Table II-3 Chemical Properties of Pit Samples (1/2)

Lab No.	Profile No.	Depth (cm)	pH H_2O	pH KCl	EC (μs/cm)	OM (%)	N (%)	C/N	Available P (mg/100g)	P_2O_5 Total (%)	K_2O Total (%)	Sand (%)	Silt (%)	Clay (%)	Texture
423	1-1	0-20	6.4	5.2	58.20	1.07	0.11	6	2.00	0.032	0.12	65.12	24.28	10.60	Sandy Loam
424	1-2	20-45	6.5	5.4	29.10	0.28	0.03	5	2.52	0.023	0.09	69.12	21.28	9.60	Sandy Loam
425	2-1	10-20	5.8	4.5	34.92	0.59	0.06	6	0.60	0.012	0.10	59.12	30.28	10.60	Sandy Loam
426	2-2	30-50	6.5	4.6	31.04	0.28	0.04	4	0.64	0.012	0.18	57.12	31.28	11.60	Sandy Loam
427	4-1	0-20	5.5	3.7	28.13	1.03	0.06	10	1.40	0.044	0.22	51.12	29.28	19.60	Loam
428	4-2	30-50	5.0	3.5	32.98	0.66	0.06	6	2.68	0.060	0.30	46.12	28.28	25.60	Loam
429	6-1	10-20	4.5	3.6	37.83	1.21	0.08	9	0.36	0.039	0.36	37.12	26.28	36.60	Clay Loam
430	6-2	30-40	4.6	3.5	26.19	0.55	0.07	5	0.64	0.062	0.50	55.12	24.28	20.60	Sandy Clay Loam
431	7-1	10-20	5.8	4.4	50.44	0.69	0.08	5	0.56	0.023	0.47	37.12	35.28	27.60	Clay Loam
432	7-2	30-40	5.8	3.8	58.20	0.69	0.07	6	0.40	0.025	0.66	23.12	23.28	53.60	Clay
433	8-1	0-20	5.4	3.9	15.52	0.38	0.06	4	0.40	0.009	0.10	62.68	27.72	9.60	Sandy Loam
434	9-1	0-20	5.6	4.0	58.20	1.17	0.06	11	0.48	0.023	1.18	22.68	44.72	32.60	Clay Loam
435	9-2	30-50	6.4	4.6	62.08	1.72	0.08	12	0.40	0.032	0.86	21.40	29.56	49.04	Clay
436	10-1	0-20	5.9	4.4	25.22	2.03	0.08	15	0.60	0.041	0.32	27.40	21.56	51.04	Clay
437	11-1	0-10	5.6	4.1	41.71	1.93	0.21	10	0.56	0.039	0.52	49.40	38.56	12.04	Loam
438	12-1	0-20	5.5	4.0	16.49	1.17	0.06	11	0.40	0.012	0.24	50.40	38.56	11.04	Loam
439	13-1	0-20	5.4	4.0	27.16	1.03	0.10	6	0.40	0.032	0.92	25.40	46.56	28.04	Clay Loam
440	18-1	0-20	5.4	4.0	17.46	1.76	0.11	9	0.36	0.030	0.62	45.40	43.56	11.04	Loam
441	20-1	0-20	5.0	3.8	38.80	2.34	0.14	10	0.36	0.037	0.60	42.40	38.56	19.04	Loam
442	20-2	30-50	5.0	3.7	14.55	1.21	0.11	6	0.40	0.053	1.12	38.40	20.56	41.04	Clay

Remark: Physical descriptive criteria are based on FAO system.

Table II-3 Chemical Properties of Pit Samples (2/2)

Lab No.	Profile No.	Depth (cm)	Exchangeable cations (meq) in 100 g soil						% of Element in Sorption Complex						Soil Group
			Hh	Ca	Mg	Na	K	CEC	Hh	Ca	Mg	Na	K	BSP	
423	1-1	0-20	1.50	4.05	1.20	0.15	0.05	6.95	21.58	58.27	17.27	2.16	0.72	78.42	Acrisols $\frac{b}{3}$
424	1-2	20-45	1.35	2.25	0.70	0.13	0.06	4.49	30.07	50.11	15.59	2.90	1.34	63.93	
425	2-1	10-20	1.65	2.55	0.45	1.14	0.06	4.85	34.02	52.58	9.28	2.89	1.24	65.98	Acrisols $\frac{b}{1}$
426	2-2	30-50	1.20	2.10	1.00	0.14	0.06	4.50	26.67	46.67	22.22	3.11	1.33	73.33	
427	4-1	0-20	5.80	1.35	0.90	0.18	0.54	8.77	66.13	15.39	10.26	2.05	6.16	33.87	Acrisols $\frac{c}{4}$
428	4-2	30-50	6.75	2.05	1.65	0.18	0.26	10.89	61.98	18.82	15.15	1.65	2.39	38.02	
429	6-1	10-20	10.50	0.90	0.35	0.15	0.16	12.06	87.06	7.46	2.9	1.24	1.33	12.94	Acrisols $\frac{c}{2}$
430	6-2	30-40	11.22	0.70	0.60	0.16	0.16	12.84	87.38	5.45	4.67	1.25	1.25	12.62	
431	7-1	10-17	2.55	2.45	1.15	0.34	0.08	6.57	38.81	37.29	17.50	5.18	1.22	61.19	Acrisols $\frac{c}{1}$
432	7-2	30-40	5.05	3.95	1.75	0.64	0.07	11.46	44.07	34.47	15.27	5.58	0.61	55.93	
433	8-1	0-20	1.65	0.50	0.20	0.15	0.03	2.53	65.22	19.76	7.91	5.93	1.19	34.78	Acrisols $\frac{c}{1}$
434	9-1	0-20	3.30	3.30	1.35	0.30	0.10	8.35	39.52	39.52	16.17	3.59	1.20	60.48	Fluvisols $\frac{d}{1}$
435	9-2	30-50	2.06	4.90	1.65	0.37	0.07	9.05	22.76	54.14	18.23	4.09	0.77	77.24	
436	10-1	0-20	3.75	3.15	1.05	0.17	0.10	8.22	45.62	38.32	12.77	2.07	1.22	54.38	Acrisols $\frac{b}{3}$
437	11-1	0-10	4.80	1.25	1.00	0.14	0.24	7.43	64.60	16.82	13.46	1.88	3.23	35.40	Acrisols $\frac{c}{2}$
438	12-1	0-20	1.80	0.60	0.30	0.13	0.04	2.87	62.72	20.91	10.45	4.53	1.39	37.28	Acrisols $\frac{c}{1}$
439	13-1	0-20	4.05	2.10	0.80	0.17	0.05	7.17	56.49	29.29	11.16	2.37	0.70	43.51	Acrisols $\frac{c}{5}$
440	18-1	0-20	6.00	0.90	0.60	0.14	0.02	7.66	78.33	11.75	7.83	1.83	0.26	21.67	Acrisols $\frac{b}{3}$
441	20-1	0-20	7.80	0.50	0.45	0.13	0.35	9.23	84.51	5.42	4.88	1.41	3.79	15.49	Acrisols $\frac{b}{4}$
442	20-2	30-50	9.16	0.25	0.20	0.14	0.32	10.07	90.96	2.48	1.99	1.39	3.18	9.04	

Remark: Physical descriptive criteria are based on FAO system.

Table II-4 Soil Depth, Texture, pH, and Electric Conductivity of Auger Test Samples (1/2)

No.	Soil Depth (cm)	Soil Texture	pH (H_2O)	EC (μs/cm)	Present Land Use
1	10-15	L	5.6	20	Paddy
2	5-10	L	5.6	16	Paddy
3	5	SL	5.8	21	Paddy
4	20	SL	5.8	18	Paddy
5	20	SL	5.7	26	Paddy
6	30	L	6.0	26	Paddy
7	40	L	6.0	26	Paddy
8	50	L	6.0	36	Forest
9	15	SL	5.6	22	Paddy
10	10	L	5.6	26	Paddy
11	25	SL	5.6	22	Forest
12	> 70	L	5.8	16	Paddy
13	> 60	L	5.8	28	Paddy
14	15	FS	5.6	15	Paddy
15	5-10	L	6.0	22	Forest
16	10	SL	5.6	38	Forest
17	10	SL	5.6	20	Paddy
18	30	SL	5.6	24	Paddy
19	10	FS	5.7	34	Forest
20	10	L	5.7	23	Forest
21	50	L	5.6	21	Paddy
22	25	L	6.0	15	Paddy
23	35	SL	5.6	14	Paddy
24	30	L	5.8	16	Forest
25	35	L	5.6	20	Paddy
26	60	SCL	5.7	18	Paddy
27	> 80	L	6.0	26	Paddy
28	> 60	L	5.8	31	Paddy
29	-	-	-	-	
30	60	FS	5.6	20	Paddy
31	70	FS	5.4	12	Paddy
32	20	FS	6.1	30	Forest
33	45	SiL	5.1	22	Forest
34	25	L	5.0	26	Forest
35	80	FS	5.3	19	Paddy
36	40	L	5.5	18	Paddy
37	90	L	5.5	22	Paddy

Remarks: 1. Abbreviations represent classes of soil texture as shown below;
L=Loam, SL=Sandy loam, FS=Fine sand, SCL=Sandy clay loam, SiL=Silty loam, SiCL=Silty clay loam, LS=Loamy sand, CL=Clay loam, SiC=Silty clay,
2. Soil texture is determined by fingers feeling test.
3. Samples for texture were taken from upper layer.

Table II-4 Soil Depth, Texture, pH, and Electric Conductivity of Auger Test Samples (2/2)

No.	Soil Depth (cm)	Soil Texture	pH (H_2O)	EC (μs/cm)	Present Land Use
38	70	SiL	5.3	23	Dense Forest
39	55	SiCL	6.2	31	Paddy
40	60	SL	5.1	24	Paddy
41	65	FS	5.4	43	Paddy
42	40	FS	5.4	36	Paddy
43	65	FS	5.4	19	Paddy
44	90	FS	5.4	19	Paddy
45	90	FS	5.6	17	Paddy
46	90	FS	7.2	530	Paddy
47	80	SiL	5.8	46	Paddy
48	90	SiL	5.1	30	Paddy
49	90	LS	5.2	18	Paddy
50	90	FS	5.2	20	Paddy
51	90	L	5.2	26	Paddy
52	90	LS	5.2	16	Paddy
53	90	SiL	5.6	63	Paddy
54	90	SiCL	5.8	36	Paddy
55	90	CL	5.5	56	Paddy
56	70	SiL	5.7	33	Paddy
57	25	L	5.9	21	Paddy
58	85	SiL	5.4	23	Paddy
59	25	LS	5.0	21	Paddy
60	90	SiC	5.6	27	Paddy
61	60	L	5.3	20	Forest
62	25	SiL	6.4	31	Forest
63	25	SL	5.0	18	Forest
64	90	LS	5.0	16	Bush
65	20	LS	6.6	52	Forest
66	20	LS	5.9	43	Paddy
67	10	L	6.0	26	Forest
68	15	SL	5.9	23	Forest
69	85	LS	5.4	18	Paddy
70	-	FS	6.9	2,200	Bare land
71	-	S	6.7	>	Bare land
72	-	LS	7.0	420	Paddy
73	-	SL	7.1	230	Paddy
74	-	SiL	7.2	40	Fallow land

Remarks: 1. Abbreviations represent classes of soil texture as shown below;
L=Loam, SL=Sandy loam, FS=Fine sand, SCL=Sandy clay loam, SiL=Silty loam, SiCL=Silty clay loam, LS=Loamy sand, CL=Clay loam, SiC=Silty clay,
2. Soil texture is determined by fingers feeling test.
3. Samples for texture were taken from upper layer.

Table II-5 Extent of Each Soil Unit

(Unit: ha)

Soil Unit Texture		Originally-planned Area	Extension Area	Total
Acrisols	Sandy loam (b)	436	522	958
	Silty loam (c)	1,991	1,131	3,122
	Silty clay (d)	387	157	544
	Sub-total	(2,814)	(1,810)	(4,624)
Fluvisols	Silty clay (d)	68	-	68
Gleysols	Silty clay (d)	58	-	58
Total		2,940	1,810	4,750

Table II-6 Results of Land Classification

Name of Mapping Unit No.	Symbol of Factor for Assessment of Land Capability	t		d		g		p		l		r		(w) /3 w/4		f		n		i		a		s		e		Synthetical Assessment		Area Extent (ha) Originally planned area	Extension area	Total
		P/1	U/2	P	U	P	U	P	U	P	U	P	U	P	U	P	U	P	U	P	U	P	U	P	U	P	U	P	U			
1.	Acrisols sandy loam 1	I	I	I	I	I	I	I	I	II	-	II	-	-	(IV) II	II	II	II	II	I	I	I	I	-	I	-	I	II lrfn	IV (w)	110	48	158
2.	Acrisols sandy loam 2	I	I	I	II	I	I	I	I	II	-	II	-	-	(IV) II	II	II	II	II	I	II	I	I	-	I	-	I	II lrfn	IV (w)	-	3	3
3.	Acrisols sandy loam 3	I	I	I	II	I	II	I	I	II	-	II	-	-	(IV) II	II	II	II	II	I	II	I	I	-	I	-	I	II lrfn	IV (w)	112	71	183
4.	Acrisols sandy loam 4	I	II	II	III	II	III	I	I	II	-	II	-	-	(IV) II	II	II	II	II	II	III	I	I	-	I	-	II	II dglrfi	IV (w)	95	227	322
5.	Acrisols sandy loam 5	II	III	IV	IV	IV	IV	I	I	II	-	II	-	-	(IV) II	II	II	II	II	IV	IV	I	I	-	I	-	III	IV dgi	IV dg (w)	119	173	292
6.	Acrisols silty loam 1	I	I	I	I	I	I	II	II	II	-	II	-	-	(IV) III	II	II	II	II	I	I	II	II	-	I	-	II	II plrfna	IV (w)	1,014	251	1,265
7.	Acrisols silty loam 2	I	I	I	II	I	I	II	II	II	-	II	-	-	(IV) III	II	II	II	II	I	II	II	II	-	I	-	II	II plrfna	IV (w)	532	102	634
8.	Acrisols silty loam 3	I	I	I	II	I	II	II	II	II	-	II	-	-	(IV) III	II	II	II	II	I	II	II	II	-	I	-	II	II plrfna	IV (w)	48	409	457
9.	Acrisols silty loam 4	I	II	II	III	II	III	II	II	II	-	II	-	-	(IV) III	II	II	II	II	II	III	II	II	-	I	-	III	II dgplrfnia	IV (w)	349	254	603
10.	Acrisols silty loam 5	I	III	IV	IV	IV	IV	II	II	II	-	II	-	-	(IV) III	II	II	II	II	IV	IV	II	II	-	I	-	IV	IV dgi	IV dg (w) ie	48	115	163
11.	Acrisols silty clay 1	I	I	I	I	I	I	III	III	I	-	III	-	-	(IV) IV	II	II	II	II	I	I	III	I	-	I	-	II	III pra	IV (w) w	349	157	506
12.	Acrisols silty clay 3	I	I	I	II	I	II	III	III	I	-	III	-	-	(IV) IV	II	II	II	II	I	II	III	I	-	I	-	III	III pra	IV (w) w	38	-	38
13.	Fluvisols silty clay	I	I	I	I	I	I	III	III	I	-	III	-	-	(IV) IV	II	II	II	II	I	I	IV	IV	-	I	-	II	IV a	IV (w) wa	68	-	68
14.	Gleysols silty clay	I	I	I	I	I	I	III	III	I	-	III	-	-	(IV) IV	II	II	II	II	I	I	III	III	-	I	-	II	III pra	IV (w) w	58	-	58
	Total																													2,940	1,810	4,750

Remark: /1: Paddy field, /2: Upland crop field, /3: Dry season, /4: Rainy season

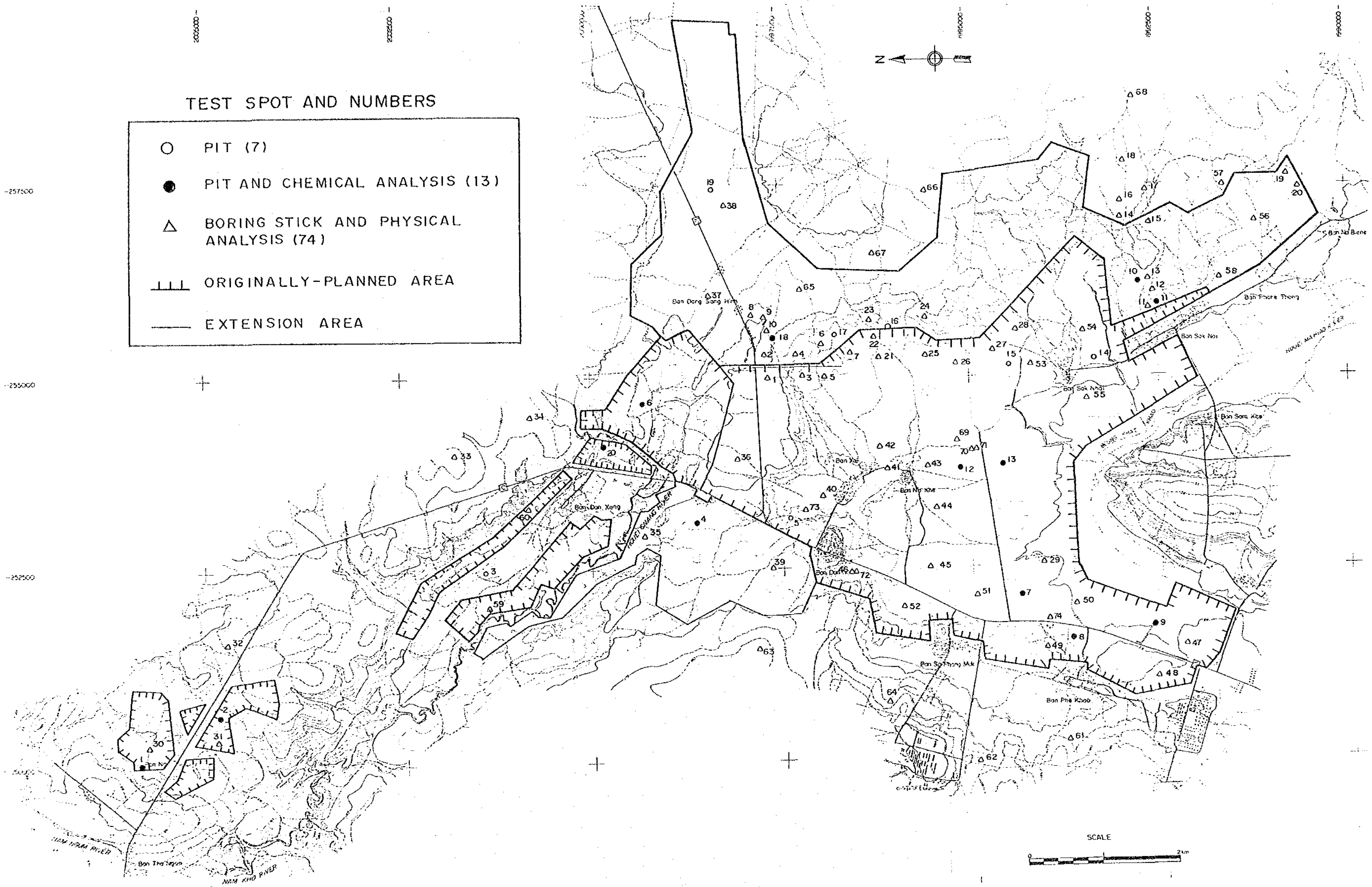

Fig. II-1 SITES OF SOIL SURVEY

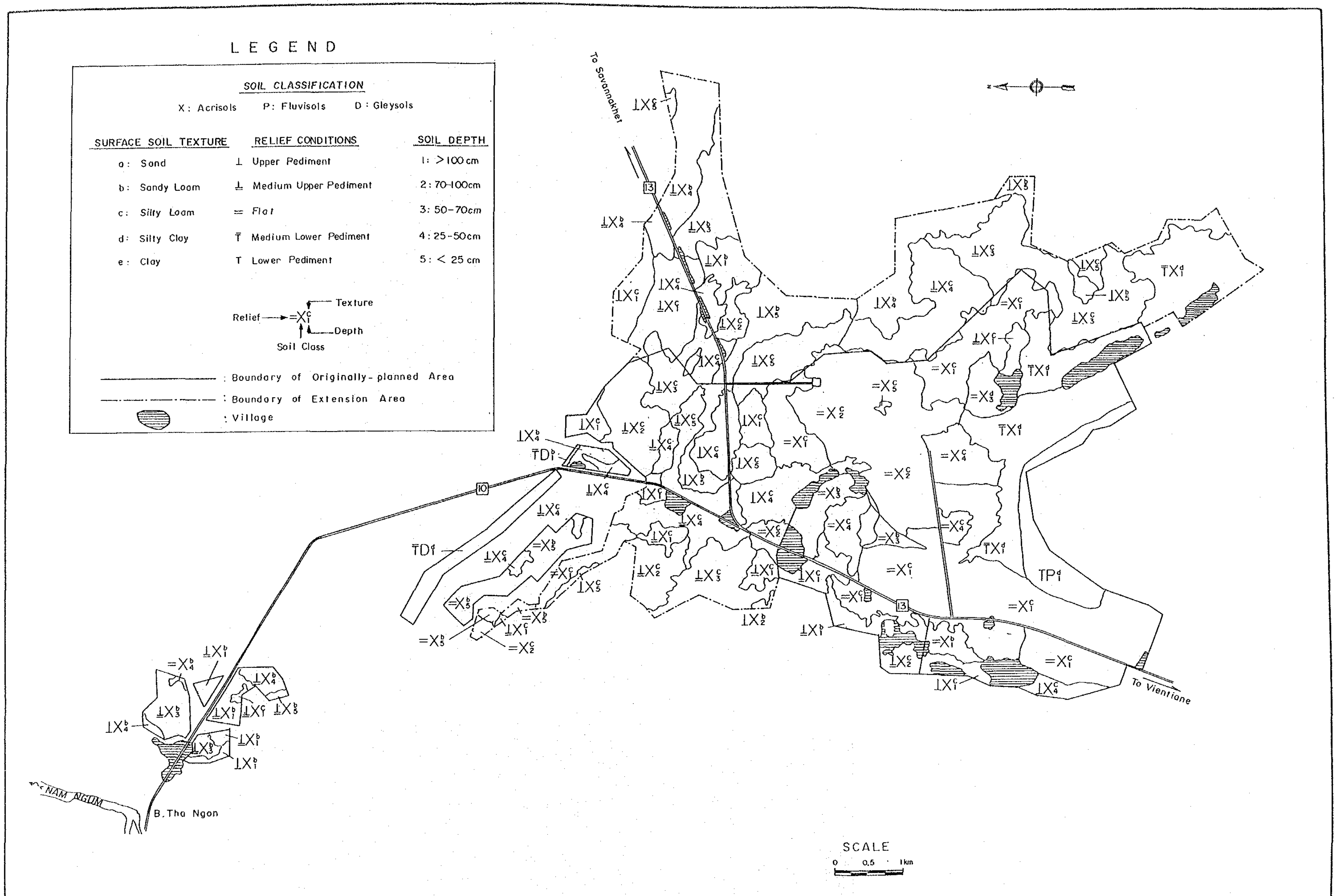

Fig. II-2 SOIL MAP

LEGEND

Mapping Symbol	Land Capability Class		Area Extent (ha)		
	Paddy	Upland	Originally-planned area	Extension area	Total
1	II lrfn	IV(w)	110	48	158
2	II lrfn	IV(w)		3	3
3	II lrfn	IV(w)	112	71	183
4	II dglrfni	IV(w)	95	227	322
5	IVdgi	IVdg(w)	119	173	292
6	II plrfna	IV(w)	1,014	251	1,265
8	II plrfna	IV(w)	532	102	634
9	II plrfna	IV(w)	48	409	457
10	II dgplrfnia	IV(w)	349	254	603
11	IVdgi	IVdg(w)ie	48	115	163
12	III pra	IV(w)w	349	157	506
13	III pra	IV(w)w	38		38
14	IVa	IV(w)wa	68		68
15	III pra	IV(w)w	58		58
Total			2,940	1,810	4,750

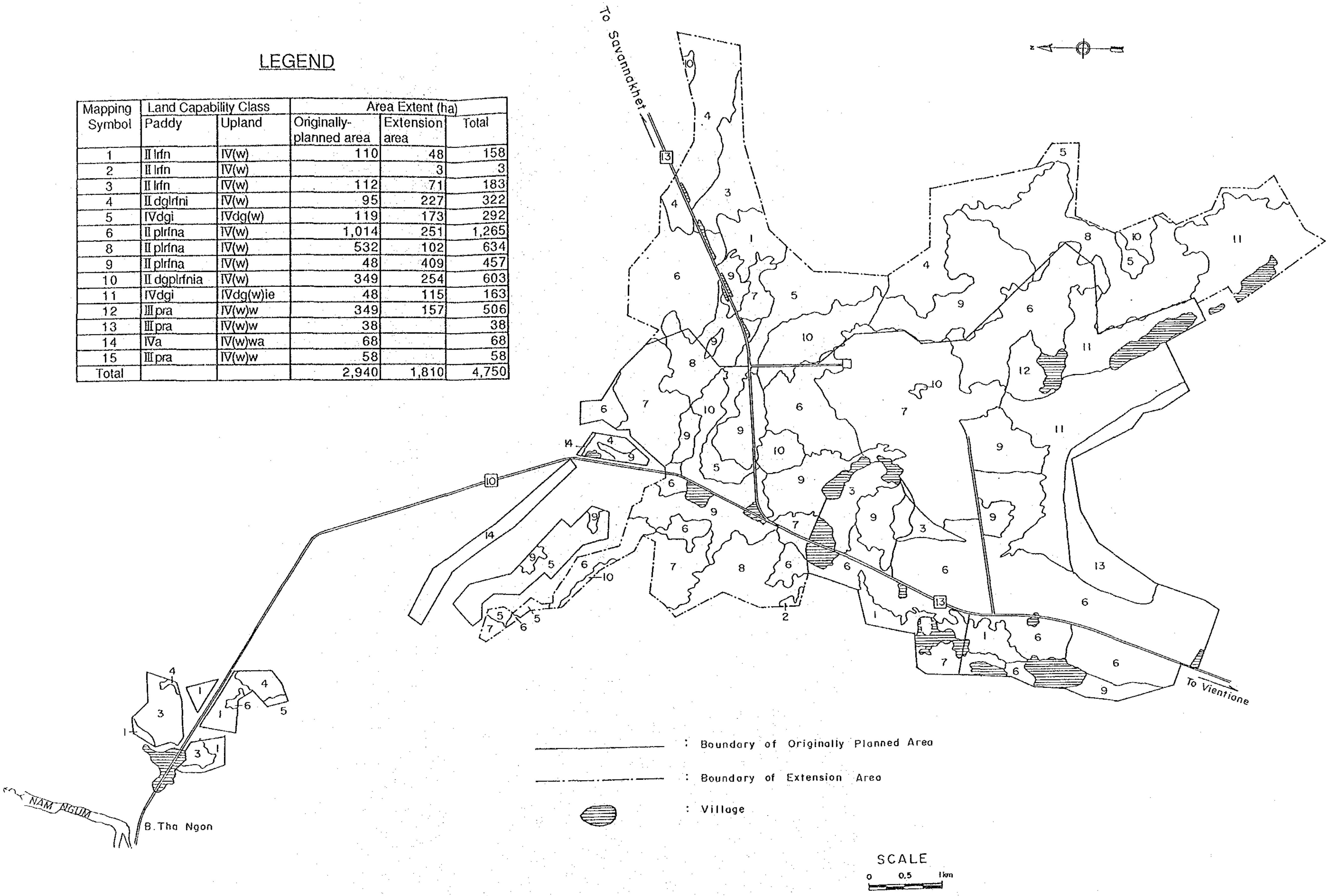

Fig. II-3 LAND CLASSIFICATION MAP

ANNEX III

GEOLOGY, HYDRO-GEOLOGY AND SOIL MECHANICS

ANNEX III

GEOLOGY, HYDRO-GEOLOGY AND SOIL MECHANICS

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List of Figures

1. Geology

1.1 General

The Project area is geologically divided into two areas: the northern and southern areas by east-west line of the national road route 13. Topographic features of the southern area were formed mainly by erosive action of the Bueng Khat Khao swamp, while those of the northern area was formed mainly by erosive action of the Houei Gnang river. Consequently in the northern area, hilly, talus and low-lying areas were created, while in the southern area, hilly, terrace and low-lying areas were created. In particular, the southern area has valley-like topography. Its central area is low-lying area and terraces exist, surrounding the low-lying area in all directions.

1.2 Geology

In the middle of the Jurassic period of the Mesozoic era, Indochina peninsular, South China Sea and Gulf of Thailand were a continent. In the latter part of the Jurassic period, several inland seas were created in the continent. Much mud, sand and gravel were deposited in those inland seas. After this period of sedimentation, these inland seas dried up, and red bed and evaporite were formed in Mesozoic Cretaceous period. After this, the continent was transformed into present Indochina peninsular, South China Sea and Gulf of Thailand by Himalayan orogeny, however, the red bed and evaporite remained.

The Project area is located on the old inland sea, and geologically consists of talus deposit, terrace deposit and alluvial deposit, which were formed in the Tertiary to Quaternary periods on the red bed and evaporite of Mesozoic Cretaceous period. The red bed and evaporite consisting of red and reddish brown clay, sandy clay and silt, are geological baserock of the area. A part of them is exposed on hilly area and gentle slope area in the Project area. This baserock is called "Xaysomboune formation" or "K_2^{xb}". "Tha Ngon formation" which is called "K_2^{tn3}" underlies Xaysomboune formation. No outcrop of Tha Ngon formation has been observed in the area.

The talus and terrace deposits are surface layers thinly extending in the area. They are unconsolidated clay, silt, sand and gravel which were transported by surface water or were produced by weathering. The alluvial deposit which is also surface layer and is mostly clay, sand and gravel, extends in very low-lying area of the Bueng Khat Khao, and the Houei Gnang river. The talus, terrace and alluvial deposits together form the "N_2-Q" layer. A geological map is shown in Fig. III-1. Boring data owned by the Department of Mining, Ministry of Industry and Handicrafts are shown in Fig. III-2.

2. Hydro-geology

2.1 General

As mentioned in the preceding section, the Project area geologically consists of talus, terrace and alluvial deposits formed on the red bed and evaporite of Xaysomboune layer. Xaysomboune formation is baserock, and talus, terrace and alluvial deposits are overburden. Xaysomboune layer consisting of clay, sandy clay and silt is rather consolidated. Consequently Xaysomboune layer becomes impervious. Talus, terrace and alluvial deposits formed on it (so-called N_2-Q layer) are aquifer. There are many wells in the Project area and most of wells depend on groundwater in N_2-Q layer. Although the groundwater of some wells is turbid, the turbidity is caused not by groundwater but by surface water.

2.2 Electric Prospecting

The electric prospecting was carried out by the Team in October and November 1988 for three areas of Ban Dan Xang, Ban Dong Sang Hinh, Ban Phone Thong areas in order to sound hydro-geological condition. These locations are shown in Fig.III-3. Prospecting points, depth, and method, and equipment used for the prospecting are as follows:

- Prospecting points		
Ban Dan Xang area	:	20 points
Ban Dong Sang Hinh area	:	19 points
Ban Phone Thong	:	48 points
- Prospecting depth	:	30 to 60 m
- Prospecting method	:	Wenner's method
- Equipment	:	No.3244 (Yokogawa-hokushin Denki)

The prospecting results are given in the form of apparent resistivity curves (ρ-a curves) as shown in the Data Book (separate volume). These curves are analysed by the Sundbeg's standard curve method.

The results of analysis show that all the curves obtained are similar and indicate existence of two different layers, namely the N_2-Q layer and the Xaysomboune layer. The relationship between resistivity and geological layers is summarized as follows:

Layer	Apparent Resistivity (Ω - m)	Contents
N_2-Q layer	12 - 3,300	clay, sand, gravels (unconsolidated)
Xaysomboune layer	0.17-16	clay, sandy clay (weathered)

2.3 Hydro-geology

On the basis of electric prospecting and available boring data, geological profiles of three areas are prepared as shown in Fig. III-4, III-5 and III-6. From those profiles, the following hydro-geological conditions are clarified :

i) Maximum depth to Xaysomboune layer is 8 m in Ban Dan Xang and Ban Dong Sang Hinh area and 28 m in Ban Sok Noi area.

ii) There are six underground valleys which were formed by Xaysomboune layer. In concave area of each valley, N_2-Q layer exists. Groundwater moves in N_2-Q layer and concentrates in such underground valley. There are three valleys in Ban Dan Xang area, one valley in Ban Dong Sang Hinh area and two valleys in Ban Phone Thong area. Locations of underground valleys are shown in Fig. III-7, and III-8 and III-9.

iii) In case that groundwater is required in Ban Dan Xang area and Ban Dong Sang Hinh area, it is proposed to dig shallow wells with a diameter of 1.5 to 2 m and a depth of 8 m at respective underground valleys. In case of Ban Phone Thong area, it is proposed to drill deep tubewells with a diameter of more than 250 mm and a depth of 30 m at two points of N-33 and N-41. Locations of these points are shown in Fig. III-9, and tentatively designed wells are shown in Fig. III-15.

2.4 Pumping-test

In order to countercheck the results of electric prospecting and to execute pumping-test, geological boring with a depth of 30 m and a diameter of 250 mm was made at N-41 point of Ban Phone Thong area. Electric logging was also made at the point. The boring log and logging data are shown in Fig. III-10. This result almost coincides with the results of electric prospecting.

Using the drilled hole, pumping-test was carried out in two methods, i.e step drawdown test and continuous pumping-test.

(1) Step drawdown test

Discharge was changed at five steps and drawdown of groundwater table was observed at each step. Relationship among discharge (Q), drawdown(s) and pumping time(t) is shown in Fig. III-11, and relationship between discharge (Q) and drawdown(s) is shown in Fig. III-12. Discharges at five steps and respective drawdown are as follows:

Step	Discharge (m^3/day)	Drawdown (m)
1	157	5.44
2	134	4.25
3	108	3.35
4	106	2.89
5	80	2.71

(2) Continuous pumping test

Constant discharge of 157 m^3/day was pumped for 300 minutes and drawdown of groundwater was observed as shown in Fig. III-13. The maximum drawdown was 5.48 m. Since the drawdown of step drawdown test for 180 minutes is 5.44 m, a difference of drawdown for the balance of 120 minutes is only 0.04 m. By the analysis of Theis' formula, the following values are obtained:

- Transmissivity (T) = 11.4 m^3/day/m
- Permeability (K) = 7.33×10^{-4} cm/sec

After the pumping-tests, recovery test was carried out and the result shown in Fig.III-14 is obtained.

Generally, as discharge (Q) increases, drawdown of groundwater table(s) suddenly increases at a certain discharge and Q-S curve breaks. This discharge is called maximum yield of well. As shown in Fig.III-12, such discharge is not found. This is because pump capacity is less than the maximum yield. Considering those matters, it is concluded that well at N-41 point can yield at least 157 m^3/day equivalent to 1.8 lit/sec. In addition, since N-33 point is assumed to have the same hydro-geological conditions as that of N-41 point, well at N-33 point also could yield at least 157 m^3/day.

3. Soil Mechanics

In order to study mechanical properties of soils in the Project area, soil mechanical survey was carried out in September and October 1988. Eight test pits were selected and samples were taken. Locations of those sites are shown in Fig. IV-6. The following soil mechanical tests were executed at the material laboratory of State Enterprise for Building Design, Ministry of Communication, Post, Transport and Construction of Lao PDR:

- Specific gravity
- Sieve analysis
- Liquid limit
- Plastic limit
- Natural moisture content
- Unit weight
- Compaction
- Permeability
- Direct shear

Testing methods are in conformity with American Association of State Highway Officials (AASHO). In addition, concrete aggregates, i.e. sand and gravel were tested at the same laboratory. Sieve analysis, and organic impurities, unit weight and specific gravity tests were carried out. All the results are compiled in the Data Book.

From those tests, the following findings are obtained.

i) Most of samples are clay, clayey silt and sandy silt.

ii) Since natural moisture content is mostly higher than optimum moisture content, embankment work in the rainy season will need soil-drying work.

iii) Since soils in low-lying area of the originally-planned area is very cohesive, selection of compaction equipment has to be made carefully.

iv) Two borrow-pit areas, i.e. No. 3 and No. 6 sites shown in Fig. IV-6 are proposed for the construction work of irrigation facilities. Quality of soils in those borrow-pit areas will be satisfactory.

v) Sand and gravel taken from the Mekong river will be suitable for concrete aggregates.

Average values of test data are as follows:

Average Values of Soil Mechanical Test Data

	Items	Soil	Gravel	Sand
1.	Liquid limit	40.2%	-	-
2.	Plastic limit	23.4%	-	-
3.	Plasticity index	16.7%	-	-
4.	Unit weight	1.75 ton/m^2	1.70 ton/m^2	1.62 ton/m^2
5.	Specific gravity	2.72	2.60	2.58
6.	Natural moisture content	23.7%	-	-
7.	Optimum moisture content	14.5%	-	-
8.	Porosity	43%	-	-
9.	Cohesion	7.4 ton/m^2	-	-
10.	Internal friction angle	19.5°	-	-
11.	Fineness modulus	-	6.49	2.78

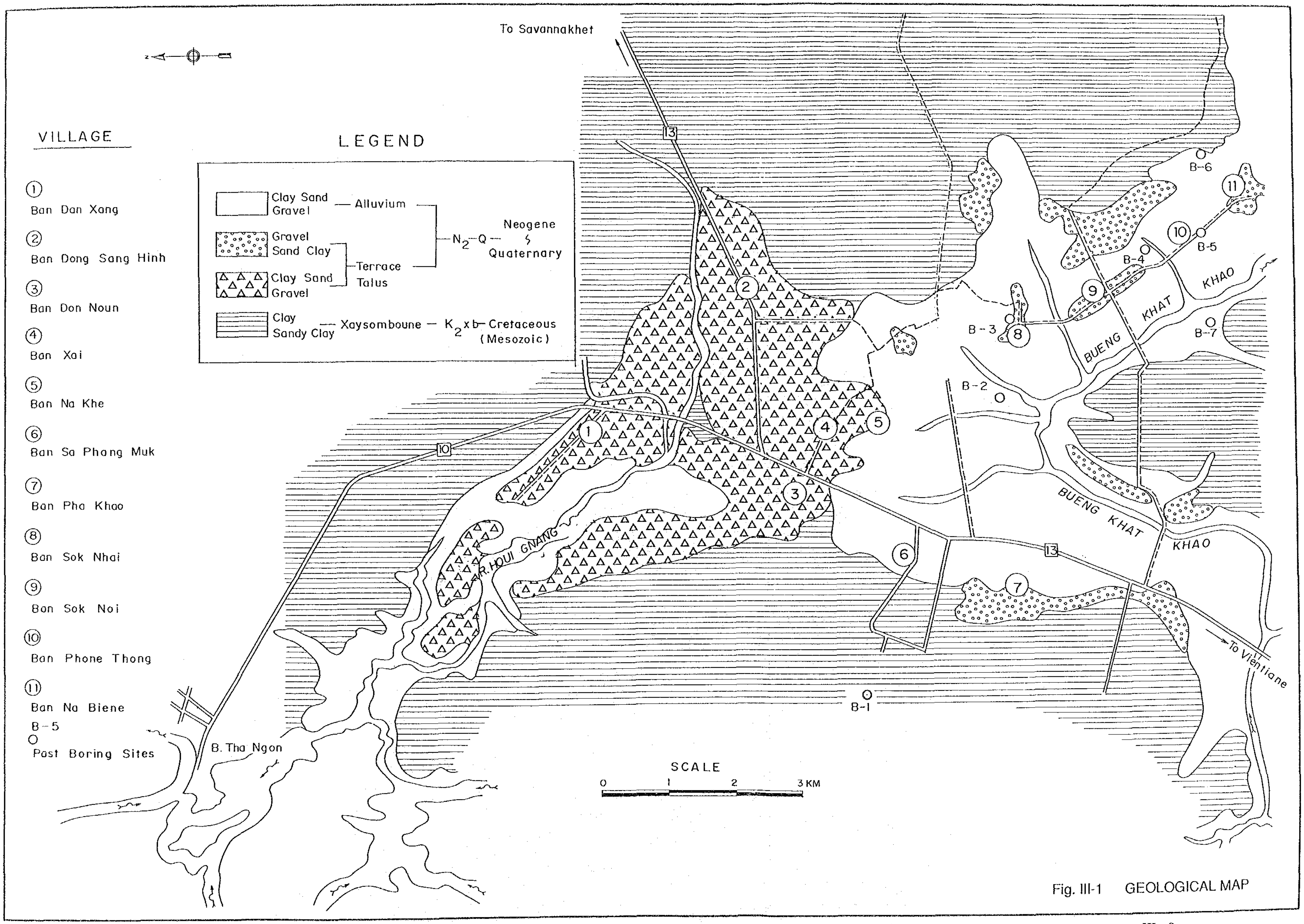


Fig. III-1 GEOLOGICAL MAP

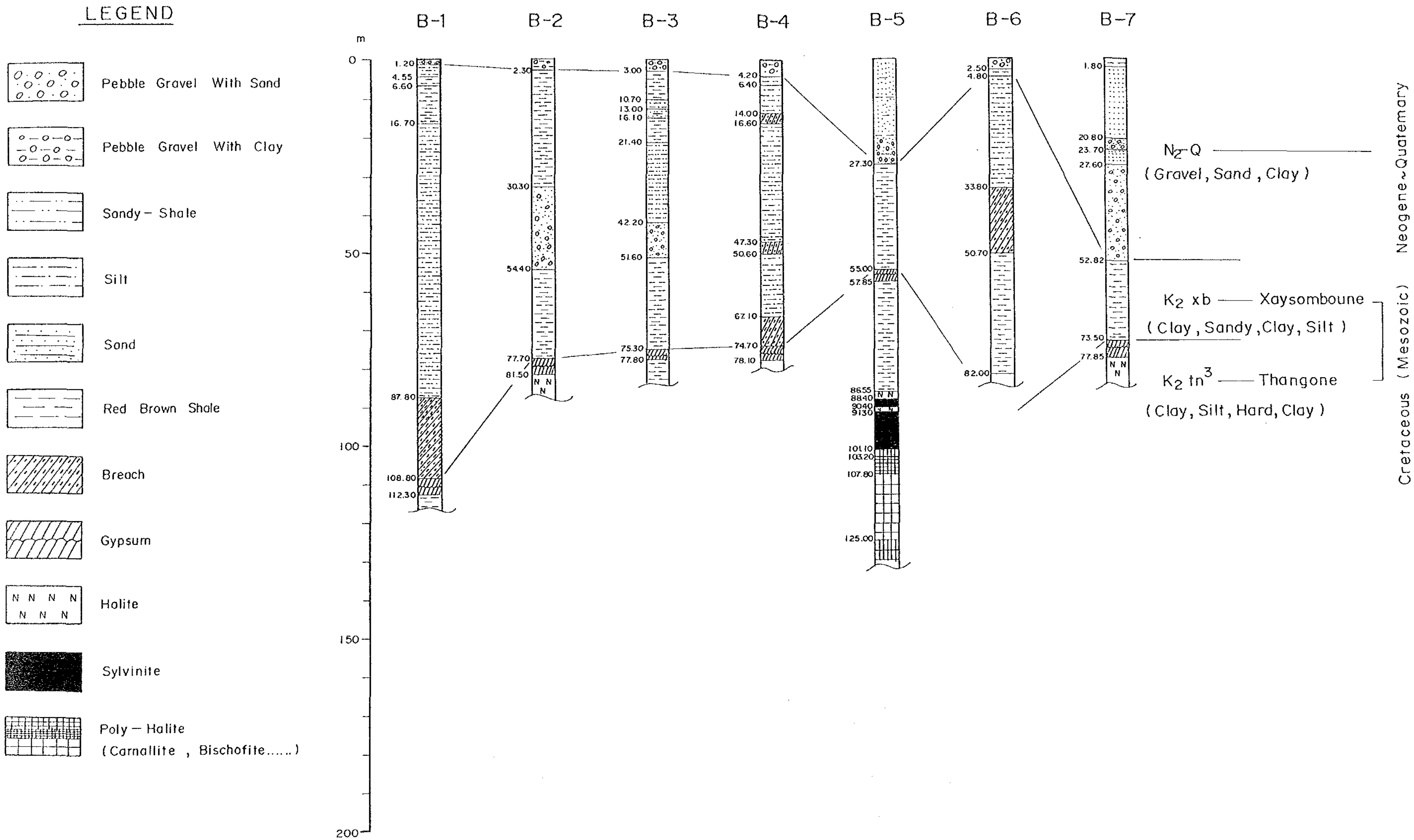


Fig. III-2 BORING DATA

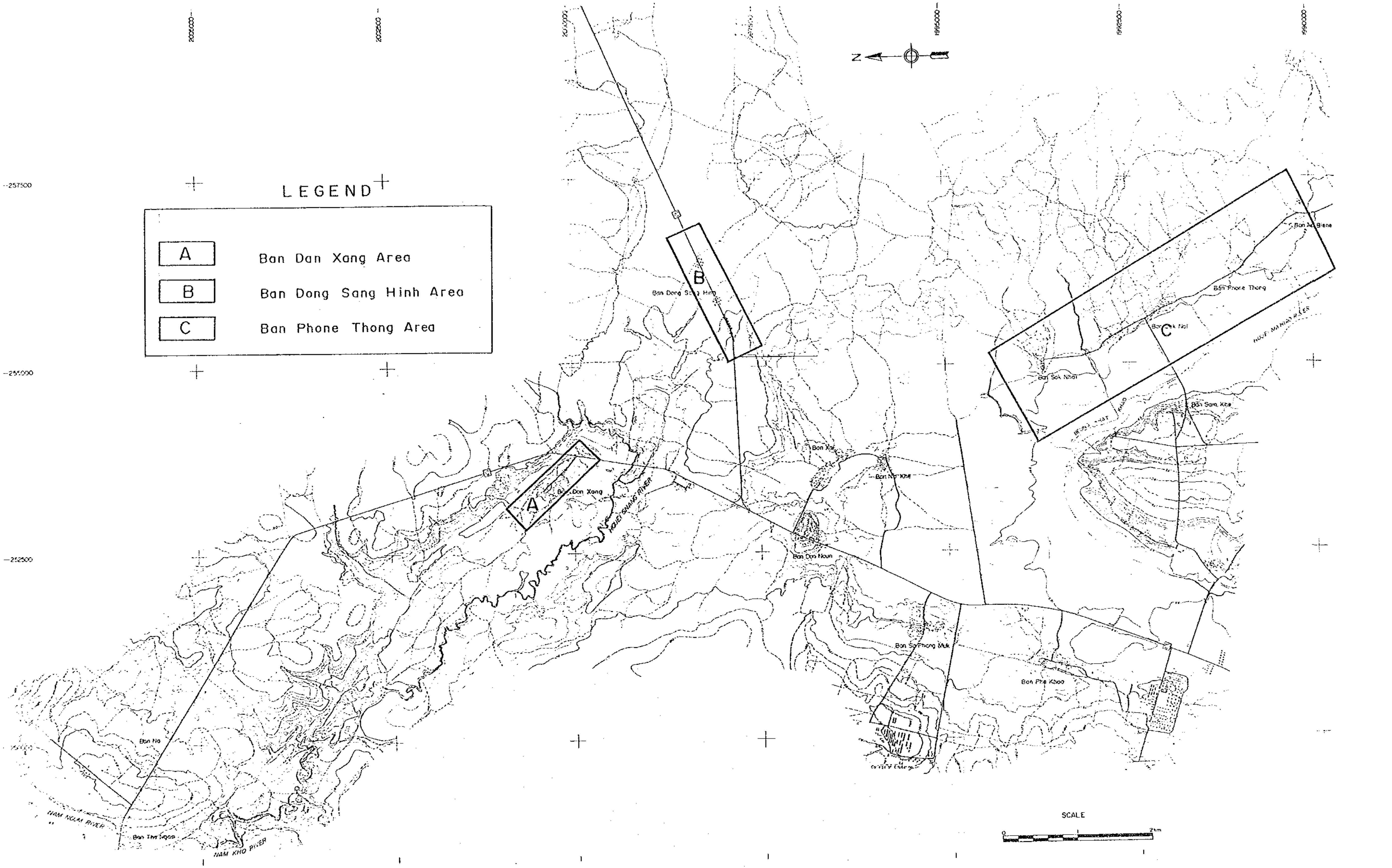


Fig. III-3 ELECTRIC PROSPECTING SITES

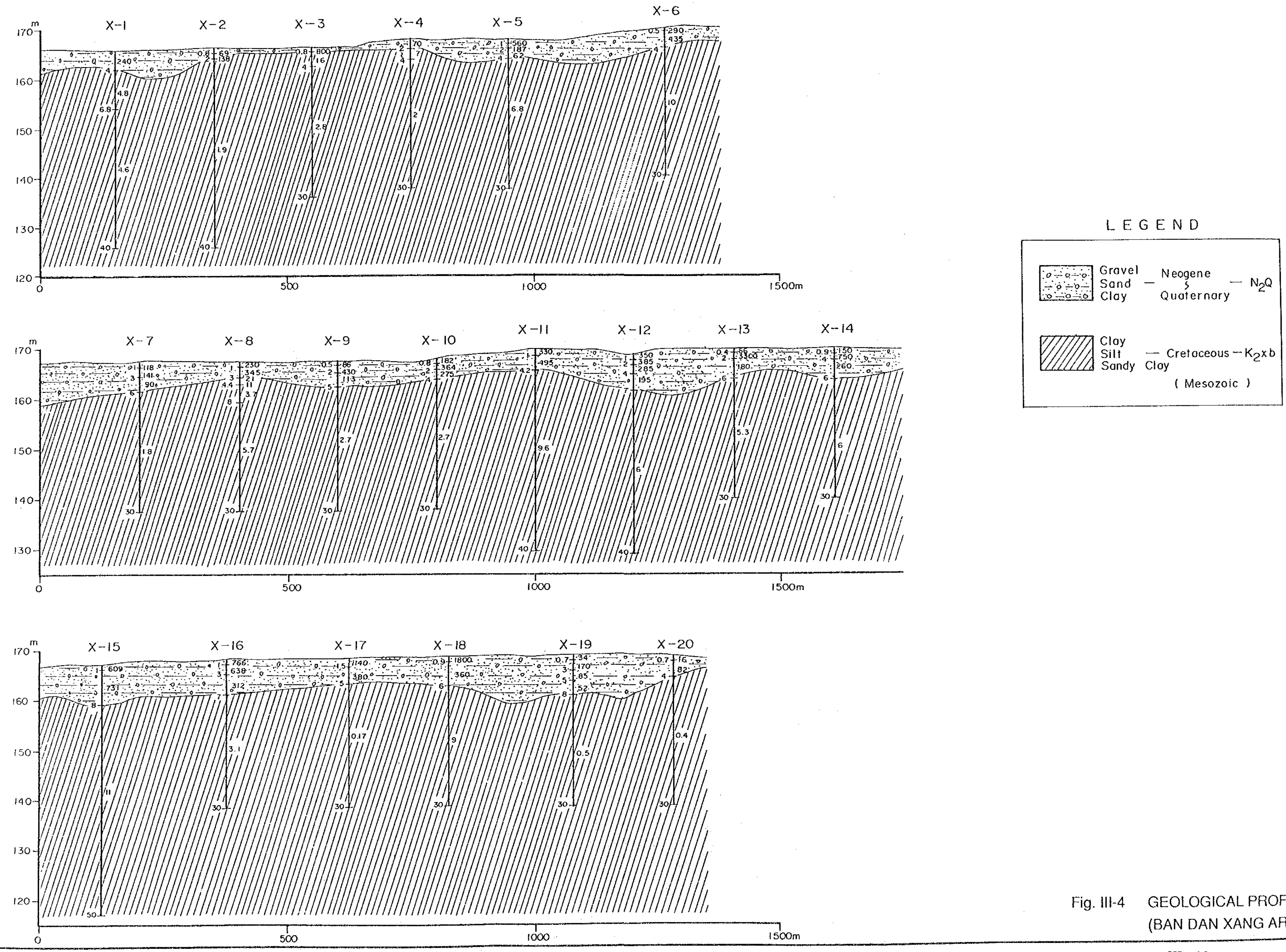


Fig. III-4 GEOLOGICAL PROFILE (BAN DAN XANG AREA)

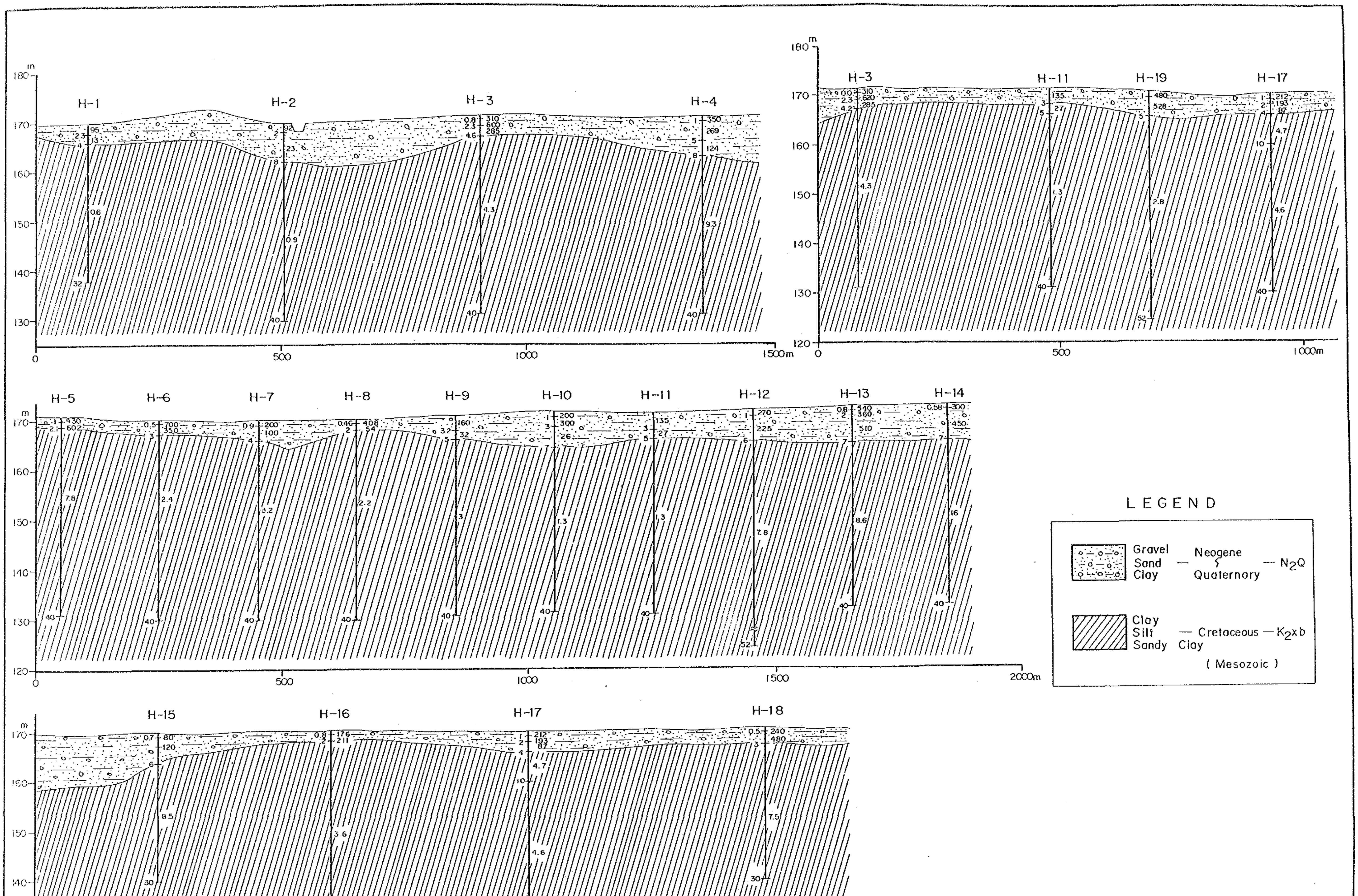


Fig. III-5 GEOLOGICAL PROFILE
(BAN DONG SANG HINH AREA)

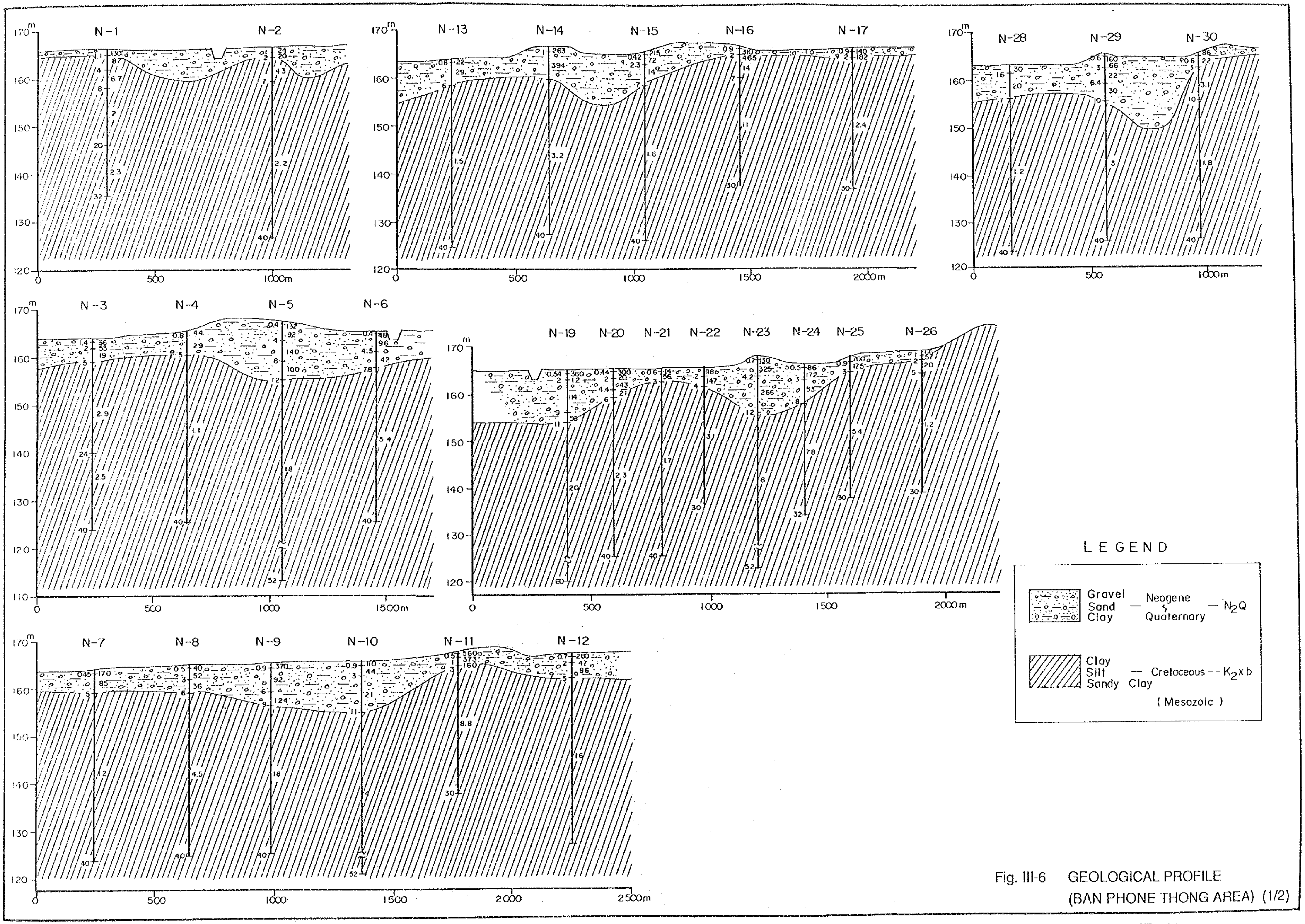


Fig. III-6 GEOLOGICAL PROFILE
(BAN PHONE THONG AREA) (1/2)

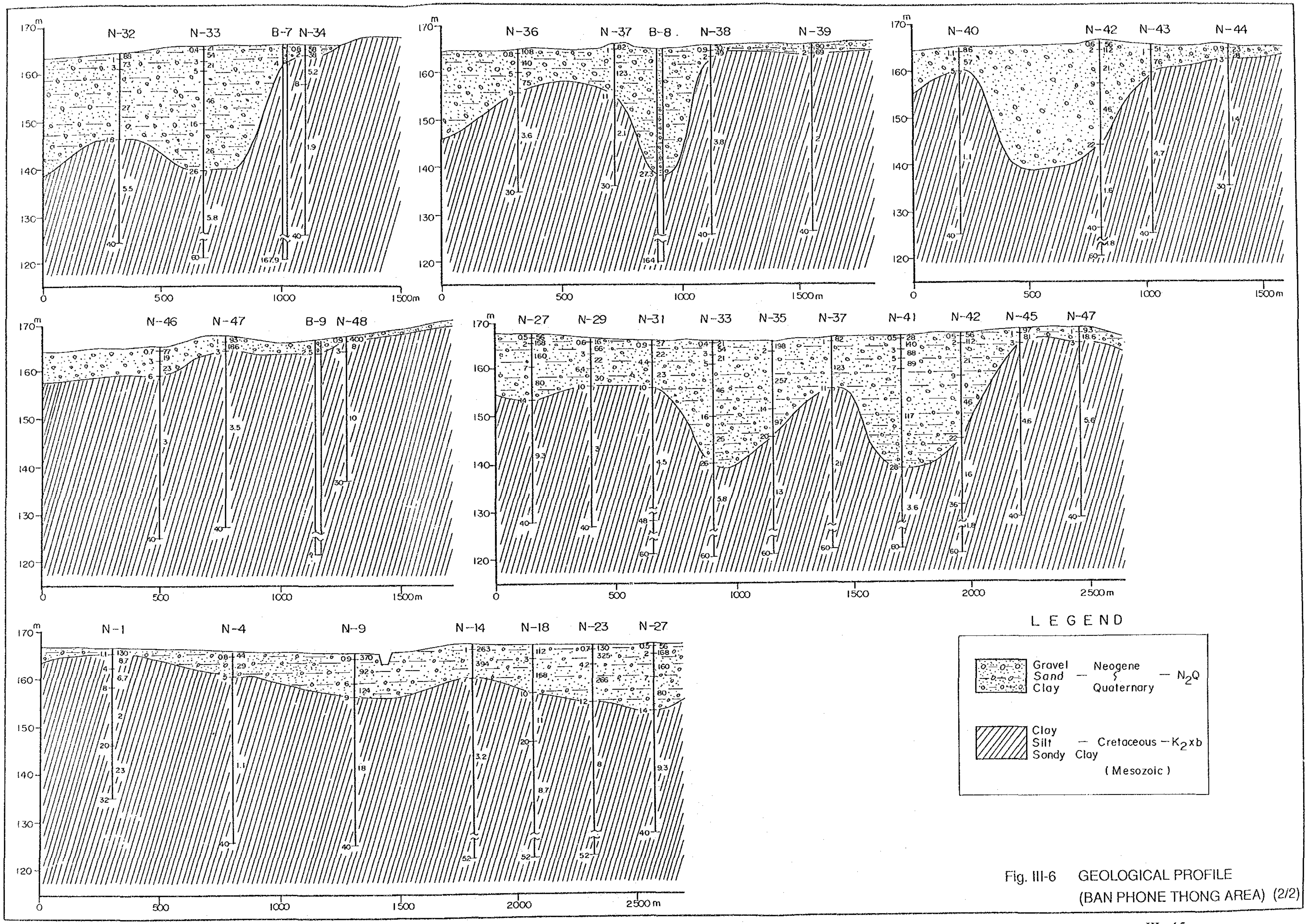


Fig. III-6 GEOLOGICAL PROFILE (BAN PHONE THONG AREA) (2/2)

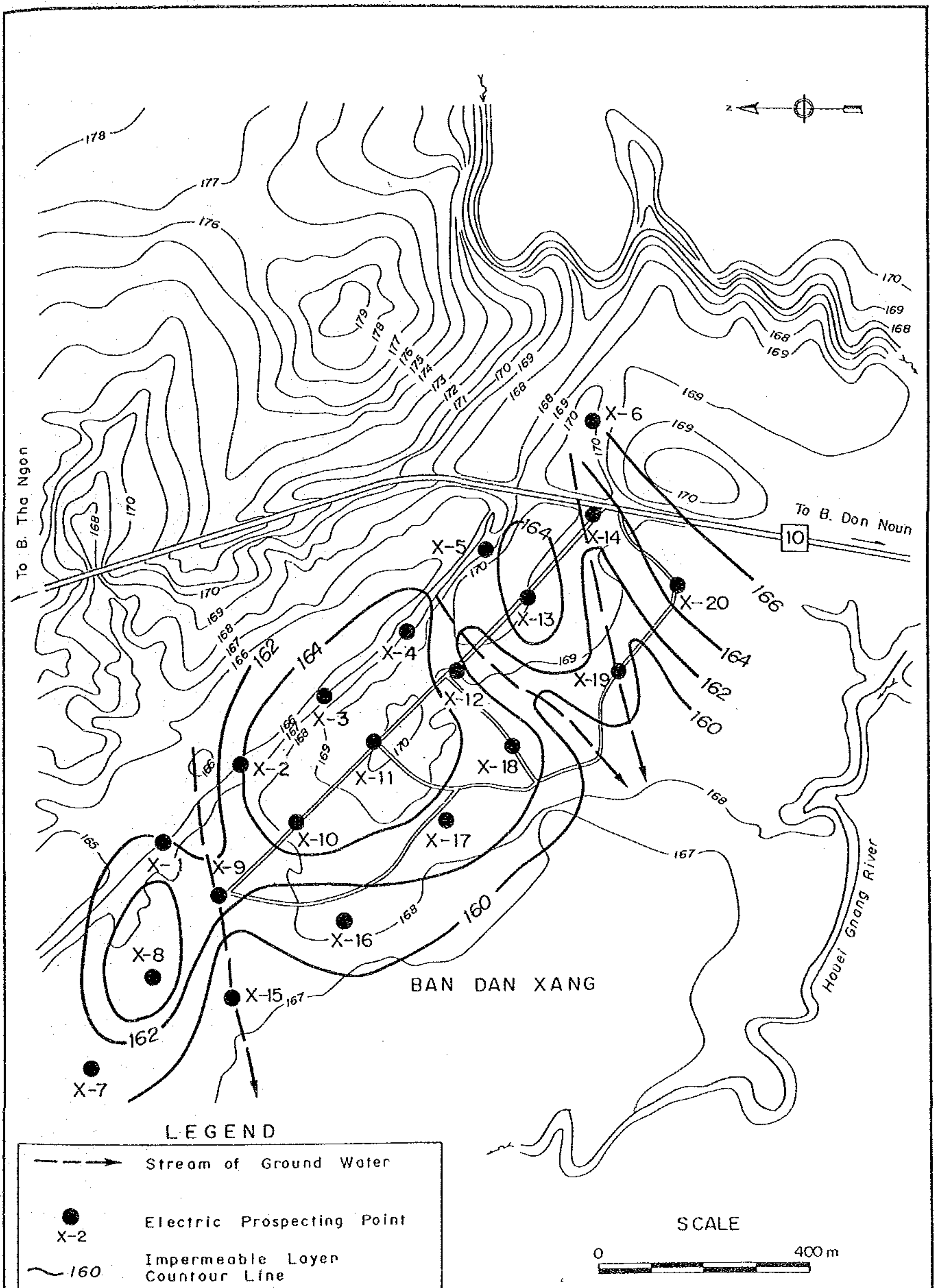


Fig. III-7 IMPERMEABLE LAYER CONTOUR LINE
(BAN DAN XANG AREA)

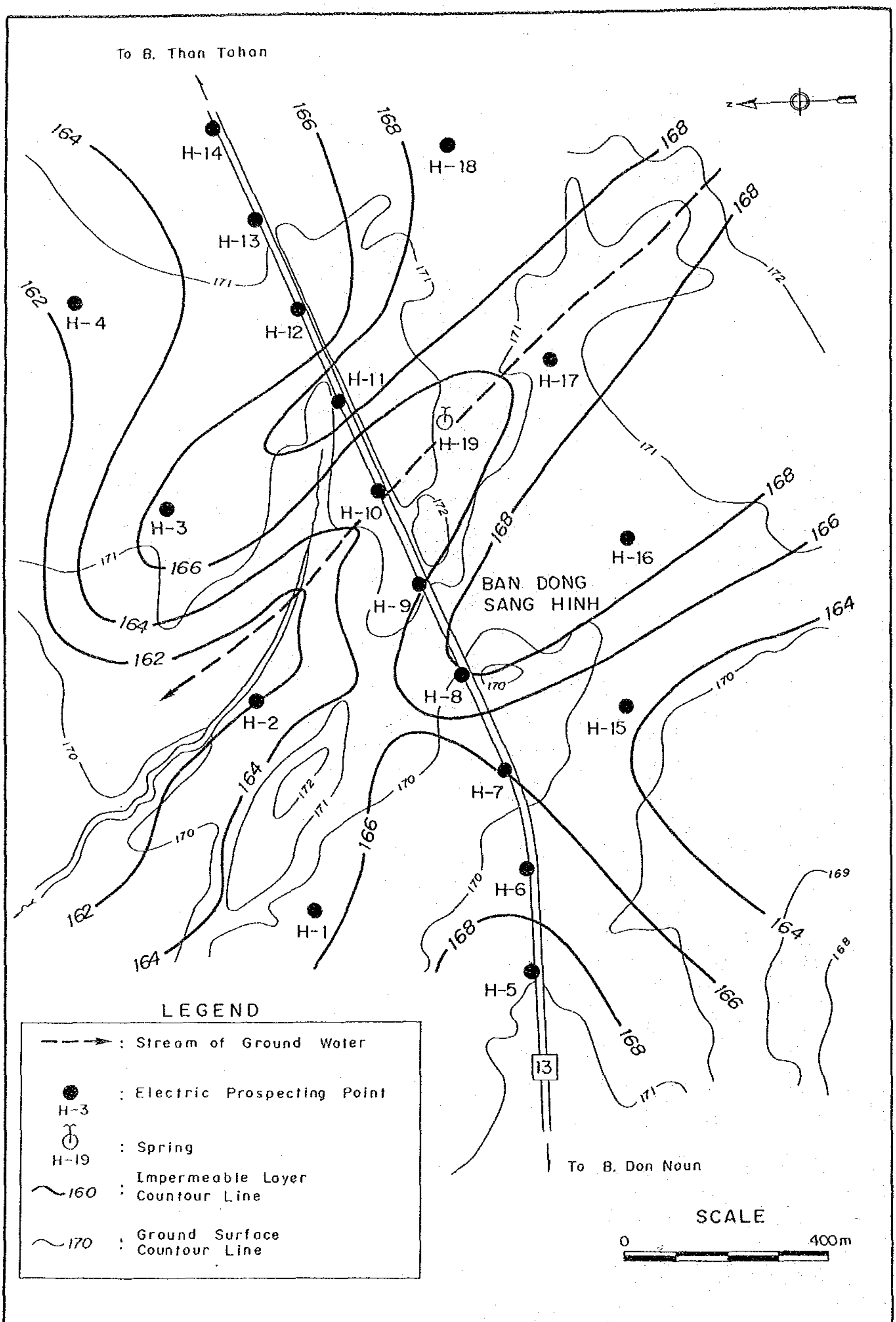


Fig. III-8 IMPERMEABLE LAYER CONTOUR LINE (BAN DONG SANG HINH AREA)

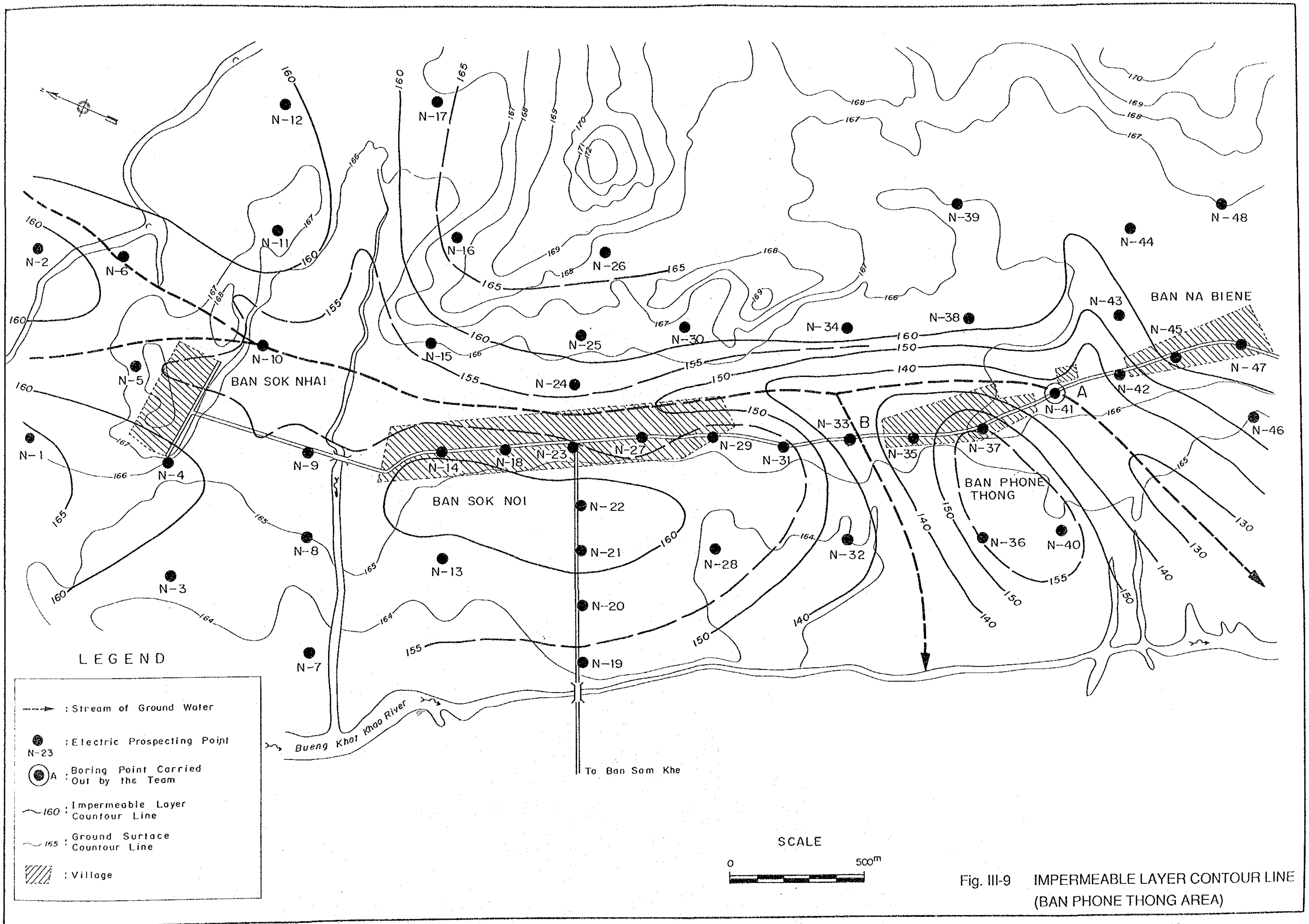


Fig. III-9 IMPERMEABLE LAYER CONTOUR LINE (BAN PHONE THONG AREA)

Depth : 30m
Hole dia : ø250mm
Casing dia : ø150mm
Screen : From 10 to 28m

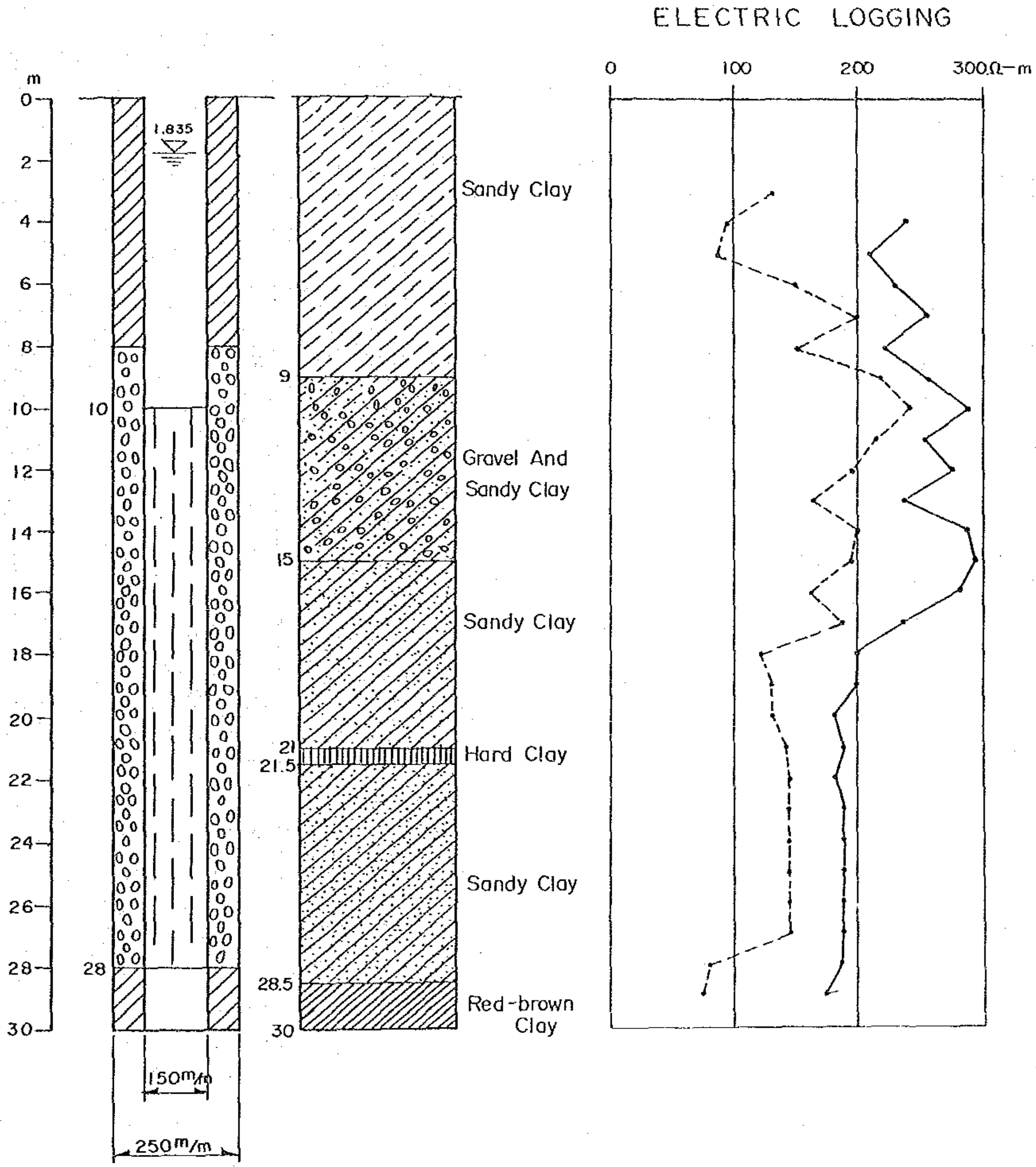


Fig. III-10 BORING DATA AT N-41 POINT

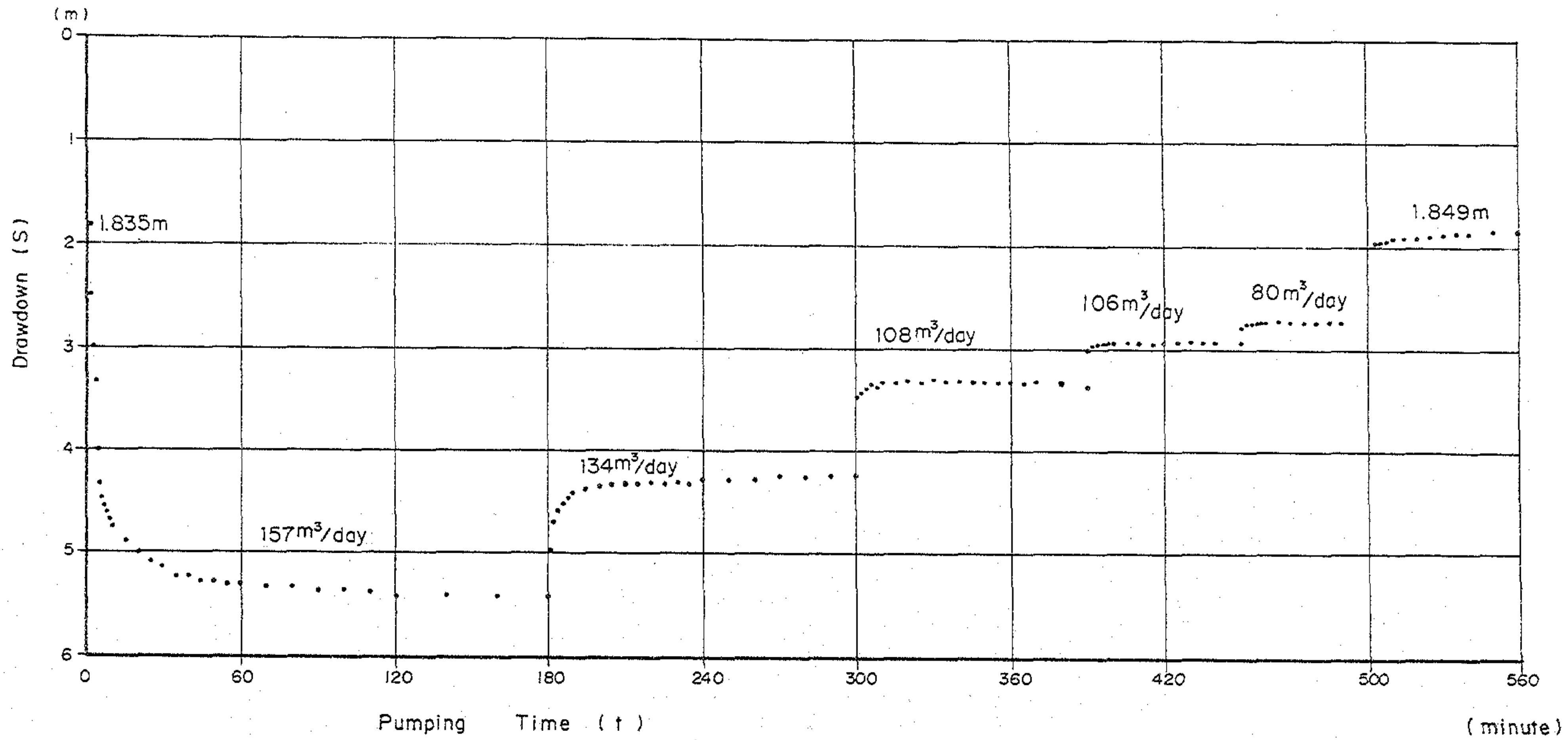
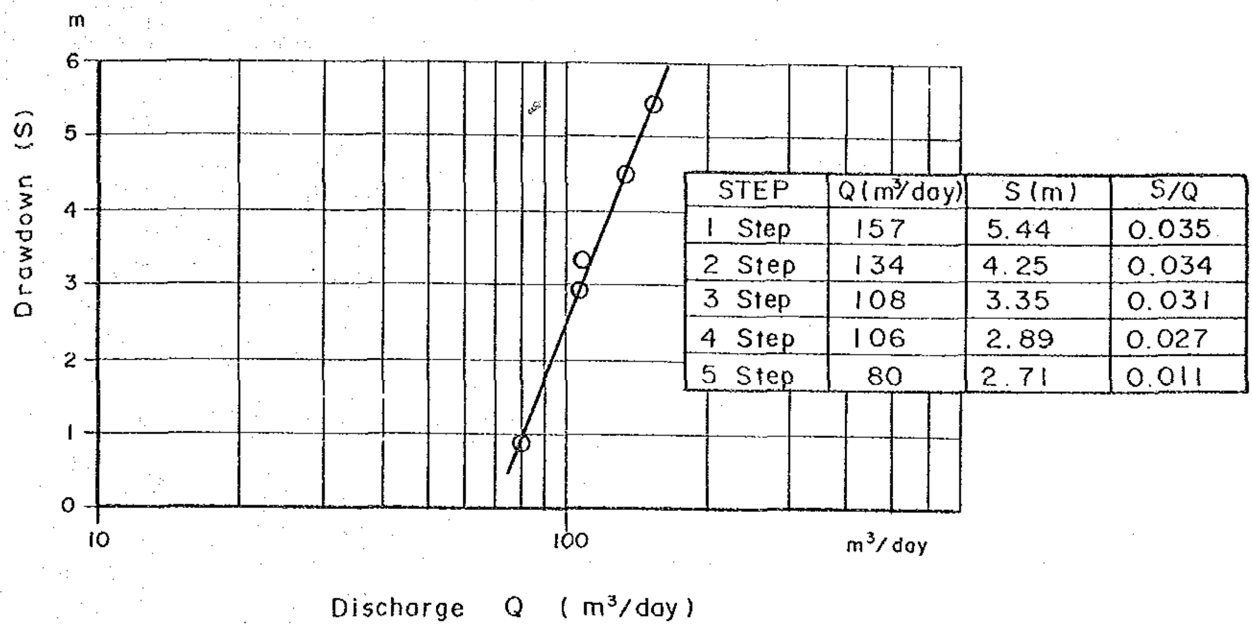
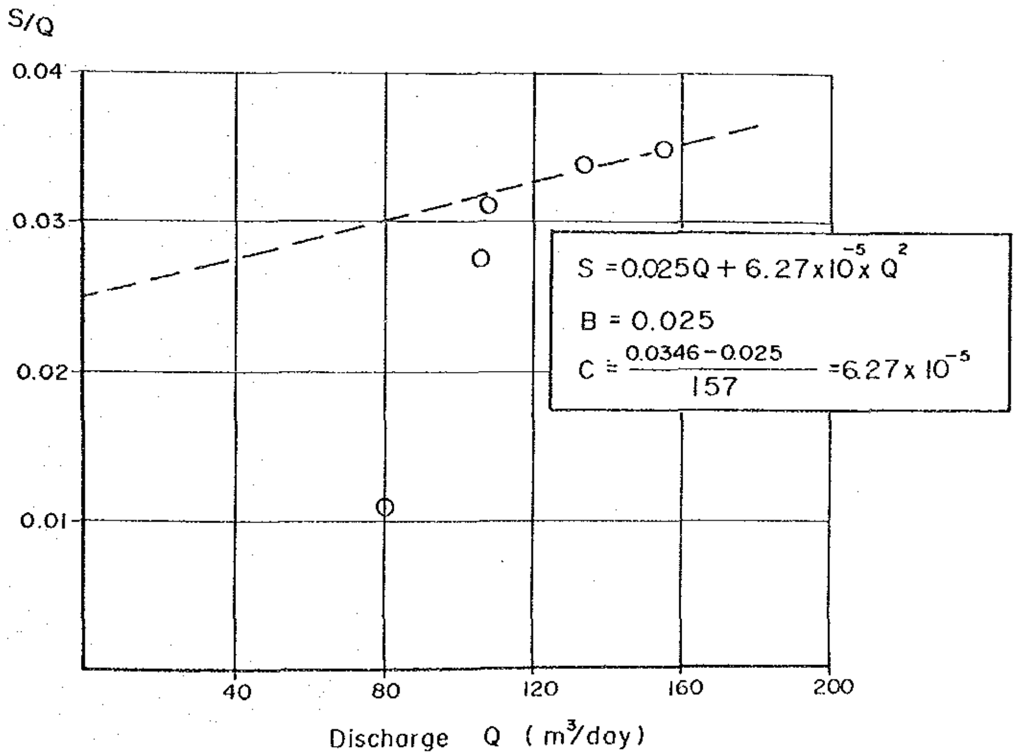


Fig. III-11 DISCHARGE (Q), DRAWDOWN(S) AND PUMPING TIME(T)



STEP	Q (m³/day)	S (m)	S/Q
1 Step	157	5.44	0.035
2 Step	134	4.25	0.034
3 Step	108	3.35	0.031
4 Step	106	2.89	0.027
5 Step	80	2.71	0.011



$$S = 0.025Q + 6.27 \times 10^{-5} \times Q^2$$

$$B = 0.025$$

$$C \doteqdot \frac{0.0346 - 0.025}{157} = 6.27 \times 10^{-5}$$

Fig. III-12 ANALYSIS OF STEP DRAWDOWN TEST

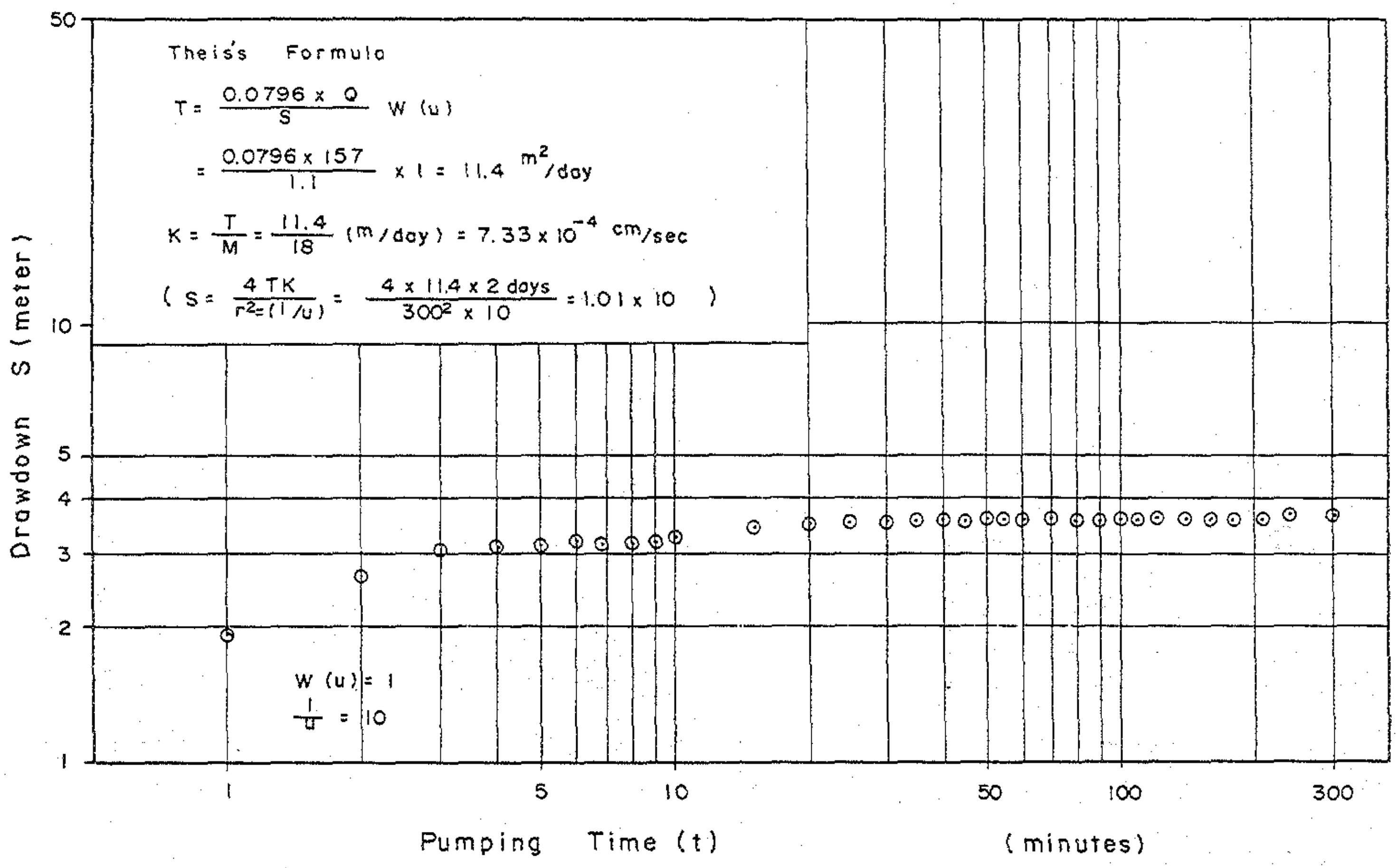


Fig. III-13 DRAWDOWN(S) AND PUMPING TIME(T)

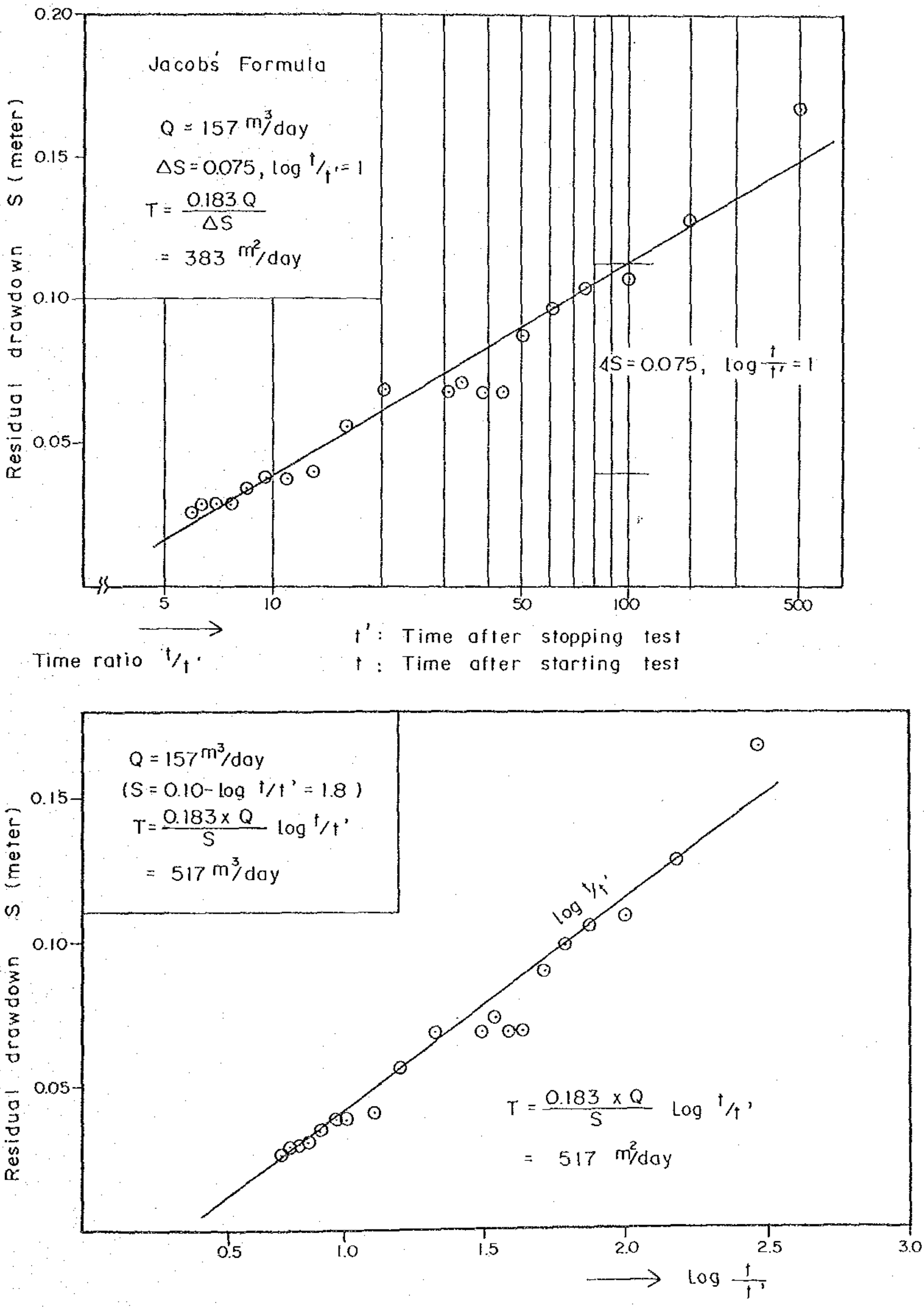


Fig. III-14 ANALYSIS OF RECOVERY TEST

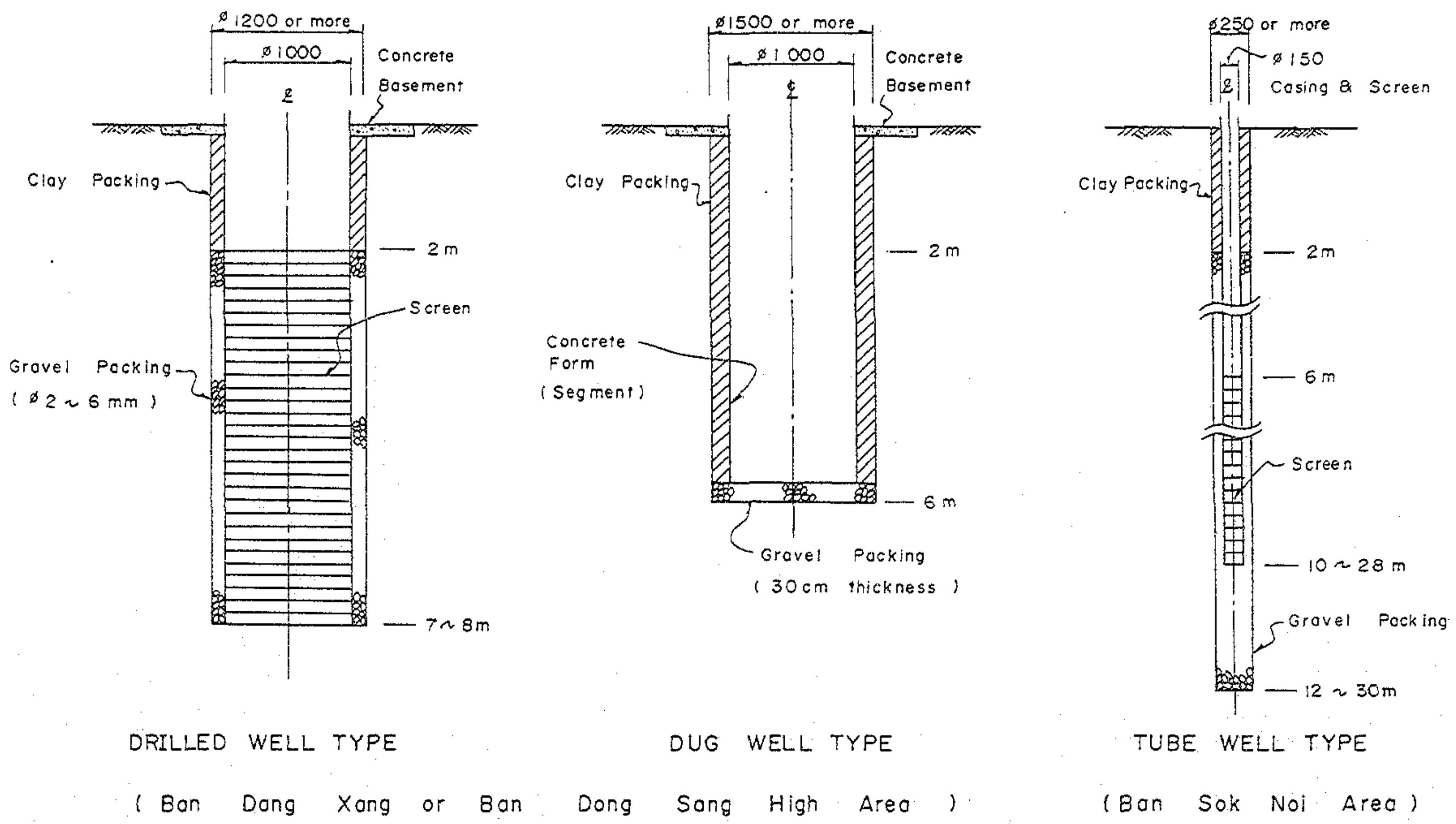


Fig. III-15 PROPOSED DESIGN OF WELLS

ANNEX IV

IRRIGATION AND DRAINAGE

ANNEX IV

IRRIGATION AND DRAINAGE

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1. Existing Irrigation Projects

1.1 Existing Irrigation Projects

In and around the Project area, there are eleven (11) irrigation projects with a total irrigation area of 4,330 ha. All the projects have employed pump-irrigation system and irrigation area of one project ranges from 70 ha to 1,100 ha. Out of eleven (11) projects, four (4) projects, i.e. Kao Liao II irrigation project and Pakpa Sack project take water from the Mekong river. The Kao Liao II irrigation project with an irrigation area of 1,000 ha is being operated under Lao-Australian irrigation project. The Pakpa Sack project involves only a pump station which lifts water from the Mekong river to the Hong Seng river in order to supply the water to four downstream irrigation projects, i.e. Hong Seng I, Hong Seng II, Vieng Chareun, Sok Noi and Sam Khe projects located along the Hong Seng river and Bueng Khat Khao swamp.

One (1) project out of the remaining seven (7) projects takes water from the Nam Ngum river. This is the Tha Ngon irrigation project with an irrigation area of 610 ha, which was completed in 1974 and is being rehabilitated under grant aid of the Japanese Government. The rehabilitation is scheduled to be completed in March, 1989. The remaining six (6) projects take water from the Hong Seng river, Bueng Khat Khao swamp and That Luang marsh in the southern Vientiane plain.

A part of the Hong Seng II and the Sok Noi irrigation projects, say 300 ha and 100 ha, are included in the proposed Project area, taking into consideration water shortage and local condition prevailing in those areas.

All the existing projects are listed in Table IV-1 and their locations are shown in Fig. IV-1.

1.2 Water Rights

No law or regulation on water rights has yet been enacted in Lao PDR although one has been drafted. At present, surface water in rivers and groundwater is the property of the National Community of Lao PDR, but people have the right to make use of it. In the Project area, farmers make use of water in rivers freely and share it with other users. No serious water conflict has occurred so far. If any trouble over water rights occurs, it is settled by the village administration, taking into account tradional water rights. In case of failure of settlement, it is settled by sub-district and district administration.

1.3 Irrigation Practice

Most of the Project area is covered with rainfed paddy fields, and paddy cultivation is done only in the rainy season (May to October). Even in the existing irrigation project areas, rainfed paddy cultivation is generally practiced in the rainy season. This is mainly because water users have to pay actual cost of operators and electricity required for pump operation as water charge. In the dry season (November to April), pumps are operated in the existing irrigation project areas. Pump operation hours during the dry season range from 16 to 24 hours in a day from November to March, and those in April of harvest time range from 4 to 10 hours in a day. Pumped water is conveyed through unlined canal to fields, and a plot to plot irrigation is practiced in the fields. Main and secondary canals of those projects are under the control of the Governmental agency, and tertiary canals and lesser canals are managed by water users association. Prior to irrigation commencement, water users clean and rehabilitate canals and structures, however such work is only temporary and is generally insufficient for smooth distribution of canal water. Consequently, it occurs that some areas are not sufficiently irrigated. Integrated plot arrangement or land consolidation is not undertaken over the Vientiane Plain except for the Tha Ngon Project.

2. Irrigation Water Requirements

2.1 General

The crops proposed to be grown in the area are paddy rice and upland crops such as soybean, groundnuts and garlic. The irrigation water requirement for them is separately estimated based on the proposed cropping pattern. The irrigation water requirement consists of crop water consumption, irrigation losses and ancillary water demands for respective crops.

The irrigation water requirement for the crops is estimated on a monthly basis, using climatic data observed at Vientiane meteorological station for 20 years from 1968 to 1987.

The irrigation water requirement is estimated by the following procedure :

Paddy Rice

- Estimate of paddy rice water consumption (CU) from potential evapotranspiration calculated by climatic data and crop coefficients (Kc) varying with growth stages
- Estimate of percolation rate (P)
- Estimate of effective rainfall (ER)
- Estimate of nursery water (NW) and puddling water requirement (PW)
- Estimate of net irrigation water requirement (NR)
  NR = CU + P - ER + NW + PW
- Estimate of gross irrigation water requirement (GR) based on (NR) divided by irrigation efficiency

Upland Crops

- Estimate of crop water consumption (CU)
- Estimate of effective rainfall (ER)
- Estimate of net irrigation water requirement (NR)
  NR = CU - ER
- Estimate of gross irrigation water requirement (GR) based on (NR) divided by irrigation efficiency

2.2 Water Consumption

(1) Potential evapotranspiration

Crop water consumption is estimated as a product of potential evapotranspiration (ETo) and crop coefficient (Kc), which varies with crop growth stage. The potential evapotranspiration is calculated by the following modified Penman method recommended in " Crop Water Requirements, FAO Irrigation and Drainage Paper No.24, 1977 (FAO Paper)" since this method is generally accepted in the world as the most accurate formula.

Eto = C x [W x Rn + (1-W) x f (u) x (ea - ed)]

Where;

ETo = Potential evapotranspiration in mm/day

W = Temperature-related weighing factor

Rn = Net radiation in equivalent evaporation in mm/day

f(u) = Wind-related function

(ea-ed) = Difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in m bar

C = Adjustment factor to compensate for the effect of day and night weather conditions

Each factor mentioned above is shown in Table IV-2 and the calculated potential evapotranspirations are as follows:

Potential Evapotranspiration (ETo)

(Unit: mm/day)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
4.1	4.7	5.4	6.1	5.8	4.8	4.6	4.4	4.6	4.7	4.4	3.6

(2) Crop coefficient

The proposed cropping pattern consists of rainy season paddy, dry season paddy and upland crops. The crop coefficient varies with kind of crop, time of planting or sowing and stage of crop development. The determination of crop coefficient is made based on the said FAO paper. Since no data on crop coefficient for respective kinds of upland crops are available, crop coefficient of soybean is employed, representing that of upland crops. Crop coefficient curves are shown in Fig. IV-2, and the estimated crop coefficients are shown in Fig. IV-3, IV-4 and IV-5.

(3) Water consumption

Water consumption by each proposed crop is calculated by multiplying potential evapotranspiration by crop coefficient shown in Fig. IV-3, IV-4 and IV-5.

2.3 Percolation

The field measurement of vertical percolation rate in the existing paddy field during the rainy season was carried out by a steel cylinder. The test results show that the average percolation rate is 1 mm/day in the rainy season. The soil in the Project area is mostly silt. Considering the test results, soil type and available information obtained from the existing irrigation projects, the percolation rate is conservatively determined at 1.5 mm/day for the rainy season and 3 mm/day for the dry season.

2.4 Measurement Results of Evapotranspiration and Percolation

Evapotranspiration by paddy and percolation in the paddy field were daily measured for 48 days from August 24 to September 30, 1988 at two existing paddy fields, i.e. site No.1 and site No.2 by means of rectangular frames and cylinders made of steel. Site No.1 represents the central low land of the Project area, while site No.2 represents relatively elevated area. The location of these sites is shown in Fig. IV-6. The test results are shown in Table IV-3 in comparison with the evapotranspiration estimated by the modified Penman method. Although the measurement was made during the limited period in the rainy season, it could be understood from Table IV-3 that the employment of the modified Penman method and proposed percolation results in slightly conservative values.

2.5 Other Water Demands

(1) Puddling water requirement

The puddling water requirement consists of water equivalent to the difference in soil moisture before and after puddling, standing water required in soil surface, and evaporation and percolation losses from paddy field. The amount largely depends on such factors as soil properties, puddling method and period, groundwater table in the paddy field, etc. Taking into consideration these factors, the puddling water requirement is assessed as follows :

i)	Depth of soil and porosity		
	Surface soil (15 cm)	:	50%
	Subsoil (15 cm)	:	50%
ii)	Soil vapour phase after puddling	:	5%
iii)	Soil moisture before water supply	:	20%
iv)	Water to be supplied		
	Water to be supplied to soil profile	:	75 mm
	Evaporation	:	40 mm
	Percolation	:	30 mm
	Standing water depth after puddling	:	30 mm
	Total	:	175 mm, say 180mm

(2) Nursery water requirement

The nursery water requirement consists of water needed for preparation of nursery bed, and evapotranspiration and percolation during nursery period. The nursery water requirement is estimated at 420 mm on the following conditions :

i)	Nursery bed	:	1/20 of paddy field
ii)	Nursery period	:	30 days
iii)	Required water for 30 days		
	Preparation of nursery bed	:	180 mm
	Evapotranspiration (5 mm/day)	:	150 mm
	Percolation (3 mm/day)	:	90 mm
	Total	:	420 mm

2.6 Effective Rainfall

Design rainfall for the estimate of water requirement is probable minimum rainfall with a 10-year return period, corresponding to 1,243 mm in a year. The effective rainfall is estimated on a monthly basis, using " monthly effective rainfall curve" developed by the Committee for Coordination of Investigation of the Lower Mekong Basin (the Mekong Committee) as shown in Fig.IV-7. The estimated effective rainfall with 90% dependability is as follows:

Effective Rainfall

(Unit : mm/month)

Items	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
- Design rainfall	0	0	30	63	179	218	227	238	226	62	0	0	1,243
- Effective rainfall for paddy rice	0	0	20	50	150	175	185	195	185	50	0	0	1,010
- Effective rainfall for upland crops	0	0	20	50	120	125	130	130	130	50	0	0	755

2.7 Irrigation Efficiency

The irrigation loss consists of farm application loss, operation loss and conveyance loss. The farm application loss in paddy field is considered small, but that in upland crop irrigation is significant since it includes percolation, surface runoff, etc. Taking into account the soil characteristics, topography, climate, irrigation practices and experience, etc., the application efficiency is assumed to be 85% for paddy rice irrigation and 65% for upland crop irrigation.

The operation loss is the irrigation water wasted due to improper canal gate operations and unskilled water management in the field. According to the actually measured results in the irrigated paddy field in South Asian countries, a total operation loss is 50 to 100% of net irrigation water requirement. Even after the canal operation practices and water management are improved through appropriate guidance to farmers, a certain amount of irrigation water, say 10-30% of net irrigation water requirement will be wasted. Considering these factors, the operation efficiency is assumed to be 80%.

The canal conveyance loss is caused by seepage through the wetted perimeter of canal and evaporation from the canal water surface. In order to measure the canal conveyance loss, the measurement was made by the Team in the existing Sok Noi canal during 3 days from August 7 to 9, 1988. As a result, averaged conveyance loss of 0.11 m^3/m^2/day was obtained. When this value is applied to the proposed irrigation canal, the conveyance loss of 0.51 m^3/sec corresponding to about 10% of diversion water requirement (4.86 m^3/sec) is estimated. This calculation is shown in Table IV-4. The conveyance efficiency is assumed to be 90% on the basis of this value.

Overall irrigation efficiency is estimated at 61% for paddy rice irrigation and at 47% for upland crop irrigation as shown below:

Efficiency	Paddy Rice	Upland Crop
Application efficiency	85%	65%
Operation efficiency	80%	80%
Conveyance efficiency	90%	90%
Overall efficiency	61%	47%

2.8 Diversion Water Requirement

Diversion water requirement is estimated by dividing total net irrigation water requirement by overall irrigation efficiency. The total net irrigation water requirement consists of net irrigation water requirements for paddy rice and upland crops. However, since net irrigation water requirement for upland crops is smaller than that for paddy rice, and irrigation area for upland crops is much smaller than that for paddy rice, it is assumed in the estimate of the diversion water requirement that all the area is paddy field. This assumption is also taken up from a view point of future crop diversification. As a result, the maximum diversion water requirement is estimated at 4.86 m^3/sec.

The net irrigation water requirements for paddy rice and upland crops are shown in Fig.IV-3, IV-4 and IV-5.

The estimated monthly diversion water requirement for the Project is shown below:

Diversion water Requirement

(m^3/sec/2,700 ha)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
3.73	4.86	4.65	1.68	-	0.78	2.84	0.06	0.25	2.00	0.19	0.14
(1.8 lit/sec/ha)											

2.9 Design Discharge

The maximum diversion water requirement of 4.86 m^3/sec corresponds to 1.8 lit/sec/ha when pump operation and irrigation are made on a 24-hour basis. Design discharge for irrigation canals and related structures depends on pump operation and irrigation hours. In the existing irrigation projects, irrigation to the paddy field is mostly made during 16 to 24 hours per day. However, the midnight irrigation is not nearly supervised by farmers, and it results in waste of water and improper water distribution. Taking into consideration practical irrigation hours, a 18-hour irrigation is employed for this Project.

In order to store the irrigation water for non-irrigation six (6) hours, a regulation pond is required. The regulation pond will be provided on a point about 11 km downstream from the diversion site. Two design discharges are determined as follows for the canals and related structures:

(1) Design discharge for main pump station and headreach : 1.8 lit/sec/ha
(2) Design discharge for booster pump stations and all canals : 1.8 x 24/18 = 2.4 lit/sec/ha

3. Soil Characteristics and Irrigation Schedule

3.1 Available Soil Moisture

The available moisture in the soil is expressed as moisture amount held by the soil between field capacity and wilting point. The moisture level at 1/3 atmospheric pressure is usually considered to be the field capacity. The wilting point corresponds to the moisture held at 15 atmospheric pressures. The available moisture largely depends on soil type, soil texture and rooting depth of soil. The soil in the proposed upland area is identified sandy loam. The main crop is soybeans. The available moisture is estimated at 130 mm/m from the relationship among soil type, kind of crop and available moisture which is shown in FAO paper. The readily available moisture is calculated at 39 mm as follows :

(1)	Available soil moisture	:	130 mm/m
(2)	Fraction of available soil moisture	:	0.5
(3)	Rooting depth	:	0.6 m
(4)	Readily available moisture	:	(1) x (2) x (3) = 39 mm
(5)	Application efficiency	:	65%
(6)	Depth of irrigation application	:	(4)/(5) = 60 mm

3.2 Cylinder Intake Rate

The cylinder intake rate tests were carried out at eleven (11) sites in the Project area from August 24 to August 28,1988. The locations of test sites are shown in Fig. IV-6. The test results, i.e. relationships between the accumulated intake depth of water and the elapsed time, and the intake rate and the elapsed time are graphically analyzed as shown in Fig. IV-8. The accumulated intake is expressed by the following formula:

$$D = CT^n \text{ (mm)}$$

Where;

D	=	Accumulated intake (mm)
C	=	Accumulated intake at first one minute (mm)
T	=	Elapsed time
n	=	Slope of line

The intake rate (I) is expressed by differentiating the above formula as follows :

$$I = 60CnT^{n-1}$$

The basic intake rate (IB) is an intake rate when water infiltration into soil becomes nearly constant. The basic intake rate is, however, practically obtained as the intake rate at the elapsed time of 600 (1-n) minutes after test commencement as follows :

$$IB = 60Cn[600(1-n)]^{n-1}$$

The estimated basic intake rates for eleven (11) sites are shown in Table IV-5. The test results show that all the basic intake rates are less than 0.38 mm/hr, which are considered very small in amount.

3.3 Irrigation Schedule

Irrigation interval for the soybeans is estimated by the net depth of irrigation application and rate of evapotranspiration. Since the evapotranspiration is 4.9 mm/day, the irrigation interval is 8 days as follows:

$$\text{Irrigation Interval (day)} = \frac{\text{Net depth of irrigation application (mm)}}{\text{Evapotranspiration (mm/day)}}$$

$$= \frac{39\ \text{(mm)}}{4.9\ \text{(mm/day)}} = 8\ \text{days}$$

4. Drainage Water Requirements

4.1 General

The Project area will consist of Paddy field and upland field. The upland field in the estimate of drainage water requirement is defined as non-paddy field such as upland field, fallow land, forests, etc. Since drainage characteristics of these lands are different particularly in runoff time and runoff discharge, the drainage water requirement for paddy field and that for upland field are separately estimated. In this estimate, the daily maximum rainfall with a 10-year return period is employed as design rainfall.

4.2 Drainage Water Requirement for Paddy Field

(1) Duration for draining excess water from paddy field

In order to determine allowable duration for draining excess water from paddy field, the frequency of the rainfall occurred before and after the occurrence of annual maximum daily rainfall is examined, using daily rainfall data recorded at Vientiane meteorological station during the recent 21 years. This study result shows that a 2-day continuous storm rainfall with more than 50 mm/day scarcely occurs. The probability of the occurrence is as low as 5% (once in 21 years). The duration for draining excess water from paddy field is determined to be 2 days. The study result is as follows:

Frequency

Daily Rainfall	Number of Day after Annual Max. Daily Rainfall							
(mm/day)	-1	0	1	2	3	4	5	6
No rainfall	6	-	2	7	5	9	9	9
Less than 50	14	-	18	11	16	12	11	11
More than 50	1	-	1	3	0	0	1	1

(2) Damage to paddy by inundation

Since a part of the design rainfall is stored in paddy fields, an effect to yield of paddy rice is studied, making reference to the "Hand Book on Estimating Yield

Reduction Rates of Summer Crop due to Various Causes" published by the Ministry of Agriculture, Forestry and Fisheries of Japan in 1975. The following are quoted from the book:

i) The submergence at the growing stage of young panicle formation gives the serious damage to paddy, while that at the maturing stage does not give the serious damage to paddy.

ii) The duration of submergence within 1 to 3 days is insignificant, but the damage to paddy remarkably increases, if the submergence lasts for more than 3 days.

Based on the above, it is concluded that a 2-day duration for draining excess water from paddy field will not damage the yield of paddy rice.

(3) Design rainfall

The probable annual maximum daily rainfall is analyzed by application of logarithmic Pearson Type III distribution. The annual maximum daily rainfall with a 10-year return period is estimated at 164 mm, which is adopted as design rainfall. The annual maximum daily rainfalls with different return periods are as follows:

Annual Maximum Daily Rainfall

(Unit: mm/day))

2-year	5-year	10-year	25-year
105	139	164	199

(4) Drainage water requirement for paddy field

Based on the conditions mentioned above, drainage water requirement is estimated at 5.4 lit/sec/ha as shown below:

<u>Assumptions</u>

i) Design rainfall is 164 mm/day

ii) Effective water depth in the paddy field is 100 mm.

iii) Standing water depth in the paddy field is 30 mm.

iv) Excess rainfall to be drained from the paddy field within 48 hours is 94 mm.

<u>Calculations</u>

Q	=	q x A
q	=	RE24 x 10 m^2 / (3,600 sec x 48 hours)
	=	0.058 x 94 = 5.4 lit/sec/ha
RE24	=	R24 - (D1-D2) = 164 - (100-30) = 94 mm

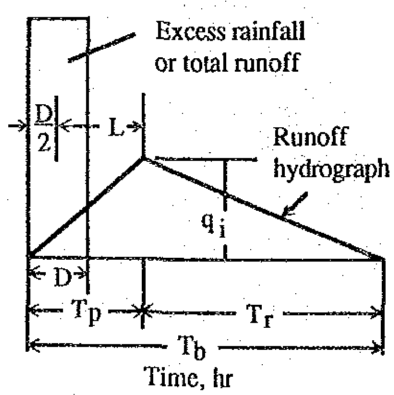
Where;

Q	=	Design drainage water requirement (m^3/sec)
q	=	Unit drainage water requirement per ha
A	=	Drainage area (ha)
R24	=	Design rainfall, 164 mm/day
D1	=	Effective water depth in the paddy field, 100 mm
D2	=	Standing water depth in the paddy field, 30 mm
RE24	=	Excess rainfall to be drained, 94 mm

4.3 Drainage Water Requirement for Upland Field

Rainfall water runs off from upland field immediately after rainfall. There is no storage function in the upland field. The drainage water requirement for the upland field is considered to be peak runoff from the upland field. In order to estimate the peak runoff, the upland field including outer drainage area of the Project is divided into 26 subareas, considering topography and future layout of drains. The peak runoffs from those areas are individually estimated by applying the following triangular unit hydrograph:

qi = 2 x Q / (Tp + Tr)



Where;

Q	=	Total runoff in mm
qi	=	Peak rate in mm
Tp	=	Time in hour from start of rise to peak rate
Tr	=	Time in hour from peak rate to end of triangle

Tb	=	Total time of hydrograph
D	=	Rainfall period in hour
L	=	Lag time from center of excess rainfall to peak time in hour

In the estimate, the following assumptions are made:

i) Q is 40% of design rainfall.
ii) D is 12 hours by referring the hourly rainfall data at Vientiane.
iii) L is determined by V.T. Chow's equation which was developed from correlation analysis of 60 peak runoffs from 20 small basins (1.1 to 1,830 ha).
iv) Tp is the sum of D/2 and L.
v) Tr is two times of Tp.

All the results thus computed are shown in Table IV-6.

Table IV-1 Existing Irrigation Projects

Project	Water Source	Area (ha)	Completion Year	Discharge (m^3/s)	Nos. of Pumps (HP x Unit)
1. Kao Liao II	Mekong	1,000	1982	2.4	175 x 4
2. Hong Seng II	Hong Seng	1,100	1985	0.9	100 x 3
3. Pakpa Sack	Mekong	-	1984	0.9	100 x 3
4. Hong Seng I	Hong Seng	100	1987	0.4	25 x 2
5. Vieng Chareun	Hong Seng	70	1987	0.2	25 x 1
6. Sok Noi	Bueng Khat Khao	200	1987	0.5	40 x 2
7. Sam Khe	Bueng Khat Khao	200	1987	0.8	25 x 4
8. Houa Khoua	That Luang	300	1984	0.6	100 x 2
9. Phanh Manh	Mekong	600	1982	1.6	125 x 4
10. Hong Thong	Mekong	150	1987	1.6	150 x 4
11. Tha Ngon	Nam Ngum	610	1974	1.6	220 x 3

Table IV-2 Potential Evapotranspiration (ETo)

Factor	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
e a (m bar)	27.1	31.1	36.5	40.1	39.4	38.7	38.0	37.0	37.0	35.7	31.5	26.9
e d (m bar)	18.4	20.2	23.4	26.5	28.8	29.8	29.6	29.2	28.9	26.4	21.7	18.0
f(u)	0.54	0.54	0.54	0.59	0.61	0.57	0.57	0.57	0.54	0.51	0.54	0.54
W	0.71	0.74	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.76	0.74	0.71
Rn (mm/day)	3.68	4.06	4.62	5.13	5.22	4.57	4.45	4.33	4.43	4.45	3.90	3.08
C	1.03	1.04	1.05	1.06	1.05	1.03	1.02	1.02	1.03	1.04	1.03	1.00
Eto (mm/day)	4.1	4.7	5.4	6.1	5.8	4.8	4.6	4.4	4.6	4.7	4.4	3.6

Table IV-3 Measured Evapotranspiration and Percolation

Period	Evapotranspiration (mm/day)			Percolation (mm/day)		
	No.1 Site	No.2 Site	Design Value	No.1 Site	No.2 Site	Design Value
Aug. 24 - 31	4.2	3.9	5.0	0.7	0.7	1.5
Sept. 1 - 15	4.8	4.7	5.3	0.9	0.9	1.5
Sept. 16 - 30	4.8	5.1	5.2	0.9	1.1	1.5

Table IV-4 Estimated Conveyance Loss

Canal	Length (m)	Wetted Perimeter (m)	Test Result ($m^3/m^2/day$)	Estimated Convey. Loss (m^3/s)
Headreach	11,000	8.03	0.11	0.12
Main Canals	20,000	5.49	0.11	0.14
Secondary Canals	21,000	3.59	0.11	0.10
Tertiary Canals	71,000	1.56	0.11	0.14
Total			(0.50 / 4.86 x 100 = 10.3%)	0.51

Table IV-5 Basic Intake Rates

Site No.	Accumulated Intake	Cylinder Intake Rate	Basic Intake Rate (mm/hr)
C-1	$D = 0.47T^{0.28}$	$I = 7.896T^{-0.72}$	IB = 0.10
C-2	$D = 0.16T^{0.49}$	$I = 4.704T^{-0.51}$	IB = 0.25
C-3	$D = 0.054T^{0.67}$	$I = 2.171T^{-0.33}$	IB = 0.38
C-4	$D = 0.15T^{0.33}$	$I = 2.970T^{-0.67}$	IB = 0.06
C-5	$D = 0.42T^{0.29}$	$I = 7.308T^{-0.71}$	IB = 0.10
C-6	$D = 0.058T^{0.20}$	$I = 0.696T^{-0.80}$	IB = 0.005
C-7	$D = 0.045T^{0.65}$	$I = 1.775T^{-0.35}$	IB = 0.27
C-8	$D = 0.021T^{0.46}$	$I = 0.580T^{-0.54}$	IB = 0.03
C-9	$D = 0.05T^{0.13}$	$I = 0.39T^{-0.87}$	IB = 0.002
C-10	$D = 0.07T^{0.081}$	$I = 0.34T^{-0.72}$	IB = 0.001
C-11	$D = 0.08T^{0.057}$	$I = 0.27T^{-0.943}$	IB = 0.00

Table IV-6 Peak Discharge by Triangular Unit Hydrograph

No.		1	2	3	4	5	6	7	8	9	Total
Area	(ha)	117	111	258	113	58	139	10	27	248	1081
Length of the watershed	(km)	1.8	1.8	1.3	1.7	1.1	1.7	0.6	1.1	1.9	
Length of drainage canal	(km)	1.4	1.8	5.1	5.1	5.8	6.2	5.8	3.6	5.5	
EL at the remotest point	(m)	187	187	190	185	173	180	173	172	180	
EL at the outlet of area	(m)	168	168	167	168	170	173	170	170	172	
Tl/1	(hr)	2.6	2.6	1.8	2.5	2.9	3.4	1.6	3.3	3.6	
Tp/2	(hr)	8.6	8.6	7.8	8.5	8.9	9.4	7.6	9.3	9.6	
Tr/3	(hr)	17.2	17.2	15.6	17.1	17.8	18.8	15.3	18.7	19.2	
Q	(mm)	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	
qp	(m^3/sec)	1.7	1.6	4.0	1.6	0.8	1.8	0.2	0.4	3.1	15.1
Td/4	(hr)	0.4	0.6	1.6	1.6	1.8	1.9	1.8	1.1	1.7	

No.		10	11	12	13	14	15	16	17		Total
Area	(ha)	43	444	22	322	37	63	19	480		1430
Length of the watershed	(km)	0.9	2.5	1.1	2.5	1.5	1.3	1.2	3.0		
Length of drainage canal	(km)	5.5	4.3	4.3	3.5	0.8	1.6	1.9	0.0		
EL at the remotest point	(m)	172	178	172	178	171	173	169	183		
EL at the outlet of area	(m)	170	170	170	168	170	170	168	163		
Tl/1	(hr)	2.7	4.7	3.3	4.4	5.6	3.4	4.5	4.2		
Tp/2	(hr)	8.7	10.7	9.3	10.4	11.6	9.4	10.5	10.2		
Tr/3	(hr)	17.5	21.4	18.7	20.8	23.2	18.9	21.0	20.4		
Q	(mm)	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6		
qp	(m^3/sec)	0.6	5.0	0.3	3.8	0.4	0.8	0.2	5.7		16.8
Td/4	(hr)	1.7	1.3	1.3	1.1	0.2	0.5	0.6	0.0		

No.		18	19	20	21	22	23	24	25	26	Total
Area	(ha)	32	185	50	107	67	67	433	248	594	1783
Length of the watershed	(km)	0.85	2	1.8	2.5	1.3	0.95	3.4	2	5	
Length of drainage canal	(km)	0.65	5	3.2	3.2	1.5	2	0	4	1.4	
EL at the remotest point	(m)	171.5	184	175	183	171	183	194.5	184.5	194.5	
EL at the outlet of area	(m)	169.9	175	171.5	171.5	169	170	171	166	165.5	
Tl/1	(hr)	2.8	3.7	4.5	4.2	3.9	1.6	4.5	2.9	6.1	
Tp/2	(hr)	8.8	9.7	10.5	10.2	9.9	7.6	10.5	8.9	12.1	
Tr/3	(hr)	17.6	19.3	20.9	20.4	19.8	15.2	20.9	17.8	24.1	
Q	(mm)	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	
qp	(m^3/sec)	0.4	2.3	0.6	1.3	0.8	1.1	5.0	3.4	6.0	20.9
Td/4	(hr)	0.2	1.5	1.0	1.0	0.5	0.6	0.0	1.2	0.4	

/1 : Tl lag time by Chow
/2 : Tp time from rise to peak
/3 : Tr time from peak to end
/4 : Td time in the drainage canal

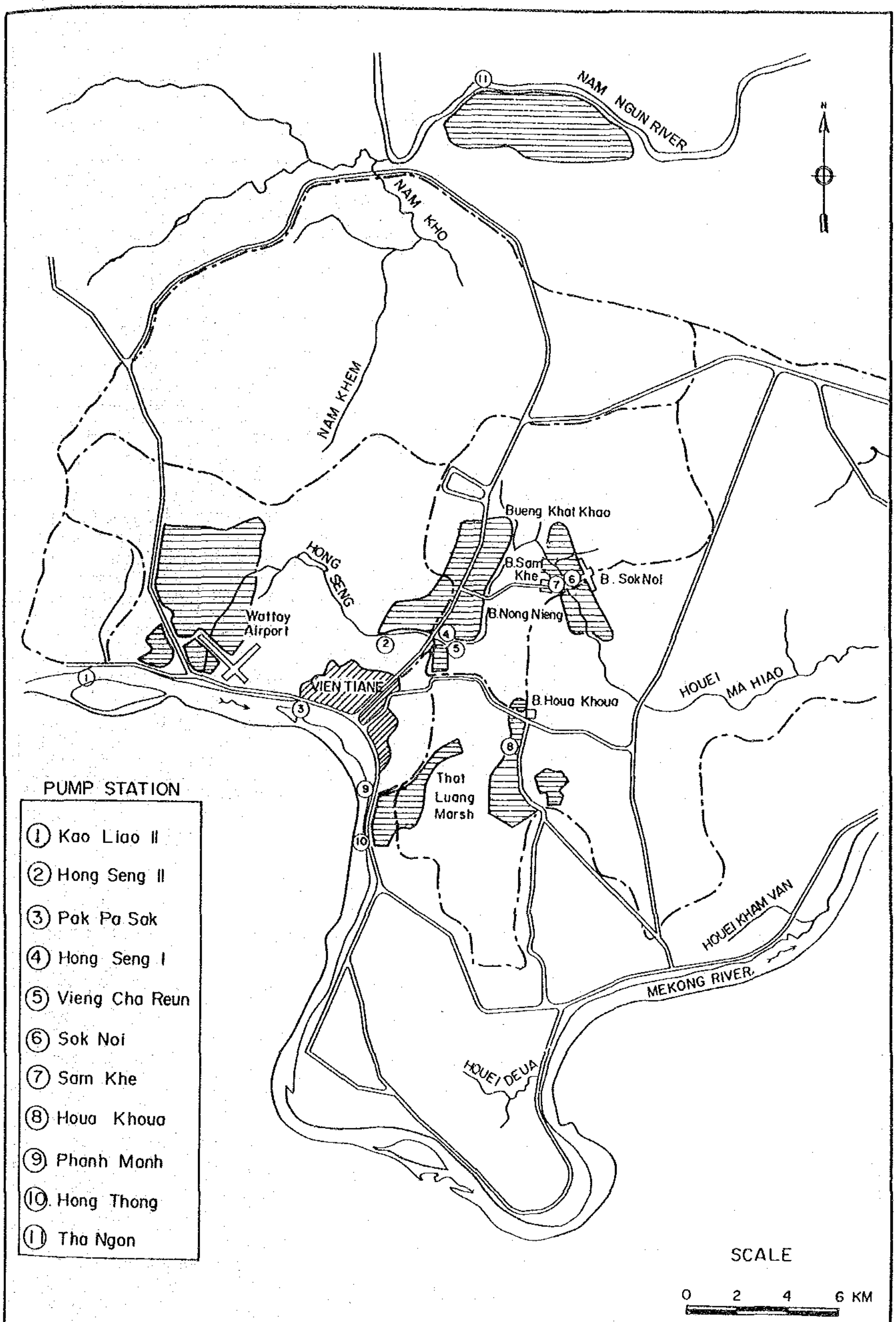


Fig. IV-1 EXISTING IRRIGATION PROJECTS

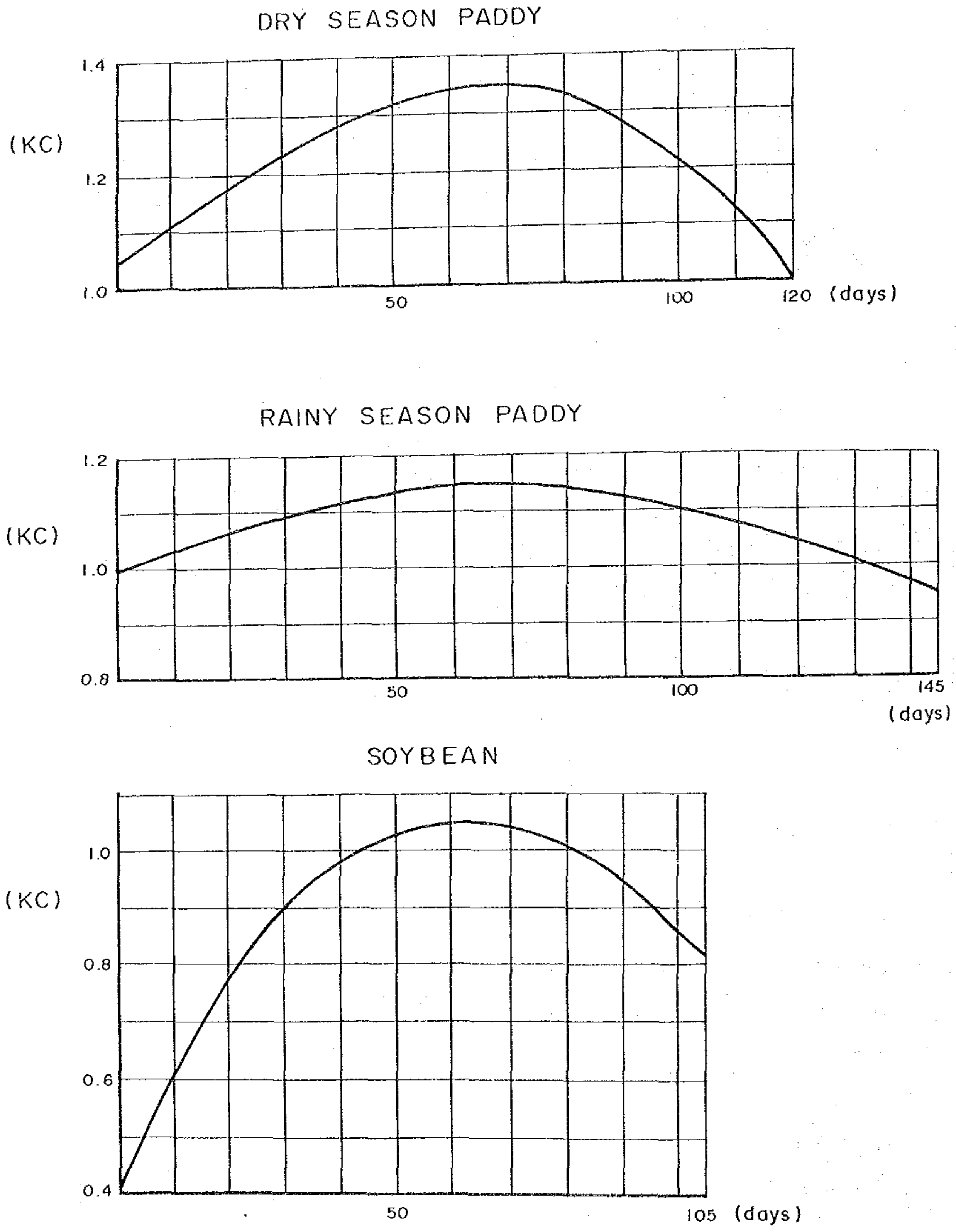
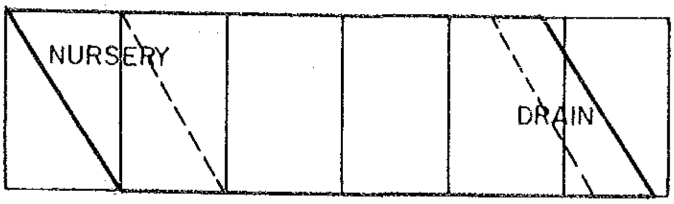


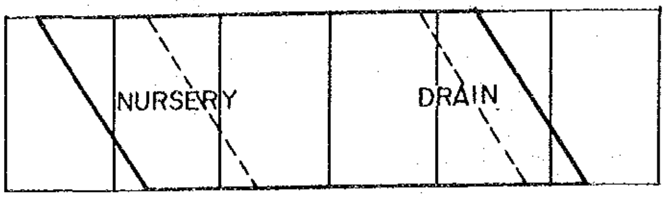
Fig. IV-2 CROP COEFFICIENTS

	J	J	A	S	O	N



		J	J	A	S	O	N
(1) E To	(mm)	–	138	132	138	141	88
(2) KC		–	1.13	1.14	1.12	1.09	1.03
(3) =(1)x(2)	(mm)	–	156	151	155	154	91
(4) Percolation	(mm)	–	45	45	45	45	90
(5) Effective Rainfall	(mm)	–	185	195	185	50	–
(6) = (3) + (4) – (5)	(mm)	–	16	1	15	149	181
(7) Area Factor		–	0.5	1	1	0.78	0.06
(8) = (6) x (7)	(mm)	–	8	1	15	116	11
(9) Puddling Water	(mm)	30	150	–	–	–	–
(10) Nursery Water	(mm)	14	7	–	–	–	–
(11) NW(8)+(9)+(10)	(mm)	44	165	1	15	116	11
(12) DW(11)÷EF	(mm)	72	271	2	25	190	18
(lit/sec/ha)		0.28	1.05	0.02	0.09	0.74	0.07

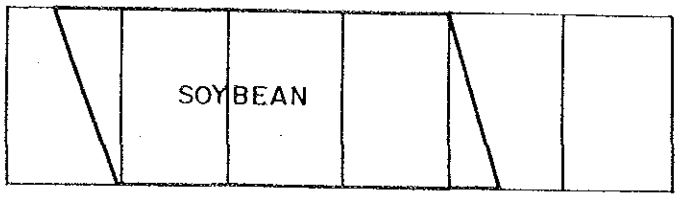
Fig. IV-3 IRRIGATION WATER REQUIREMENT
(RAINY SEASON PADDY)



		D	J	F	M	A	M
(1) E To	(mm)	108	123	141	162	183	–
(2) KC		–	1.21	1.30	1.29	1.28	–
(3) = (1)x(2)	(mm)	–	149	183	209	235	–
(4) Percolation	(mm)	–	90	90	90	90	–
(5) Effective Rainfall	(mm)	–	0	0	20	50	–
(6) = (3)+(4)–(5)	(mm)	–	239	273	279	275	–
(7) Area Factor		–	0.22	0.94	0.97	0.35	–
(8) = (6) x (7)	(mm)	–	53	256	271	97	–
(9) Puddling Water	(mm)	–	150	30	–	–	–
(10) Nursery Water	(mm)	7	14	–	–	–	–
(11) NW (8)+(9)+(10)	(mm)	7	217	286	271	87	–
(12) DW (11) ÷ EF	(mm)	12	356	469	445	159	–
(lit/sec/ha)		0.05	1.38	1.80	1.72	0.62	–

Fig. IV-4 IRRIGATION WATER REQUIREMENT
(DRY SEASON PADDY)

		D	J	F	M	A	F



		D	J	F	M	A	F
(1) ETo	(mm)	108	123	141	162	183	174
(2) KC		0.20	0.80	1.03	0.97	0.40	
(3) = (1) x (2)	(mm)	22	99	145	157	74	
(4) Effective Rainfall	(mm)	0	0	0	20	50	120
(5) = (3) − (4)	(mm)	22	99	145	137	24	
(6) Area Factor		0.25	1	1	1	0.25	
(7) NW (5) x (6)	(mm)	6	99	145	137	6	
(8) DW (7) ÷ EF	(mm)	13	211	309	292	13	
(lit/sec/ha)		0.05	0.81	1.19	1.13	0.05	

Fig. IV-5 IRRIGATION WATER REQUIREMENT
(SOYBEAN)

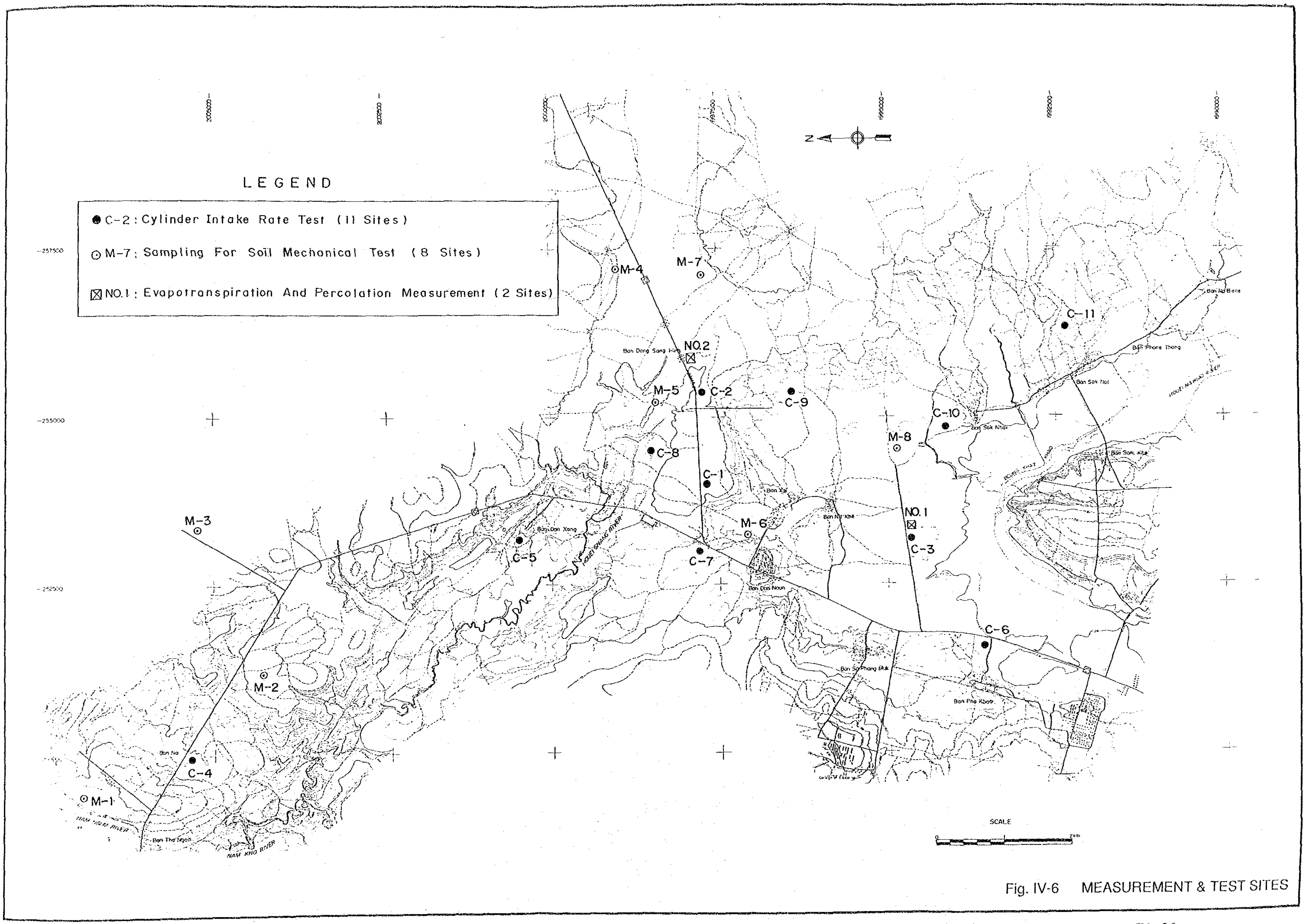


Fig. IV-6 MEASUREMENT & TEST SITES

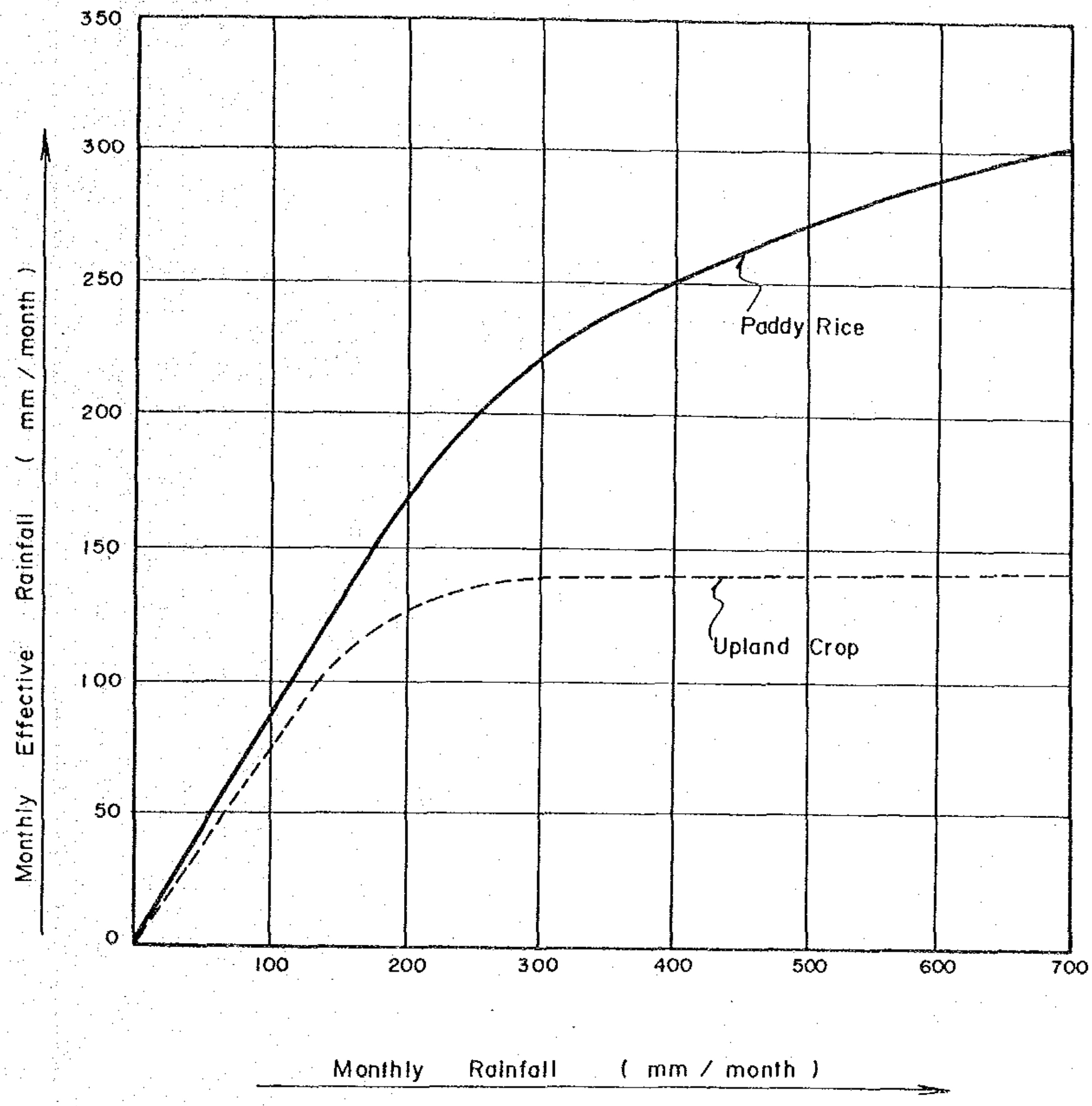


Fig. IV-7 EFFECTIVE RAINFALL CURVE

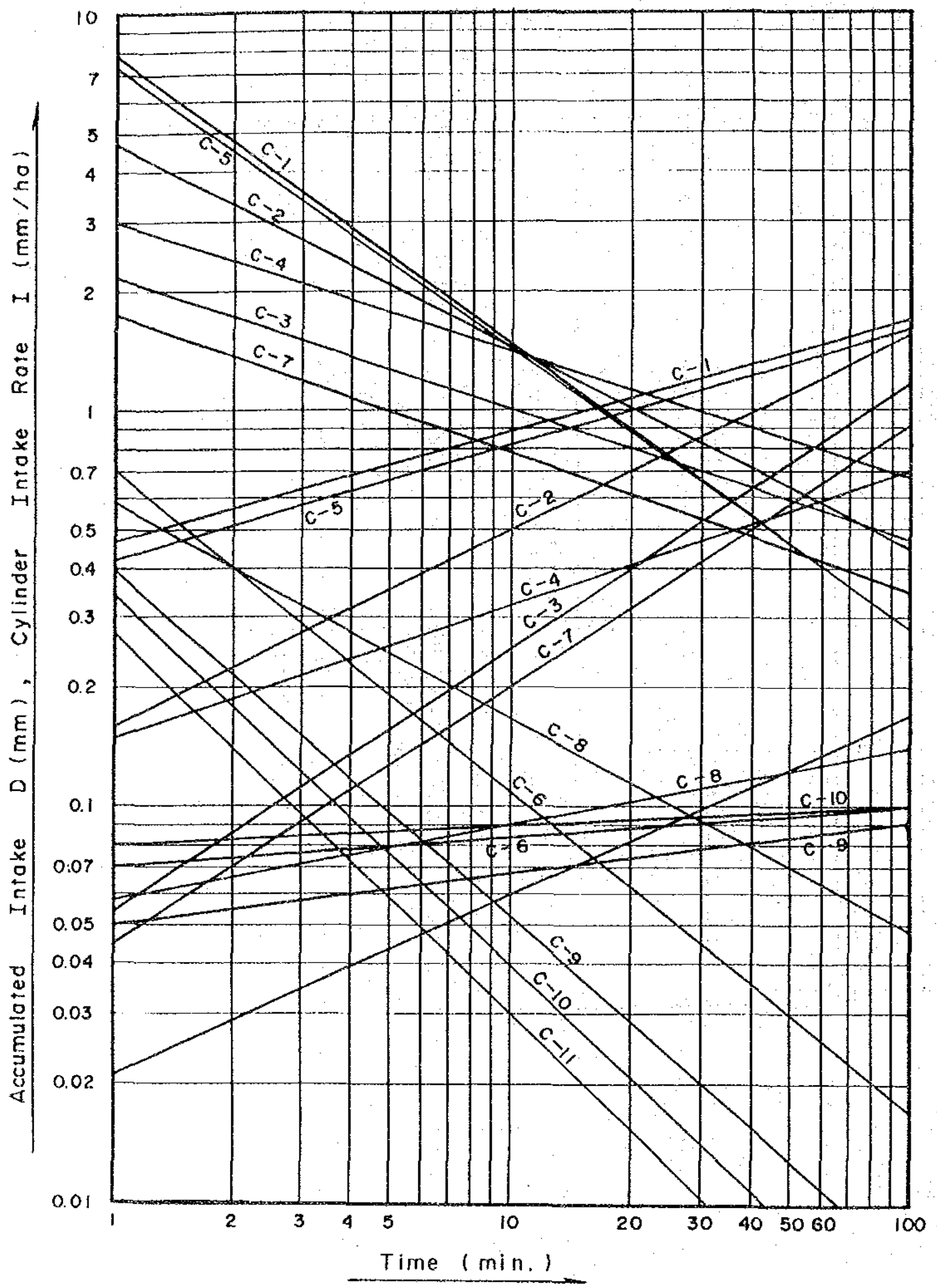


Fig. IV-8 CYLINDER INTAKE RATES

ANNEX V

AGRICULTURE

ANNEX V

AGRICULTURE

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1. General

The agricultural field investigation and studies were carried out in and around the Project area to clarify the present agricultural conditions and to assess the potential land productivity in the Project area. For this purpose, data and information were collected concerning land use, cropping patterns, yield and production of crops, farm inputs, etc. in the Project area.

The data and information were obtained mainly from the Vientiane Municipality office, the Saythany and Saysetha district offices, Integrated Agricultural Development Project (MAF), Salakham Rice Research Station (MAF), Napok Seed Production Center (MAF), Agricultural Research and Experiment Station at Hat Dok Keo (MAF), Foodstuff Company of Vientiane Municipality, State Company Agro-Impex, etc. In addition, a field interview with farmers and village officials was made to obtain more practical information particularly on crop yields, farming practices and labor requirements. The yield survey for rainy season paddy was also carried out in order to obtain the data on paddy yield components and to identify implicated defects of present farming practices.

Taking into account the physical nature of the land, the present agricultural conditions, the socioeconomic background of agriculture and the governmental policy on further agricultural development, the most applicable and profitable agricultural plan is formulated through the following studies:

(1) Land use plan is proposed considering present land use, results of land classification, topographic condition and irrigation development plan.

(2) Suitable crops are selected based on their suitability for land and climate, profitability and familiarity to farmers.

(3) Cropping pattern and farming practices are determined based on the climatic condition, soil condition, available labor force and animals, etc.

(4) Required inputs and expected outputs are estimated based on the present inputs and outputs and the proposed farming practices. Results of crop experiments at research stations of MAF are referred to.

2. Present Condition of Agriculture

2.1 Land Use

Present land use is studied through aerial photo interpretation, and it is confirmed and adjusted through interpretation of satellite photos of SPOT image and field investigation. The series of aerial photos used for the study was shot in November 1981 on a scale of 1:30,000 and SPOT image was shot in December 1986 on a scale of 1:1,000,000.

The lands in the Project area are classified into seven categories comprising paddy field, grass land, forest, village, road, fish pond and river. Present land use in the Project area is illustrated in Fig. V-1.

The extent of each category is as follows:

Category	Originally-planned Area (ha)	Extension Area (ha)	Total (ha)	Proportional Extent (%)
Paddy field	2,259	771	3,030	64
Grass land	34	17	51	1
Forest	435	983	1,418	30
Village	179	28	207	4
Road	17	11	28	1
Fish pond	8	-	8	0
River/stream	8	-	8	0
Total	2,940	1,810	4,750	100

Paddy field occupies 3,030 ha or 64% of the Project area. No other crop is cultivated in a large scale though vegetables are commonly planted in the backyard of farm house.

2.2 Cropping Pattern

The Project area is characterized as a paddy mono-culture area. Almost all the paddy fields are cultivated under rainfed condition in the rainy season. In the dry season of 1987, only 139 ha of paddy fields located in the southern part of the Project area (Ban Pha Khao and