges and hills, faces on the Indian Ocean on the south, and borders on the Barisan Range in the rear.

In Bengkulu, there are 13 big rivers which were formed by incorporation of many small streams and flow into the Indian Ocean.

The Air Selagan (the Selagan river) also has many small tributaries, and rises among the Barisan Range. The distance between the coast and the ridge is about 50 km long, and the coastal plain with about 15 km length extends to the inland area. Therefore, the river has steep gradient of about 1/200 in the middle reaches, and meanders with gentle gradient of about 1/2,000 in the lower reaches.

The flat area in Bengkulu has been formed on the levees and the deltas, thus it is small. Behind the levees, the back swamp has been formed. Through the Air Dikit to West Sumatra province, the back swamp is widely distributed, the lower reaches of the Air Selagan Project being included in this region.

3.2 Geological Features in the Proposed Project Area

In the upper reaches of the Air Selagan, the basement rock consists of Breccia tuff containing Cenozoic Tertiary basalt, on which Tertiary Pliocene pumice-tuff is deposited.

In the Air Selagan basin excepting the lower reaches, Tertiary Pliocene pumice sandy tuff is the basement rock, which is covered with clay containing andesite cobble.

The basement rock has been differently formed on either bank in the upper reaches; on the right bank the basement rock is composed of tertiary Miocene tuffaceous sandstone, and on the left bank Quaternary Pleistocene breccia tuff which has been thickly deposited owing to different volcanic condition on either bank.

In the middle reaches, andesite sandy pumice-tuff is the basement rock. In the area extending from Muko-Muko to the Air Manjuto which are located in the low-most reaches of the Air Selagan, Quaternary Pleistocene hard sandstone is widely distributed as the basement rock which has been formed by sedimentation at the coast. Behind the levees, back swamp is seen which was formed in Alluvion.

(a) Topography, Geology, and Soil at Weir Site

The location of a weir to be constructed is proposed to be about 30 km upstream from the river mouth of the Air Selagan, and is higher than the sea level by about 25 m. The Air Selagan is meandering from the east to west through the project area, and the river gradients are about 1/150 - 1/200 at the proposed weir site, and about 1/2,000 - 1/3,000 at 15 km of the lower reaches.

During the period from 1984 to 1985, the alternative of weir sites was studied by Indonesian Consultant for the upstream and downstream plans which were proposed within 1 km from the weir site studied this year. According to the upstream plan, the weir site was proposed where the river is meandering clockwise and is flowing comparatively fast. At the site, the left bank slope is steep and flat area is stretching largely at the right bank.

Weathered pumice-tuff crops out on either bank, and tuffaceous sandstone exists at EL.20 m on the river bed, on which andesite gravel deposits 1.7 m deep. This was caused by the fact that weathered tuff on the river bed was scored and was replaced by deposited gravel. Therefore, outcrop on either bank is weathered 0.50 - 1.00 m deep. The terraces on both banks are covered with 2 m of tuffaceous clay containing Quaternary Pleistocene andesite gravels, and Pleistocene reddish clay cover the surface.

The downstream plan was proposed where the river channel was wide and deep sand bed was formed.

JICA Study Team surveyed another site which is located 200 m upstream from the weir site of the downstream plan, taking into consideration of construction for cofferdams and diversion channels.

At the site, the left bank is gentle slope, and flat area is extending on the right bank, leading to the terrace situated 100m from the river channel. Behind the terrace, a small stream flows. The elevation of the right, and the left bank is 28m and 27m respectively. The river bed elevation is 22.20m, and the river gradient is about 1/400 where the channel is 50m across, and is in a straight.

According to the results of boring test performed at the proposed weir site, sandy tuff are deposited on EL.17.6m at the left bank, and on EL.18.2m at the right bank. The surface of 0.5m which has been heavily weathered and has been coarse keeps stability mechanically due to N value of more than 50. The coefficient of water conductivity k, however, is rather large, being 10^{-3}-10^{-4} cm/sec. Tuff below heavily weathered stratum has been welded including pumice. The k value is less than 10^{-5} cm/sec, the consolidated stratum is 11.0m in depth, and the lower layer which has been heavily weathered is coarse.

The deposit slope of tuff is about 1/200, and the deposit may have occurred as it has flowed from the upstream to the downstream.

The upper layer of tuff with 4m depth consists of tuffaceous clay containing andesite gravel which was deposited during the period from Tertiary Pliocene to Quaternary Pleistocene. The N value keeps stable, being more than 50. However, the coefficient of water conductivity k, is rather high, being 10^{-3} cm/sec.

The surface layer excepting 0.6m of surface soil is composed of Quaternary Pleistocene volcanic ash clay of 2-5m depth. It is deposited with the condition of the N value of 6-9 and the medium consistency. Although the ground is stable mechanically, settlement may occur. The soil may be inorganic fine-grained soil having comparatively high compressibility because the soil characteristics is plotted in CL, and CH of plasticity chart.

Allowable bearing capacity is 8-20 t/m^2 according to cone tests. The strength of soil near the Air Selagan is low, being cohesion C, 0.4-1.08 kg/cm^2, and internal friction angle ϕ, 10° - 16°, according to the results of soil test. The compression index Cc, 0.14-0.30, based on consolidation test may be identified with compressibility, and it is affected by ground water as the sampling location is approaching to the river channel.

Below the upper clayer layer, the gravel layer containing cobbles formed in Quaternary Pleistocene is deposited 2.0m deep, from which it is estimated that the new river channel deviated 40-50m aside from the old one. The coefficient of water conductivity for the soil at the old river channel is 10^{-2} cm/sec, being high permeable.

The aggregate for concrete can be fully supplied at the gravel yard located 2 km downstream from the proposed weir site. However, it is sediment having little coarse sand.

(b) Geology in Irrigation Area, and on Main Canal Route

Irrigation is planned for the existing immigration areas, SP-II,III,IV and VI, either bank area of the Air Selagan, and the swampy area located between the Air Manjuto and the Air Hitam. The existing immigration areas are located on terrace. Consequently, foundation ground is stable for constructing canals and related structures because deposit mainly consists of tuffaceous clay.

The allowable bearing power, qa is 7.5 t/m^2 at the surface, and increases to more than 25 t/m^2 at about 2 m depth. The main canal route is planned to run through various size of swamp areas where fallen trees have been buried, and become poor ground. The layer depth is 1.50-4.00 m, and the bearing power, qa is less than 2.5 t/m^2, although it depends on the location.

The embankment material may be easily supplied because there exists a lot of terrace. The soils for embankment have real specific gravity, GS, of 2.54-2.56, and natural water content, Wn, of 42.63% at TP-1, 33.46% at TP-2, and 50.94% at TP-3 which vary with the sampling sites. They all are volcanic ash clay, judging from their specific gravity. According to grain size distribution at TP-II, the soil consists of sand of 30%, and clayey content of 70% which includes colloid of 20% and small gravel of some 3%. Therefore, it may be low water content.

The consistency is LL of 64%, PL of 35%, PI of 29% at TP-1, and LL of 47%, PL of 32%, PI of 15% at TP-2, and TP-3. The compaction tests show that Wopt=33.7%, Idmax=1.37g/cm^3 at TP-1, Wopt=32%, Idmax=1.4g/cm^3 at TP02 and Wopt=34%, Idmax=1.4g/cm^3 at TP-3.

Mechanical properties for oil after compaction are cohesion, C, of 0.45-0.75kg/cm^2, and internal friction angle, ø, of 2°-8°, thus cohesion is higher at IP-2. As the soil properties are Cc of 0.27-0.32, Cv of 8 x $10^{-3}$$cm^2$/sec, K of 10^{-5}cm/sec, and Pc of 0.9-1.2kg/cm^2, small consolidation and settlement may be expected, and it is suitable for embankment.

(c) Soil on Secondary Canal Route

The secondary canal diverted from the main canal passes through low-lying swampy area. The base layer consists of soil formed in Quaternary Pleistocene and the upper layer is the deposit in back swamp which was formed during the period from the alluvion to the present. Therefore, the poor layer is comparatively thick. The gravity drainage has been deteriorated because the swampy area is located along the coast, and the formation of soil is delayed for fallen trees.

The river deposit covers to the extent of 200-300m on either bank from the present river channel, which has bearing capacity, qc, of 5-7t/m^2, and is suitable for the foundation of the secondary canal. In the middle of the swampy area, however, there exists thick poor layer. Especially, in the low lying and flat area located between the Air Hitam and the Air Manjuto, the poor layer is thick.

The sand deposited on coastal levee is distributed to the extent of 1.5km from the coast, and the area extending to the mountainous area from 1.5km shows a tendency to become deeper poor layer gradually. The deepest layer is about 5m, and the bearing capacity qa of 2.5t/m^2 (qc=1-2kg/cm^2).

The embankment materials can not be found in the area passing through the secondary canal. Consequently, the materials will be conveyed from the terrace area. In the case of embankment constructed on the poor layer, woods should be placed under the embankment to distribute the load. Therefore, the canal route should be selected along the Air Selagan.

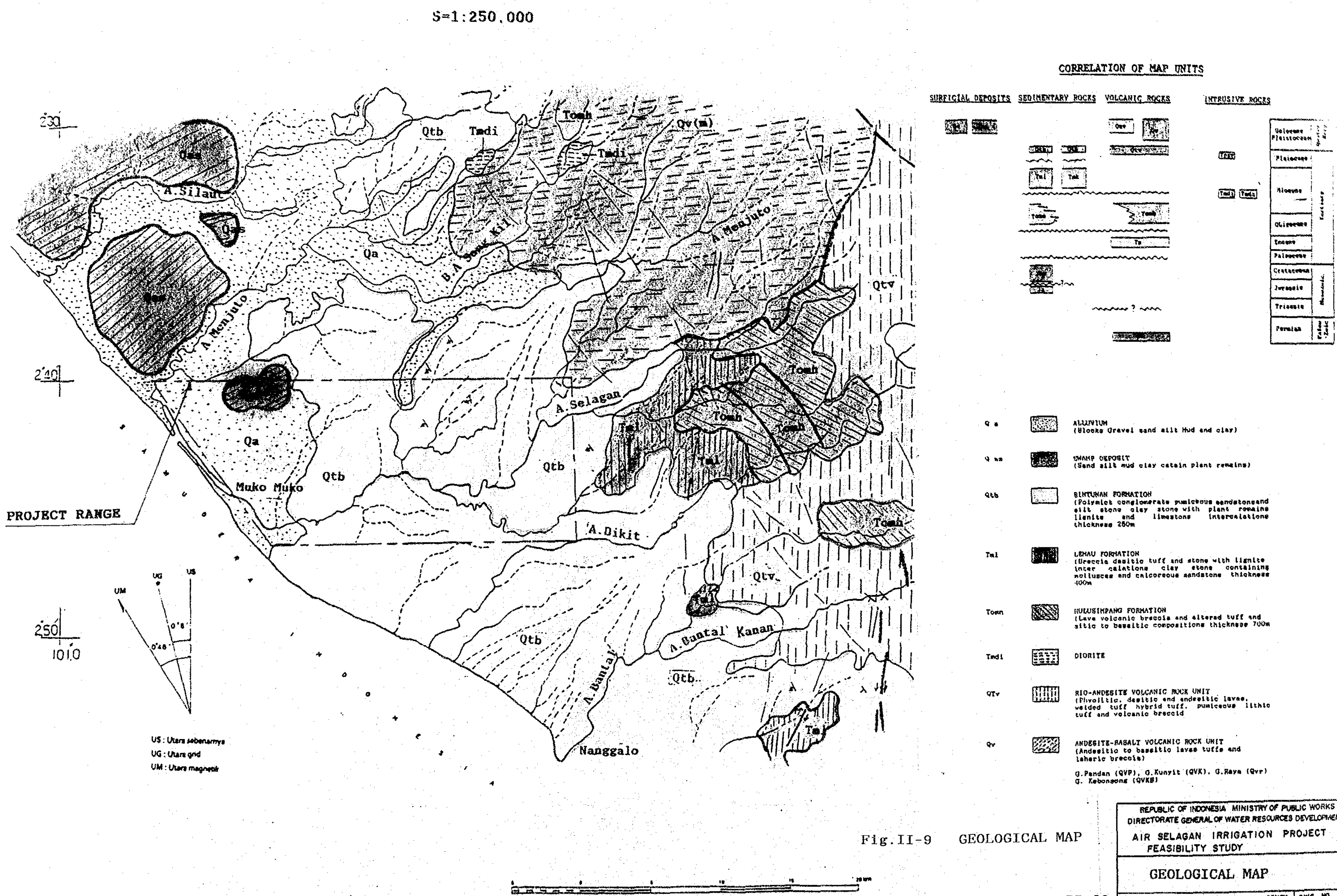
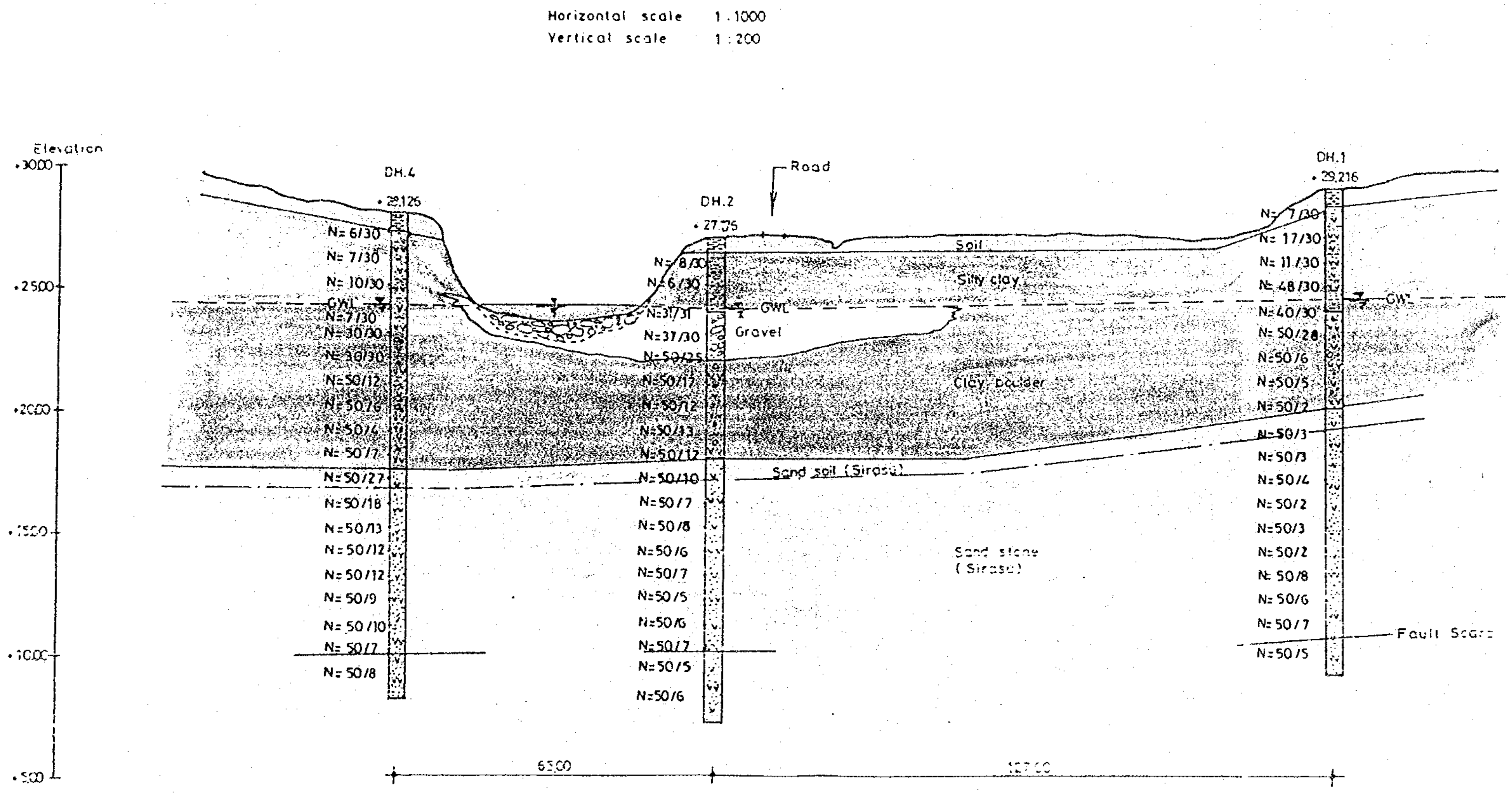


Fig.II-9 GEOLOGICAL MAP

REPUBLIC OF INDONESIA MINISTRY OF PUBLIC WORKS DIRECTORATE GENERAL OF WATER RESOURCES DEVELOPMENT	
AIR SELAGAN IRRIGATION PROJECT FEASIBILITY STUDY	
GEOLOGICAL MAP	
JAPAN INTERNATIONAL COOPERATION AGENCY TOKYO (JICA)	DWG. NO. 8

Fig.II-10 GEOLOGICAL CROSS SECTION ON PROPOSED WEIR AXIS



LEGEND

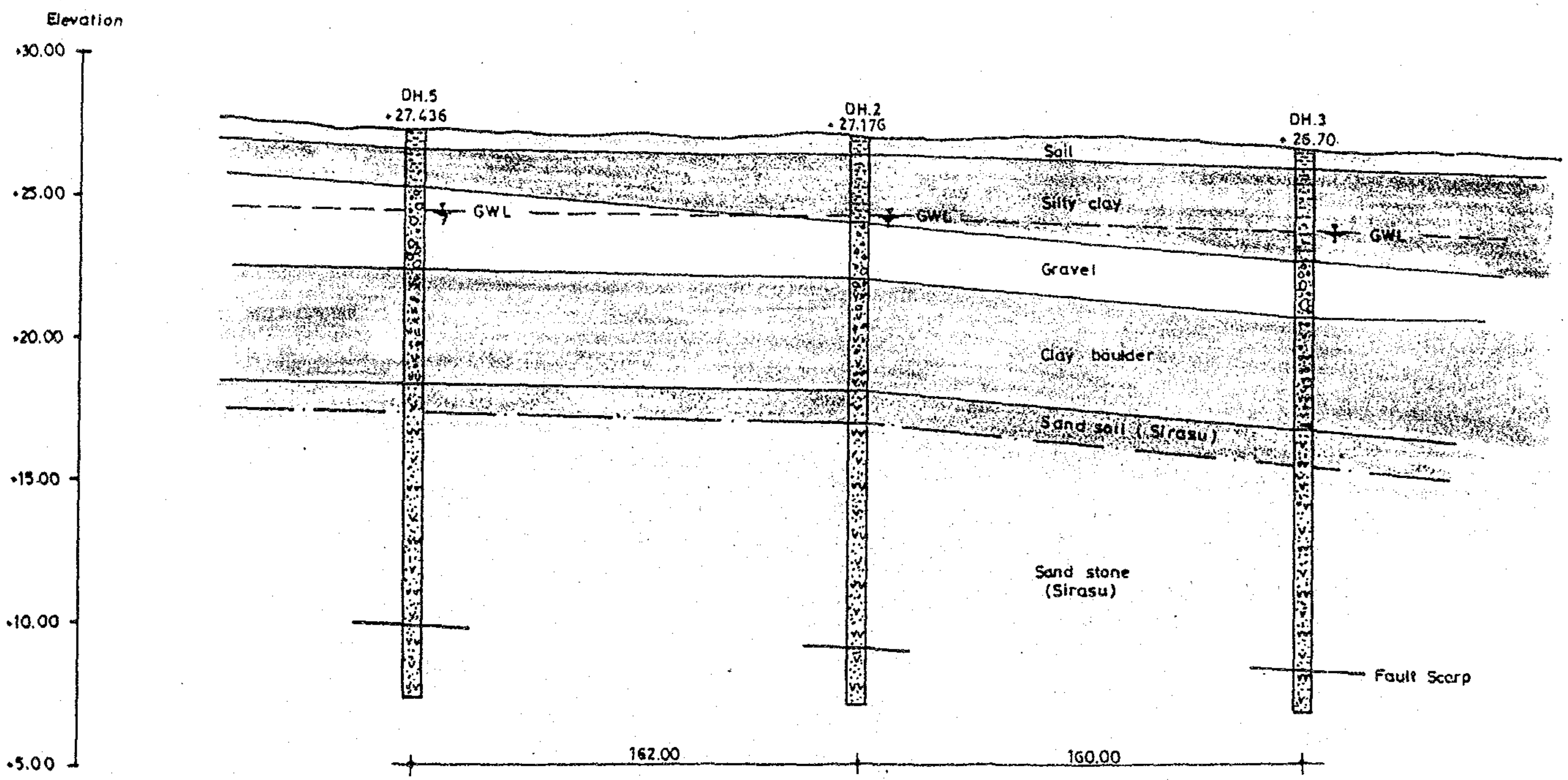
- Top soil / sandy-clayey silt, dark brown, soft.
- Breccia tuff, brownish gray, slight weathered-Medium weathered; sand, gravel, pebble with andesite fragments Ø 1-25 cm, sub angular-sub rounded, hard.
- Volcanic tuff, grayey-white, andesite fragments, minerals component cuartz, plagioclas and mica, stationary mass is volcanic glass; sub angular-sub rounded, rock hardness RH.1.
- Clayey-sandy silt, brown.
- Sandy gravel, pebble and boulder (andesite) Ø 1-25cm, brownish gray, sub angular-sub rounded, looses.

GWL Ground Water Level

N Standard Penetration Test

Fig.II-11 GEOLOGICAL LONGITUDINAL SECTION ON PROPO: ED WEIR AXIS

Horizontal scale 1:2000
Vertical scale 1:200



LEGEND

- Top soil / Sandy-clayey silt, dark brown, soft.
- Breccia tuff; brownish gray, slight weathered-Medium weathered, sand, gravel, pebble with andesite fragments Ø1-25 cm, sub angular - sub rounded; hard.
- Volcanic tuff, grayey - white; andesite fragments; minerals component quartz, plagiocls, orthoclas and mica; stationary mass is volcanic glass; sub angular - sub rounded; rock hardness RH. 1.

Clayey-sandy silt, brown.

Sandy gravel, pebble and boulder (andesite) Ø 1-25cm, brownish gray, sub angular-sub rounded, looses.

GWL Ground Water Level

N Standard Penetration Test

3.3 Seismic Design for Structures and Foundation

Destructive damage due to earthquakes occurs when a foundation ground fails because of liquefaction or important structures are destroyed and affect social conditions.

The seismic events within 300 Km radius centering around the proposed weir site are recorded as shown Fig. II-12*.

* Earthquakes in Indonesia; Ministry of Communication Meteorological and Geophysical Institute, Jakarta, Indonesia.

1) Maximum acceleration (max)

In the case that epicentral distance is less than 300 Km, the maximum acceleration at 100-year basal period is estimated by the Gntenberg-Richler Formula as follows:

$$max = 232.5 \times 10^{0.313M} \times (x + 30)^{-1.218}$$

where, max : maximum acceleration (gal)
M : magnitude on Richter scale
x : epicentral distance (Km)

For example, when, M = 7.0 and x = 25 Km (Short distance type)
max = 274 gal

and, when M = 7.5 and x = 125 Km (Long distance type)
max = 111 gal

According to Fig. II-12, magnitude more than 7 was recorded near 50 Km from the proposed weir site, therefore, the maximum acceleration at the weir site is estimated at 174 gal.

2) Design Intensity

(i) the method by the use of max

Coefficient of earthquake (Kh) can be computed by using the passed maximum max shown in the following formula.

$$Kh = 0.5 \times \frac{max}{g}$$

where, : Compensation coefficient on ground condition,
Alluvials, Deluvials: = 1.2
Tertiary soft rocks : = 1.0
Tertiary hard rocks : = 0.9

g : gravity acceleration

Kh : coefficient of earthquakes
0.5 : 0.5 x 1.0 x 174/980 = 0.089 ≑ 0.09

(ii) the method of "DPMA"

the formula by DPMA is;

$$Kh = \frac{ad}{g} = \frac{1}{g} \times b1 \times (ac \times z)^{b2}$$

where, Kh: coefficient of earthquake
ad: design earthquake acceleration
g: gravity acceleration
b1, b2: coefficient for soil or rock
z: coefficient of zone (Fig. II-13)
ac: basal acceleration

If the basal period is 100 years, ac is 160, then Kh is as follows.

b1 = 2.76, b2 = 0.71 (rock foundation), z = 1.56
$Kh = 2.76 \times (160 \times 1.56)^{0.71}/980 = 0.142$

(iii) Design intensity

Taking the calculation results above and the fact that the Project area faces the Sunda Trench Plate which cause many earthquakes into account, coefficient of earthquakes 0.15 is recommended to apply for the aseismatic design for the Project.

Fig.II-12 EARTHQUAKE EPICENTERS AND SEISMIC ZONE IN SUMATRA

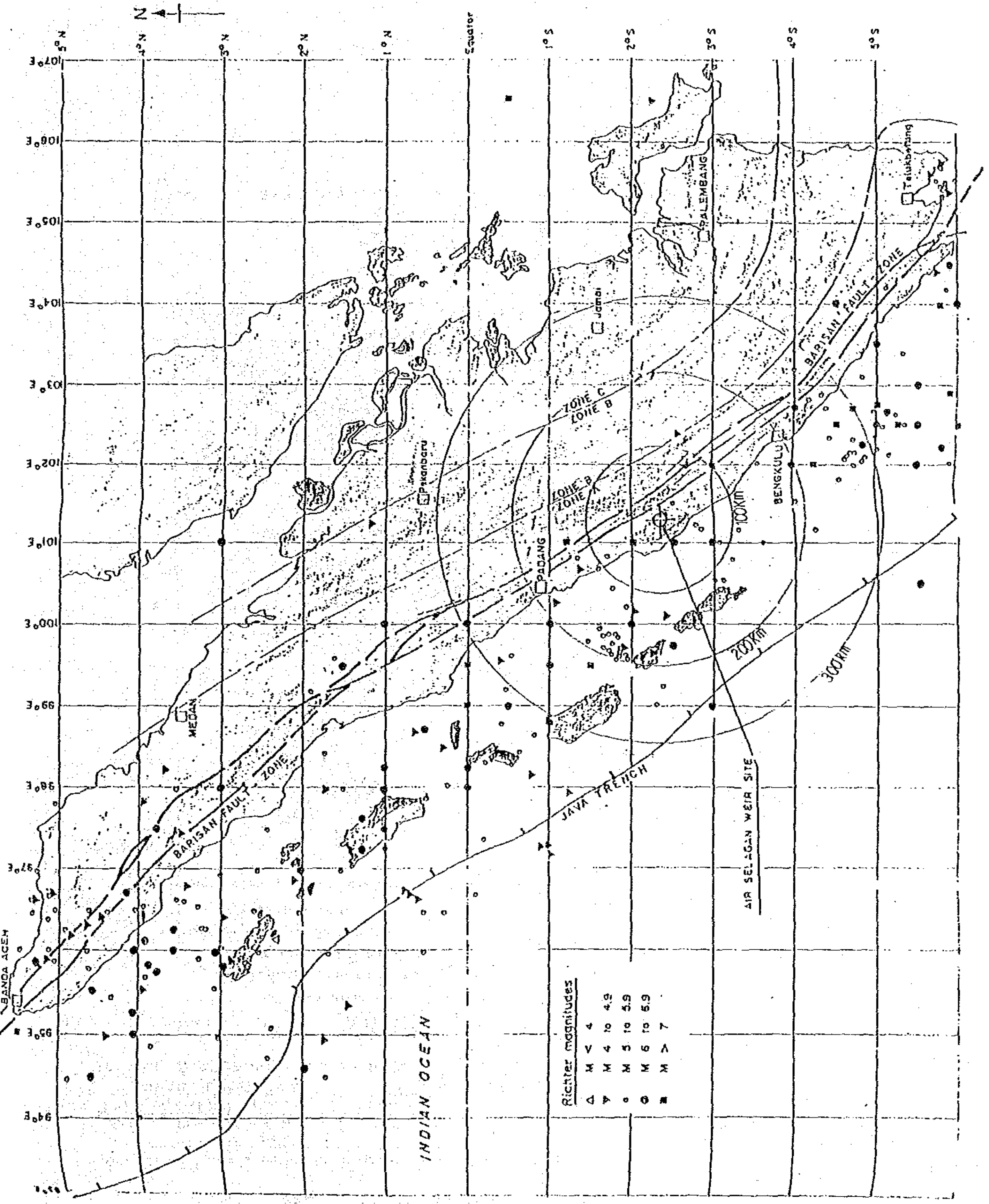
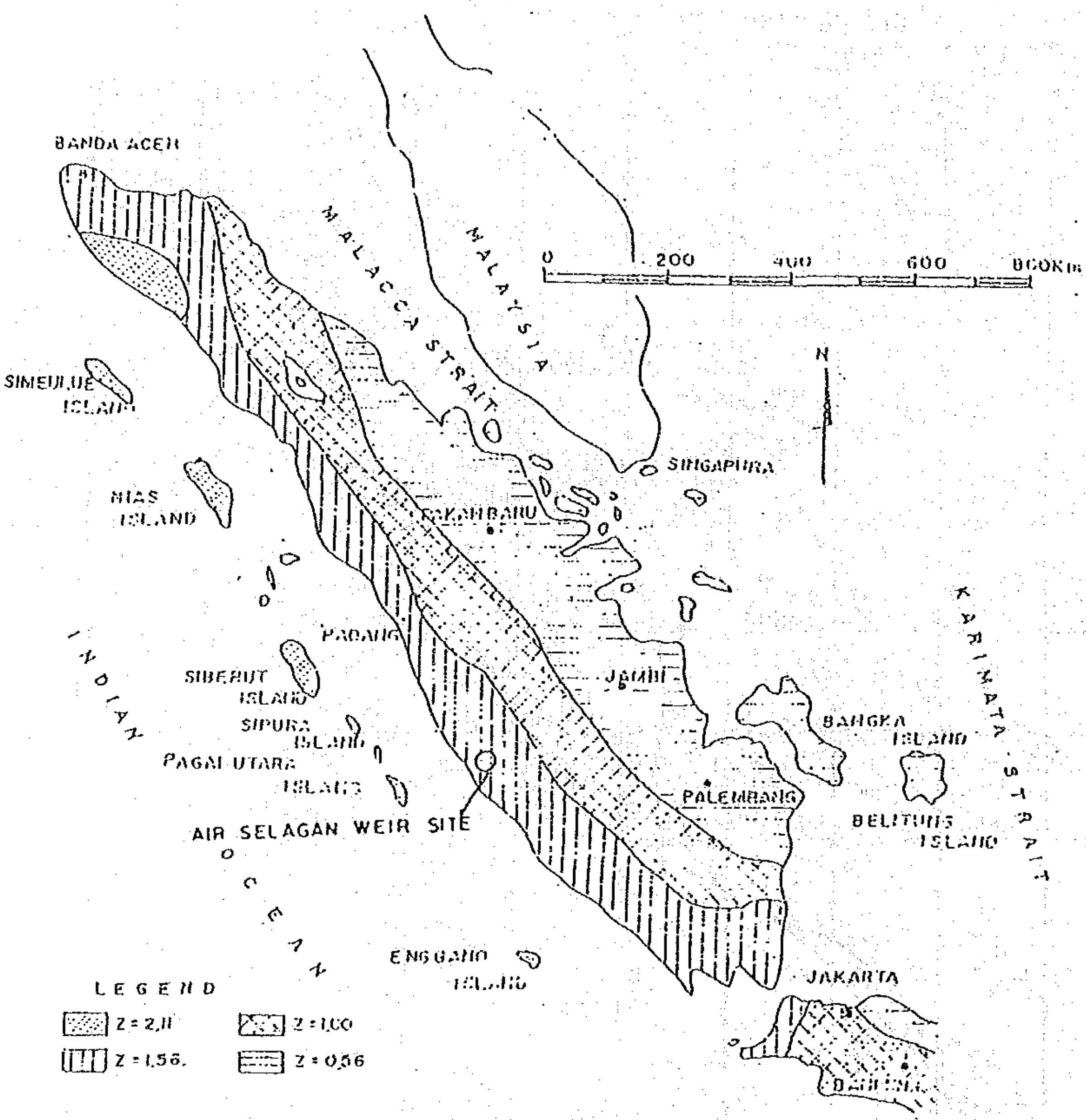


Fig.II-13 MAP OF SEISMIC ZONE FOR DESIGN OF RESIST AGAINST EARTHQUAKE STRUCTURES



FORMULA

$$a_d = b_1 (a_c \times z)^{b_2}$$

$$K = \frac{a_d}{g}$$

a_d = Acceleration of design earthquake
b_1, b_2 = Coeficient of soil/rock
a_c = Acceleration of base earthquake
k = Coeficient of earthquake
g = Gravitation = 980 (cm/sec^2)
T = Turnperiod average
1 gal = 1 cm/det^2
Z = Coeficient of zone

CORRECTION FACTOR OF SOIL/ROCK CLASS

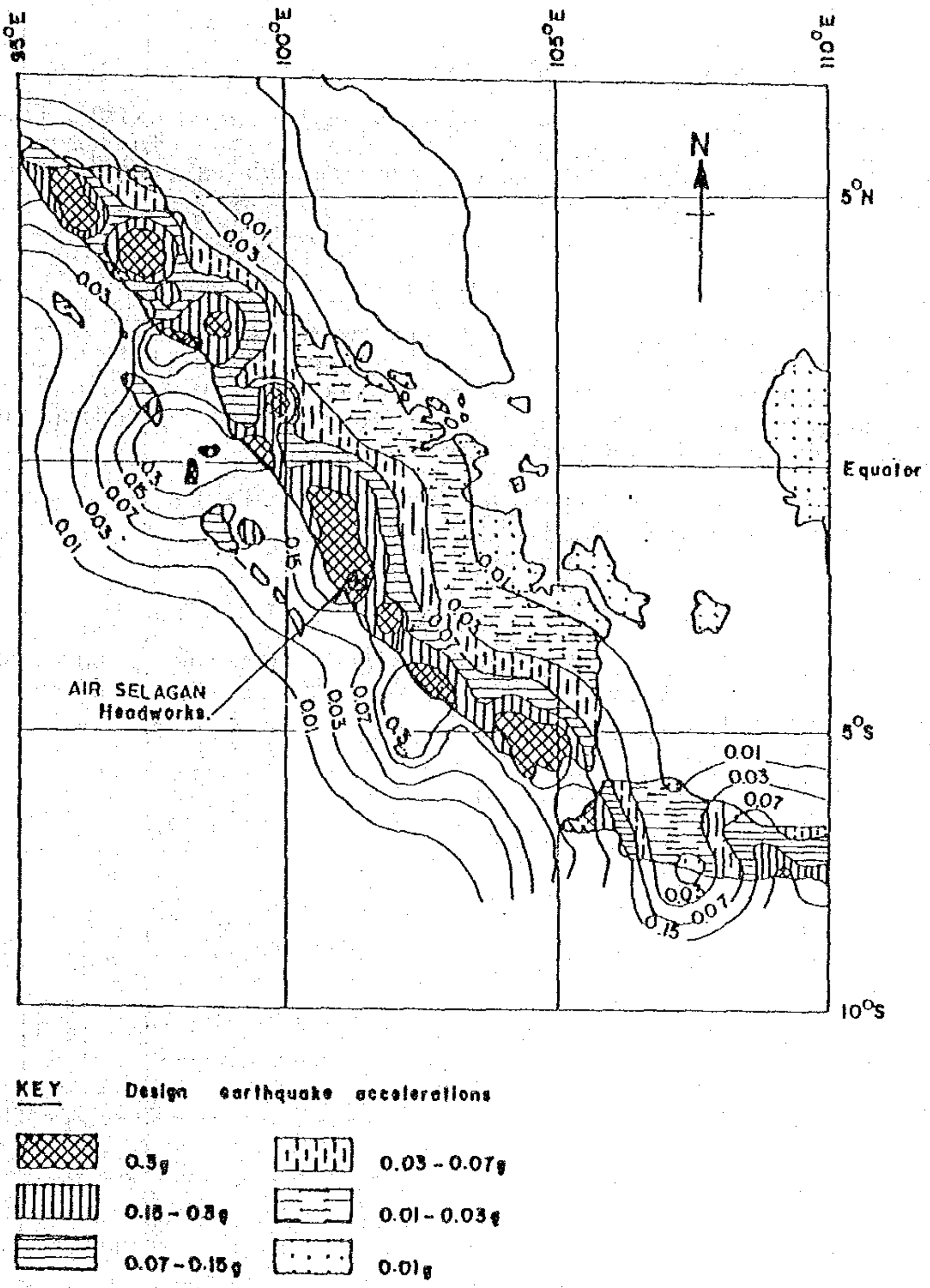
SOIL CLASS	b_1	b_2
Rock	2.76	0.71
Olluvium	0.87	1.05
Alluvium	1,56	0,89
Soft Alluvium	0,29	1,32

TURN PERIOD(T) ACCELERATION OF BASE EARTHQUAKE

T (year)	a_c (gal)	T (year)	a_c (gal)
20	85	50	113
100	160		

Interval values can be counted by interpolation

Fig.II-14 CVT EARTHQUAKE ACCELERATION MAP



Source : Lembaga Meteorologi Geofisika (Map taken from CVT reports)

CHAPTER 4 FOUNDATION OF PROPOSED WEIR SITE

4.1 Geological Structure

The foundation of the proposed weir site consists of top soil with sandy-clayey silt layer, silty clay later , sandy gravel and bounder (andente) layer, breccia tuff and volcanic tuff.

4.2 Bearing Capacity for the Weir

N-values of breccia tuff with 4m depth where exists less the EL.22.0m show more than 50 as shown Fib. II-15. This means the foundation of this site may have enough strength for the foundation of the proposed weir.

4.3 Permeability of the Foundation

The coefficient of permeability k in the sandy tuff layer where deposited less than EL.17.6m at the left bank and EL.18.2m at the right bank is rather large, being 10^{-3}-10^{-4} cm/sec. Tuff below heavily weathered stratum has been welded including pumice. The k value is less than 10^{-5} cm/sec.

The k values of the upper layer (breccia tuff) are rather high, being 10^{-3} cm/sec.

4.4 Shear Strength

No data for shear strength at the foundation of the proposed weir site are available. Therefore, further laboratory test shall be required.

Fig.II-15 BOREHOLE LOG (1/5)

1

BORE HOLE LOG

Project : Proposed Weir.
Location : Air Selagan
Boring No. : PH I.
Elev. of groundsurface :
Bed rock elevation :

Depth : 0.00 – 15.00 m.
Inclinational :
Started / Finished :
Drilled by : Anang S.

Logged by : Sukino
Approved by : Sutomo

DATE	ELEVATION (m)	DEPTH (m)	CORE RECOVERY %	DESCRIPTION	DRILLING WATER SWIFEL COLOR	DRILLING WATER SWIFEL %	DRILLING WATER SWIFEL MATERIAL	DRILLING SPEED	PERMEABILITY TEST	SPT
27/9-89		0.00 – 0.75	100	Top soil. Silty Clay, Sand, blackish brown mixed plant roots.						
		0.75 – 3.00	95 90	Brecciaoutuff completely weathered (CW) to Highly Weathered (HW) yellow brown Silty clay, Sands, moderately Soft, rather Compact.	Whitish brown		Sand and clays		2.46x10^-3 1.20x10^-2 1.86x10^-2 4.35x10^-2 2.77x10^-2	7/30 17/30 11/30 48/30 40/30
28/9-89		3.00 – 9.00	75 80	Breccious tuff, moderately weathered (MW) to Slightly Weathered (SW) Whitish grey to yellow. Sands, Silts gravels, andesite fragments rock Ø 1.00 – 25.00 Cm, fine to Coarse, Sub angular - Sub rounded Compact.	Whitish grey				1.49x10^-2 5.16x10^-3 3.84x10^-3 3.25x10^-3	50/28 50/6 50/5 50/2
29/9-89 30/9-89		9.00 – 15.00	75 80 85	Volcanic tuff grayey - White, andesite fragments, mineral component quarts, plagioclas and mica, Stationary mass is Volcanic glass, Sub angular - Sub rounded, rock hardness RH.1.	Whitish grey		Sand and silt		1.04x10^-4 8.74x10^-5 2.32x10^-4 1.11x10^-4 1.14x10^-4 2.12x10^-5	50/3 50/3 50/4 50/2 50/3 50/2
1/10-89		15.00 – 20.00	75 80 75	Volcanic tuff grayey - white, andesite fragments, mineral component quarts plagioclas and mica Stationary mass is Volcanic glass, Subangular - Sub rounded, rock hardness RH.1	Whitish grey		Sand and silt		1.16x10^-4 9.54x10^-5 6.86x10^-5 1.09x10^-5 9.67x10^-5	50/8 50/6 50/7 50/5

REMARK:

▮ Undisturbed Sample 1.50 – 2.00 m.

Standard penetration test and permeability Interval 1.00 m.

GWL = 4.50 m

Fig.II-15 BOREHOLE LOG (2/5)

3

BORE HOLE LOG

Project : Proposed Weir.
Location : Air Selogan
Boring No. : DH Ⅱ.
Elev of groundsurface :
Bed rock elevation :

Depth : 0.00 – 15.00 m
Inclinational :
Started / Finished :
Drilled by : Anang S.

Logged by : Sukino
Approved by : Sutomo

DATE	ELEVATION (m)	DEPTH (m)	CORE RECOVERY %	DESCRIPTION	DRILLING WATER SWIFEL COLOR	%	MATERIAL
10/10-89		0.00 – 0.60	100	Top soil, Silt, sandy clay blackish brown mixed plant roots. Soft.			
		0.60 – 3.00	95	Silty Sands Clay, brown, Sub angular – Sub rounded. loose.	brown		Sands and silt
		3.00 – 5.00	60	Sands, gravels, pebbles, boolders, andesite fragments ø 1.00–25.00cm blackish grey, Sub angular – Sub rounded. loose.	Whitish yellow		Sands and silt
11/10-89		5.00 – 9.00	75, 80	Breccious tuff, moderately Weathered (MW) to Slightly Weathered (SW) Whitish grey, Sands, gravel, pebbles, Silts andesite fragments ø 1.00–25.00cm fine to Coarse, Sub angular – Sub rounded hard.	Whitish yellow		Sands and silt
12/10-89		9.00 – 15.00	85, 90, 75	Volcanic tuff greyey – White andesite fragments, mineral Component quartz Plagioclas, Orthoclas, Stationary mass is Volcanic glass, Sub angular – Sub rounded rock hardness RH.1.	Whitish grey		Sands and silt
13/10-89		15.00 – 20.00	90, 85, 90	Volcanic tuff greyey – White andesite fragments, mineral Component quartz Plagioclas, orthoclas, stationary mass is Volcanic glass, Sub angular – Sub rounded rock hardness RH.1.	Whites grey		Sands and silt

PERMEABILITY TEST	SPT
3.33×10^{-3}	8/30
1.76×10^{-3}	6/30
1.78×10^{-2}	31/30
3.84×10^{-3}	37/30
1.63×10^{-2}	50/25
1.06×10^{-2}	50/17
5.11×10^{-3}	50/12
5.14×10^{-3}	50/15
1.36×10^{-5}	50/12
2.60×10^{-4}	50/10
9.42×10^{-5}	50/7
8.32×10^{-5}	50/8
6.20×10^{-5}	50/6
6.94×10^{-5}	50/7
6.09×10^{-5}	50/5
1.01×10^{-4}	50/6
5.46×10^{-5}	50/7
4.16×10^{-5}	50/5
4.90×10^{-5}	50/6

REMARK

▮ Undisturbed Sample 1.50 – 2.00 m

Standard penetration test and permeability, interval 1.00 m

GWL = 2.85 m.

Fig.II-15 BOREHOLE LOG (3/5)

BORE HOLE LOG

5

Project : Proposed weir
Location : Air Selagan
Boring No. : DH III
Elev of groundsurface :
Bed rock elevation :

Depth : 0.00 – 15.00 m
Inclinational :
Started / Finished :
Drilled by : Anang S.

Logged by : Sukino
Approved by : Suromo.

DATE	ELEVATION (m)	DEPTH (m)	CORE RECOVERY %	DESCRIPTION	DRILLING WATER SWIFEL COLOR	%	MATERIAL	DRILLING SPEED	PERMEABILITY TEST	SPT	REMARK
21/10-89		0.75	100	Top soil silty Sandy Clay, blackish brown, mixed plant roots. Soft.			Sands and Silt		2.46×10^{-3}	8/30	Undisturbed Sample 2.50 – 3.00 m
			75 90	Sands, Clayly Silt, brown, Sub angular – Sub rounder rather loose					1.20×10^{-2} 1.86×10^{-2} 4.35×10^{-3}	8/30 9/30 37/30	Standard penetration tes and permeability interval 1.00 m
22/10-89		4.00	75	Sands, gravels, pebbles, boulders andesite Ø 1.00 – 25.00 cm, brownish grey Subangular – Sub rounded loose	brown				2.77×10^{-2} 1.07×10^{-2}	44/30 50/27	
23/10-89		6.00	80 75	Brecciaous tuff moderately Weathered (MW) to Slightly Weathered (SW) Whitish grey, Sands, gravels, pebbles, Silts. andesite fragment Ø 1.00 – 25.00 cm fine to Coarse Subangular – Sub rounded hards.	Whitish Yellow		Sands and Silt		5.16×10^{-3} 3.84×10^{-3} 3.25×10^{-3} 5.87×10^{-5}	50/28 50/25 50/14 50/13	
24/10-89		10.00	80 75	Volcanic tuff, greyey white andesite fragments, mineral Component quarts plagioclas orthoclas, mica, Stationary mass is Volcanil glass. Sub angular – Sub rounded, rock hardness RH.1	Whitish Grey		Sands and Silt		5.50×10^{-5} 5.52×10^{-5} 4.77×10^{-5} 4.33×10^{-5} 4.22×10^{-5}	50/12 50/13 50/11 50/12 50/10	
		15.00									
25/10-89		15.00	80 75 80	Volcanic tuff, greyey white andesite fragments, mineral Component quarts plagioclas orthoclas, mica stationary mass is Volcanic glass, Subangular – Sub rounded, rock hardness RH.1	Whitish grey		Sands and Silt		2.23×10^{-5} 2.47×10^{-5} 7.36×10^{-5} 7.68×10^{-5}	50/11 50/12 50/10 50/8	
		20.00									GWL = 2.90 m.

Fig.II-15 BOREHOLE LOG (4/5)

BORE HOLE LOG

7

Project	: Proposed Weir	Depth	: 0.00 – 15.00 m
Location	: Air Selagon	Inclinational	:
Boring No.	: DH IV	Started / Finished	:
Elev. of groundsurface	:	Drilled by	: Anang S.
Bed rock elevation	:		

Logged by : Sukmo
Approved by : Sutomo

DATE	ELEVATION (m)	DEPTH (m)	CORE RECOVERY %	DESCRIPTION	COLOR	MATERIAL	PERMEABILITY TEST	SPT	REMARK
4/10-89		0.00 – 0.75	100	Top soil clay, Sandy Silt blackish brown mixed plant roots.	brown	Sand and fill	7.68×10^{-5}	6/30	Undisturbed Sample 1.50 – 2.00 m
		0.75 – 5.00	90	Breccia tuff Completely Weathered (CW) to highly weathered (HW) Clay, Sandy Silt, in print, rather compact.	brown	Sand and fill	6.61×10^{-5}	7/30	Standard penetration test, interval 1.00 m
			85				3.19×10^{-5}	10/30	
							2.98×10^{-5}	7/30	
5/10-89		5.00	90				1.53×10^{-4}	30/30	
		5.00 – 10.50	90	Brecciou tuff, moderately weathered (MW) to slightly weathered (SW) whitish grey, gravels, pebbles, Sands, Silt, andesite fragments Ø 1.00 – 25.00cm, fine to Coarse Subangular – Sub rounded, Compact.	whitish yellow		1.17×10^{-4}	30/30	
			75				7.05×10^{-3}	50/12	
			70				8.25×10^{-3}	50/6	
							6.00×10^{-3}	50/4	
			75				3.71×10^{-3}	50/7	
6/10-89		10.50 – 15.00	80	Volcanic tuff greyish white, andesit, fragment, mineral Componen quarts plagioclas, orthoclas, mica, Stationary mass is Volcanic glass Sub angular – Subrounded rock hardness RH.1	Whitish grey		7.92×10^{-5}	50/27	
							7.84×10^{-5}	50/18	
			85				6.42×10^{-5}	50/13	
							3.99×10^{-5}	50/12	
7/10-89		15.00	75				3.78×10^{-5}	50/12	
8/10-89		15.00 – 20.00		Volcanic tuff greyish white, andesit, fragment, mineral Componen quarts plagioclas, orthoclas, mica, Stationary mass is Volcanic glass Subangular – Subrounded, rock hardness RH.1	Whitish grey	Sand and fill	5.52×10^{-5}	50/9	
							3.62×10^{-5}	50/10	
							7.96×10^{-5}	50/7	
		20.00					3.47×10^{-5}	50/8	

GWL = 3.87 m.

Fig.II-15 BOREHOLE LOG (5/5)

BORE HOLE LOG

9

Project	: Proposed Weir	Depth	: 0.00 - 15.00 m
Location	: Air Selagan	Inclinational	:
Boring No.	: PH V.	Started / Finished	:
Elev of groundsurface	:	Drilled by	: Anong S.
Bed rock elevation	:	Logged by	: Sukino
		Approved by	: Sutama

DATE	ELEVATION (m)	DEPTH (m)	CORE RECORVERY %	DESCRIPTION	DRILLING WATER SWIFEL COLOR	%	MATERIAL
15/-89 /10		0.00	100	Top soil, silt, sandy clay, blackish brown mixed plant roots, soft	brown		Sand and silt
		0.70	95	Sands, clayey silt brown, Subangular - Subrounded rather loose.	brown		Sand and silt
		2.00	70	Sands, gravels, pebbles andesite boulder, ∅ 1.00-25.00 cm brownesh grey Sub angular - Subrounded loose.	brown		Sand and silt
16/-89 /10		5.00	75, 70	Brecciaus tuff. moderately weathered (MW) to slightly weathered (SW) brawnesh grey, Sands, gravel, pebbles, silt andesite fragments ∅ 1.00-25.00cm, fine to Coarse Subangular - Subrounded, hards.	Whitish yellow		Sand and silt
17/-89 /10		9.00 - 15.00	75, 80, 75	Volcanic tuff greyey - White, andesite fragments, mineral component quarts plagioclas, orthoclas, Stationary mass is volconices glass Subangular - Sub rounded, rock hardnes RH.1	Whitish grey		Sands and silt
18/-89 /10		15.00 - 20.00	80, 75, 80	Volcanic tuff greyey - White, andesite fragments, mineral component quarts plagioclas, orthoclar, Stationary mass is Volcanics glass Subangular - Sub rounded, rock hardnes RH.1	Whitish grey		Sand and silt

DRILLING SPEED	PERMEABILITY TEST	SPT
	3.40×10^{-3}	7/30
	3.86×10^{-3}	9/30
	1.19×10^{-2}	49/30
	7.38×10^{-3}	50/27
	1.67×10^{-2}	50/20
	7.86×10^{-3}	50/24
	8.04×10^{-3}	50/27
	5.82×10^{-3}	50/23
	6.01×10^{-5}	50/15
	5.86×10^{-6}	50/11
	5.62×10^{-5}	50/12
	4.36×10^{-5}	50/10
	4.47×10^{-5}	50/11
	4.19×10^{-5}	50/10
	4.04×10^{-5}	50/8
	3.79×10^{-5}	50/9
	3.38×10^{-5}	50/8
	4.30×10^{-5}	50/11
	3.20×10^{-5}	50/10

REMARK

▮ Undisturbed Sample

Standard penetration test. interval 1.00 m

GWL = 2.80 m

CHAPTER 5 CANAL EMBANKMENT

5.1 Canal Embankment on Soft Soil Foundation

Soft soil foundation is widely spreaded in the downstream of the project area. According to the dutch cone test results, qd values on the organic foundation show 2 to 4 t/m^2.

The maximum embankment height can be estimated by the following formula.

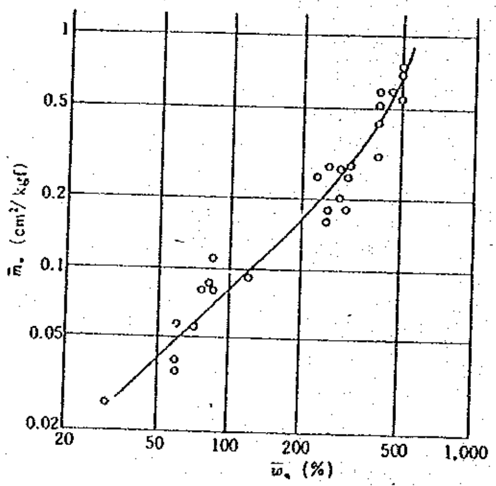
HEC = qd/rE

where, HEC : maximum embankment height (m)
qd : ultimate bearing capacity (t/m^2)
rE : unit weight of embankment material (t/m^3)

When, rE is 1.8 t/m^3

HEC = 2 - 4/1.8 = 1.1 - 2.2m

If the thickness of organic soil layer is estimated at 3.0m, coefficient of volume compressibility $\bar{m}v$ can be obtained as $\bar{m}v$ = 0.2 cm/kgt, using Wn-$\bar{m}v$ curve shown below.



Total settlement of the foundation can be calculated by the following formula.

S = mv · H · Wn

where, S : total settlement (cm)
mv : coefficient of volume compressibility
rE : unit weight (t/m^3)

Wn : natural moisture content (%)

therefore,
S = 0.2 x 1.8 x 2.2 x 300 = 237.6 cm

Consequently, proper counter measure for the canal embankment on organic soil foundation is required.

5.2 Canal Embankment on Hilly Area

The ultimate bearing capacity qd, at hilly area of the downstream of the Project show more than 10 t/m^2. Therefore, the maximum height of embankment will be

HEC = 10/1.8 = 5.6m

On the other hand, since clay in hilly area is overconsolidated condition, judging from qc value, settlement of the foundation will be negligible.

APPENDIX III

SOIL AND LAND SUITABILITY

CHAPTER 1. INTRODUCTION

1.1 General

The soils and land use survey for the Air Selagan Irrigation Development Project was conducted, at reconnaissance level, over a 22 day period, in the field, from mid-October to early November, 1989. This report presents the findings of the field survey of the project area, and makes land suitability recommendations for the production of irrigated paddy rice, palawija (predominantly maize, soya beans and peanuts), and non-irrigated tree crops being, rubber, oil palm and coffee.

1.2 Survey Area

The project lies to the east of Muko Muko where the longitude is 101° 7'E and latitude 2° 35'S. Most of the survey area consists of the lower part of the Air Selagan catchment area to the east of Muko Muko. This covers an area of 14,800 hectares, from below the proposed weir site which is just up-stream from the village of Lubuk Sahung, down to the road bridge over the Air Selagan at Muko Muko, which is within one kilometer of the coast. The project area is divided by the river, which flows from the east to the west, with the right bank forming the northern sector, which is 9,300 hectares and the larger area. The Air Hitam is a major tributary to the Selagan and flows from north to south dissecting the right bank area to converge with the main river near Pondok Batu. The left bank is 5,300 hectares, with the balance of 300 hectares being the area occupied by the river.

The northern boundary of the project area follows a line approximately one kilometer north of the river to the top of the hill behind to Pondok Kopi and then north of west to encompass the transmigration area of SP-III and includes very small parts of SP-VI and SP-II. The boundary then turns south of west, along the main drain, which divides the project area from the Air Manjuto Project and joins with the road at the north western end of Muko Muko. The southern boundary follows the line of the road towards Teras Trunjam for about two kilometers,and then the Air Petung. At just south of Teras Trunjam, the boundary runs due south along the P.T. Tolan Tiga plantation area all the way to the main Bengkulu road south of Tanah Rekah. The western boundary is formed by the line of gardens which run parallel to the main road behind Muko Muko, and is approximately one kilometer from the coast. The eastern boundary is formed by the southern and northern boundaries, which both turn north to converge just upstream of the proposed weir site.

Parts of the northern and eastern sectors are hilly, whilst the western sector is low lying and swampy. There is an established infrastructure system which covers the northern part of the area. This system provided access to the old established villages in the project area and has now been expanded to include the new transmigration villages of SP-VI, SP-IV, SP-III and SP-II. There is also a new road which runs through the middle of the project area from Pondok Batu, at the southern end of Muko Muko,to SP-III. This road runs partly along the right bank of the Air Selagan providing access to the center.

The survey area can be divided into four separate edaphic and morphological zones. Firstly there are the coastal sands which are about one kilometer wide and parallel to the sea. Secondly there is the hilly interior. Thirdly between the two lie the peat lands which stretch from the marine sands to the hills, a distance which varies between two and six kilometers. Fourthly there are the alluvial soils be left by the major rivers which dissect the first three groups.

CHAPTER 2. REVIEW OF DATA-BASE

2.1 Literature

Four surveys have been identified which have included part of the Air Selagan lower catchment area within their survey boundaries. These surveys were published between 1982 and 1988. A copy of the original feasibility study for the Air Manjuto project, which lies immediately to the north west and includes the western sector of the Air Selagan Project Area, could not be located. However an Action Plan for the Muko Muko Scheme prepared in 1988 was located.

The other sources of data were the Land Suitability for the Air Selagan prepared by the Institute Pertanian, Bogor. This does not include parts of the north west, which were covered by the Air Manjuto Project and are outside the catchment area of the Selagan. The other documents were a survey of the Air Manjuto by the Departmen Pertanian for the Department of Transmigration, and maps from the Department of Transmigration for the planning of the villages SP-III, -IV, and -VI in the area.

All reports divide the area into the four broad soil groups of the sandy coastal strip, the hilly land of the interior, the organic materials which lie between the two and the alluvial soils of the rivers. However, the major soil classifications into which the different soils are grouped variously between the different reports. This variation between the reports places the same soils in orders and sub-orders of cambisols, nitosols, podzols and latosols. The latter description is probably the most accurate description of the soils on the hilly areas. The lowland peats are also grouped and classified differently in each survey. It would appear that one common factor is that the peat areas have been both underestimated in their extent and in their significance by all these surveys.

Several papers have been studied on the formation and possible management of the peat areas. These have been discussed, where necessary, under the relevant sections, and as a separate issue in Data Book.

2.2 Topographic Maps

The base map available for the survey was a map with a scale of 1:25,000. The original was drawn from a toposurvey with a scale of 1;5000.

Some of the mapping was not accurate, so that the lakes in the P.T Tolan Tiga Plantation area did not agree with the aerial photographs, and several small stream lines appear to have been incorrectly drawn. The contour lines were not always consistent and the datum point for the contours was not Mean Sea Level and not common between other surveys. The coordinates used on the 1:25,000 maps were not the same as those used by the Department of Transmigration or the Air Manjuto Project, so that it was difficult to transpose information from other sources accurately onto the maps.

Finally because of very recent settlement in the transmigration areas, since the map was produced, new roads and land marks have developed which are not on the maps, and some of the old land marks which were on the map have now disappeared.

2.3 Aerial Photograph

The aerial photographs were produced in 1985 at a scale of 1:10,000. They were not available until the second half of the survey and freedom of use was restricted to Government officials being present and they could not be used in the field for verification. Only every other photograph had been printed, so that stereoscopic imagery was limited to less than ten percent on some photographs and never more than 40 percent. Stereoscopic analysis could not be completed so that it was not possible to plot and transpose accurate soil and land use information.

CHAPTER 3. SOIL SURVEY METHODOLOGY

3.1 General

There was heavy rain particularly at the beginning of the survey which filled most of the soil pits with water. Much of the lowlands were inundated with a temporary water level of between ten and thirty centimeters above the ground surface. Flooding from the Air Hitam frequently prevented access and made the sinking of auger holes difficult or impossible. This affected the methodology and limited access to some of the survey areas, especially in the low lying peats close to Muko Muko.

3.2 Methodology

Practical considerations for the completion of the survey within the time-frame available, dictated that the best method was to use the existing infrastructure of roads and canals which would provide check line transacts across the survey area. The features thus provided, gave fixed identifiable positions, which could be located on the map.

Where roads and paths were not available, it was necessary to cut transacts into the forest to reach areas of particular interest from the existing road and canal network. Along the roads, measurements were made using the distance readout from the vehicle. Where there were discrepancies between the vehicle readings and the map or there was any doubt, distances were checked with a tape. The survey traces through the rain forest were completed using a 100 meter tape measure with pegs and a compass.

Auger borings were made to a minimum depth of one meter every 500 meters along the roads, canals and survey traces in the forest. These were supplemented by using a five meter penetrometer probe to test the depth of the swamp areas with their associated peats. A series of test pits, to a depth of between one and a half and two meters, had been dug, on all the representative soils, except the peats where it was impossible. Soil pits were examined and supplemented by using roadside and canal side cuttings, often providing a unique cross section of the soil profile.

Descriptive details were made of all auger borings and soil pits using the guidelines laid down by FAO and the USDA Soil Survey Manual. The auger borings included notes on soil type, texture, color, mottling, rooting depth, depth to water table, and pH. A total of over 100 auger borings and test probes with the penetrometer were made, together with an examination of the 15 soil pits which represented the three remaining major soil groupings within the project area.

Finally, at the end of the survey, spot checks were made on selected areas to confirm that the interpretation and extrapolation of data was correct. Notes were made on all current land use information and vegetation as it was observed during the survey. To complete the survey in the available time, it was necessary to cover approximately 700 hectares every day.

Additional land use information was obtained from an uncontrolled mosaic which was made from a layout of the aerial photographs whilst in Muko Muko.

3.3 Map Production

Soil, land use and land suitability maps were produced on the 1:25,000 base maps. The project boundaries were drawn on using the data provided, together with the lines of the canals from the Air Manjuto Project. A survey of the transmigration villages was made, locating ground features which were identifiable on the maps. It was then possible, without the use of coordinates, to mark an approximate position of the road layout and transmigration villages onto the map. Data from the field survey was mapped using these assumed positions. Final correlation was made between the data which had been marked on the maps with data from other sources.

It is important to note that the position of the transmigration villages and their associated road layout, which has been drawn on the maps, can only be approximate. Where derived data has been used to locate positions on the maps, the approximation will effect the position of soil boundaries, and land use features.

CHAPTER 4. SOILS OF THE AIR SELAGAN PROJECT AREA

4.1 Background

The west coast of Sumatra has been influenced by fluctuations in the sea level attributed to the melting of the polar icecaps in post-glacial times between 10,000 and 5000 years ago. This has resulted in the formation of a series of coastal sand bars developing along the west coast of Sumatra. These have diverted the rivers, forming spits, of which the sand bar on the Air Selagan at Muko Muko is a typical example. These marine influences and sand bars prevented surface run-off water, from the adjacent hills, from flowing into the sea, so that a series of shallow fresh water lakes developed behind the shoals on beds of clay.

These lakes have subsequently developed into the peat swamps, where now only a few remanents of the original lake are left. It would appear that a nucleus of peat started to accumulate inland, rather than along the coastal strip or in the center. These nuclei extend radially until the whole basin is covered. Over time the peat has developed from mesotrophic or eutrophic topogenous peats to the oligotrophic ombrogenous peats found on the surface today. Because of the accumulation of organic matter, which has been developing longer on the inland side of the lake, it is much deeper there. This has created an increase in elevation of about five meters between the fibric peat inland and the more hemic or even sapric peat on the coast, resulting in a gradient of about 1 % across the peat, and causing the formation of a peat dome. This peat dome is still developing in undisturbed areas.

The formation of lacustrine peat has affected the interface between the histosols and the ferralsols which comprise the hilly land behind the swamps. The design of any irrigation system will be influenced by the interface between the peat with the ferralsols. It is on the ferralsols where the greatest agricultural potential lies. A development process for the peats is illustrated in Fig. III-1.

One difference between the peat formation on the project site and that cited in most of the literature is the presence of the coastal sand bars. It is not clear whether the lake and fresh water peat formed because of the development of the shoals or whether tidal saltwater peat formed first and the sand bars followed. Fresh water peats are reportedly more eutric and easier to develop.

The hilly area inland is volcanic in origin, and has provided material for the alluvial soils which have been deposited by the rivers. The coastal sand bars are defined by the line of regosols between the sea and the peat lands. A map showing the different soils of the project area is provided in Fig. III-2.

4.2 Soil Classification

The soil classification system which has been used in the survey is the FAO-Unesco system, which was confirmed in a subsequent meeting with the Directorate of Irrigation-II. A comparison of the different soil taxonomy systems is provided in Table III-1 . Profile descriptions of the auger borings and soil pits representing the four distinct soil types are given in Data Book for Soil, respectively. The soils of the project area can divided into four distinct edaphic and morphological groups. Firstly, along the coast a series of marine sand have developed into a band of regosols. Secondly, there are the uplands of the interior, comprising deep brown forest soils. Thirdly lying between the two, is an area of peat swamp which varies between two and six kilometers wide. Finally, dissecting all three groups are the alluvials soils, which have been deposited by the rivers flowing across the project area.

4.3 Regosols

The regosols have formed from the deposition of unconsolidated marine sands. Generally there were no clear diagnostic horizons, except at one site near Padang Pinang, where a hard cementation had formed a pan, and the profile was very podzolic [Soil Pit P1]. Colors vary between dark reddish brown (5YR 2.5/2) to yellowish brown (10YR 5/4). This soil group lies approximately one kilometer wide and parallel to the coast. The area is low lying, with a maximum elevation of three to four meters above Mean Sea Level, with slopes less than 1%. A series of narrow terraces, parallel to the sea have been formed. The area between the terraces was flooded during the survey.

The regosols can be divided into two sub-groups, however both are described as dystric, but one group has a higher proportion of clay and silt in the profile, making it more suitable for rice production. These soils are infertile, weakly acid and poor. Frequently drainage is impeded. During the survey standing water to 20 cm was common and water tables were high. The high water table was probably a result of the recent rain and the high level of water from the adjacent peat lands. At Pondok Batu near the Air Hitam running sand can be found within 50 cm of the surface. During the examination of the soil pits water flowed in continually through the profile, indicating a very high horizontal hydraulic conductivity. One pit was impossible to empty.

The areas of regosol in fine textured sub-group is 260 hectares, and in the coarse textured sub-group is 980 Hectares.

The total area of regosol is 1,240 hectares.

4.4 Histosols

A large proportion of the coast plain is covered by the peat swamp. The peat would appear to have very little clay within it, and no silt or sand. The material can be described as very immature fibric histosol, which is still being formed. The peats consist of a very high proportion of soft semi-decayed woody material within a very liquid medium. The color was very dusky red (10R 2.5/2). It was not possible to obtain samples from depth because the material flowed out of the bucket auger.

Because of the depth limitations of the soil auger, the surveyors were unable to obtain samples of the clay which would appear to underlie the peat, however the penetrometer did extract small samples of a soft white clay. It is not known what sort of clay this is, but a check in the future detailed survey must be made for catclay. In areas where the peat had been disturbed during the construction of the Air Manjuto canal and drainage system, a characteristic smell of rotten eggs was observed, together with the presence of ochre, indicating the possible development of acid sulphate soil formation. These signs were noticed along the canals which had been constructed within the project area as a result of the Air Manjuto project, particularly on BB4, BB5 and BB2 canals.

There appeared to be little variation within the peats over the whole survey area except where there had been some recent drainage adjacent to the Air Manjuto project and the P.T. Tolan Tiga Plantation. Here the peat has partially dried out and consolidated and can be walked on easily and would now be described as sapric. In some places it has become hard, crusty and very light weight. The drying process is reported to be irreversible, and if the land is flooded again the dried out peat will float away, as a form of erosion. Slopes are so slight that the area can be described as flat. Where there was some natural drainage near the Air Hitam where the peats tended to be more hemic than fibric.

In general these histosols have a very low bearing capacity and can easily be penetrated to the clay below. Walking across was sometimes difficult to impossible particularly where the peat had been recently drained, but was still wet. The water table was often 30 centimeters above ground level. The increasing depth of the organic material from the coast ranges from between one to two meters near the sea, before draining, to between four and five meters near SP III and SP VI. The average depth of undrained peat is estimated to be between two and a half and three and a half meters. The depth of the peat in the center was reported to be seven meters, but this report was not confirmed. Judging from the two transacts made across the drained peat, (see Fig. III-2), where the depth was exposed on the side of the drain, it would appear that the depth may not be more than three or four meters in the center. The greatest depth of peat recorded was more than ten meters, at the end of the BB4 canal.

Because of the lacustrine development, the interface between the histosols and the ferralsols approximates to a contour line. However it is not known which contour line does form the abrupt boundary between the two. An arbitery line has been taken for the mapping unit to demonstrate the effect. The result is that there are long and often narrow protrusions of peat up the old flooded valleys, which are frequently more than three meters deep. Likewise, the hills protrude into the peat forming a series of islands within the swamp. These have been mapped from the contour lines. A spot check was made at the end of the survey and the mapping system was confirmed at the end of the BB8 canal, and on the Air Hitam.

The FAO/Unesco soil classification provides three classes for peat soils. The peats of the project area have been mapped as dystric, being the most accurate available, although fibric would be a better description.

The total area of histosols is 4,400 hectares.

4.5 Ferralsols

All the soils of the upland interior, within the survey area, are very similar and would appear to differ in color rather than any other feature. These dark yellowish brown(10YR 3/4),to strong brown(7.5YR 5/6) forest soils have been grouped into four types of ferralsols. They are strongly weathered, weakly structured, erodible, tropical brown forest soils with an indeterminate oxic B horizon which is low in organic matter. Texture was usually silty loam to silty clay loam, with enough clay in some areas to enable the manufacture of bricks. Generally the soils were well drained with little evidence of mottling which was confined to the lower slopes. Fertility is reported to be low.

The area is hilly, with narrow crest lines between steep slopes, often greater than 30%, with a vertical interval of more than 20 meters. Between the hills are narrow " v " shaped valleys. The roads follow the crest lines, and the topography is hidden by the rubber plantations and forest, giving a different impression. Where land has been cleared, the true nature of the terrain is more obvious.

In the western sectors of this soil unit, and in a few other isolated areas within the major soil group, the slopes are less than 20%, with a vertical interval below 15 meters, the valleys and hill tops are wider presenting more extensive areas for irrigation.

The area to the north west between SP-VI and SP-III has the greatest variation from the rest of the upland area and is more like some of the areas of the Air Manjuto Project. Here the soils are deep reddish brown plinthic ferralsols. Further south, around SP-III, the plinthite is deeper, but the soils have retained a reddish hue. To the north of the survey area and to the east of SP-IV, the ferralsols are orthic with the plinthite two to three meters deep, which can be observed in roadside cuttings. To the east of SP-IV, the soils are more yellow and have been classed as xanthic. This description are supported by the Institut Pertanian at Bogor which describes the soils as latosols haplic, chromic, and rhodic. However this classification does not fall within the FAO/Unesco classification system, although it is included in the Indonesian taxonomic system. (see Table III-1).

In the field, there is an abrupt transition between the histosols and the ferralsols. It is important to note that long protrusions of peat, too narrow to map, may be found more than one kilometer within the ferralsols boundaries indicated on the soil map in Fig. III-2.

The total area of 6,760 ha of ferralsols is broken down as follows.:

Orthic ferralsols	:	3,200 ha
Plinthic ferralsols	:	660 ha
Rhodic ferralsols	:	1,200 ha
Xanthic ferralsols	:	1,700 ha

4.6 Fluvisols

Across these three major soil types are the alluvial soils which have been deposited by the Air Selagan, Air Hitam and other minor streams like the Bodi and the Badak which are left bank tributaries to the Air Selagan, north of the SP-IV. These soils could be classed as gleysols, but because of the recent nature of their deposition, they have been classed as dystric fluvisols. The areas are flat, and the soils are fine clays to silty clay loams and are often stratified. The colors are yellow (10YR 7/8) to very dark grayish brown (10YR 3/2). They are not fertile, they are poorly drained and often subject to flooding after heavy rain, so that water management will be a important component of their development. Stream bank erosion is a common on the main river, resulting in soft marshy deposits on the inside of the bends. The presence of ox-bow lakes and marshes is a regular feature in the lower part of the river basin.

Alluvial soils have been deposited in some places over the peats where there is currently no stream, indicating that rivers and small streams change course from time to time. Layers of alluvial soil over the peat, were observed on the Hitam just north of the canal crossing north of SP-III. Here a cutting had been made to realign the stream. In the bank of the cutting there was a 50 centimeter layer of alluvium over a 10 cm layer of peat. This was overlying another 20 cm layer of alluvium, which in turn was over a second layer of peat. This final layer of peat was measured and found to be greater than five meters deep. The alluvium on the Air Hitam to the south of the canal crossing was also found to be overlying peat. This feature has influenced canal stability on the Air Manjuto project west of SP-VI, in which canals have been constructed over peat and can be seen to have settled.

The total area of fluvisols is 2,100 hectares.

A summary of the areas for the different soil units is presented as follows:

AREAS OF SOIL UNITS IN THE PROJECT AREA

Soil Unit	Symbol	ha
Regosols, dystric	Rd	1,240
Histosols, dystric	Od	4,400
Ferralsols, orthic	Fo	3,200
Ferralsols, plinthic	Fp	660
Ferralsols, rhodic	Fr	1,200
Ferralsols, xanthic	Fx	1,700
Fluvisols, dystric	Jd	2,100
Others	-	300
Total		14,800

CHAPTER 5. PRESENT LAND USE

Until recently the area has been sparsely populated, with the main centers of population along the coastal strip or in the uplands behind the swamps. The rivers formed the main line of communication between the coast and the uplands and roads were confined to the hilly areas because the deep broad rivers were difficult to cross. This infrastructure effected the traditional land use patterns. Within the last five years transmigration villages, with populations of up 500 families per village have been introduced to the uplands behind the swampy areas.

The area has been classified into seven different land use classifications, which are defined below.

5.1 Wetland rice

The difference between wetland rice and upland rice, when being used for the definition of cropping systems, is not clear. For the purpose of this report wetland rice is defined as rice being grown with the use of surface bunds to impound and control water in the field. This applies even if the field happens to be dry at the time of inspection, which is a reflection of management and the available water resources, rather than the system.

Total area of paddy rice is 140 hectares.

5.2 Upland rice

Upland rice is defined as rice being grown on the flat or hillside, but where there has been no attempt to construct surface bunds to control the surface water. After harvesting upland rice, upland crops have been cultivated consecutively.

Total area of upland rice is 950 hectares.

5.3 Rubber

Rubber is currently an important crop and covers much of the well drained areas. Rubber is now being, or has been tapped on a regular basis for the last few years. Activity in the rubber plantations has increased with recent improvements in the price of rubber, but no young or immature plantations of rubber were found. The rubber has been planted in partially felled forest, or on open land after a few years of annual cropping. Poor management has brought about low yield and low quality.

The total area of rubber is 2,300 hectares.

5.4 Gardens

The definition of gardens and mixed cropping covers a wide combination of any two or more perennial or annual crops which are being grown together in small areas. This will often include upland rice, but not when it is being grown as a sole crop. The gardens may be productive and well kept or in the process of being abandoned. They have been included if they are still being used, regardless of apparent productivity. Major crops may include maize, groundnuts, soybeans, cassava and a few vegetables and tree crops. Many of these gardens are too small to map at the scale provided.

The total area under gardens is 1,200 hectares.

5.5 Natural forest

This area includes all types of forest, from the swamp forest over the peat, the natural forest over the hills to the alluvial plain. It also includes those areas of mature secondary forest where the trees are 5 meters high or more.

The total area of natural forest is 8,620 hectares.

5.6 Scrubland

The area of scrubland or thicket and secondary growth, is a result of abandoning cultivated areas. These areas would appear to be in a five to ten year cycle near the villages. The cycle would appear to be shorter near to Muko Muko and longer in the uplands. The scrublands are covered by a wide range of different species. Some pockets of scrublands are too small to map at the scale provided.

Total area of scrubland is 1,040 hectares.

5.7 Cleared and half burnt forest

There are several areas, particularly around the transmigration villages where the forest has been recently cut down and partially burnt. In many of these areas there has not been enough time for a cropping system to become established. Land clearing activities were continuing during the survey.

Total area of cleared and half burnt forest is currently 250 hectares. The present land use practices are presented in Fig. III-3.

A summary of the areas is provided as follows:

A SUMMARY OF THE CURRENT LAND USE

Land use	hectares
Paddy rice (padi sawah)	140
Upland rice (padi gogo)	950
Rubber	2,300
Gardens	1,200
Natural forest	8,620
Scrubland	1,040
Cleared and half burnt forest	250
Others	300
Total	14,800

Note) The results from the land use survey, October 1989

CHAPTER 6. LAND SUITABILITY

6.1 Land Suitability Classification

The land suitability system follows the principles of the FAO/Unesco Land Classification System which groups land suitability, for the specific purpose for which it is being planned, into five different classes. These classes are:

(1) S1, highly suitable
(2) S2, Moderately suitable
(3) S3, Marginally suitable
(4) N1, Currently unsuitable
(5) N2, Permanently unsuitable

A full definition of these classifications is given in Table III-2. The subscripts which are attached to each of the classifications to substantiate the grading, are defined in Table III-3.

6.2 General Framework

For the purpose of developing a practical irrigation project, there is little difference between the four ferralsols groupings for land suitability classification for irrigated or for rain-fed crop production. For the purpose of land suitability classification the ferralsols differences have been ignored. The main influencing factor on the upland areas is the slopes, rather than the intrinsic nature of the soils.

Although the uplands are dominated by steep slopes, often more than 30 % which present a severe erosion hazard, there are parcels of land along the crest lines and in the valley bottoms where slopes range from level to 10%, and can be terraced and irrigated. Land with slopes between 10% and 20% are considered marginal. Land with slopes greater than 20% are considered not to be suitable for terracing and irrigation. The original land classification grouped most of this area into N2. This would have meant that the total area for paddy was only 5690 hectares. However there are areas within the hills, some very small, which are irrigable. These form discrete parcels of land where the main consideration is the cost of providing the irrigation water. An upgrading from N2 to N1 would not be applicable, because time will not change the slope factor, so that the hilly land has been upgraded to S3 with at least half being permanently unsuitable.

6.3 Land Suitability of Paddy

Paddy will grow on a wide range of soils, and there is no preferred soil type, but heavy alluvial soils are better than light sandy soils. The optimum pH is between 5.5 and 6.5 when dry, and can be up to 7.2 when flooded. The Land suitability map for paddy rice is given in Fig. III-4.

There is no S1 land for paddy rice.

6.3.1 Fluvisols

The fluvisols have been classed as S2 for paddy rice, with limitations of flooding, drainage and fertility. Water management, to remove surplus flood water, will be an important component of the production system.

Total area for the land unit $S2_{fy}$ is 2,100 hectares.

6.3.2 Ferralsols

Most of the ferralsols have been classed as $S3_{ety}$. The land unit is limited by steep topography, with average slopes greater than 20 % and a vertical interval greater than 15 meters resulting a severe erosion hazard. Less than 50% of this land will be available for irrigation.

There are two other land units with in the ferralsols, these are based on a reduced slope where the classifications are $S2_{ty}$ and $S2_{y}$.

Total area of $S2_{y}$ is 380 hectares.
Total area of $S2_{ty}$ is 1,930 hectares.
Gross area of $S3_{ety}$ is 4,450 hectares.
Net area of $S3_{ety}$ is $<$2,225 hectares.

Total area of ferralsols suitable for paddy rice is 4,535 hectares.

The total figure above does not reflect the command area below the canal, but covers the land unit as a whole.

6.3.3 Regosols

Regosols are limited by coarse sandy texture, low fertility, and the need for drainage. There is one sub-unit within this classification where the texture is marginally better. This area is currently being used to grow upland rice.

Total area of $S2_{ly}$ is 200 hectares.
Total area of $S3_{dvy}$ is 1,040 hectares

6.3.4 Histosols

Rice is being grown on peat soils and the peat land on the Air Manjuto Project had been drained prior to the planting of paddy rice. Some of the transmigration farmers have planted rice on the peat soils. However all the peat has been classed as $N1_p$. At the time of writing there was no firm evidence that a sustainable crop of rice can be grown on the peat soils. The management of the peat soils is not yet fully understood, and is discussed in Data Book. It is hoped that eventually it will be possible to bring these areas into productive paddy production but more knowledge is needed before a recommendation can be made.

Personal communication with the Soils Center at Bogor recommended that peat soils should not be used for rice production if they are greater than one meter deep before drainage. The main reasons for this recommendation are two fold, one because of the difficulties of managing the drainage and irrigation on the peat, and secondly because the load bearing capacity is so low that farmers sink to the bottom, and are unable to move, to plant the rice, if the peat is too deep. In addition, based on the experiences which rice production has been carried out in the peat land, the peat has been classified as N1. It is recommended that development for rice should not take place yet.

Total area $N1_p$ is 4,400 hectares.

6.3.5 Summary

Areas of land suitable for paddy rice production are:

S2	4,610	hectares
S3	3,265	hectares
Total	7,875	hectares

6.4 Land Suitability for Palawija

For the purpose of the land classification system the palawija crops have been taken to be maize, peanuts and soybeans. Maize will tolerate a wide range of soil types, but likes good drainage, and well aerated silty loams. Peanuts like well drained friable soil, heavy soils make pegging and harvesting difficult. Soybeans will also accept a wide range of soil types, but are not tolerant of poor drainage. The land suitability map for palawija crops is given in Fig. III-5.

There is no S1 land for palawija crops.

6.4.1 Fluvisols

The fluvisols have been classed as S3 for palawija, with limitations of flooding, drainage and fertility. Water management, to reduce the effects of flooding, will be an important component of the production system.

Total area for the land unit $S3_{fy}$ is 2,100 hectares.

6.4.2 Ferralsols

Most of the ferralsols have been classed as $S3_{ety}$ for palawija. The two other land units for palawija within the ferralsols are classified as $S2_{ty}$ and $S2_{y}$.

Total area of $S2_{y}$ is 380 hectares.
Total area of $S2_{ty}$ is 1,930 hectares.
Gross area of $S3_{ety}$ is 4,450 hectares.
Net area of $S3_{ety}$ is 2,225 hectares.
Total area of ferralsols is 4,535 hectares.

6.4.3 Regosols

Regosols for palawija are limited by coarse sandy texture, low fertility, and poor drainage.

Total area of $S2_{ly}$ is 200 hectares.
Total area of $S3_{dvy}$ is 1,040 hectares

6.4.4 Histosols

The histosols have been classed as N1 for palawija. The need for maintenance of a high water table will prevent the production of most annual crops.

Total area is 4,400 hectares.

6.4.5 Summary

Areas of land suitable for palawija are:

S2	2,510 hectares
S3	5,365 hectares
Total	7,965 hectares

6.5 Land Suitability for Non-irrigated Tree Crops

For the purpose of the land classification system the non irrigated tree crops have been taken to be oil palm, rubber and coffee.

There is no S1 land suitability classification for tree crops. The land suitability map is presented in Fig. III-6, which shows the different land suitability classifications for each crop for each of the seven soil groups defined in chapter 4.

6.5.1 Oil Palm

Oil palm has a shallow adventitious root system. The crop likes deep permeable well structured soils, with good drainage. Effective soil depth should be greater than one meter and slopes should be less than 15 per cent. Poorly drained soils and coastal sands should be avoided.

All references recommend that oil palm is not grown on peat soils. However PT Tolan Tiga Estates have recently begun planting extensive areas of the peats to oil palm. These areas are now becoming established and the plants look healthy at six months of age. PT Tolan Tiga claim to have experience of growing oil palm commercially on peat soils, and are confidently developing their concession. There are three main difficulties to be overcome when growing oil palm on peat soils, these are:

(1) maintenance of the water table
(2) control of pH
(3) prevention of lodging in the mature crop.

Because of the apparent success of the plantation company the peats have been classified as S3, but careful research is recommended before final commitment to the establishment of oil palm on the peat.

Land suitability classification for oil palm are as follows:

Soil group 1:	
All the fluvisols:	$S2_{dfy}$ (2,110 hectares).
Soil group 2:	
Part of the xanthic ferralsols:	$S2_{y}$ (380 hectares).
Soil group 3:	
Parts of the xanthic, rhodic and plinthic ferralsols:	$S3_{t2y}$ (1,930 hectares).
Soil group 4:	
The remainder of the ferralsols:	$N2_{t3ey}$ (4,450 hectares).
Soil group 5:	
The better textured regosols:	$S2_{y}$ (200 hectares)
Soil group 6:	
The poorer textured regosols:	$N2_{dvy}$ (1,040 hectares).
Soil Group 7:	
The histosols:	$S3_{dfy}$ (4,400 hectares).

Areas of land suitable for oil palm production are summarized as follows:

S2	2,680 hectares
S3	6,330 hectares
Total	9,010 hectares

6.5.2 Rubber

Rubber has a deep tap root that can penetrate up to 4 meters deep, whilst lateral roots can extend more than 20 meters. Consequently rubber likes deep well drained soils, with a sandy clay loam to clay loam texture. Rubber will tolerate infertile soils provided that it is adequately fertilized. The acceptable pH range is between 3.6 and 8.0 with an optimum pH between 4.4 and 5.2.

Land suitability classification for rubber is as follows:

Soil group 1:		
All the fluvisols:	$S3_{dfy}$	(2,100 hectares)
Soil group 2:		
Part of the xanthic ferralsols:	$S2_{y}$	(380 hectares)
Soil group 3:		
Parts of the xanthic, rhodic and plinthic ferralsols:	$S2_{t2y}$	(1,930 hectares)
Soil group 4:		
The remainder of the ferralsols	$S2_{t3ey}$	(4,450 hectares)
Soil group 5:		
The better textured regosols:	$S2_{y}$	(200 hectares)
Soil group 6:		
The poorer textured regosols:	$S3_{dvy}$	(1,040 hectares)
Soil Group 7:		
The histosols: (4,400 hectares)	N2 (peat)	

Areas of land suitable for rubber production are summarized as follows:

S2	6,960 hectares
S3	3,140 hectares
Total	10,210 hectares

6.5.3 Robusta Coffee

Robusta coffee is grown in the tropical lowlands and will tolerate a wider range of conditions than arabica coffee. Coffee likes deep slightly acid soils which must be well drained, because the soils have to be aerated, but robusta will take temporary flooding.

Land suitability classification is as follows:

Soil group 1:'		
All the fluvisols:	$N2_{dfy}$	(2,100 hectares)
Soil group 2:		
Part of the xanthic ferralsols:	$S2_{y}$	(380 hectares)
Soil group 3:		
Parts of the xanthic, rhodic and plinthic ferralsols:	$S2_{t2y}$	(1,930 hectares)

Soil group 4:
The remainder of the ferralsols: $S2_{t3ey}$ (4,450 hectares)
Soil group 5:
The better textured regosols: $S2_{y}$ (200 Hectares)
Soil group 6:
The poorer textured regosols: $S3_{dvy}$ (1,040 hectares)
Soil Group 7:
The histosols: N2 (peat) (4,400 hectares)

Areas of land suitable for coffee production are summarized as follows:

S2	6,960 hectares
S3	1,040 hectares
Total	8,000 hectares

A full summary of the project area of 14,800 ha for each land suitability classification for the main crops being considered is given as follows.

SUMMARY OF AREAS OF LAND SUITABILITY CLASSIFICATIONS

(Unit : ha)

Crop	Suitability classification				
	S1	S2	S3	N1	N2
Paddy	-	4,610	3,265	4,400	2,225
Palawija	-	2,510	5,365	4,400	2,225
Oil palm	-	2,680	6,330	-	5,490
Rubber	-	6,960	3,140	-	4,400
Coffee	-	6,960	1,040	-	6,500

Table III-1 INDONESIAN SOIL CLASSIFICATION SYSTEM CORRELATED WITH FAO/UNESCO AND USDA SOIL TAXONOMY SYSTEM

Dudal & Soeprapto-harjo (1957, 1961)	Modified D/S system (1978/1981)	FAO/UNESCO (1974)	USDA Soil Taxonomy(1975)
1. Organosol	- Organosol	- Histosol	- Histosol
2. Litosol	- Litosol	- Litosol	- Entisol
	- Ranker	- Ranker	- Lithic] Sub Group
3. Aluvial	- Aluvial	- Fluvial	- Entisol
	- Kambisol	- Cambisol	- Inceptisol
4. Regosol	- Regosol	- Regosol	- Entisol
	- Kambisol	- Cambisol	- Inceptisol
5. Renzina	- Renzina	- Renzina	- Rendell
6. Grumusol	- Grumusol	- Vertisol	- Vertisol
7. Andosol	- Andosol	- Andosol	- Inceptisol
8. Podsolik Coklat	- Andosol	- Andosol	- Inceptisol
9. Podsolik Coklat Kekelabuan	- Podsolik	- Acrisol	- Ultisol
10. Brown Forest Soil	- Kambisol	- Cambisol	- Inceptisol
11. Latosol	- Kambisol	- Cambisol	- Inceptisol
12.	- Latosol	- Cambisol	- Inceptisol
	- Brunizem	- Cambisol	- Inceptisol
	- Nitosol	- Nitosol	- Ultisol
		- Phaeozem	- Alfisol
			- Mellisol
	- Oksisol	- Ferralsol	- Oxisol
	- Kambisol Molik/ Brunizem Molik	- Greyzem / Chernezem	- Mellisol
13. Podsolik Merah Kuning	- Podsolik	- Acrisol	- Ultisol
14. Mediteran Merah Kuning	- Mediteran	- Luvisol	- Alfisol
15. Podsol	- Podsol	- Podsol	- Spodosol
16. Podsol Air Tanah	- Podsol Humik	- Humic Podsol	- Spodosol
17. Laterit Air Tanah	- Oksisol Gleiik/ Plintik	- Plinthic Ferralsol	- Aquex
18. Glei Humus	- Gleisol Humik	- Gleysol	- Aquept
19. Glei Humus Rendah	- Gleisol	- Gleysol	- Aquept
20. Hidromorf Kelabu	- Podsolil Gleiik	- Gleyic Acrisol	- Aquult
21. Aluvial Hidromorf	- Gleisol Hidrik	- Fluvisol	- Hydraquent
22. Planosol	- Planosol	- Planosol	- Aqualf

Table III-2 FAO/UNESCO LAND SUITABILITY CLASSIFICATIONS

S1 Highly suitable.

Land having no significant limitation to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

S2 Moderately suitable.

Land having limitations which, in aggregate are moderately severe for sustained application of a given use; the limitation will reduce productivity or benefits, and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on class S1 land.

S3 Marginally suitable.

Land having limitations which, in aggregate, are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be marginally justified.

N1 Currently not suitable.

Land having limitations which may be surmountable in time, but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude sustained use of the land in the given manner.

N2 Permanently not suitable

Land having limitations which appear so severe as to preclude any possibility of successful sustained use of the land in the given manner.

Table III-3 DEFINITION OF LAND SUITABILITY SUBSCRIPTS

d	**Drainage**. Poor soil drainage within 75 cm of the surface will limit root growth. The excavation of a drainage system may be necessary.
e	**Erosion**. Soil erosion is likely to cause rapid degradation of the soil and land unless effective measures are introduced for a sustainable system.
f	**Flooding**. Flooding can be expected to inundate the land after a heavy storm. The construction of drains may be required to control surplus surface water.
l	**Soil texture**. Coarse sandy loams to loams.
p	**Peat**. Peat soils.
t	**Topography**. Slope limitations. Average land slopes within the area have the following characteristics:- S2 Slopes < 20%, vertical interval < 15 m. S3 Slopes > 20%, Vertical interval > 15 m.
v	**Soil texture**. Coarse sand to sandy loams.
y	**Fertility**. Low fertility reported, supported by observations on the land use, vegetation and crop conditions.

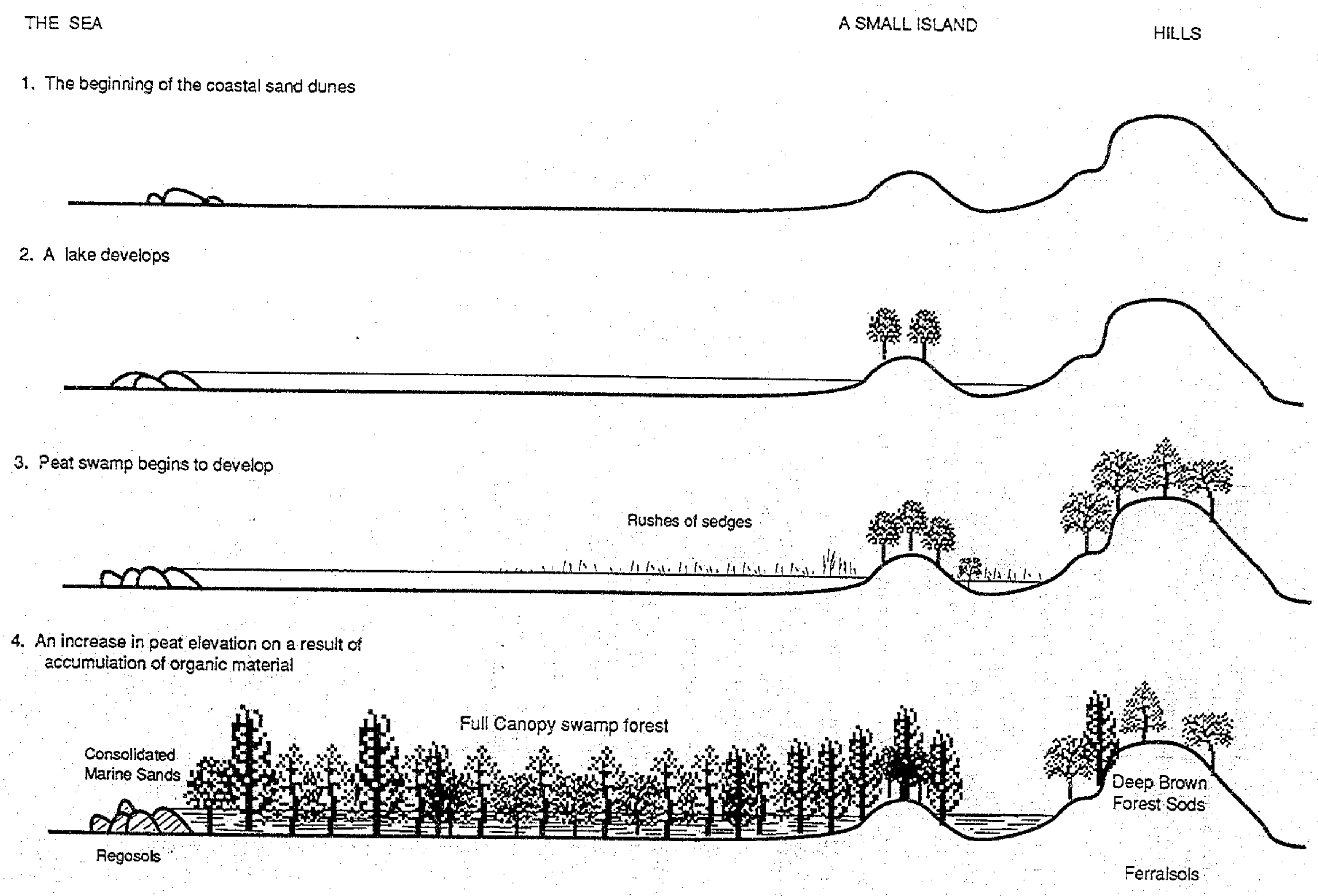
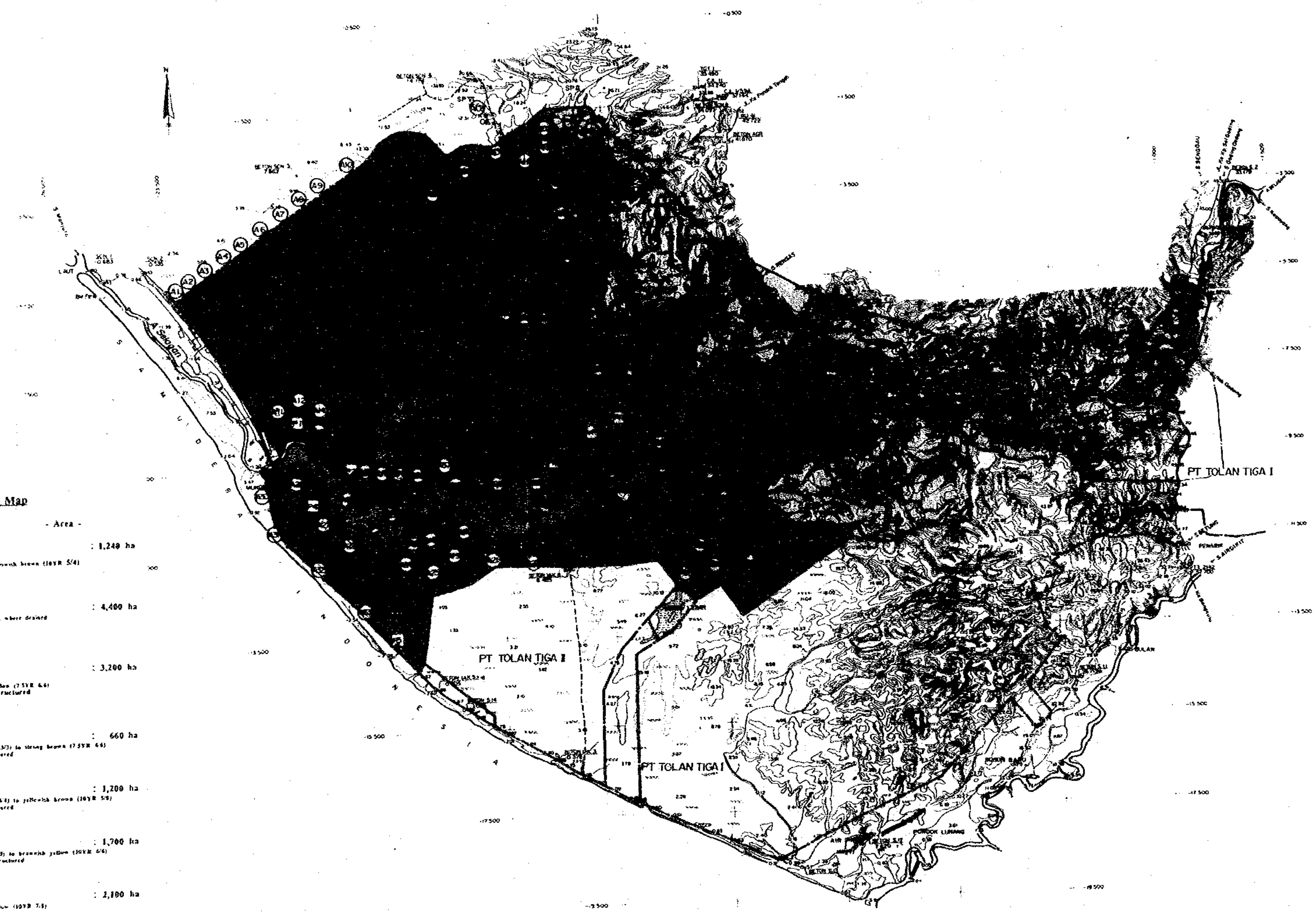


Fig. III-1 Development of the Peat Swamp



Legend for Soil Map

- Area -

Rd : Reqosols, dystric : 1,240 ha
Sand to sandy clay loam
Dark reddish brown (5YR 2.5/2) to yellowish brown (10YR 5/4)
Weakly structured
Low fertility
Drainage frequently impeded

Od : Histosols, dystric : 4,400 ha
Very immature, fibric to hemic or sapric where drained
Dusky red (10R 2.5/2)
Low fertility
Medium very liquid
Low bearing capacity

Fo : Ferralsol, orthic : 3,200 ha
Deep forest soils
Dark brown (7.5YR 3/2) to reddish yellow (7.5YR 6/6)
Silty to silty clay loams, weakly structured
Well drained, weakly acid
Deeply incised
Severe erosion hazard

Fp : Ferralsol, plinthic : 660 ha
Forest soils, dark reddish brown (5YR 3/3) to strong brown (7.5YR 4/6)
Silty to silty clay loams, weakly structured
Well drained, weakly acid
Moderate erosion hazard

Fr : Ferralsol, rhodic : 1,200 ha
Deep forest soil, reddish brown (5YR 4/4) to yellowish brown (10YR 5/8)
Silty to silty clay loams, weakly structured
Well drained, weakly acid
Moderate erosion hazard

Fx : Ferralsol, xanthic : 1,700 ha
Deep forest soil, dark brown (10YR 3/3) to brownish yellow (10YR 6/6)
Silty clay to clay loams, moderately structured
Poorly to well drained
Erosion hazard

Jd : Fluvisol, dystric : 2,100 ha
Dark grayish brown (10YR 3/2) to yellow (10YR 7/6)
Stratified
Clay to silty clay loam
Swampy in places
Moderate to strongly structured
Drainage poor, flooding common

-Others-

: Roads.
: Existing canal.
: Soil pit.
: Auger hole.
: Survey boundary
: Project boundary

SCALE 0 1 2 3 4 5 km

Fig.III-2 SOIL MAP

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SOIL MAP

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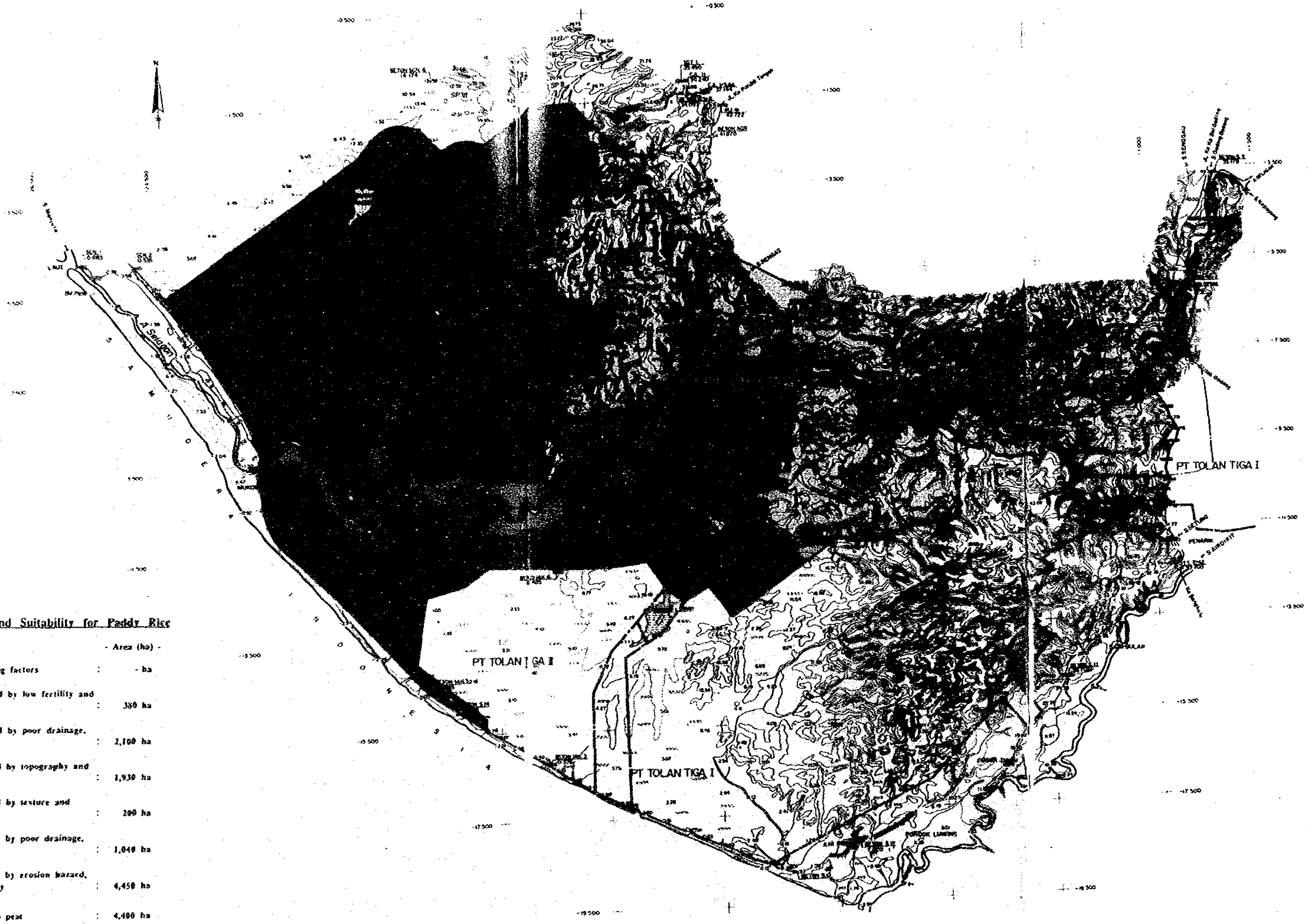

Legend for Land Suitability for Paddy Rice

- Class -		- Area (ha) -
S1	: Highly suitable, no limiting factors	: - ha
S2y	: Moderately suitable, limited by low fertility and occasional flooding	: 380 ha
S2fy	: Moderately suitable, limited by poor drainage, flooding and low fertility	: 2,100 ha
2ty	: Moderately suitable, limited by topography and low fertility	: 1,930 ha
2ly	: Moderately suitable, limited by texture and low fertility	: 200 ha
Svyd	: Marginally suitable, limited by poor drainage, texture and low fertility	: 1,040 ha
3tye	: Marginally suitable, limited by erosion hazard, topography and low fertility	: 4,450 ha
N1p	: Currently not suitable, deep peat	: 4,400 ha
N2	: Permanently unsuitable	: - ha

- Subscripts -
- d : drainage
- e : erosion hazard
- f : flooding/drainage
- l : texture, sandy loams
- p : peat
- t : topography
  - : S2 slopes : < 20%, vertical interval < 15m
  - : S3 slopes : > 20%, vertical interval > 15m
- v : texture, coarse sand
- y : low fertility

- Others -
- - - - - : Survey boundary
———— : Project boundary

Fig.III-3 PRESENT LAND USE MAP

SCALE 0 1 2 3 4 5 km

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LAND SUITABILITY MAP FOR PADDY RICE

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Legend for Present Land Use
(November 1989)

		Area (ha)
H	Hevea brasiliensis (Rubber)	2,300 ha
F	Natural forest	8,620 ha
G	Uplandfield, mixed cropping	1,200 ha
Ru	Upland rice, padi gogo	950 ha
Rp	Lowland rice, padi sawah	140 ha
C	Cleared and half burnt forest	250 ha
S	Scrubland and secondary growth	1,040 ha

SCALE 0 1 2 3 4 5 km

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PRESENT LAND USE MAP

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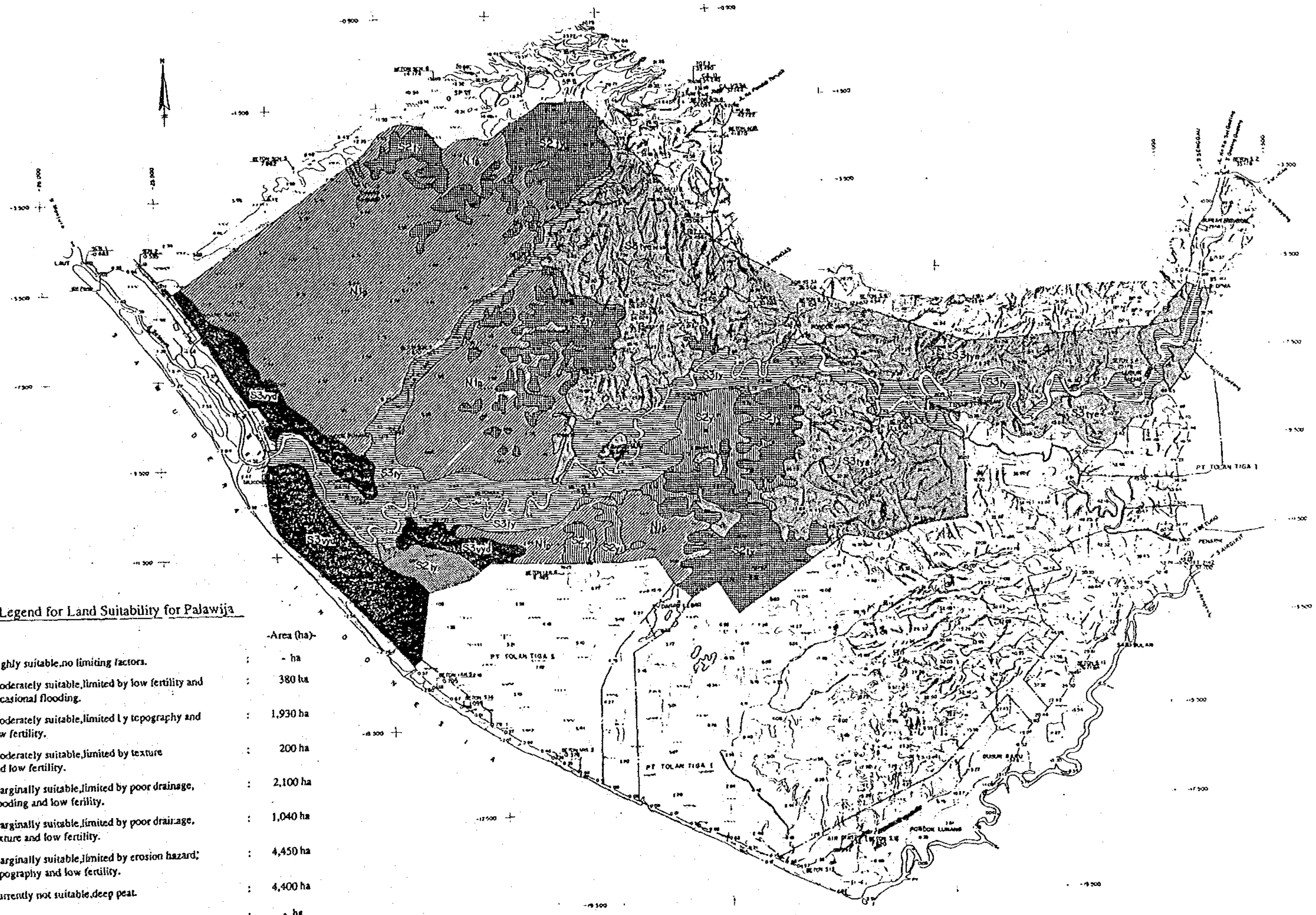
Fig.III-4 LAND SUITABILITY MAP FOR PADDY CROP

Fig.III-5 LAND SUITABILITY MAP
(PALAWIJA)



Legend for Land Suitability for Palawija

-Class-			-Area (ha)-
S1	:	Highly suitable,no limiting factors.	: - ha
S2y	:	Moderately suitable,limited by low fertility and occasional flooding.	: 380 ha
S2ty	:	Moderately suitable,limited by topography and low fertility.	: 1,930 ha
S2ly	:	Moderately suitable,limited by texture and low fertility.	: 200 ha
S3fy	:	Marginally suitable,limited by poor drainage, flooding and low fertility.	: 2,100 ha
S3vyd	:	Marginally suitable,limited by poor drainage, texture and low fertility.	: 1,040 ha
S3tye	:	Marginally suitable,limited by erosion hazard, topography and low fertility.	: 4,450 ha
N1p	:	Currently not suitable,deep peat.	: 4,400 ha
N2	:	Permanently unsuitable.	: - ha

-Subscripts-
- d : drainage.
- e : erosion hazard.
- f : flooding/drainage.
- l : texture,sandy loams.
- p : peat.
- t : topography.
  - : s2 slopes : < 20%,vertical interval < 15m.
  - : s3 slopes : > 20%,vertical interval > 15m.
- v : texture,course sand.
- y : low fertility.

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LAND SUITABILITY MAP
FOR PALAWIJA

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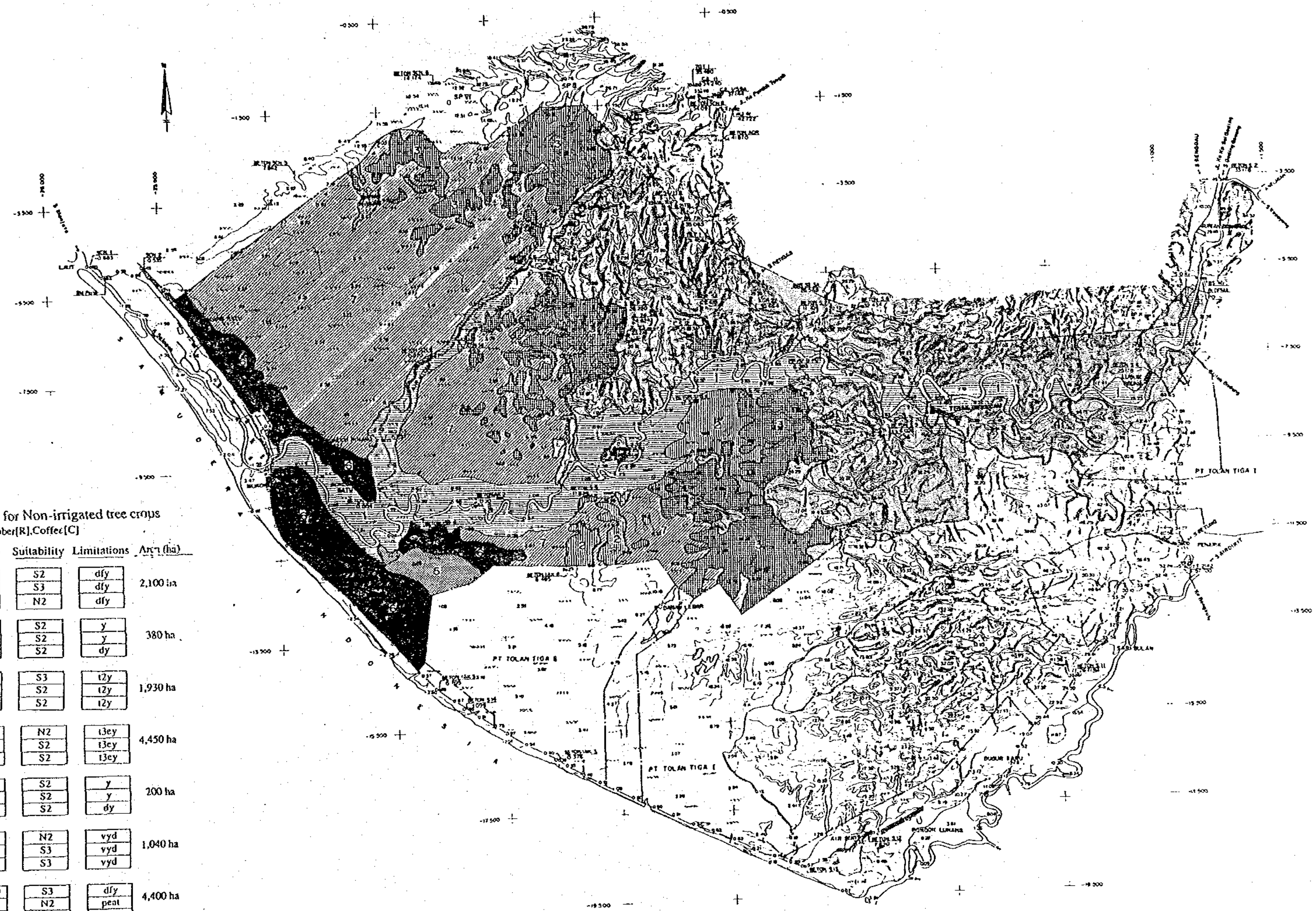
Fig.III-6 LAND SUITABILITY MAP
(TREE CROPS)



Legend for Land Suitability for Non-irrigated tree crops
Oil Palm[O],Rubber[R],Coffee[C]

Land Group	Crop	Suitability	Limitations	Area (ha)
1	O	S2	dfy	2,100 ha
	R	S3	dfy	
	C	N2	dfy	
2	O	S2	y	380 ha
	R	S2	y	
	C	S2	dy	
3	O	S3	t2y	1,930 ha
	R	S2	t2y	
	C	S2	t2y	
4	O	N2	t3ey	4,450 ha
	R	S2	t3ey	
	C	S2	t3ey	
5	O	S2	y	200 ha
	R	S2	y	
	C	S2	dy	
6	O	N2	vyd	1,040 ha
	R	S3	vyd	
	C	S3	vyd	
7	O	S3	dfy	4,400 ha
	R	N2	peat	
	C	N2	peat	

-Limitations-

- d : drainage.
- e : erosion hazard.
- f : flooding.
- l : coase sandy loam.
- p : peat.
- t2 : topography. slopes < 20%. vertical interval <15m.
- t3 : topography. slopes > 20% vertical interval >15m.
- v : coase sand to sandy loams.
- y : soil fertility.

SCALE
0 1 2 3 4 5 km

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AIR SELAGAN IRRIGATION PROJECT
FEASIBILITY STUDY

LAND SUITABILITY MAP FOR
NON-IRRIGATED TREE CROPS

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