TABLE VIII-3-5 FLOOD DAMAGE BY GROWING STAGE OF PADDY

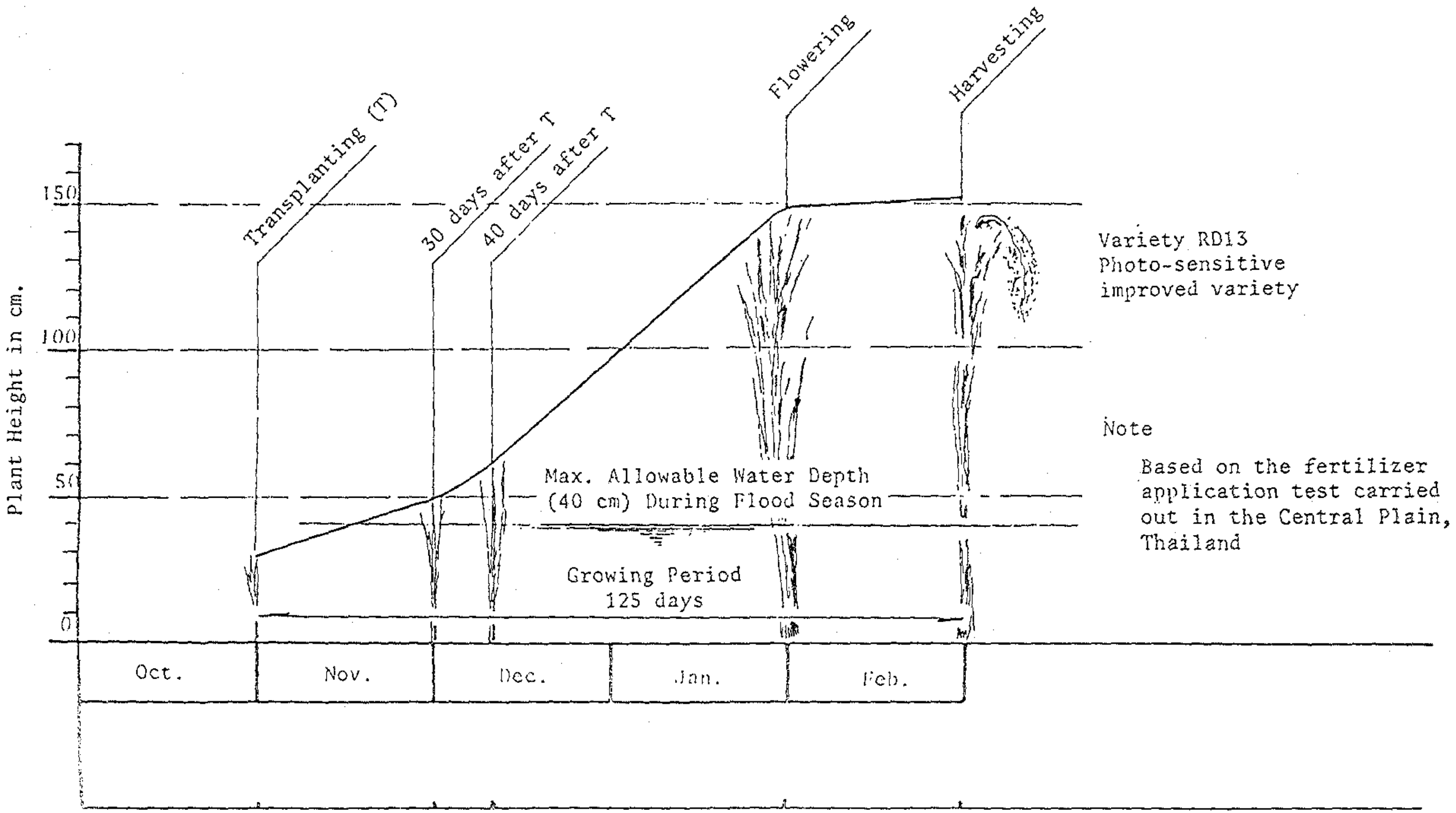
Growing Stage of Paddy	Submerged Condition	Water Quality	Yield Reduction Rate in % by Submerged Duration in days			
			1 to 2	2 to 4	5 to 7	mt 7
1. 20 days after transplanting (Tilling Stage)	Completely Submerged	Clean	10	20	30	30
2. Young Panicle Formation Stage	Partly Subm'd	Clean	10	30	65	90 - 100
	Partly Subm'd	Muddy	20	50	85	90 - 100
	Completely	Clean	25	45	80	90 - 100
	Completely	Muddy	70	80	85	90 - 100
	Frequently	Clean	35	40	45	45 - 50
3. Heading Stage	Completely	Muddy	30	80	90	90 - 100
	Completely	Clean	15	25	30	70
4. Ripening Stage	Completely	Muddy	5	20	30	30
	Completely	Clean	0	15	20	20

Note: "Partly" means leaves (9 - 15 cm long) remain above water surface.
"mt" means "more than".

TABLE VIII-3-6 DRAINAGE SERVICE AREA BY SUB-BASIN

No.	Sub-Area	Basin Area (sq.km)	Beneficial Area Paddy (ha)	Beneficial Area Rubber (ha)	Beneficial Area Total (ha)
1	Mae Nam Yakang	16.2	70	50	120
2	Khlong Ba Keng	12.6	-	-	-
3	Khlong Ku Ra Po	11.0	590	240	830
4	Khlong Mae Lamphu	11.0	-	-	-
5	Khlong Na Ko	12.0	520	280	800
6	Khlong To Che	37.6	2,290	1,740	4,030
7	Bang Nara -1	6.3	-	-	-
8	Khlong Chang	53.4	750	3,880	4,630
9	Khlong Maru Bo	7.7	-	-	-
10	Existing Pileng	51.2	-	-	-
11	Khlong Bang Toei	13.0	-	-	-
12	Khlong Khok Ngu	6.5	-	-	-
13	Khlong Lan	9.2	-	-	-
14	Bang Nara -2	6.2	-	-	-
15	Bang Nara -3	10.3	130	-	130
16	Khlong sala mai	6.8	500	-	500
17	NBR - East	16.5	-	-	-
18	Khlong Lai	9.1	-	-	-
19	Khlong To Lang	12.8	-	-	-
20	Bang Nara -4	8.5	-	-	-
21	Bang Nara -5	6.0	-	-	-
22	Khlong Ku Cham	14.5	-	-	-
23	Khlong Pru Kab Daeng	22.4	-	-	-
24	NBR - West	15.3	-	-	-
25	Khlong Ku Bae Ya Hae	14.3	-	-	-
26	Bang Nara - 6	9.8	-	-	-
27	Khlong Pu Cho Ya Mu	21.3	-	-	-
28	Khlong Sapi Yo	35.0	-	-	-
29	Bang Nara - 7	10.5	-	-	-
	Total	467.0	4,850	6,190	11,040

FIGURE VIII-3-1 PADDY STEM LENGTH BY STAGE



APPENDIX IX. PRELIMINARY DESIGN OF CIVIL WORK

IX-1 Tidal Regulator

IX-1-1 Site Topography, Geology and Soil Properties

(1) Upper Tidal Regulator (UTR-1)

Topography and Geology

The topography and geology around the site are shown in Figure IX-1-1. Location of the foundation soil investigations so far carried out is explained in Figure IX-1-2. The geological cross-sections of the UTR-1 site for regulator, closure, etc. are shown in Figures IX-1-3 to IX-1-5.

Soil Properties

Soil tests on samples taken from drill holes were carried out by the soil laboratory of Pattani Project (RID). The items are Liquid limit (4 samples), Plastic limit (4 samples) and Grading (17 samples).

. N-Value
Distribution of N-values by depth is shown in Figure IX-1-6.

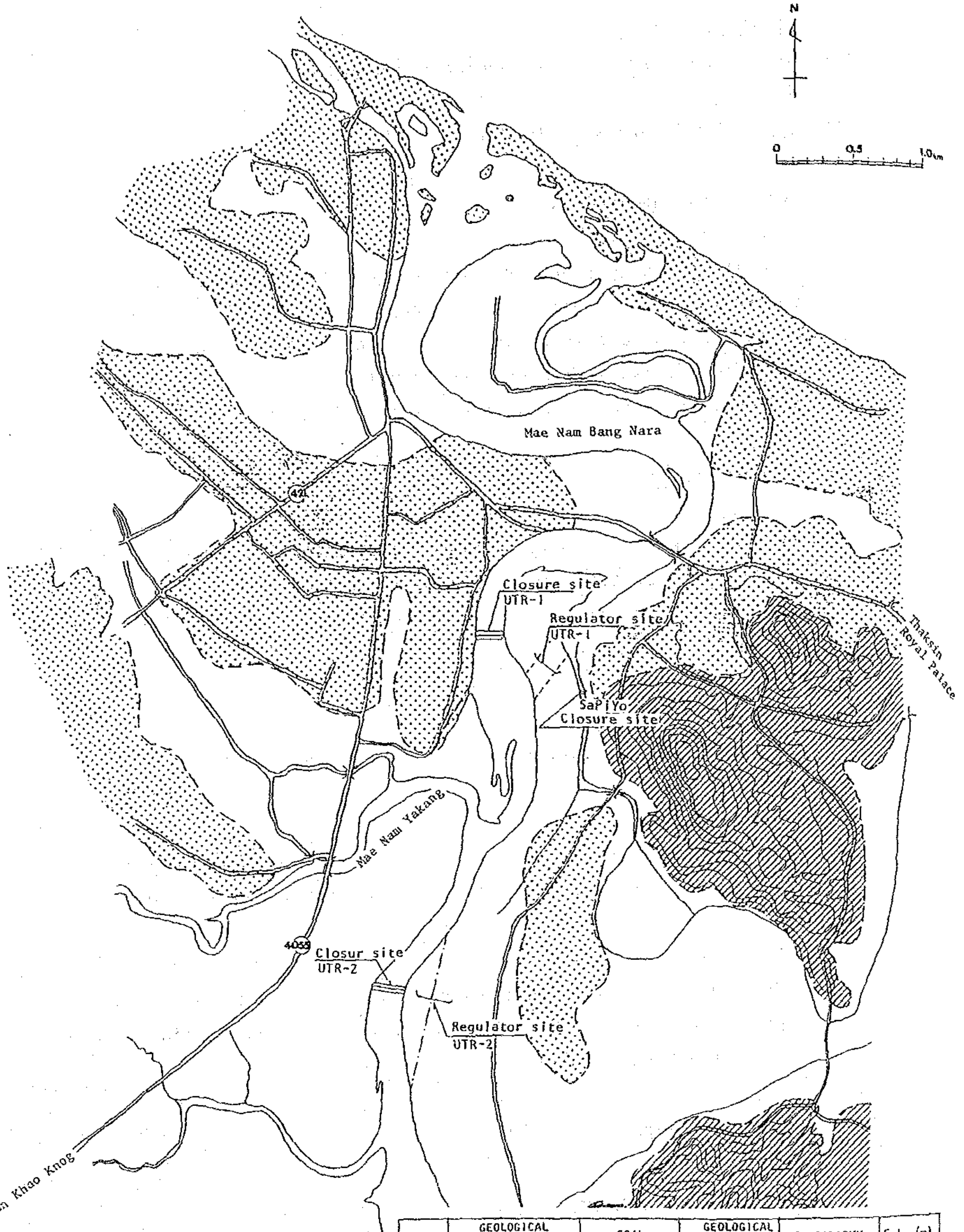
. Consistency
The Plasticity Chart of Acu layer is shown in Figure IX-1-7. The liquid limit (WL) is 50% and distributed around Line A.

. Grain Size
The Grain Size Distribution Curves for Asu Layer and Asl layer are shown in Figure IX-1-8. Asu mainly consists of fine sand and Asl of medium sand.

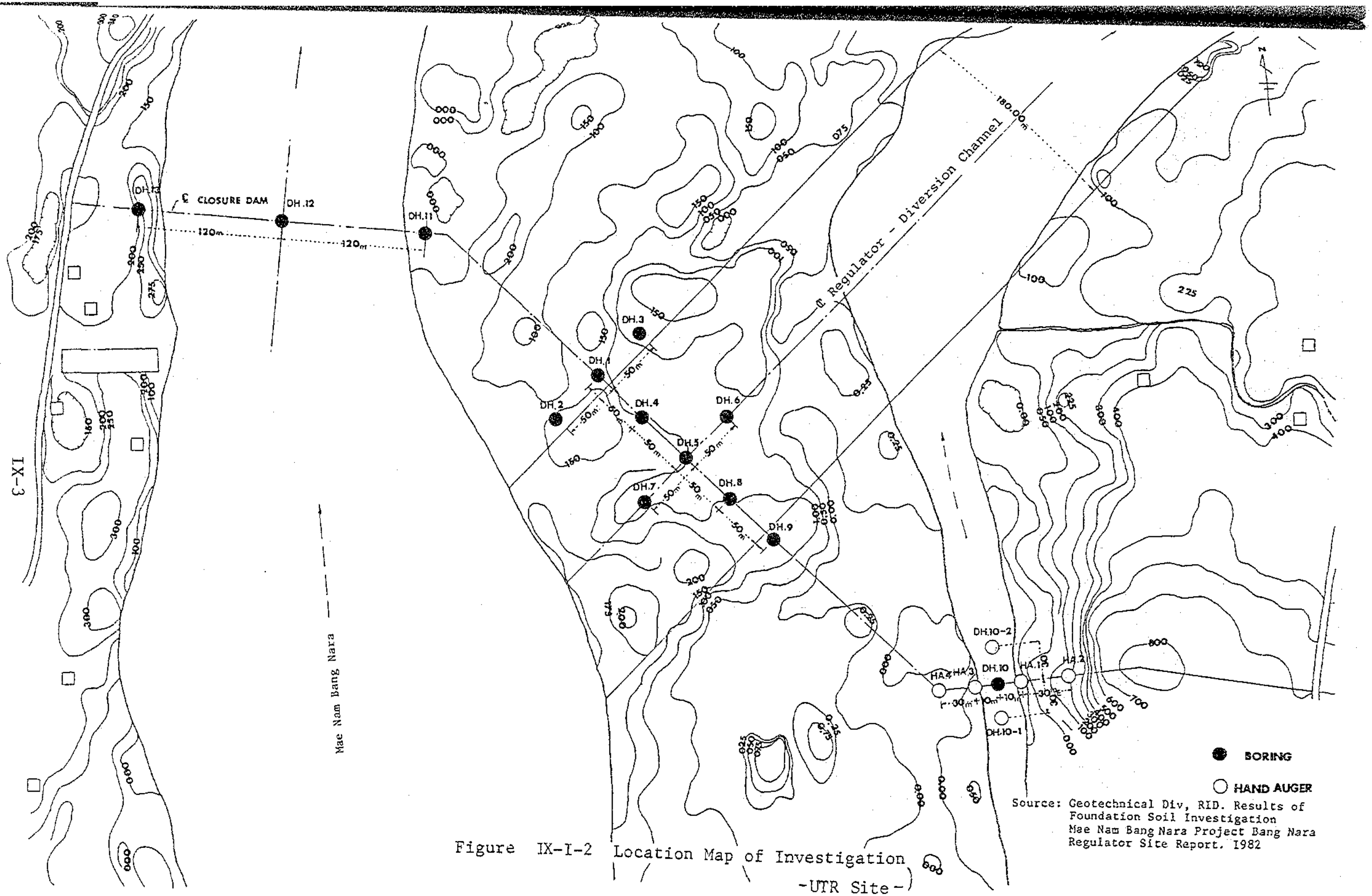
(2) Lower Tidal Regulator (LTR)

Topography and Geology

Figure IX-I-I Geology and Topography of UTR Site



MARK	GEOLOGICAL NAME	SOIL	GEOLOGICAL AGE	TOPOGRAPHY	E.L (m)
	ALLUVIUM (Riverrine and Constal Deposits)	Silt, Clay Sand and Peat	Quaternary	Lowland Lagoon Swanp	0~2
	ALLUVIUM (Beach Sand)	Sand	Quaternary	Beach ridge and Old beach ridge	2~5
	GRANITE AND RESIDAL SOIL	Granite Weathered Granite	Triassic	Mountain	50~300



Source: Geotechnical Div, RID. Results of Foundation Soil Investigation Mae Nam Bang Nara Project Bang Nara Regulator Site Report. 1982

Figure IX-I-2 Location Map of Investigation -UTR Site-

Fihure IX-I-3 Geological Cross-Section (UTR Site-Regulator Body)

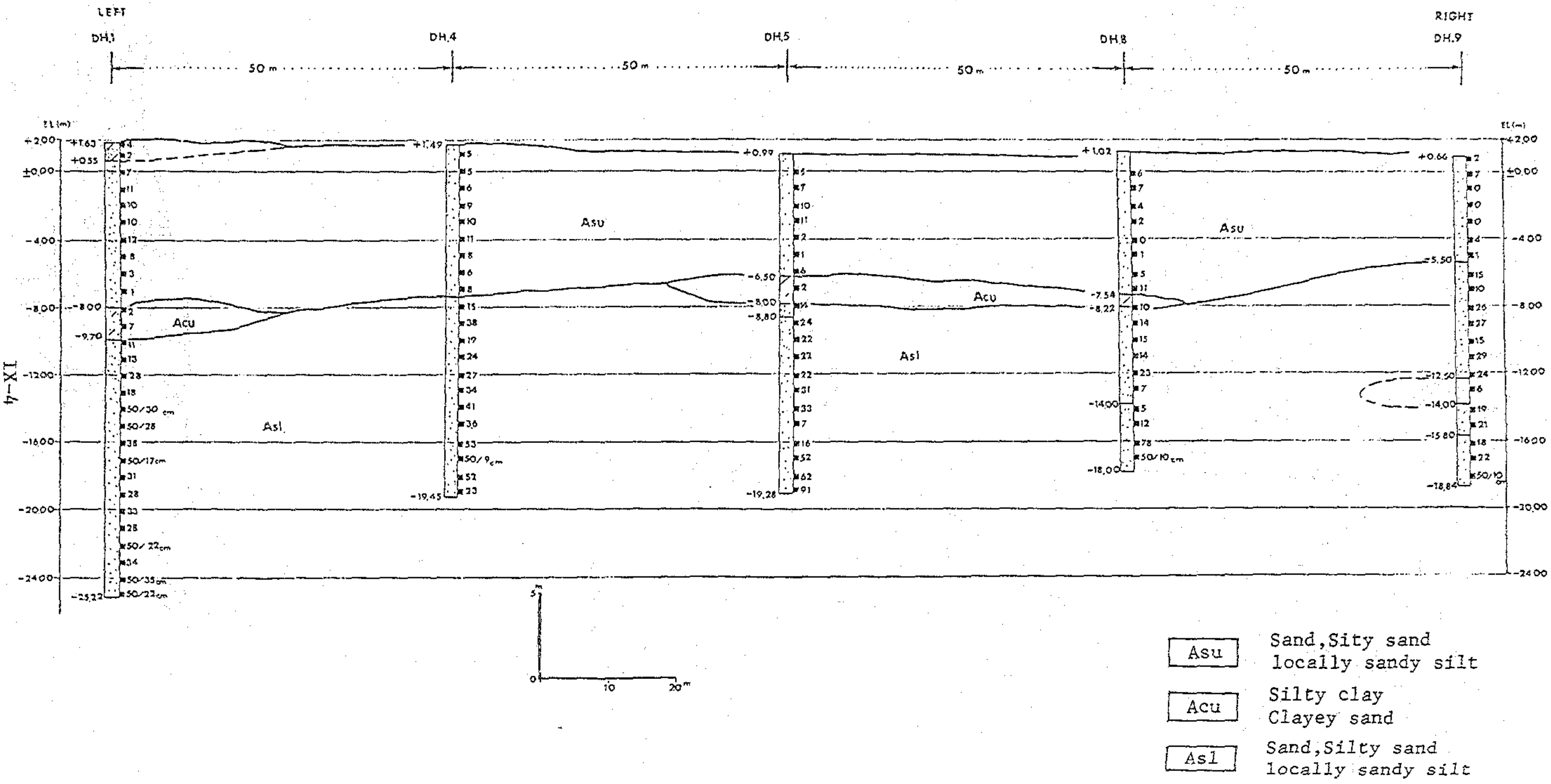


Figure IX-I-4 Geological Cross-Section (UTR Site - Closure dam)

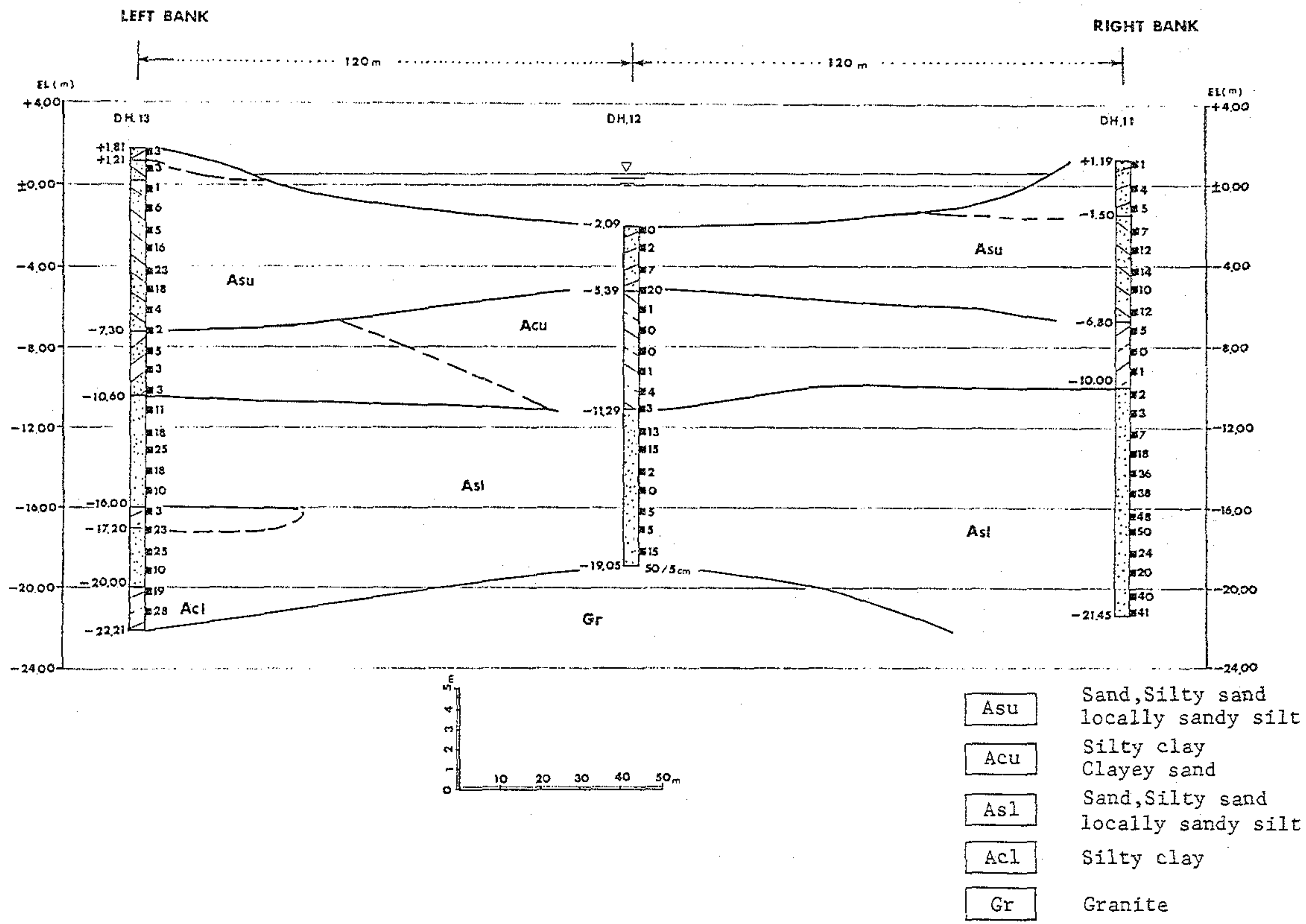


Figure IX-1-5 Geological Cross-Section (UTR Site - Sapi Yo Closure dam)

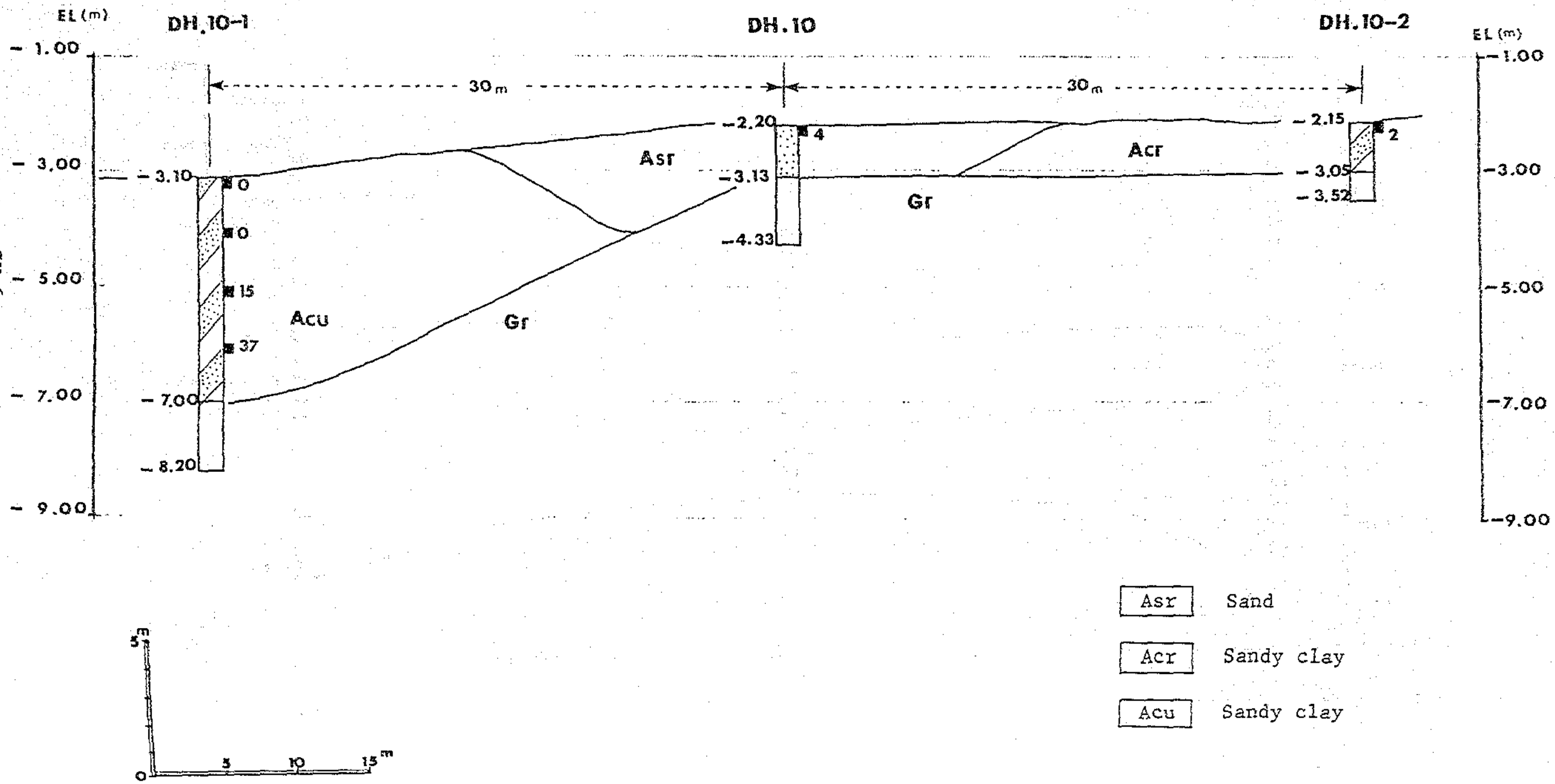
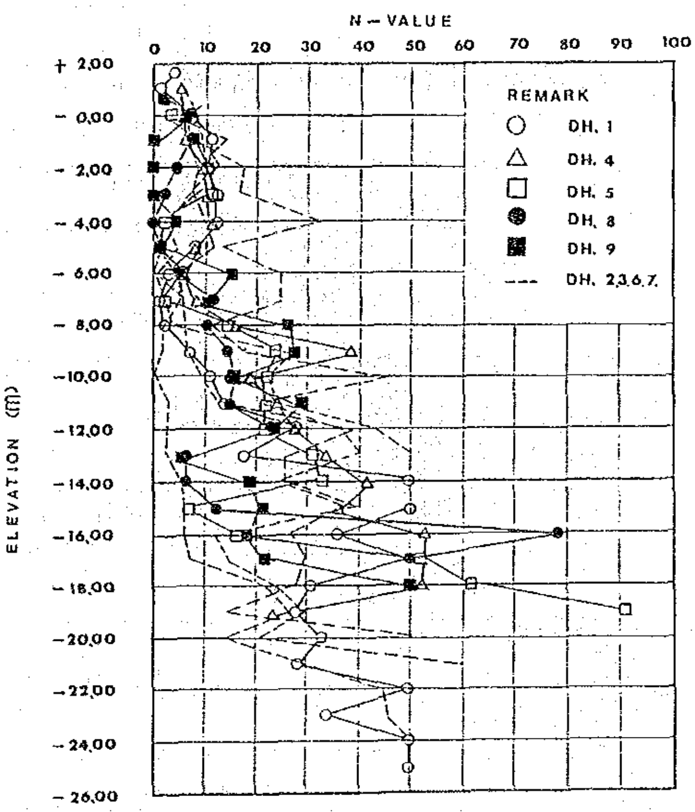
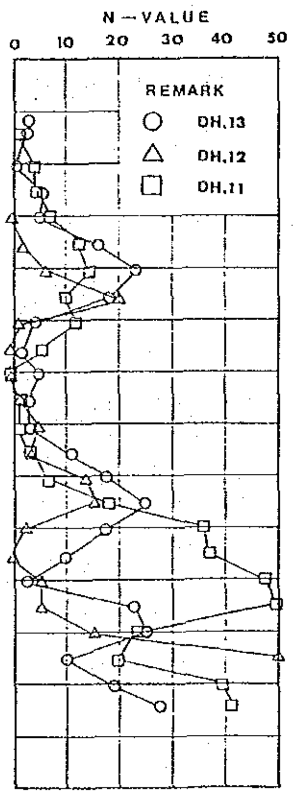


Figure IX-1-6 N-value by Elevation - UTR Site



UTR-I Site--Regulator



UTR-I Site--Closure Dam

Figure IX-1-7 Plasticity Chart (UTR Site - Acu Layer)

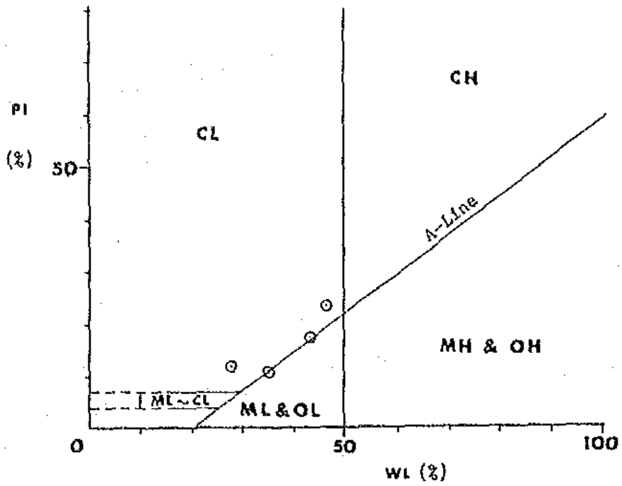


Figure IX-1-8 Grain Size Distribution Curves (UTR)

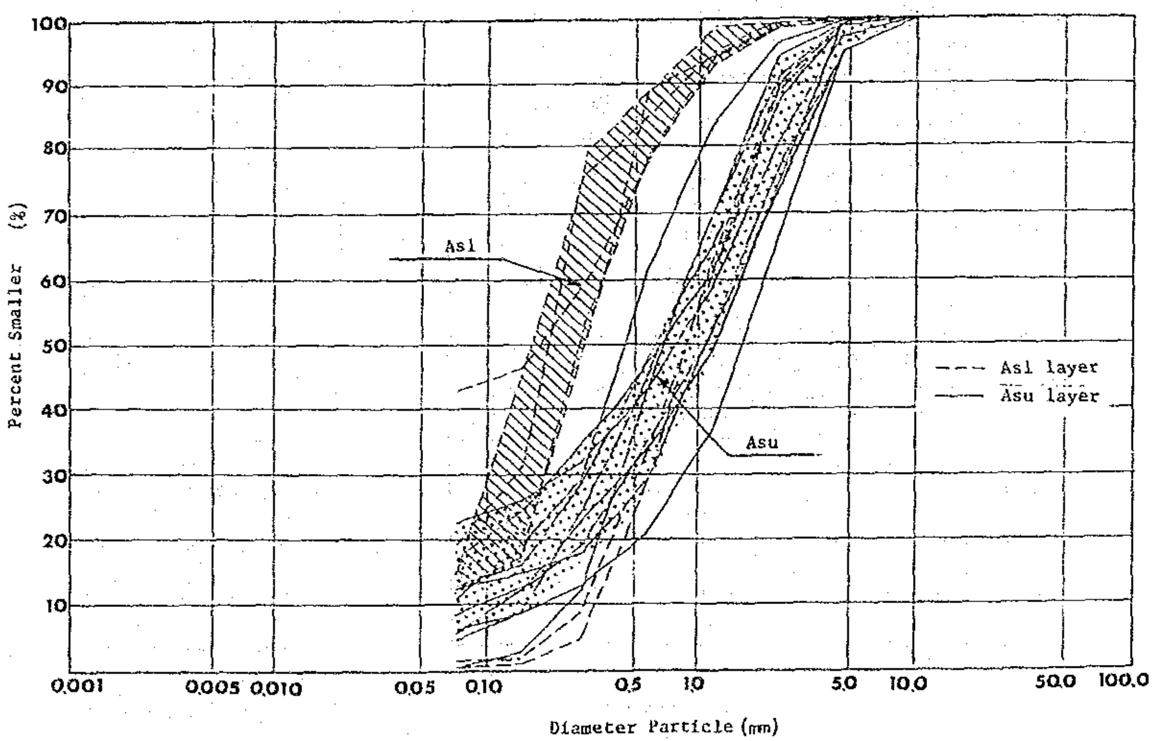
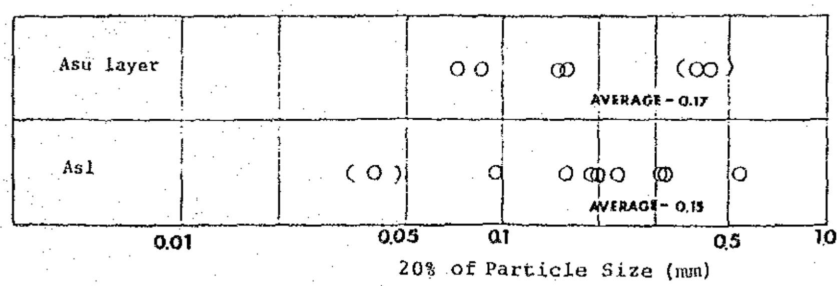


Figure IX-1-9 Distribution of 20% of Particle Grain Size-UTR Site



(2) Lower Tidal Regulator (LTR)

Topography and Geology

The geology and topography around LTR are outlined in Figure IX-1-10. Location of the foundation soil investigations so far undertaken is explained in Figure IX-1-11. Geological cross-sections of the regulator site and the closure dam are shown in Figures IX-1-12 and IX-1-13.

Soil Properties

Soil tests on samples taken from drill holes were carried out by the soil laboratory of Pattani Project (RID). The items are Liquid limit (17 samples), Plastic limit (17 samples) and Granding (8 samples).

. N-Value

Distribution of N-values by depth is shown in Figure IX-1-14. At the regulator site, it is N≈30 at a depth of 25 m, and at the dam site, N=30 at a deeper depth of 33 m.

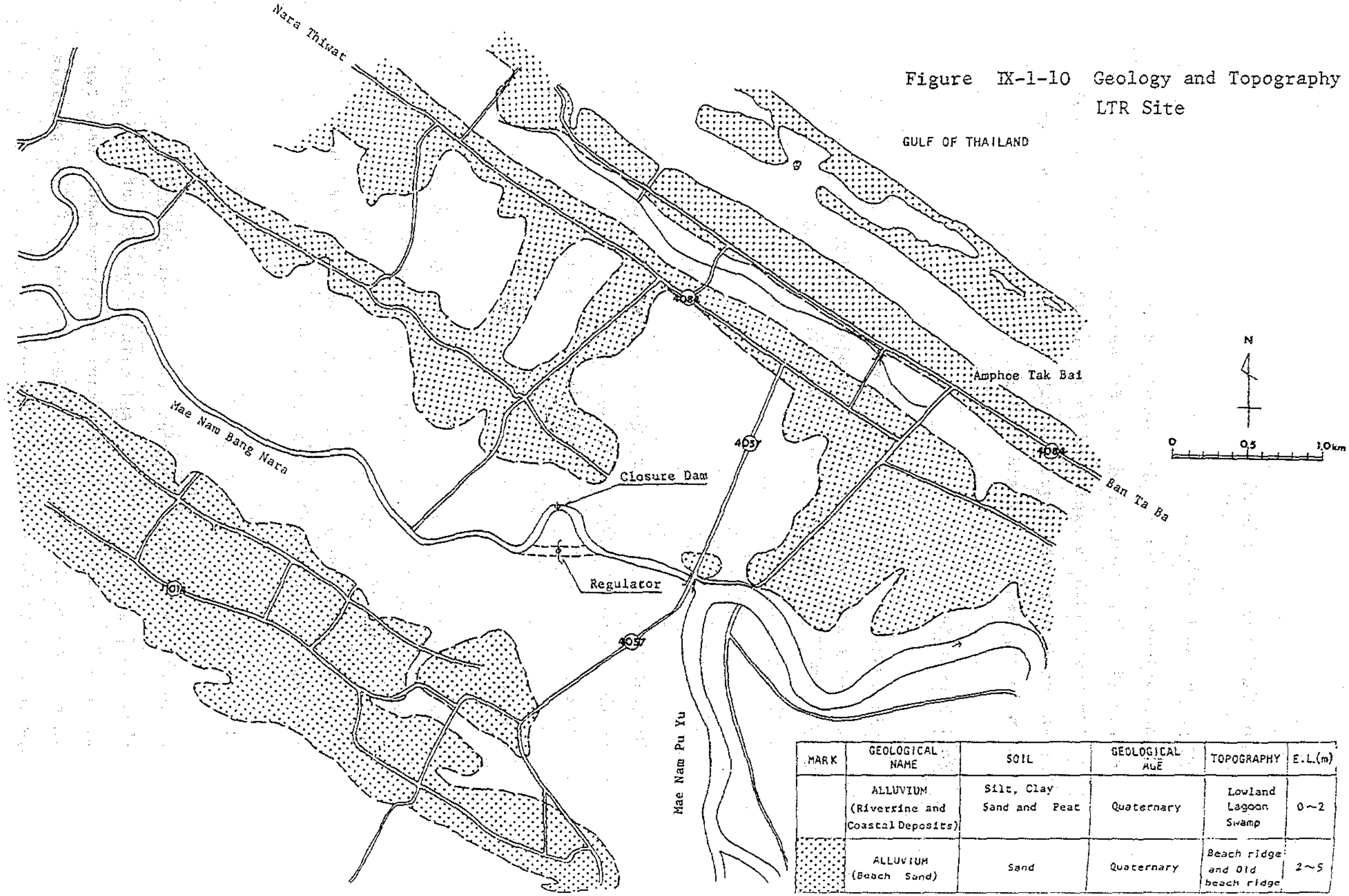
. Consistency

Plasticity charts for each of the layers, Ac1, Ac2, Ac3 and Ac4, are shown in Figure IX-1-15. Ac1 layer shows the liquid limit of WL>50% except in some part and is classified as CH. It is a layer that requires particular caution both in strength and in consolidation settlement.

. Grain Size

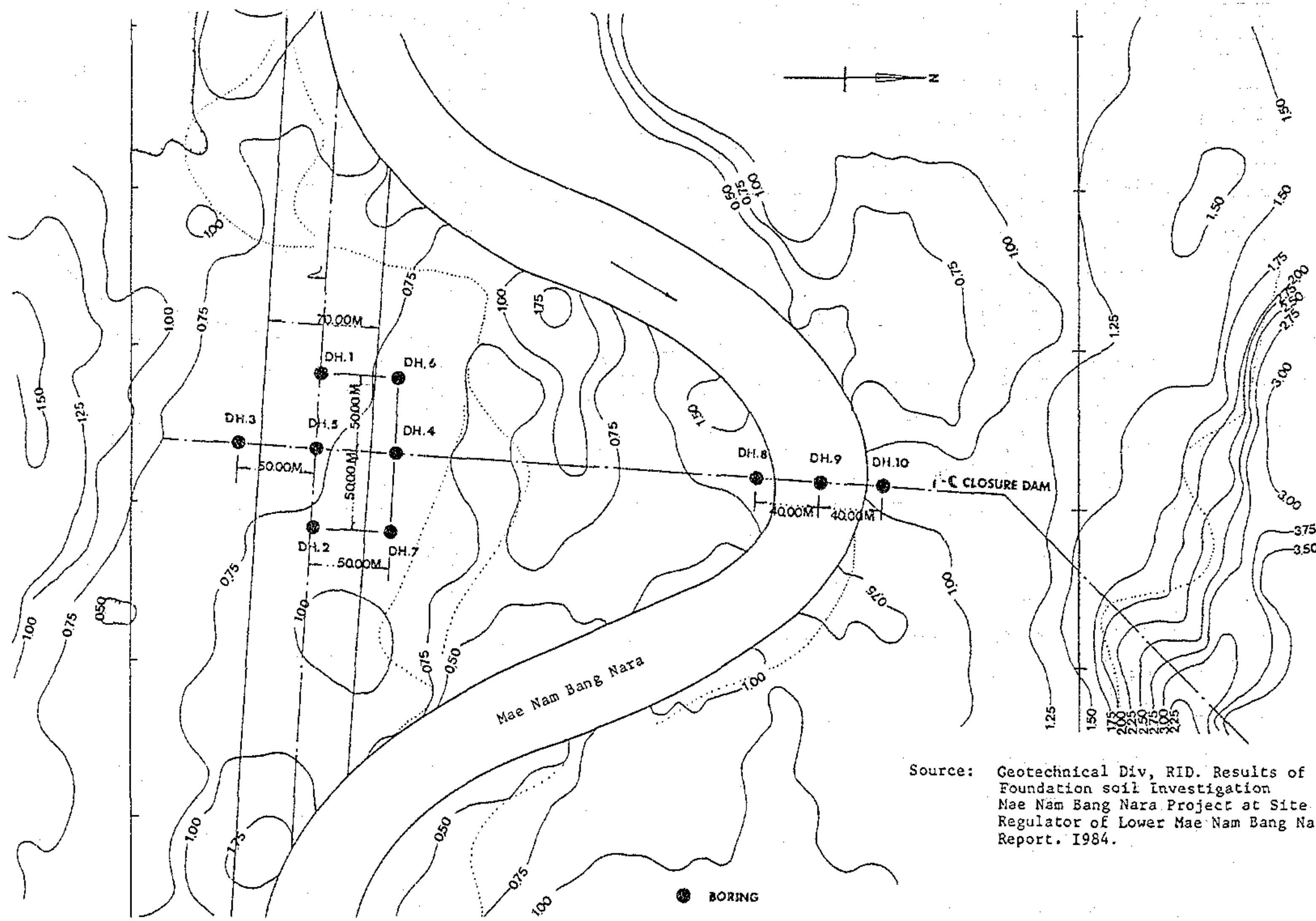
Grain size distribution curves for As1, Asℓ and As2 layers are shown in Figure IX-1-16. As As1 mainly consists of fine sand while As2 mainly consists of medium to coarse sand, these two layers can be differentiated. Distribution of 20% of particle grain size is shown in Figure IX-1-17.

Figure IX-1-10 Geology and Topography of LTR Site



MARK	GEOLOGICAL NAME	SOIL	GEOLOGICAL AGE	TOPOGRAPHY	E.L.(m)
	ALLUVIUM (Riverrine and Coastal Deposits)	Silt, Clay Sand and Peat	Quaternary	Lowland Lagoon Swamp	0~2
(dotted)	ALLUVIUM (Beach Sand)	Sand	Quaternary	Beach ridge and Old beach ridge	2~5

Figure IX-1-11 Location Map of Investigation - LTR Site



Source: Geotechnical Div, RID. Results of Foundation soil Investigation Mae Nam Bang Nara Project at Site of Regulator of Lower Mae Nam Bang Nara Report. 1984.

Figure IX-1-12 Geological Cross-Section (LTR Site - Regulator Body)

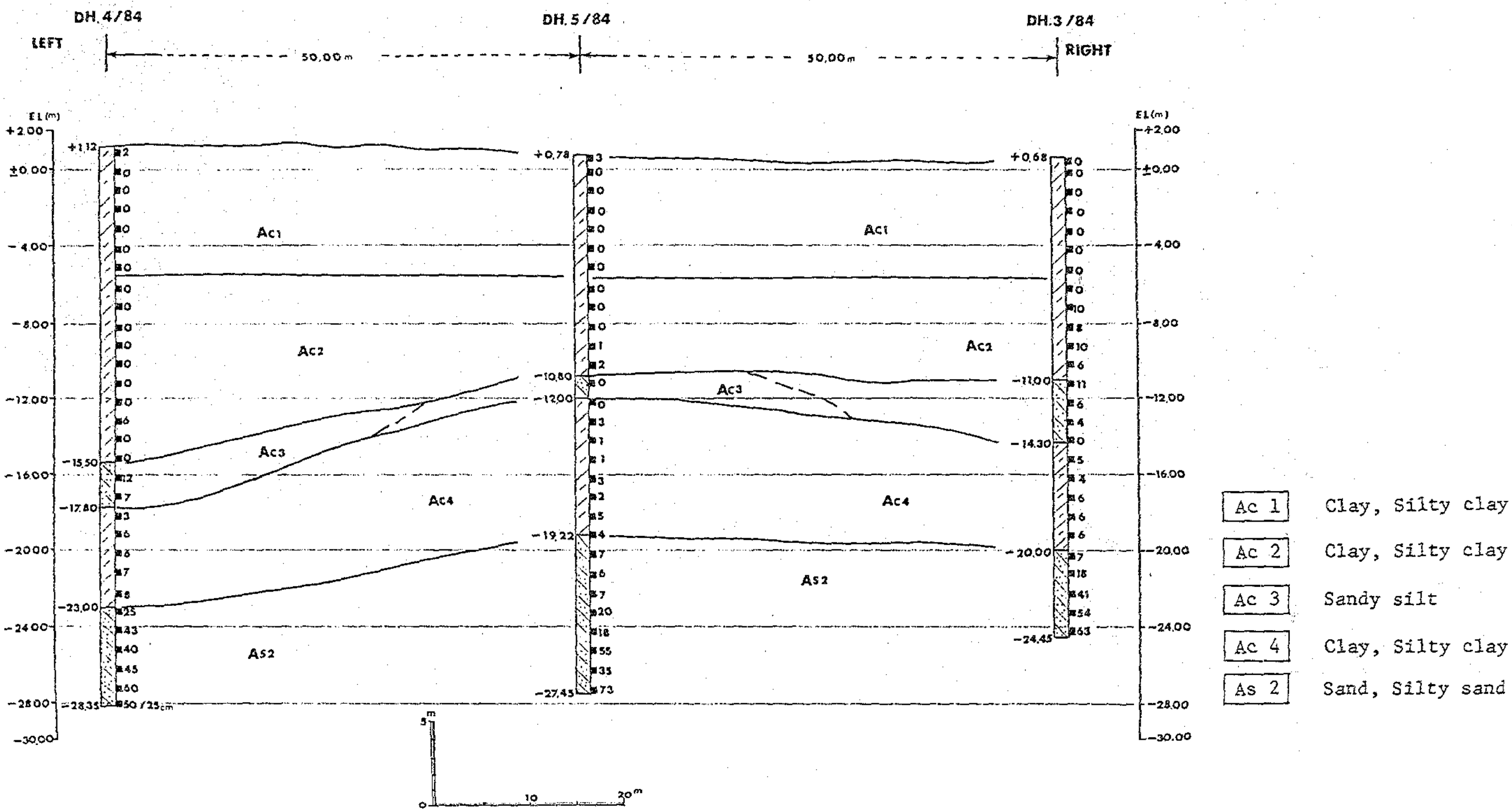


Figure IX-1-13 Geological Cross-Section (LTR Site - Closure Dam)

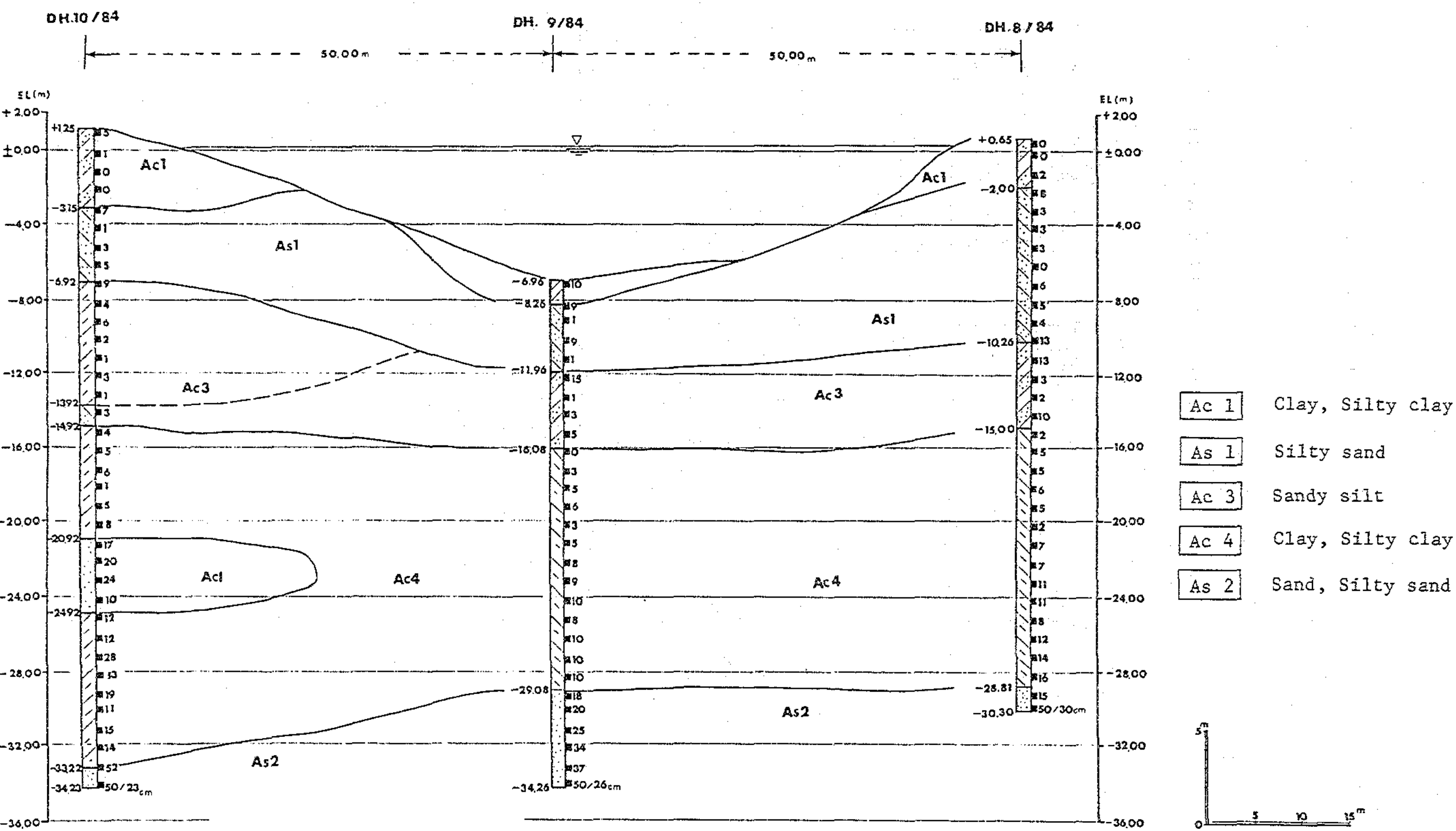
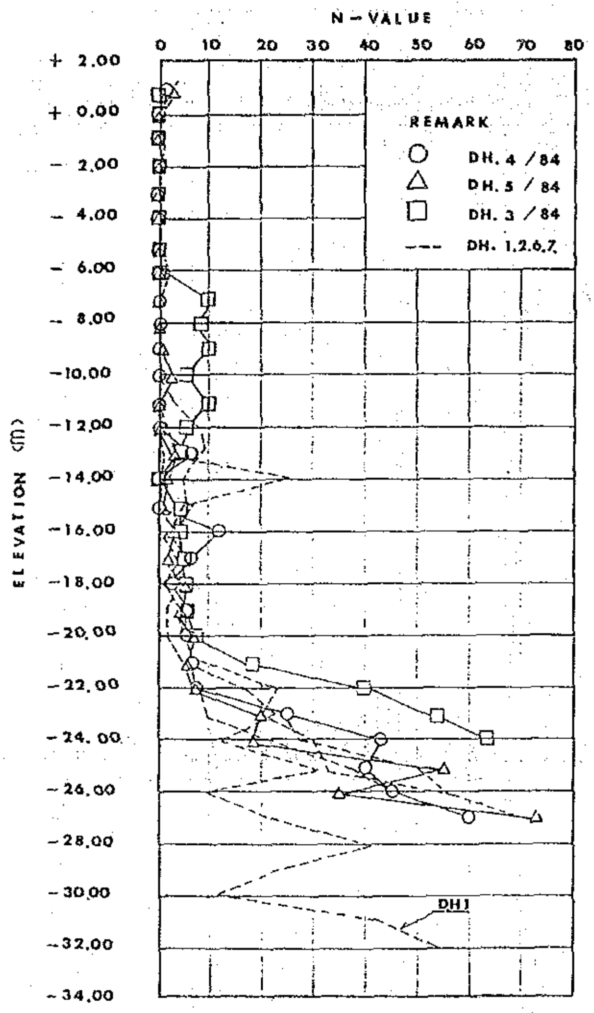
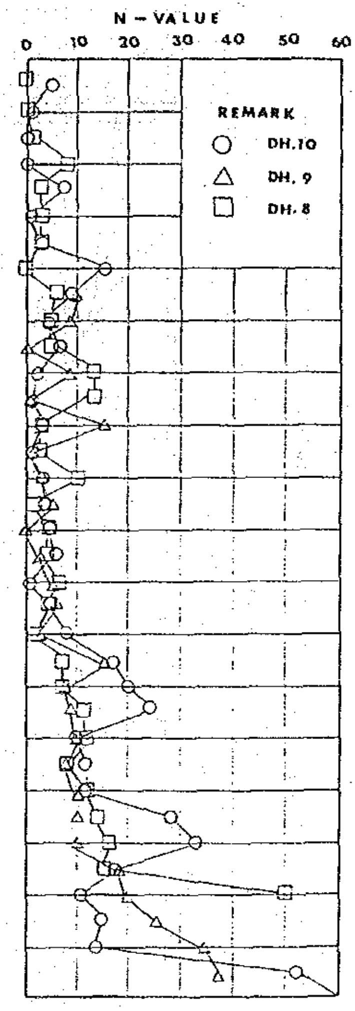


Figure IX-1-14 N-value by Elevation - LTR Site



LTR Site- Regulator



LTR Site-Closure

Figure IX-1-15 Plasticity Chart - LTR Site

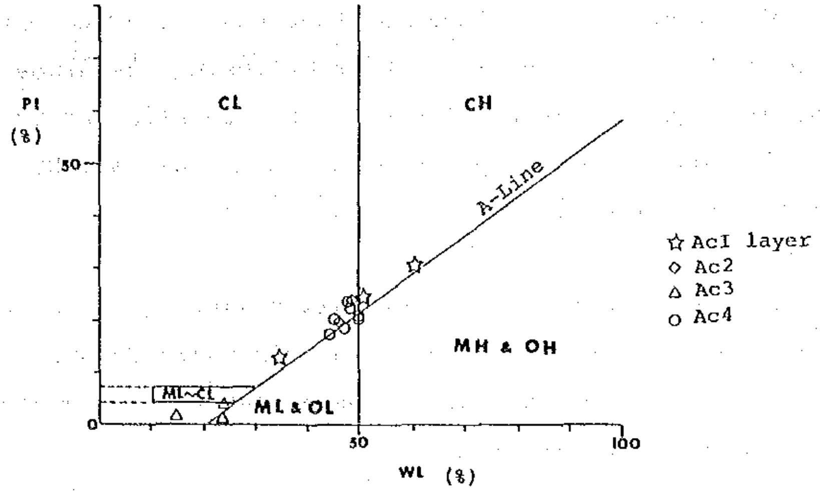


Figure IX-1-16 Grain Size - LTR Site

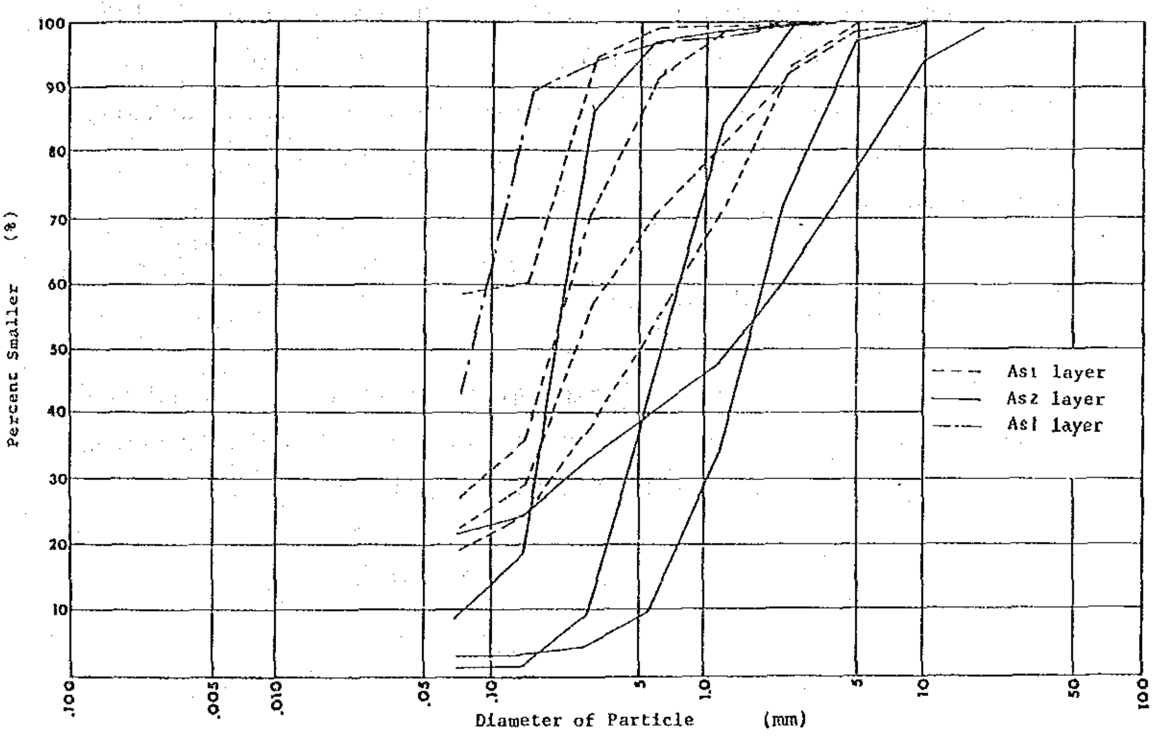
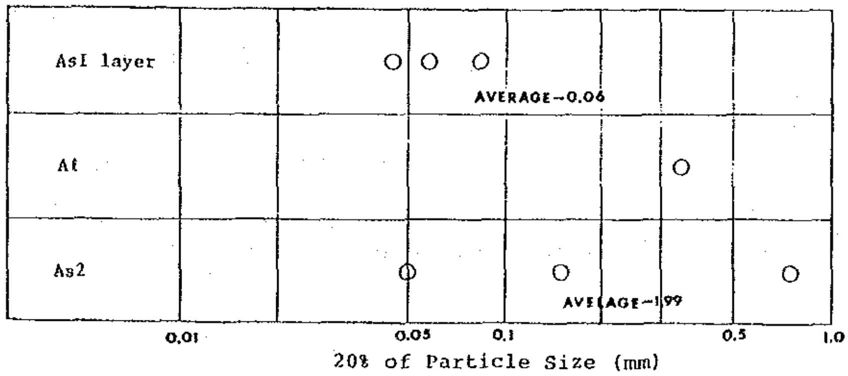


Figure IX-1-17 Distribution of 20% of Particle Grain Size - LTR Site



(3) Seismicity

Distribution of earthquakes that have occurred within the range of 0° - 10°N and 59° - 104°E enclosing the Study area is shown in Figure IX-1-18. The data were compiled by GRBDS [*1] from the NOAA-EDIS Earthquake Data File (1981) and Nutalaya and Sodsri's Data (1983).

According to the result of this study, hardly any seismicity has been recorded in the Peninsula Malaysia. Only a few earthquakes in the range of magnitude 4.0 - 5.4 have been observed in the Malaysia.

According to Seed, H.B., Idriss, I.M. and Arango, I (1983), the Study area is not subject to ground acceleration of more than 0.03 g, and even in the alluvial plain, not more than 30% of same. In other words, seismic impact on structures is considered nil.

(4) Materials of Rock and Soil

Based on the results of geological reconnaissance and the data of GRBDS, the material of rock and soil in the surrounding area of the proposed site is shown in Figure IX-1-19.

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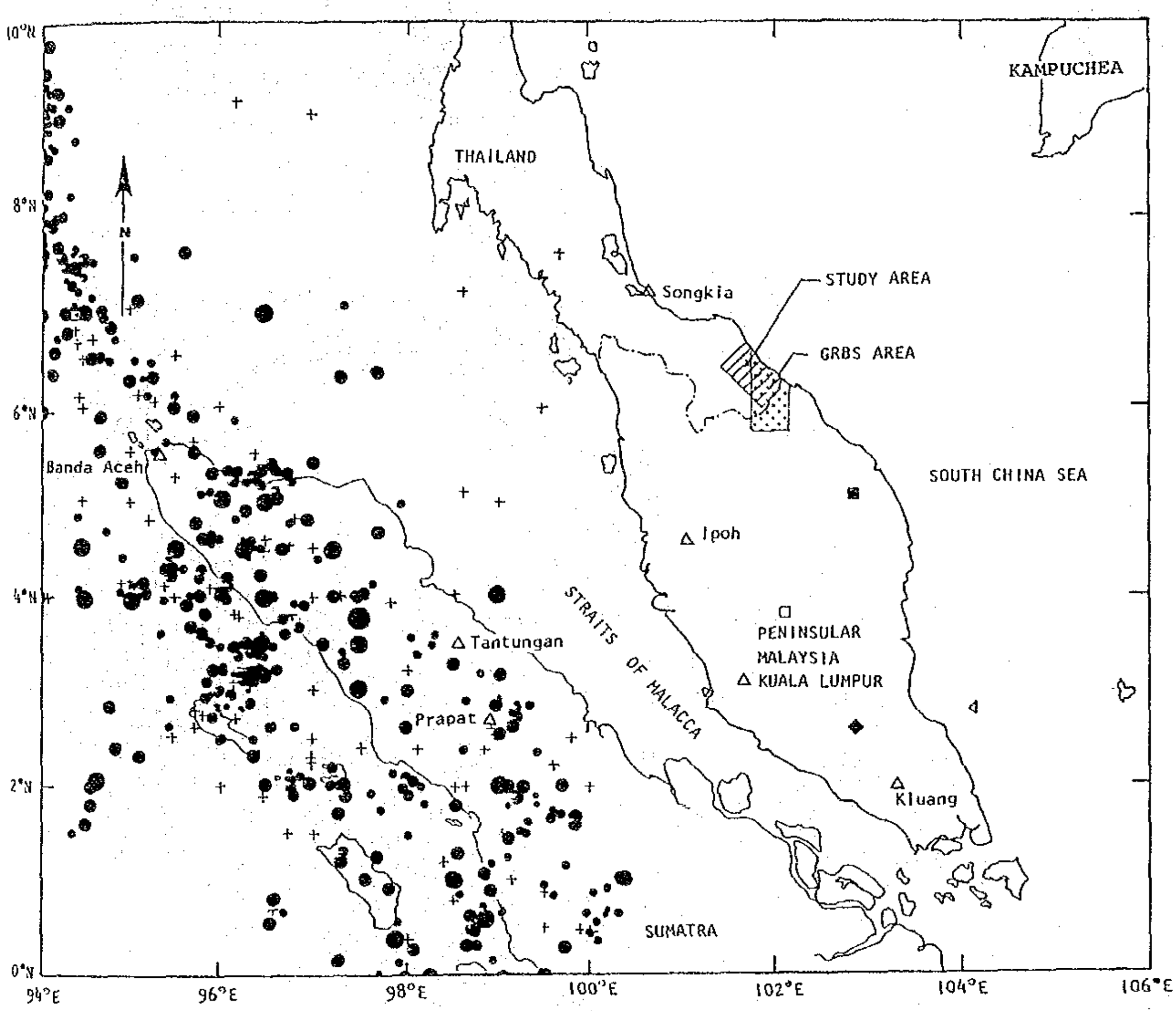
*1 Source: GRBDS Geology Report. March '85

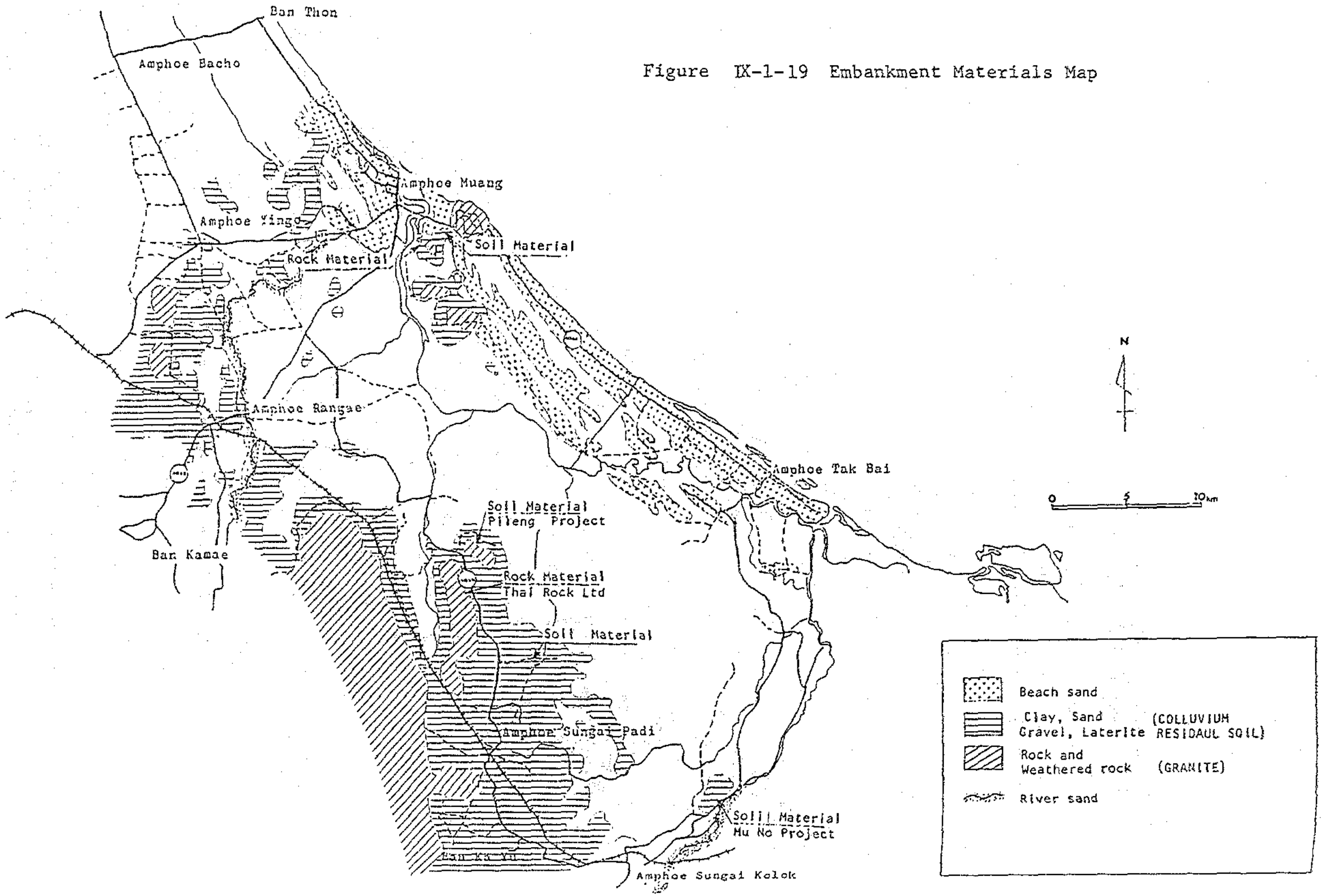
Figure IX-1-18 Seismicity Map



LEGEND

- 7.0-7.9 Magnitude earthquakes
- 6.0-6.9 Magnitude earthquakes
- 5.0-5.9 Magnitude earthquakes
- Less than 4.9 magnitude earthquakes
- + Magnitude not known
- □ Event reported by Soetadi(1962)
- ML5 event on 21 Dec 1984
  ML4 event on 13 Jan 1985
- ◆ ML3.8 event on 06Jan 1976

Figure IX-1-19 Embankment Materials Map



IX-1-2 Preliminary Design

(1) Comparison of Construction Cost for UTR-1 and UTR-2

Case 1. ALT UTR-1, 120 m

Case 2. ALT UTR-2, 60 m + Ya Kang Diversion

Alternative design study for this was carried out during the final course of Phase I field work and the relevant cost for both cases was updated during the home office work in the Phase II Study.

Table IX-1-1 Summary of Comparative Construction Cost for UTR-1 and UTR-2

(Unit : ฿x10^6)

	Case 1	Case 2		
	UTR-1	UTR-2	Ya Kang Diversion	Total
Civil Work	132.72	117.78	58.85	170.63
Gate Work	120.00	75.00	46.00	121.00
Sub-total	252.72	186.78	104.85	291.63
Contingency (20%)	50.28	37.22	20.15	57.37
Total	303.00	224.00	125.00	349.00

Detail of the construction cost for comparison is explained in Tables IX-1-2, IX-1-3 and IX-1-4.

(2) Gate Type and Span

In general, the gate type of the tidal regulator is either sluice gate or roller gate. Radial gate with 6 m-span is used for the Nam Baeng tidal regulator located in the Study area and in many other tidal regulators located nearby. Roller gate is adopted in this tidal regulator taking into consideration the action of hydrostatic pressure from both inside and outside, the considerably large size of each span, etc.

Table IX-1-2 Construction Cost of UTR-1

Description	Qty	Unit rate (₿)	Cost (₿x10³)
A Civil Work			
1. Provision			
1-1. Mobilization & demobilization	L.S.		3,500
1-2. Access road & work yard	L.S.		3,300
Sub-total			6,800
2. Regulator and Connection Channel			
2-1. Dredging excavation & reclaiming	600,000 m^3	60	36,000
2-2. Excavation	100,000 m^3	40	4,000
2-3. Embankment with compaction	100,000 m^3	15	1,500
2-4. Pile foundation (RC 12m long)	932^{nos}	10,000	9,320
2-5. Steel sheet pile (II 6m long)	110^{ton}	16,000	1,760
2-6. Main RC structure	6,500 m^3	4,500	29,250
2-7. Apron RC structure	6,000 m^3	4,000	24,000
2-8. Pitching, dry	10,000 m^3	700	7,000
2-9. Office building	L.S.		1,254
Sub-total			114,084
3. Closure Dam			
3-1 Riverbed topsoil stripping	16,800 m^3	40	763
3-2 Riprap	17,200 m^3	400	6,880
3-3 Dredger embankment	79,100 m^3	60	4,746
3-4 Above WL embankment	5,000 m^3	31.8	159
Sub-total			11,834
B Gate Work			
Gates, 20m x 5.2m	6^{nos}	20,000,000	120,000
C Contingency(20%)			50,282
D Total			303,000

Table IX-1-3 Construction Cost of UTR-2

Description	Qty	Unit rate (฿)	Cost (฿x10^3)
A Civil Work			
1. Provision			
1-1. Mobilization & demobilization	L.S.		3,500
1-2. Access road & work yard	L.S.		5,500
Sub-total			9,000
2. Regulator and Connection Channel			
2-1. Dredging excavation & reclaiming	550,000m^3	60	33,000
2-2. Excavation	100,000 m^3	40	4,000
2-3. Embankment with compaction	100,000 m^3	15	1,500
2-4. Pile foundation (RC 12m long)	686^{nos}	10,000	6,860
2-5. Steel sheet pile (II 6m long)	60^{ton}	16,000	960
2-6. Main RC structure	3,500m^3	4,500	15,750
2-7. Apron RC structure	5,000 m^3	4,000	20,000
2-8. Pitching,dry	5,000m^3	700	3,500
2-9. Office building	L.S.		1,254
Sub-total			86,824
3. Closure Dam			
3-1 Riverbed topsoil stripping	21,200m^3	40	848
3-2 Riprap	21,500 m^3	400	8,600
3-3 Dredger embankment	103,200 m^3	60	6,192
3-4 Above WL embankment	10,000 m^3	31.8	318
Sub-total			15,958
B Gate Work			
Gates, 20m x 6.2m	3^{nos}	25,000,000	75,000
C Contingency(20%)			37,218
D Total			224,000

Table IX-1-4 Construction Cost of Yakang Diversion Weir

Description	Qty	Unit rate (₿)	Cost (₿x10^3)
A Civil Work			
1. Provision			
1-1. Mobilization & demobilization	L.S.		2,300
1-2. Access road & work yard	L.S.		1,500
Sub-total			3,800
2. Weir Regulator			
2-1. Excavation	40,000m^3	40	1,600
2-2. Embankment with compaction	40,000 m^3	15	600
2-3. Pile foundation (RC 12m long)	686^{nos}	10,000	6,860
2-4. Steel sheet pile (II 6m long)	60^{ton}	16,000	960
2-5. Main RC structure	3,500m^3	4,500	15,750
2-6. Apron & Intake RC structure	5,000 m^3	4,000	20,000
2-7. Pitching,dry	5,000m^3	700	3,500
2-8. Office building	L.S.		657
Sub-total			49,927
3. Canal (1.5 km)			
3-1. Excavation	30,000m^3	21	630
3-2. Embankment with compaction	30,000 m^3	13	390
3-3. Box culvert RC structure	800 m^3	4,000	3,200
3-4. Macadam pavement	1,500m	600	900
Sub-total			5,120
B Gate Work			
Weir gates, 20m x 6.2m	3^{nos}	15,000,000	45,000
Intake gates	2^{nos}	500,000	1,000
Sub-total			46,000
C Contingency(20%)			20,153
D Total			125,000

As for the one span length of the gate, it is determined as 20 m for the UTR as a result of the comparison of the construction cost of the gate by span and the construction cost of regulator body including the road bridge (refer to Table IX-1-5). The gate specifications by span are shown in the following:

	30 m span	20 m span	15 m span
(i) Leaf type	Shell type	Shell type	Girder type
(ii) Quantity	4 span	6 span	8 span
(iii) Gate height	5.20 m		
(iv) Hoist	Wire rope winch with two motors and two drums	Wire rope winch with one motor and two drums	
(v) Motor Capacity	11KW per span	7.5KW per span	5.5KW per span
(vi) Weitht			
. Gate leaf	105 ton per span	60 ton per span	40 ton per span
. Embedded parts	24	20	15
. Hoist	30	24	19
Total	159 ton per span	104 ton per span	74 ton per span

The effective gate opening width of the UTR is 120 m, and it would be provided with 6 gates with 20 m span. Of the 6 gates in question, one would be a double stage roller gate of overflow type for water level regulation of the impounding water in the Bang Nara storage. As for the LTR, the effective gate opening width is 24 m, and it would be provided with two roller gates with 12 m span. One of the said gates would be a double stage roller gate which takes charge of the water level regulation.

Table IX-1-5 Comparative Constrcution Cost by Gate Span (UTR)

Description	Unit	Unit rate ฿	W. 30m x 4 spans		W. 20m x 6 spans		W. 15 m x 8 spans	
			Q'ty	Amount	Q'ty	Amount	Q'ty	Amount
1. Civil work				x 10^6฿		x 10^6฿		x 10^6฿
Excavation	m^3	26.37	62,500	1.65	65,300	1.72	68,100	1.80
Back fill	m^3	29.05	7,260	0.21	7,260	0.21	7,260	0.21
RC pile ℓ = 12 m	pieces	9,579	605	5.80	640	6.13	708	6.78
Steel sheet pile	ton	12,466	67.2	0.84	70.1	0.87	73.0	0.91
Main RC structure	m^3	4,439	8,850	39.29	10,020	44.48	11,200	49.72
Bridge			897.6m^2 @10,000	8.98	938.4m^2 @ 8,500	7.98	979.2m^2 @ 7,900	7.74
Lean concrete	m^3	1,133	665	0.75	687	0.78	710	0.80
Sub total				57.52		62.17		67.96
2. Gate work								
Manufacturing				81.0		77.2		76.9
Transportation				5.7		5.5		5.3
Installation				30.6		29.1		29.0
Sub total				117.3		111.8		111.2
Total				174.8		174.0		179.2

Note: Preliminarily estimated in October 1985.

(3) Gate Work

(a) Gate leaf

Gate type of UTR and the lower leaf for a two-stage gate of LTR would be of shell type with fixed wheel considering the clear span and gate height. Other LTR gates would be of girder type with fixed wheel. Shell type gate consists of a skin plate, a top plate, a bottom plate, diaphragm plates and stiffners. Girder type gate consists of a skin plate, main horizontal beams, vertical side girders and auxiliary girders.

Each gate is provided with main wheels, guide wheels and sheave blocks on each side of the gate. Skin plate of one-stage gate faces the upstream side and as for two-stage gate, skin plate of upper gate leaf faces the upstream side.

Each gate is provided with seal rubbers at the gate bottom, both sides, and the opening space of two-stage gate between upper gate leaf and lower gate leaf. These sealing rubbers keep a good sealing performance against the both side pressure.

(b) Embedded Parts

The embedded parts consist of suitable wheel tracks, sealing surfaces, sill beams, side guide frames and all other necessary components capable of transferring the loads into the concrete. The wheel tracks and all sealing surfaces are of stainless steel.

All embedded parts are set in blockouts and aligned with the use of studs field welded to embedded anchors. The blockouts are filled with concrete after final alignment.

(c) Gate hoist machinery

All gate hoists are of wire rope winch type with one electric motor and two wire rope drums. One set of hoist is provided for one-stage gate and two sets of hoists are provided for two-stage gate, one for lower gate and the other for upper gate.

Each hoist is mounted on piers located at the both side of gate and consists of the following components:

(i) One set of electric motor, brake, speed reducer, cross shaft;

(ii) Two sets of wire rope drums, pinions and spur gears, wire ropes, sheave blocks and common bases; and

(iii) Accessories.

The electric motor, brake and speed reducer are mounted on one side pier with one set of wire rope drum, pinion and spur gear. The other set of wire rope drum, pinion and spur gear are on the opposite side pier and driven through cross shaft. Gate is lifted by wire ropes wound on wire rope drums and adequate number of sheaves are provided on both side piers and both ends of gate leaf to minimize wire rope tension. Hoist for each gate is equipped with the following accessories:

(i) Dial type gate position indicator;

(ii) Gate position trans ducer for remote indication;

(iii) Limit switches to detect gate upper limit, gate lower limit, wire rope over load and wire rope slacking; and

(iv) Manual operated gate dogging device for maintenance of gate leaf.

(d) Electrical Equipment

(i) Construction

1) Local Control Panels (L.C.P.)

These are installed near the hoist on the piers to operate the gate at local position.

i) Type : Outdoor self-standing
ii) Integrated devices : Push buttons (Open, Stop, Close)
Indication lamps
Circuit breakers
Magnetic contactors
Control relays

2) Remote Control Panels (R.C.P.)

These are installed in UTR Control Center and LTR Control Room to operate the gate at remote position.

i) Type : Indoor self-standing
ii) Integrated devices : Push buttons (Open, Stop, Close)
Indication lamps
Position indicators

3) Automatic Control Panels (A.C.P.)

These are installed in UTR Control Center and LTR Control Room to operate upper leaf of two-stage gate automatically following the change of water level.

i) Type : Indoor self-standing

ii) Integrated devices : Water level indicators
Automatic control unit

4) Water level Transmitters (W.L.T.)

These are installed at upstream and downstream side of UTR and LTR.

5) Telemeter Units (T.U.)

To indicate water level of LTR at UTR Control Center, a transmitter unit is provided at LTR, and a receiver unit is provided at UTR Control Center.

6) Low Tension Cubicles (L.T.C.)

These are installed in UTR Control Center and LTR Control Room to distribute electric power to L.C.P. and other equipments.

i) Type : Indoor self-standing

ii) Integrated devices : Circuit breakers
Indication lamps

7) Emergency Generators (E.G.)

These are installed in UTR Control Center and LTR Control Room to supply electric power to L.C.P. in case of commercial power loss. E.G. has the capacity to operate two gates progressively.

i) Type : Diesel engine generator
Radiator cooling
ii) Power : AC 400V 50HZ
iii) Capacity : 56 KVA (UTR)
40 KVA (LTR)

(ii) Gate control

1) Local control

Each gate is operated by push buttons fitted on L.C.P. In case of electric power loss, the gate can be operated by handle manually.

2) Remote control

"Manual" control mode

Each gate is operated by push buttons fitted on R.C.P.

"Auto" control mode

Upper leaf of the two-stage gate is operated automatically following the change of water level.

(iii) Electric power supply

Electric power (400V, 200V 50HZ) is supplied from L.T.C. to L.C.P., R.C.P., A.C.P. and T.U.

(e) Specification of the materials and painting

(i) Gate leaf materials

Component Part	Material Group	Material Specification
a. Gate structure	. Rolled steel for General structure	ASTM A36 JIS G3101 (SS41)
	. Rolled steel for welded structure	ASTM A242 JIS G3106 (SM41)
b. Gate wheel	High tensile strength low alloy steel casting	ASTM A148 JIS G5111 (SCMnCr)
c. Gate wheel axle	Corrosion resistant steel	ASTM A473 (Type 304) JIS G4303 (SUS 304 N2)
d. Seal clamp bars	Corrosion resistant steel	ASTM A240 (Type 304) JIS G4304 (SUS 304)

(ii) Gate guide and embedded parts

Component Part	Material Group	Material Specification
a. Sealing plate	Corrosion resistant steel	ASTM A240 (Type 304) JIS G4304 (SUS 304)
b. Wheel track plate	Corrosion resistant steel	ASTM A240 (Type 304) JIS G4304 (SUS 304N2)
c. All other component identified above	. Rolled steel for welded structure	ASTM A242 JIS G3106 (SM41)
	. Rolled steel for general structure	ASTM A36 JIS G3101 (SS41)

(iii) Hoist

Component Part	Material Group	Material Specification
a. Rope drum	Rolled steel for welded structure	ASTM A242 JIS G3106 (SM41)
b. Gear	High tensile strength low alloy steel casting	ASTM A148 JIS G5111 (SCMnM)
c. Pinion	Chromium molybdenum steel	ASTM A291 JIS G4105 (SCM440)

(iv) Painting

1) Outdoor exposed surfaces of gate and gate guide

Coating Place	Process	Kind of Paint	Standard Film Thickness (μ)
Mill maker	1st stage primer	Zincrich primer (organic)	20
Shop	Under coat	Epoxy resin paint	60
	Under coat	Epoxy resin MIO paint	60
Field	Intermediate coat	Epoxy resin paint	30
	Top coat	Epoxy resin paint	30

2) Internal steel surfaces of gate

Coating Place	Process	Kind of Paint	Standard Film Thickness (μ)
Mill maker	1st stage primer	Zincrich primer (organic)	20
Shop	Under coat	Tar-epoxy resin paint	80
	Intermediate coat	Tar-epoxy resin paint	80
	Top coat	Tar-epoxy resin paint	80

3) Hoist

Coating place	Process	Kind of Paint	Standard Film Thickness (μ)
Mill maker	1st stage primer	Long term protection type wash primer	15
Shop	Under coat	Red-lead anti-corrosive paint	35
	Under coat	Red-lead anti-corrosive paint	35
Field	Intermediate coat	Phthalic resin paint	25
	Top coat	Phthalic resin paint	25

IX-2 Acidic Water Flow Check Facilities

IX-2-1 Site Geology and Soil Properties

Topography and Geology

Major check gates and investigation locations are shown in Figure IX-2-1. Investigation drillings were carried out by the staff of Geotechnical Division (RID), and the boring log is as shown in Figure IX-2-4. The allowable bearing capacities of the piles supported by the sand or granite layer are shown in Figure IX-2-3.

Soil Properties

Soil tests on samples taken from drill holes were carried out by the soil laboratory of the Pattani Project (RID). The items are Liquid limit (10 samples), Plastic limit (10 samples). The Plasticity Chart of clay - silt layer is shown:

Plasticity Chart of Clay and Silt Layer
- Check Gate Sites -

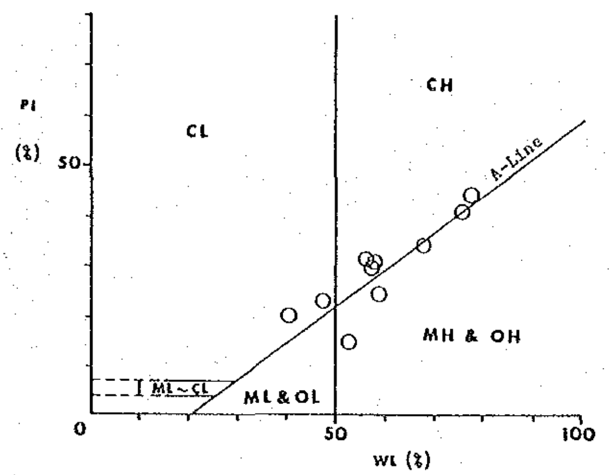


Figure IX-2-1 Major Proposed Check Gate and Investigated Points

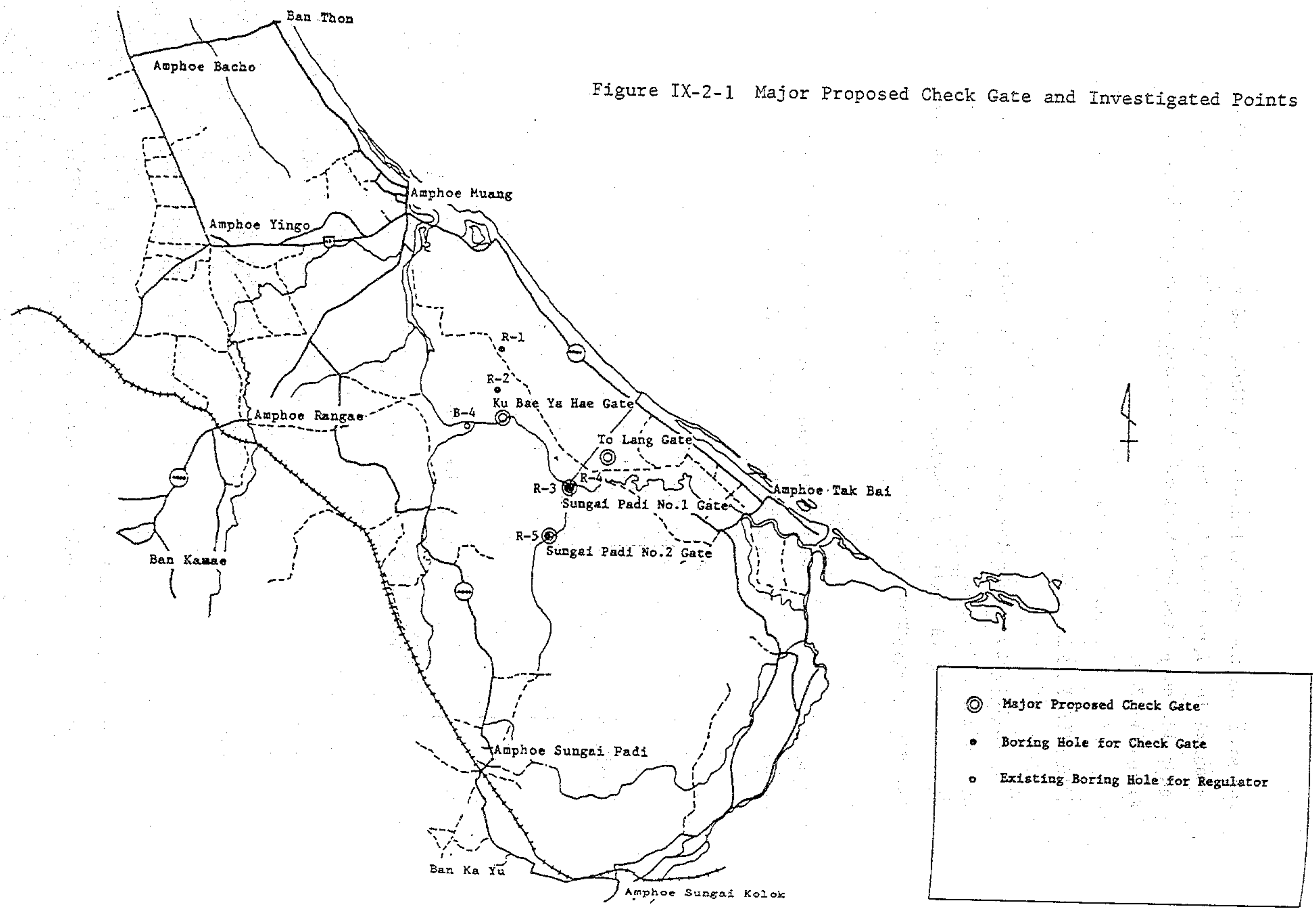


Figure IX-2-3 Boring Log and Allowable Bearing Capacity - Check Gate Sites

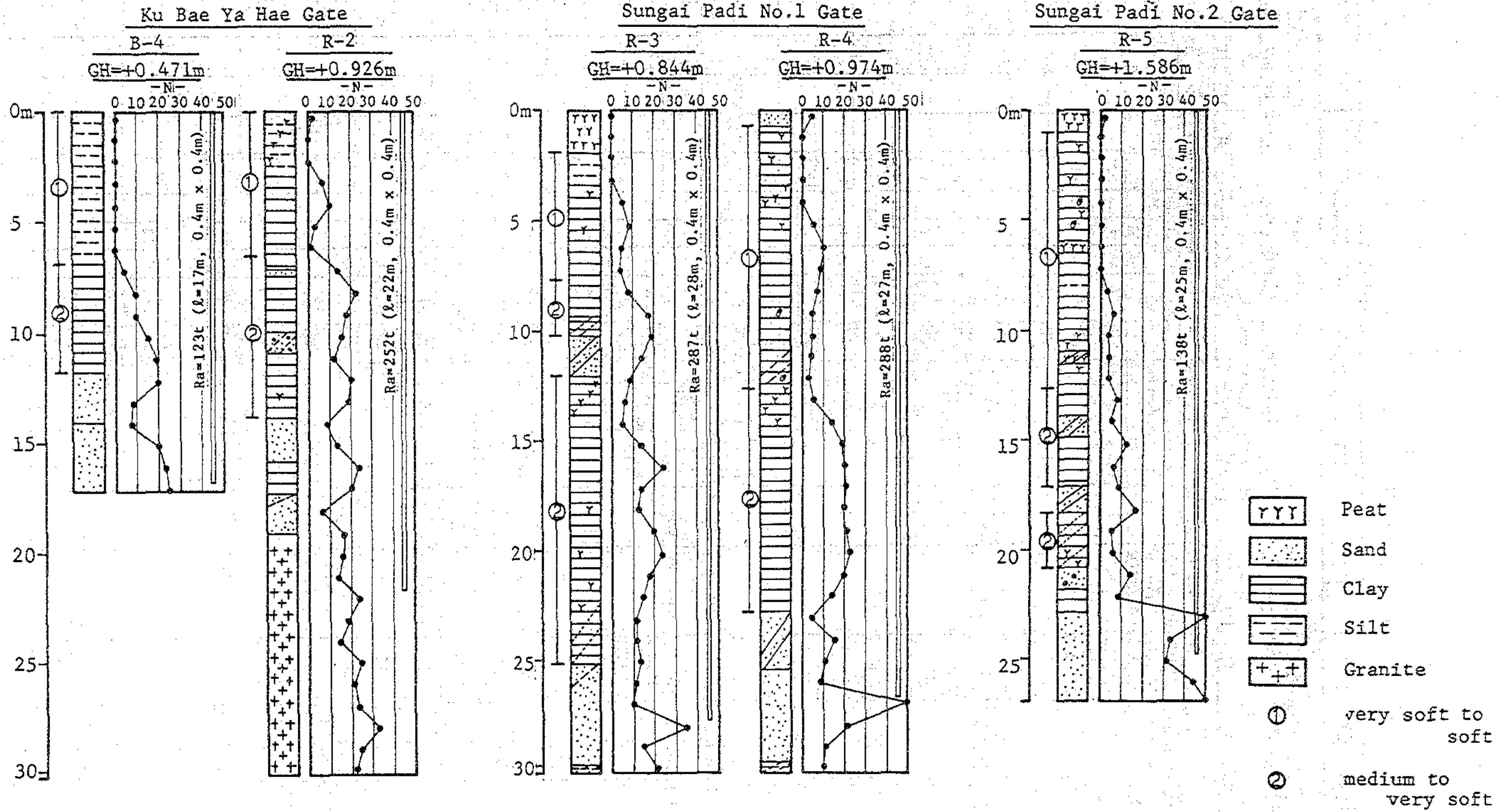


Figure IX-2-2 (1)	BORING LOG (Soil exploration)

PROJECT · LOCATION: Ban Ku Bae Sa Lo, Amphoe Muang
GROUND ELEVATION: 2.228 m
DATE OF INVESTIGATION: Feb.11,1986
BORING HOLE No.: R – 1
DEPTH TO GROUND WATER LEVEL IN HOLE: – 0.302 m
INVESTIGATED BY: P.Chalean

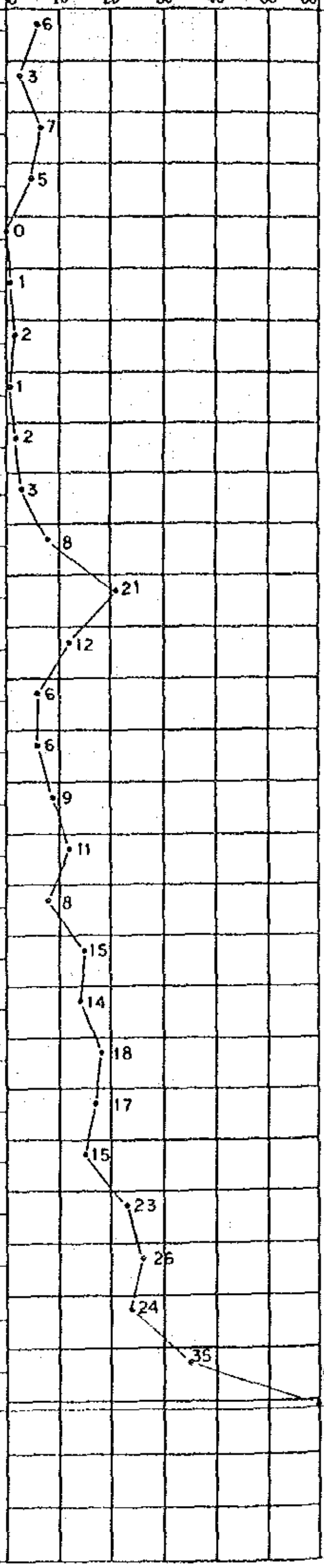
FIELD OBSERVATIONAL RECORD

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	Soil or Rock NAME OF CLASSIFICATION	COLOR TONE	DESCRIPTION
1.77	4.00	4.00	Silt	light grey to redish brown; grey to yellowish brown	soft to midium. 2.5-3.5m silt to very fine sand, some mica
-8.77	11.00	6.00	Clay	dark grey	very soft to soft, high plasticity. 9.5-11.0m shell and organic matter are contained.
-9.77	12.00	1.00	Silty sand	light grey	fine to medium sand with silt. medium.
-12.77	15.00	3.00	Silty clay	light grey with red patches	silty clay with fine sand. medium.
-13.77	16.00	1.00	Silty sand		coarse to medium sand with silt.
-14.17	16.40	0.40	Clay		some sandy silt.
-15.87	18.10	1.70	Sandy silt	light grey with red patches.	stiff.
-18.77	21.00	2.90	Silty sand	light grey	caorse to fine sand. medium.
-19.77	22.00	1.00	Sand	light grey	fine sand. some clay.
-21.47	23.70	1.70	Clayey silt	light grey	very stiff. 23.4-23.7m silty sand
-24.94	27.17	3.47	Sand	light grey	fine sand. dense.

STANDARD PENETRATION TEST

Depth (m)	N / INTER-PENE	15 cm	30 cm
0.15–0.45	6/30	3	3
1.15–1.45	3/30	2	1
2.15–2.45	7/30	3	4
3.15–3.45	5/30	3	2
4.15–4.45	0/30	0	0
5.15–5.45	1/30	0	1
6.15–6.45	2/30	1	1
7.15–7.45	1/30	0	1
8.15–8.45	2/30	1	1
9.15–9.45	3/30	2	1
10.15–10.45	8/30	4	4
11.15–11.45	21/30	8	13
12.15–12.45	12/30	5	7
13.15–13.45	6/30	2	4
14.15–14.45	6/30	3	3
15.15–15.45	9/30	4	5
16.15–16.45	11/30	5	6
17.15–17.45	8/30	3	5
18.15–18.45	15/30	7	8
19.15–19.45	14/30	5	9
20.15–20.45	18/30	10	8
21.15–21.45	17/30	8	9
22.15–22.45	15/30	6	9
23.15–23.45	23/30	7	16
24.15–24.45	26/30	13	13
25.15–25.45	24/30	11	13
26.15–26.45	35/30		
27.00–27.17	50/28		

NUMBER OF BLOWS N



SAMPLING: Sample No. | Depth m

Figure IX-2-2 (2) | **BORING LOG** (Soil exploration)

PROJECT · LOCATION: Ku Bae Ya Hae Canal, Amphoe Muang

GROUND ELEVATION: 0.926 m

DATE OF INVESTIGATION: Feb.22,1986

BORING HOLE No.: R-2

DEPTH TO GROUND WATER LEVEL IN HOLE: 0.300 m

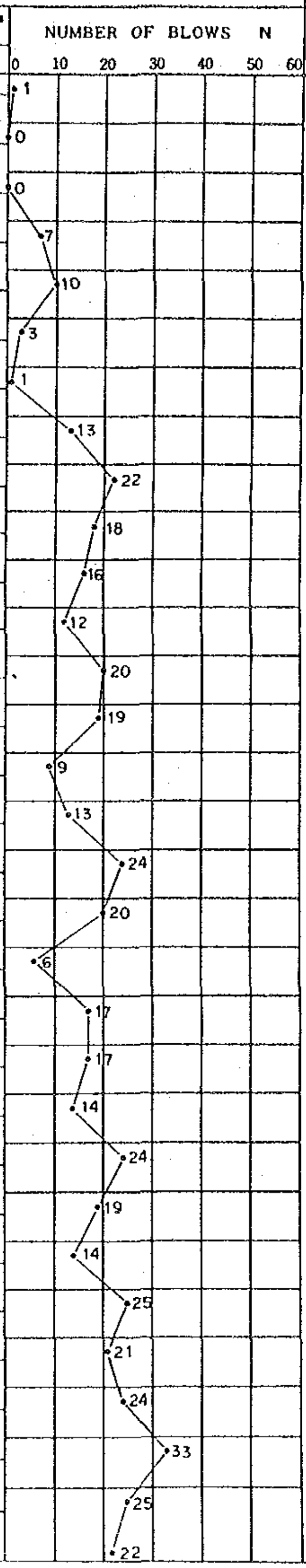
INVESTIGATED BY: P.Chalean

FIELD OBSERVATIONAL RECORD

ELEVATION m	DEPTH m	THICKNESS m	Soil or Rock NAME OF CLASSIFICATION	COLOR TONE	DESCRIPTION
-2.08	3.00	3.00	Organic silt	brackish brown	unresolved organic matter and silt. upper portion organic rich. very soft.
-6.22	7.15	4.15	Clay	light grey / dark grey	3.00-5.00m medium to stiff. 5.00-7.15m very soft to soft. 5m some red patches.
-6.47	7.40	0.25	Sand	lightgrey	fine sand.
-9.07	10.00	2.60	Clay	light grey with red patches	contained some fine sand. very stiff.
-10.07	11.00	1.00	Silty sand		coarse sand,quartz rich.some gravel (2 3mm).
-13.07	14.00	3.00	Clay	light grey	upper portion silty clay. stiff to very stiff. some organic matter.
-15.07	16.00	2.00	Sand	light grey	coarse sand, quartz rich. loose to medium.
-16.47	17.40	1.40	Clay	light grey	very stiff. lower portion some fine sand.
-18.32	19.25	1.85	Silty sand	light grey	fine sand to medium sand with silt. quartz rich. loose.
-29.52	30.45	11.20	Weatered granite	greyey white	19.25-24.00m look like a sandy silt,mica rich. very stiff. 24.00-30.45m look like a silty sand,mica and feldspar rich. medium to dense.

STANDARD PENETRATION TEST

Depth m	N / INTER-PENE cm	15 cm	30 cm
0.15-0.45	1/30	1	0
1.15-1.45	0/30	0	0
2.15-2.45	0/30	0	0
3.15-3.45	7/30	3	4
4.15-4.45	10/30	5	5
5.15-5.45	3/30	1	2
6.15-6.45	1/30	0	1
7.15-7.45	13/30	6	7
8.15-8.45	22/30	9	13
9.15-9.45	18/30	9	9
10.15-10.45	16/30	8	8
11.15-11.45	12/30	6	6
12.15-12.45	20/30	9	11
13.15-13.45	19/30	9	10
14.15-14.45	9/30	4	5
15.15-15.45	13/30	7	6
16.15-16.45	24/30	10	14
17.15-17.45	20/30	9	11
18.15-18.45	6/30	3	3
19.15-19.45	17/30	8	9
20.15-20.45	17/30	6	11
21.15-21.45	14/30	6	8
22.15-22.45	24/30	9	15
23.15-22.45	19/30	8	11
24.15-24.45	14/30	9	5
25.15-25.48	25/30	9	16
26.15-26.45	21/30	7	14
27.16-27.45	24/30	9	15
28.15-28.45	33/30	12	21
29.15-29.45	25/30	9	16
30.15-30.45	22/30	10	12



SAMPLING: Sample No. | Depth m | Method

Figure IX-2-2 (3) | **BORING LOG** (Soil exploration)

PROJECT · LOCATION: left bank of Khlong Nam Baeng Amphoe Rangae

GROUND ELEVATION: 0.844 m

DATE OF INVESTIGATION: Jan.29,1986

BORING HOLE No.: R-3

DEPTH TO GROUND WATER LEVEL IN HOLE: 0.000 m

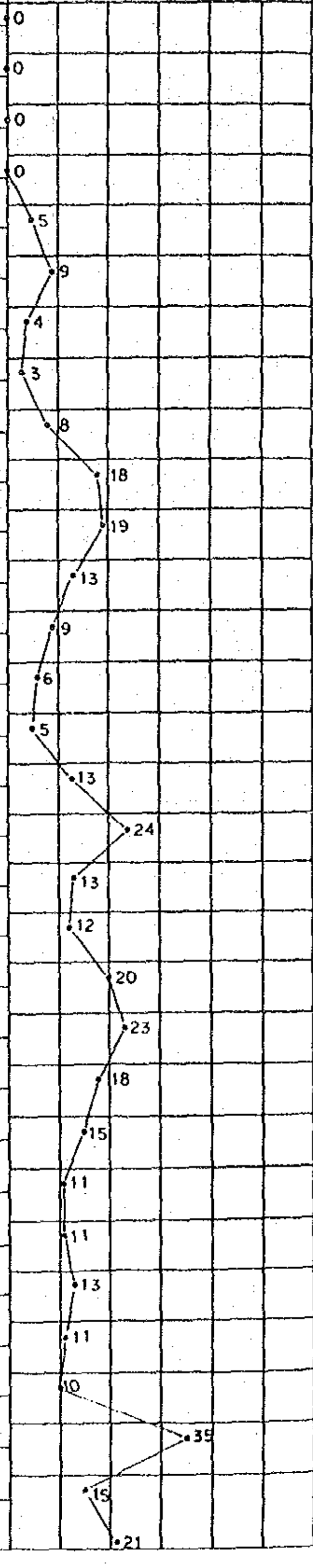
INVESTIGATED BY: D.Throngrit

FIELD OBSERVATIONAL RECORD

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	Soil or Rock NAME OF CLASSIFICATION	COLOR TONE	DESCRIPTION
-1.16	200	200	Peat	brackish brown	unresolved organic matter. very soft.
-266	350	150	Silt		
-861	945	595	Clay	light grey with red patches; light grey	3.5-6.0m medium. soft organic matter. 6.0-8.0m soft. 8.00-9.45m medium to stiff. some quartz coarse sand.
-936	1020	075	Sandy clay	light grey	clay with coarse sand(quartz).
-1131	1215	195	Clayey sand	light grey	quartz coarse sand with clay.
-2156	2240	1025	Clay	brownish grey; light grey and patches	12.15-14.00m medium. with organic matter. 14.0-22.4m stiff to very stiff.
-2446	2530	290	Sand clay	brownish light grey	clay with fine to coarse sand. stiff. some organic matter.
-2921	3005	475	Sand	light grey	medium to coarse sand, quartz rich. medium to dense.
-2961	3045	040	Sandy silt		very stiff.

STANDARD PENETRATION TEST

Depth (m)	N / INTER-PENE (cm)	Num. of blows 15 cm	Num. of blows 30 cm	NUMBER OF BLOWS N
015–045	0/30	0	0	0
115–145	0/30	0	0	0
215–245	0/30	0	0	0
315–345	0/30	0	0	0
415–445	5/30			5
515–545	9/30			9
615–645	4/30			4
715–745	3/30			3
815–845	8/30			8
915–945	18/30			18
1015–1045	19/30			19
1115–1145	13/30			13
1215–1245	9/30			9
1315–1345	6/30			6
1415–1445	5/30			5
1515–1545	13/30			13
1615–1645	24/30			24
1715–1745	13/30			13
1815–1845	12/30			12
1915–1945	20/30			20
2015–2045	23/30			23
2115–2145	18/30			18
2215–2245	15/30			15
2315–2345	11/30			11
2415–2445	11/30			11
2515–2545	13/30			13
2615–2645	11/30			11
2715–2745	10/30			10
2815–2845	35/30			35
2915–2945	15/30			15
3015–3045	21/30			21



SAMPLING: Sample No. | Depth m

Figure IX-2-2 (4)

BORING LOG (Soil exploration)

PROJECT · LOCATION: Right bank of Khlong Nam Baeng Amphoe Tak Bai

GROUND ELEVATION: 0.974 m

DATE OF INVESTIGATION: Feb.4,1986

BORING HOLE No.: R – 4

DEPTH TO GROUND WATER LEVEL IN HOLE: 0.500 m

INVESTIGATED BY: D.Throngrit

FIELD OBSERVATIONAL RECORD

ELEVATION m	DEPTH m	THICKNESS m	Soil or Rock NAME OF CLASSIFICATION	COLOR TONE	DESCRIPTION
0.17	0.80	0.80	Sand	light brownish grey	fine sand, quartz rich.
-3.53	4.50	3.70	Clay	light brownish grey	very soft. some organic matter. 3.5-4.5m organic matter rich.
-10.03	11.00	6.50	Clay	whitish grey and red patches; dark grey	stiff. some organic matter(4.5-7.0m). some shells (9.0-11.0m).
-11.73	12.70	1.70	Silty clay	dark grey	soft. some shells.
-22.03	23.00	10.30	Clay	whitish grey and red patches	12.7-14.0m clay with organic matter. medium. 14.0-15.0m some fine sand and organic matter. 15.0-23.0m very stiff.
-24.83	25.80	2.80	Clayey sand	light grey	upper portion fine sand with clay. lower portion coarse sand with clay and some gravel(0.5mm). medium.
-29.03	30.00	4.20	Sand	light grey	qpartz coarse sand. loose to very dense medium portion fine to medium sand with silt.
-29.48	30.45	0.45	Sandy silt		with fine sand.

STANDARD PENETRATION TEST

Depth m	N / INTER-PENE cm	NUMBER OF BLOWS N
0.15–0.45	4/30	4
1.15–1.45	0/30	0
2.15–2.45	0/30	0
3.15–3.45	0/30	0
4.15–4.45	0/30	0
5.15–5.45	6/30	6
6.15–6.45	11/30	11
7.15–7.45	9/30	9
8.15–8.45	7/30	7
9.15–9.45	5/30	5
10.15–10.45	5/30	5
11.15–11.45	4/30	4
12.15–12.45	3/30	3
13.15–13.45	5/30	5
14.15–14.45	14/30	14
15.15–15.45	19/30	19
16.15–16.45	21/30	21
17.15–17.45	21/30	21
18.15–18.45	20/30	20
19.15–19.45	21/30	21
20.15–20.45	22/30	22
21.15–21.45	20/30	20
22.15–22.45	14/30	14
23.15–23.45	4/30	4
24.15–24.45	15/30	15
25.15–25.45	11/30	11
26.15–26.45	9/30	9
27.15–27.45	50/30	50
28.15–28.45	21/30	21
29.15–29.45	11/30	11
30.15–30.45	10/30	10

Figure IX-2-2 (5) | BORING LOG (Soil exploration)

PROJECT · LOCATION: Khlong Nam Baeng Amphoe Rangae

GROUND ELEVATION: 1.586 m

DATE OF INVESTIGATION: Jan.29,1986

BORING HOLE No.: R-5

DEPTH TO GROUND WATER LEVEL IN HOLE: 0.150 m

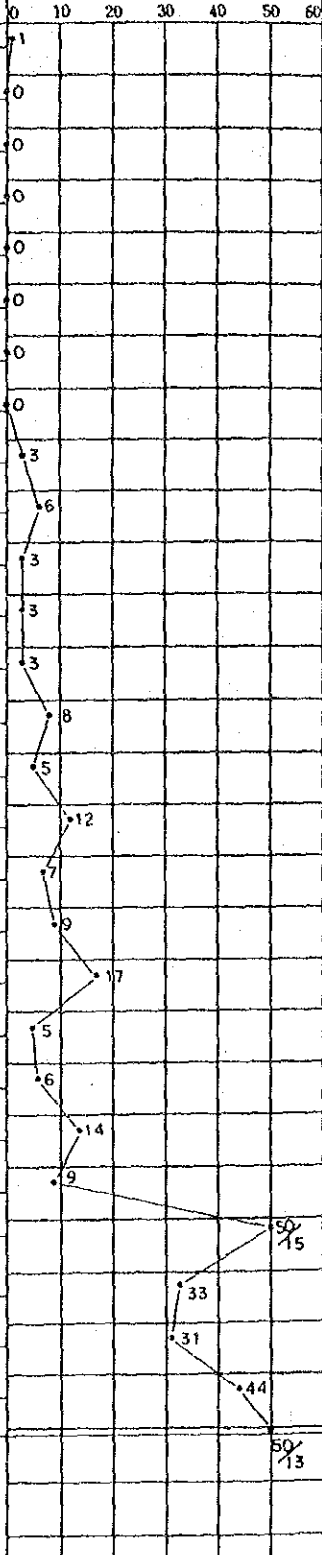
INVESTIGATED BY: P.Chalearw

FIELD OBSERVATIONAL RECORD

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	Soil or Rock NAME OF CLASSIFICATION	COLOR TONE	DESCRIPTION
0.59	1.00	1.00	Peat	brackish brown	unresolved organic matter.very soft.
-4.41	6.00	5.00	Clay	dark grey	very soft. some organic matter. 4.5-5.0m some shells.
-4.91	6.50	0.50	Peat	brackish brown	some thin clay.
-6.41	8.00	1.50	Clay	light grey	very soft.
-9.41	11.00	3.00	Clay	light grey and light brown	soft to medium. 10.0-11.0m some organic matter.
-9.91	11.50	0.50	Clayey peat		thin clay .soft.
-12.41	14.00	2.50	Clay	light grey	soft to medium. upper portion some organic matter.
-13.41	15.00	1.00	Clay sand	light grey	quartz fine to medium sand, loose.
-15.56	17.15	2.15	Clay	light grey light brownish grey	medium to stiff. some organic matter.
-16.81	18.40	1.25	Clayey sand	grey	quartz fine to medium sand. medium.
-19.41	21.00	2.60	Sandy clay	light grey light brownish grey	clay with fine sand(quartz). some organic matter.
-20.41	22.00	1.00	Sand	light brownish grey	fine to coarse sand.somegravel (2 3mm)medium.
-21.41	23.00	1.00	Clay	light brownish grey	some fine sand, stiff.
-25.54	27.13	4.13	Sand	light grey	coarse to medium sand,quartz rich. upper portion some clay.

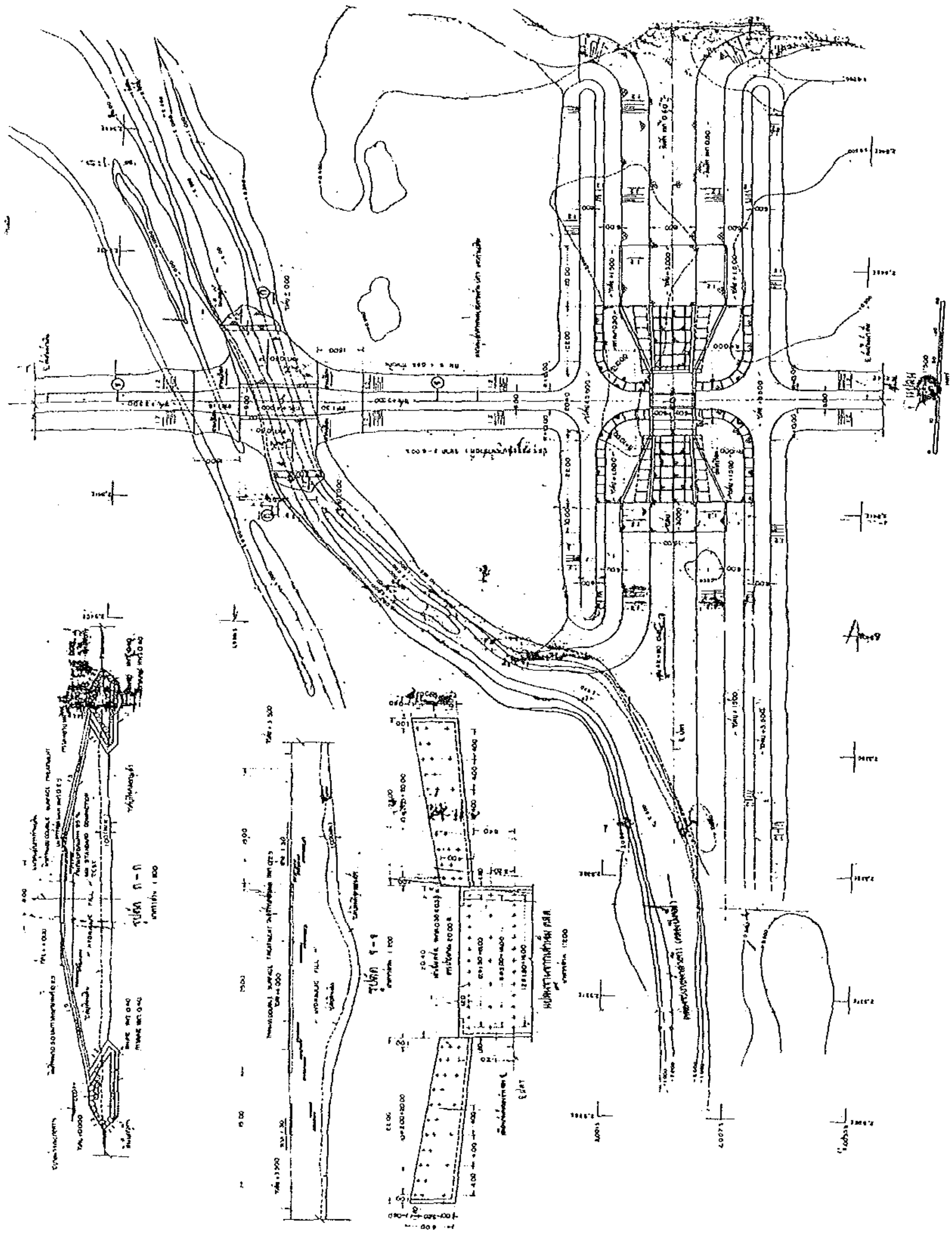
STANDARD PENETRATION TEST

Depth (m)	N / INTER-PENE (cm)	Num. of blows 15 cm	Num. of blows 30 cm
0.15–0.45	1/30	0	1
1.15–1.45	0/30	0	0
2.15–2.45	0/30	0	0
3.15–3.45	0/30	0	0
4.15–4.45	0/30	0	0
5.15–5.45	0/30	0	0
6.15–6.45	0/30	0	0
7.15–7.45	0/30	0	0
8.15–8.45	3/30	1	2
9.15–9.45	6/30	3	3
10.15–10.45	3/30	1	2
11.15–11.45	3/30	1	2
12.15–12.45	3/30	0	3
13.15–13.45	8/30	3	5
14.15–14.45	5/30	2	3
15.15–15.45	12/30	5	7
16.15–16.45	7/30	3	4
17.15–17.45	9/30	4	5
18.15–18.45	17/30	11	6
19.15–19.45	5/30	2	3
20.15–20.45	6/30	2	4
21.15–21.45	14/30	8	6
22.15–22.45	9/30	4	5
23.15–23.30	50/15		
24.15–24.45	33/30	12	21
25.15–25.45	31/30	12	19
26.15–26.45	44/30	21	23
27.00–27.13	50/13		

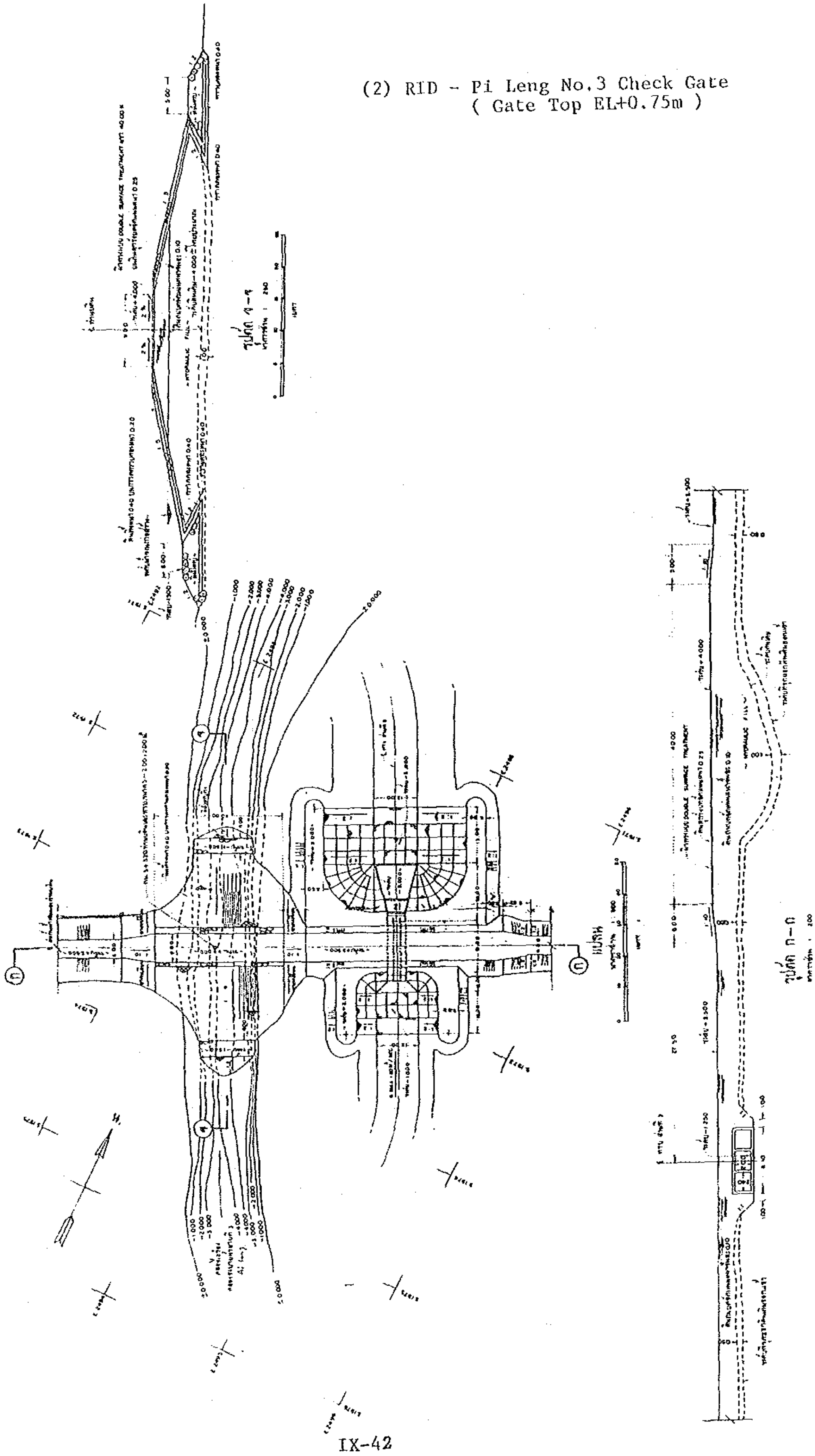


IX-2-2 Acidic Water Flow Check Facilities - Pileng Project

(1) RID - Pi Leng No.1 Check Gate
(Gate Top EL+2.00m)

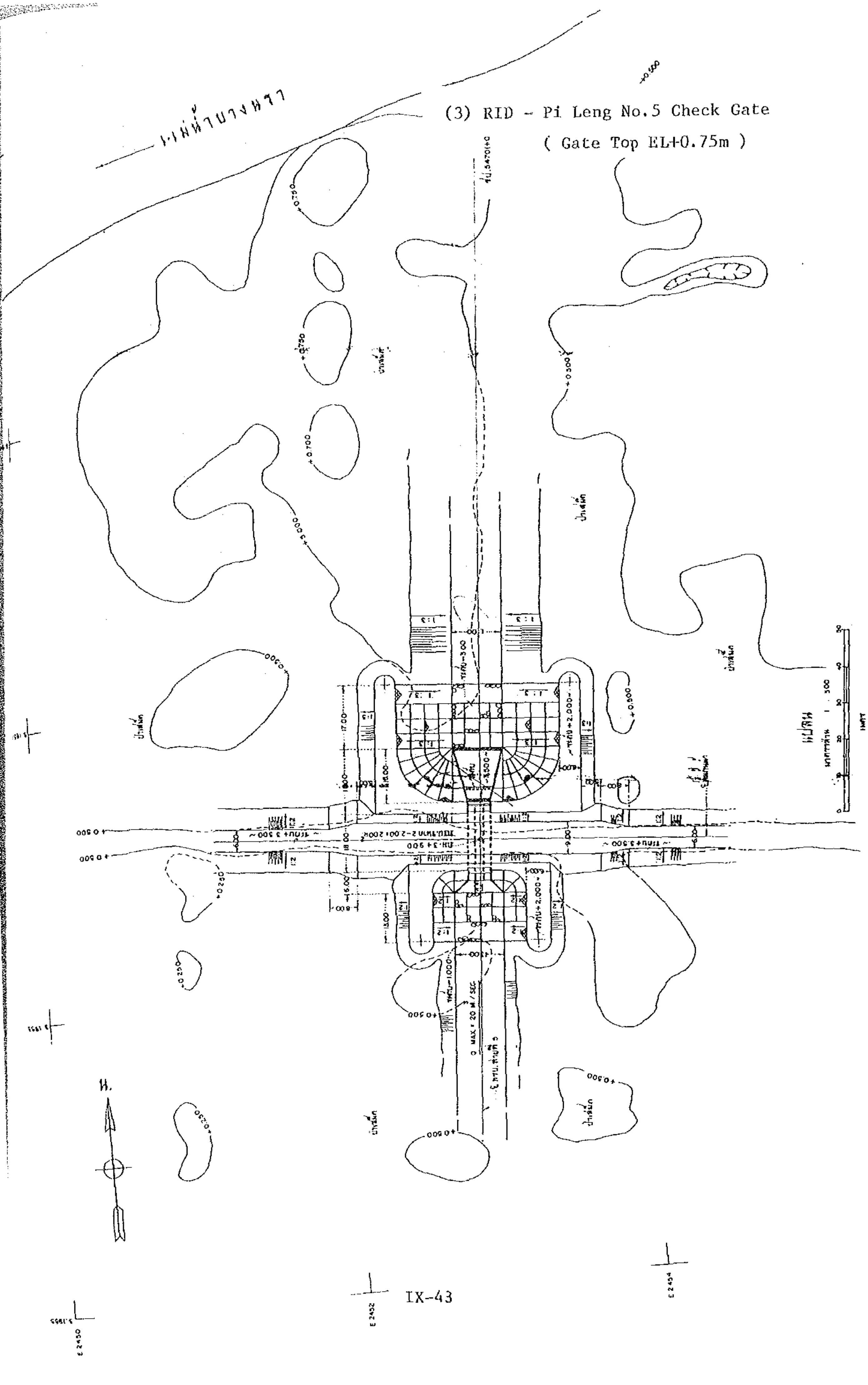


(2) RID - Pi Leng No.3 Check Gate
(Gate Top EL+0.75m)

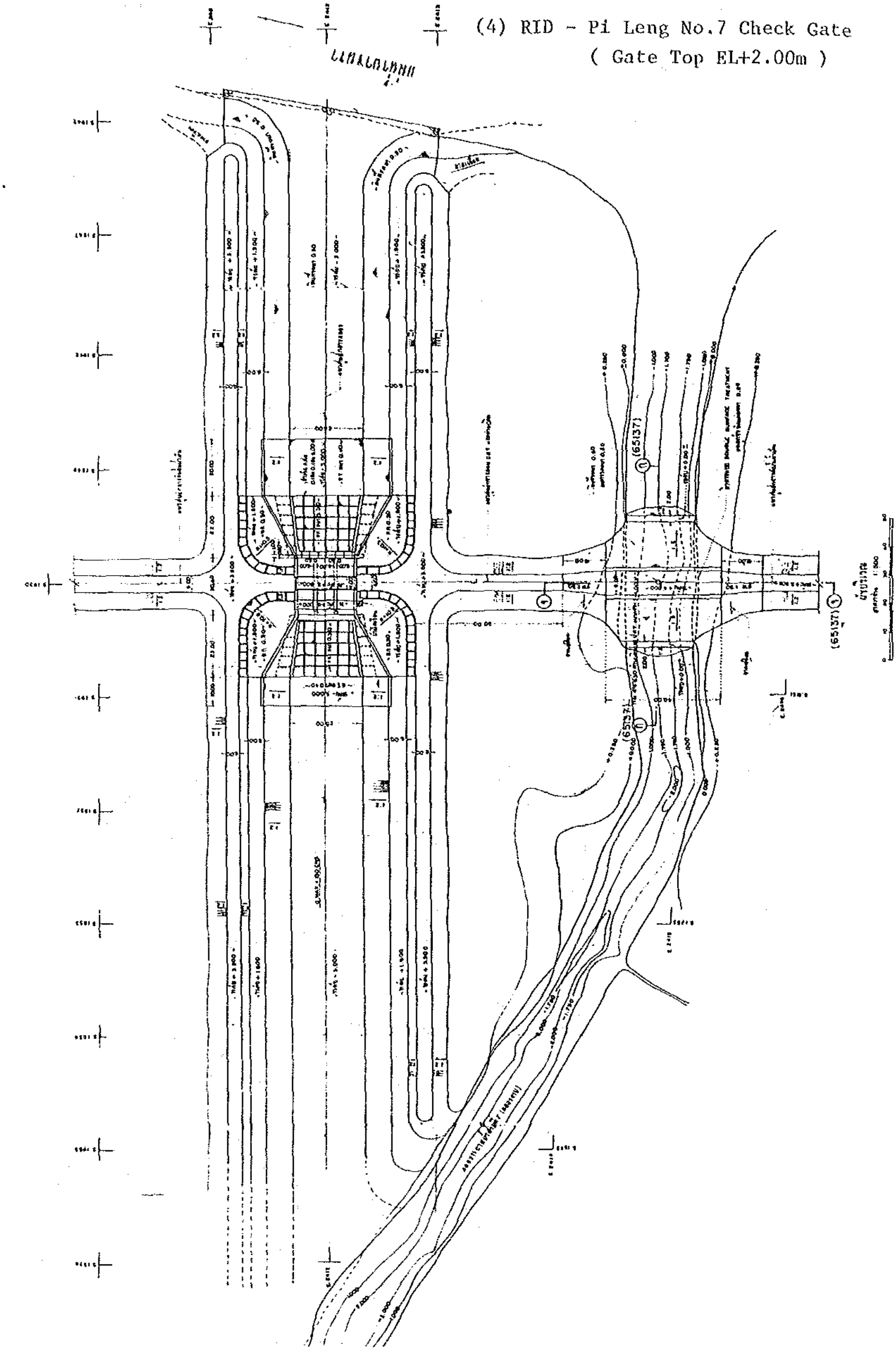


(3) RID - Pi Leng No.5 Check Gate

(Gate Top EL+0.75m)



(4) RID - Pi Leng No.7 Check Gate
(Gate Top EL+2.00m)



IX-3 Drainage Improvement

IX-3-1 Site Geology

The bearing ground of small-sized structures such as bridges and pumping stations is considered based on the boring investigations as well as on the foundation structures of existing bridges and regulators. The proposed site consists of beach-sand area, swamp and old swamp area, and flood plain area. As is clear from Figure IX-3-1, each area possesses the characteristic subsurface geology, and the bearing ground can be classified for each area.

Beach-sand area

The subsurface geology of the beach-sand area consists, from upper to lower depth, of a beach-sand layer, a soft to medium clay layer, and a gravel layer, all distributed at a depth of between 0 - 20 m. The relationship between N-value and depth is shown in Figure IX-3-4. Existing bridges are supported by the beach-sand layer with piles 12 - 15 m long.

Based on the boring investigation, the bearing piles and their allowable bearing capacities (Ra) are calculated by applying the following equation, and the relationship between pile lengths and allowable hearing capacities is shown in Figure IX-3-4.

$$Ra = \frac{1}{3} \{ 40 \cdot N \cdot Ap + (\frac{Ns \cdot Ls}{5} + 2 \cdot Nc \cdot Lc) \cdot U \}$$

where Ra: Allowable bearing capacity

N : $N = 15 + 1/2\ (N'-15),\ N'>15$

Ap: Cross-sectional area of pile

Ns: Average of N-value in the sand

Ls: Length of pile in the sand

Nc: Average of N-value in the clay

Lc: Length of pile in the clay

U : Perimeter of pile

Type of pile: Reinforced concrete pile

Size of pile: 400 mm x 400 mm

Existing borehole at B-6 located at the border with the swamp area is of a thin beach-sand layer showing a small Ra value, but Ra of other points would be greater than 23 ton when the pile of 10 m or greater is used. However, as is observed at borehole P-6, if a pile of excessive length is used, it would penetrate the beach-sand layer resulting in a smaller Ra, so caution should be exercised. Also, the vicinity of river mouth lacks beach-sand as in the LTR point, or is replaced with clay rendering the interpretation of the foundation ground difficult.

Swamp and old swamp area

The subsurface geology of the swamp and old swamp area consists, from upper to lower depth, of a peat layer, a very soft clay layer, a medium to hard clay layer, and a sand or gravel layer.

The relationship between N-value and depth is shown in Figure IX-3-4, in which proper N-values are generally situated at considerable depth because of a thick clay layer being widely distributed. In particular, the consistency of the material at a depth of 0 to 14 m varies from very soft to soft in many places.

The relationship between pile lengths and allowable bearing capacities is shown in Figure IX-3-5. With a pile of length greater than 15 m, Ra would be greater than 33 ton, and the greater the pile length, the greater the value of Ra. The results of the pile driving test under the Pileng project indicate the pile length of 8 to 18 m with Ra being 30 to 38 ton, both of which are proximate to the above calculation results.

Flood plain area

The subsurface geology of the flood plain area consists, from upper to lower depts, of a medium to hard clay layer, a sand layer, a colluvium soil layer, and a granite layer, differing in that the area is free from layers of peat and very soft clay and that the colluvium soil layer and the granite layer distribution starts from a shallow depth.

The relationship between N-value and depth as is in Figure IX-3-4 shows variations, but compared with the swamp and old swamp area, large N-values are indicated from a shallow depth. The relationship between pile length and Ra is shown in Figure IX-3-5, in which Ra is greater than 57 ton when pile length exceeds 10 m.

Figure IX-3-1 Geotechnical Engineering Map

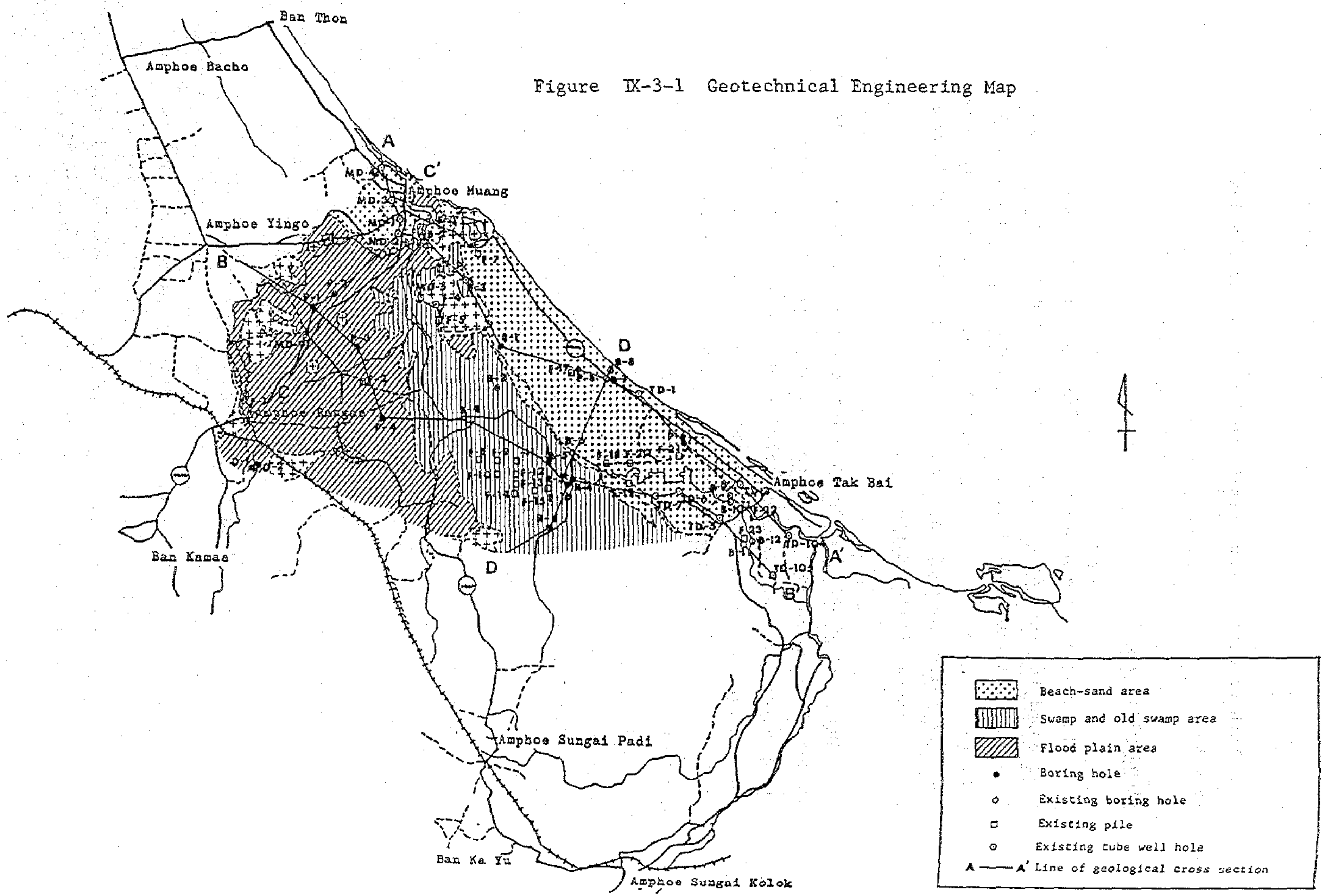


Figure IX-3-3 (1) Geological Cross-Section

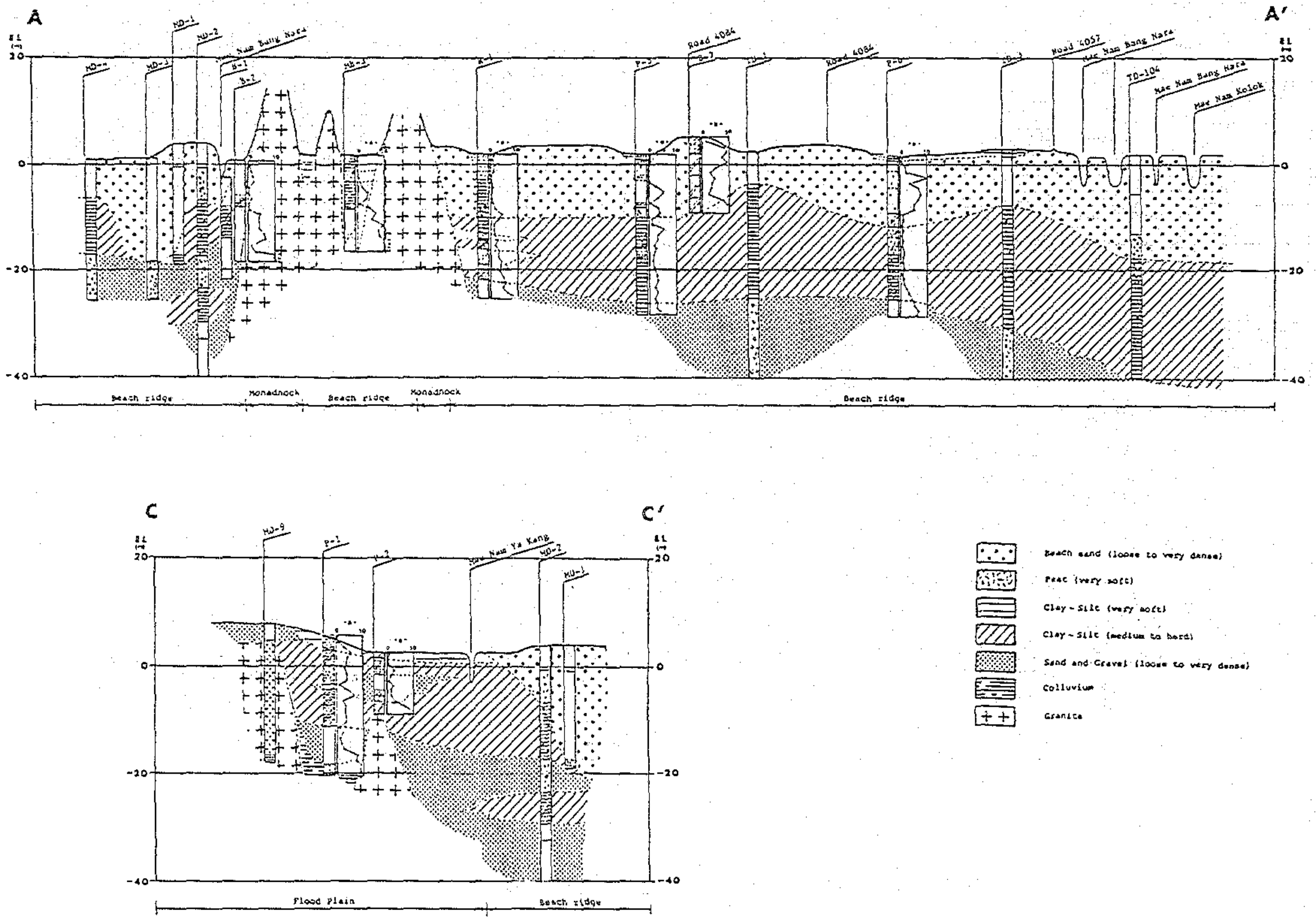


Figure IX-3-3 (2) Geological Cross-Section

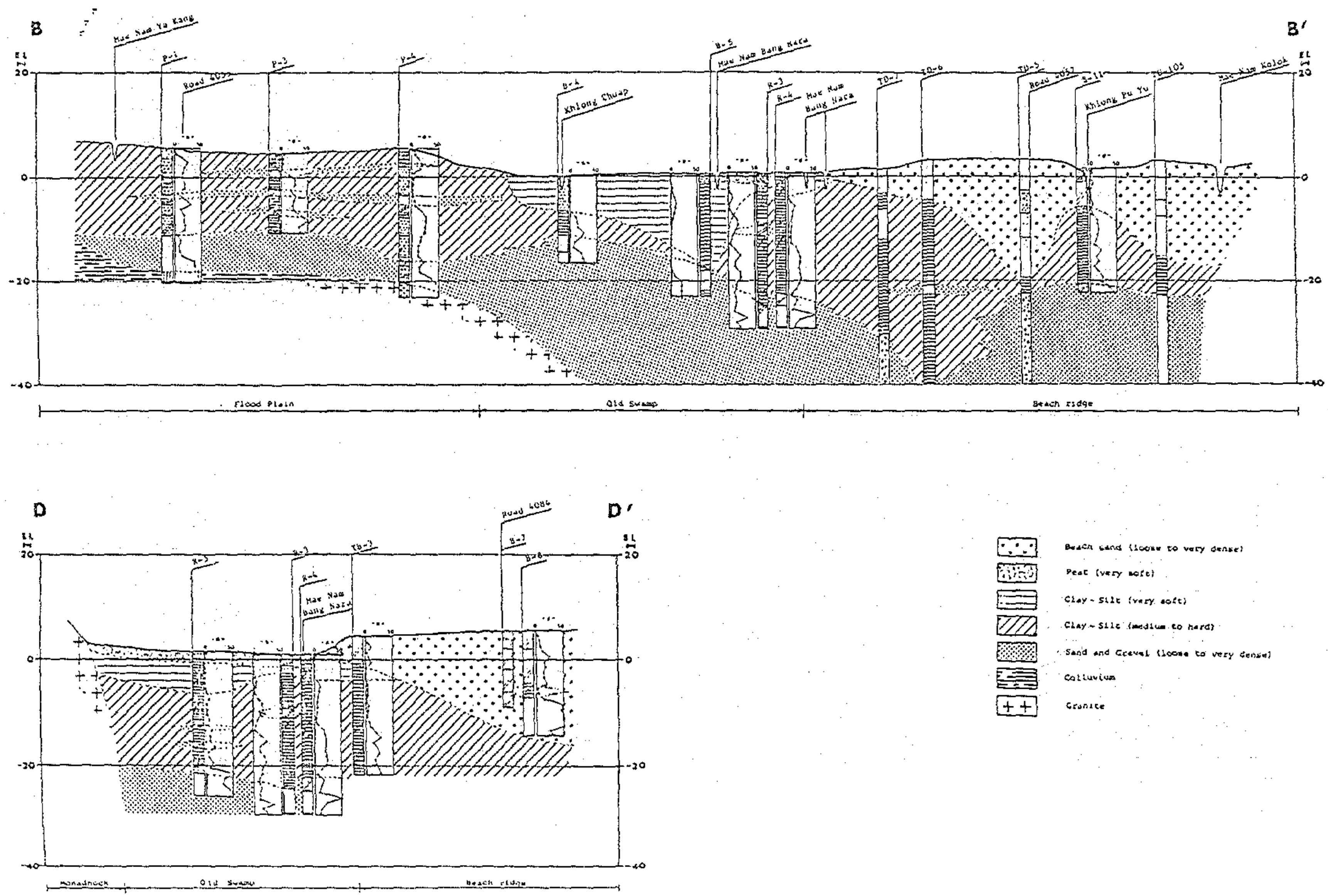
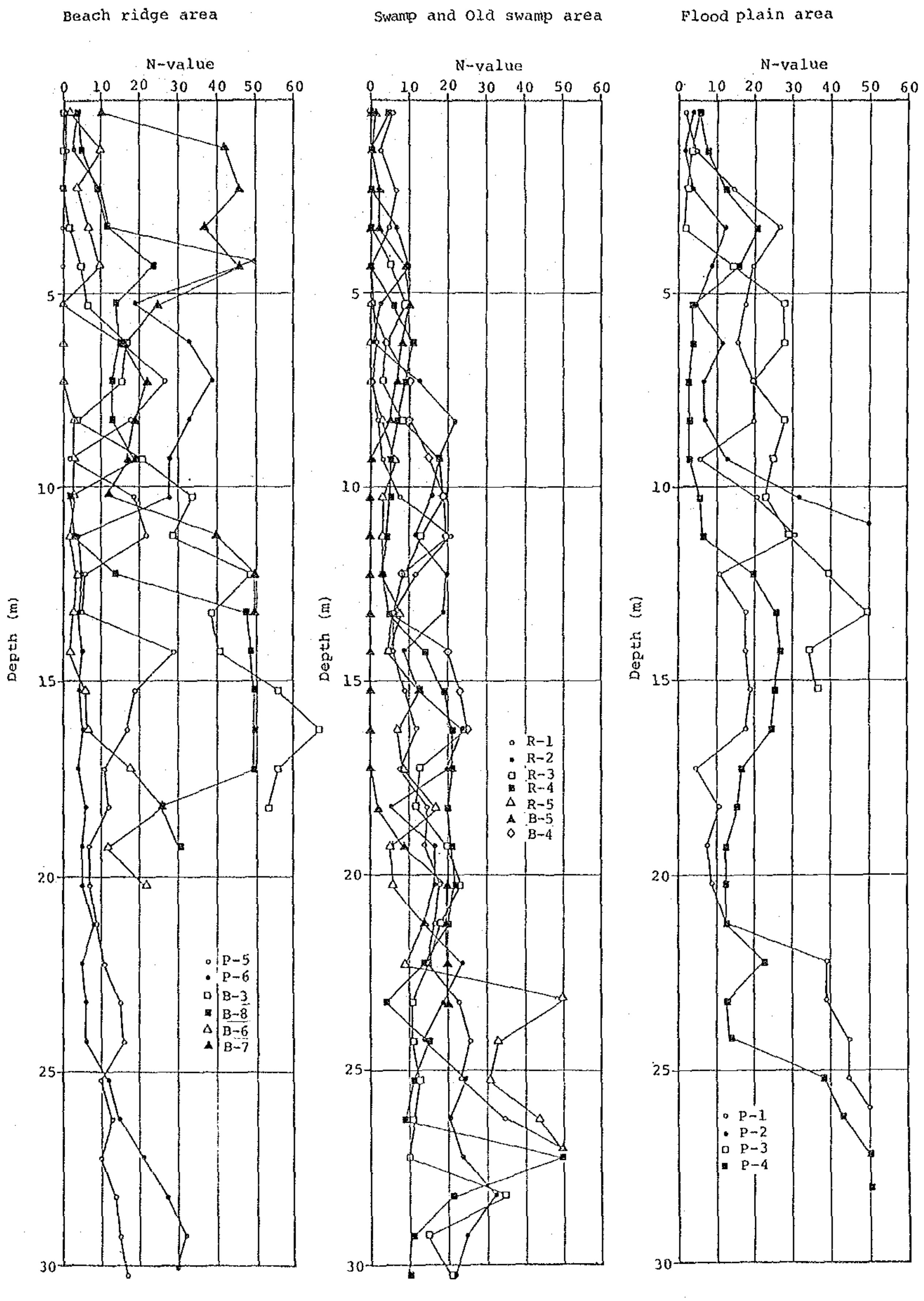
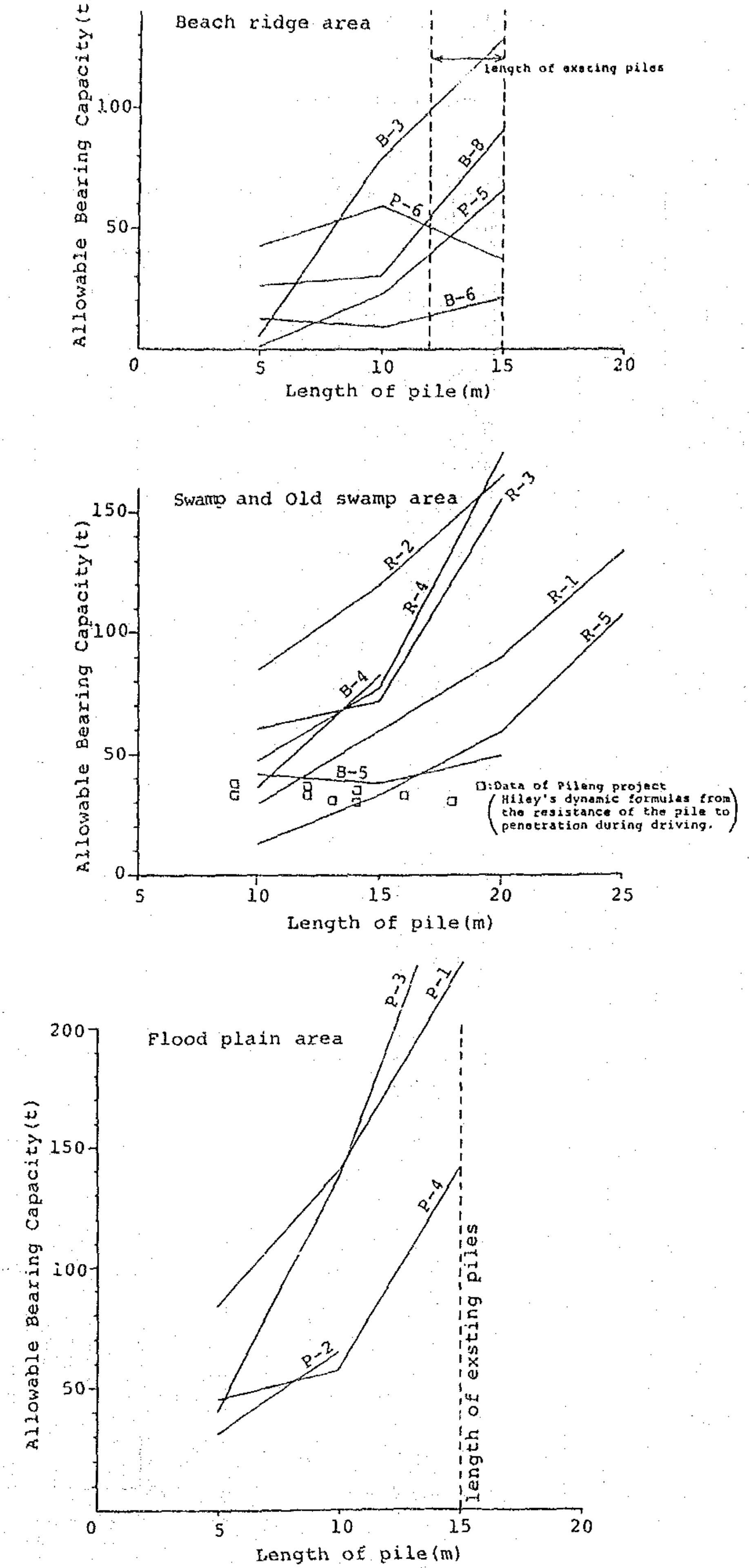


Figure IX-3-4 N-value by Depth





note:diameter of pile=400mm

Figure IX-3-5 Allowable Bearing Capacity by Length of Pile

Figure IX-3-2 (1)

BORING LOG (Soil exploration)

PROJECT · LOCATION: Ban Khao Kong, Amphoe Muang

GROUND ELEVATION: 5.811 m

DATE OF INVESTIGATION: Feb.14,1986

BORING HOLE No.: P-1

DEPTH TO GROUND WATER LEVEL IN HOLE: 0.200 m

INVESTIGATED BY: P.Chalearw

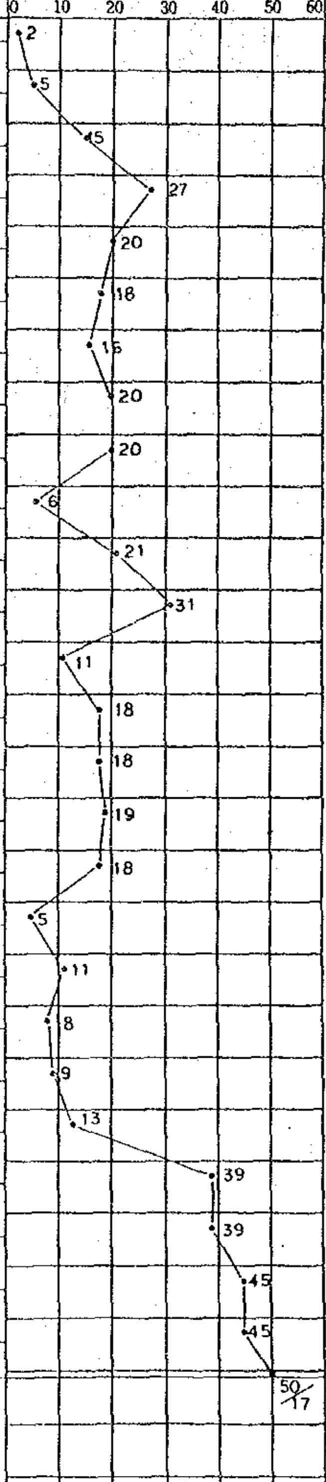
FIELD OBSERVATIONAL RECORD

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	Soil or Rock NAME OF CLASSIFICATION	COLOR TONE	DESCRIPTION
3.81	2.00	2.00	Silt	light grey to brownish grey	very soft to medium. some organic matter.
0.41	5.40	3.40	Clayey silt	light grey with red patches	stiff to very stitt.
-3.19	9.00	3.60	Sandy silt	light grey	silt with fine sand. very stiff. 8.0-9.0m sand rich.
-4.19	10.00	1.00	Sand	light grey	fine to coarse sand, loose. some silt.
-5.19	11.00	1.00	Clayey silt	light grey	very stiff. some fine sand.
-7.19	13.00	2.00	Sandy silt	light grey	clayey silt with fine sand. some coarse sand. stiff to hard.
-11.19	17.00	4.00	Clayey silt	light grey	very stiff. some find sond.
-18.19	24.00	7.00	Sand	light grey	coarse sand, quartz rich. 17.5-18.5m coarse to fine sand. medium to dense.
-20.29	26.10	2.10	Weatherd silt stone	dark grey	look like a hard silt.

STANDARD PENETRATION TEST

Depth (m)	N / INTER-PENE (cm)	Num. of blows Every 10cm: 15 cm	30 cm
0.15–0.45	2/30	1	1
1.15–1.45	5/30	2	3
2.15–2.45	15/30	5	10
3.15–3.45	27/30	12	15
4.15–4.45	20/30	9	11
5.15–5.45	18/30	8	10
6.15–6.45	16/30	7	9
7.15–7.45	20/30	9	11
8.15–8.45	20/30	9	11
9.15–9.45	6/30	3	3
10.15–10.45	21/30	7	14
11.15–11.45	31/30	13	18
12.15–12.45	11/30	5	6
13.15–13.45	18/30	8	10
14.15–14.45	18/30	8	10
15.15–15.45	19/30	6	13
16.15–16.45	18/30	8	10
17.15–17.45	5/30	2	3
18.15–18.45	11/30	6	5
19.15–19.45	8/30	4	4
20.15–20.45	9/30	4	5
21.15–21.45	13/30	6	7
22.15–22.45	39/30		
23.15–23.45	39/30		
24.15–24.45	45/30		
25.15–25.45	45/30		
26.00–26.10	50/17		

NUMBER OF BLOWS N



SAMPLING: Sample No. | Depth (m) | Method

Figure IX-3-2 (2) BORING LOG (Soil exploration)

PROJECT · LOCATION: Ban Khao Kong, Amphoe Muang

GROUND ELEVATION: 2.705 m

DATE OF INVESTIGATION: Feb.13,1986

BORING HOLE No.: P - 2

DEPTH TO GROUND WATER LEVEL IN HOLE: 1.700 m

INVESTIGATED BY: P.Chalearw

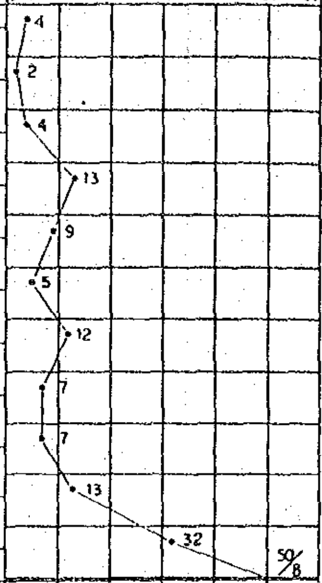
FIELD OBSERVATIONAL RECORD

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	Soil or Rock NAME OF CLASSIFICATION	COLOR TONE	DESCRIPTION
1.71	1.00	1.00	Sandy silt	light grey	silt with fine to coarse sand. soft.
-0.30	3.00	2.00	Clay	light grey	soft. some organic matter.
-1.30	4.00	1.00	Sandy silt	light grey	silt with fine sand.
-4.30	7.00	3.00	Sand	light grey	fine to coarse sand, some silt. quartz rich. loose to medium.
-5.30	8.00	1.00	Graveley sand	light grey	corse sand with gravel(10mm). loose.
-6.50	9.20	1.20	Silty sand	light grey	loose. some gravel (5mm)
-8.35	11.05	1.85	Graveley silt	light grey with red patches	silt with gravel (5 30mm). medium to very dense.

STANDARD PENETRATION TEST

Depth (m)	N / INTER-PENE (cm)	Num. of blows Every 10cm: 15 cm	30 cm
0.15–0.45	4/30	2	2
1.15–1.45	2/30	1	1
2.15–2.45	4/30	2	2
3.15–3.45	13/30	6	7
4.15–4.45	9/30	4	5
5.15–5.45	5/30	2	3
6.15–6.45	12/30	5	7
7.15–7.45	7/30	2	5
8.15–8.45	7/30	1	6
9.15–9.45	13/30	4	9
10.15–10.45	32/30		
11.00–11.05	50/8		

NUMBER OF BLOWS N



SAMPLING: Sample No. | Depth m | Method

Figure IX-3-2 (3) | **BORING LOG** (Soil exploration)

PROJECT · LOCATION: Ban Du Song, Amphoe Muang

GROUND ELEVATION: 4.946 m

DATE OF INVESTIGATION: Feb. 11, 1986

BORING HOLE No.: D-3

DEPTH TO GROUND WATER LEVEL IN HOLE: 0.800 m

INVESTIGATED BY: D. Throngrit

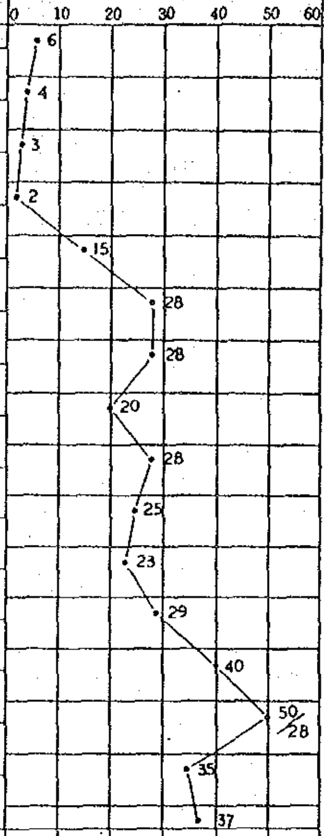
FIELD OBSERVATIONAL RECORD

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	Soil or Rock NAME OF CLASSIFICATION	COLOR TONE	DESCRIPTION
3.85	1.10	1.10	Sandy silt		silt with fine sand, loose.
2.95	2.00	0.90	Silty sand		fine sand with some silt.
1.75	3.20	1.20	Clay		2.4m some organic matter, soft.
0.45	4.50	1.30	Silty sand		fine to coarse sand with silt, medium.
-2.05	7.00	2.50	Silty clay	light grey to redish brown	very stiff, some fine sand.
-3.35	8.30	1.30	Silty sand	light grey	fine sand with silt, dense
-5.85	10.80	2.50	Silty clay	light grey with red patches	very stiff, upper portion some fine sand.
-7.05	12.00	1.20	Silty sand		coarse sand with silt, dense, some gravel (3mm) hard.
-10.15	15.10	3.10	Silty clay	light grey with red patches.	
-10.50	15.45	0.35	Silty sand		

STANDARD PENETRATION TEST

Depth (m)	N / INTER-PENE (cm)
0.15 – 0.45	6/30
1.15 – 1.45	4/30
2.15 – 2.45	3/30
3.15 – 3.45	2/30
4.15 – 4.45	15/30
5.15 – 5.45	28/30
6.15 – 6.45	28/30
7.15 – 7.45	20/30
8.15 – 8.45	28/30
9.15 – 9.45	25/30
10.15 – 10.45	23/30
11.15 – 11.45	29/30
12.15 – 12.45	40/30
13.15 – 13.43	50/28
14.15 – 14.45	35/30
15.15 – 15.45	37/30

NUMBER OF BLOWS N



SAMPLING: Sample No. | Depth m | Method

Figure IX-3-2 (4)	BORING LOG (Soil exploration)

PROJECT · LOCATION: Ban Thung Krang Amphoe Rangae

GROUND ELEVATION: 5872 m

DATE OF INVESTIGATION: Feb.8,1986

BORING HOLE No.: P－4

DEPTH TO GROUND WATER LEVEL IN HOLE: 0500 m

INVESTIGATED BY: D.Throngrit

FIELD OBSERVATIONAL RECORD

ELEVATION m	DEPTH m	THICKNESS m	Soil or Rock NAME OF CLASSIFICATION	COLOR TONE	DESCRIPTION
287	300	300	Silty clay	light grey to redish brown	medium to stiff.
207	380	080	Silty sand	light grey	coarse sand(1mm) with silt.medium.
-028	615	235	Silt	light grey	medium to stiff.
-343	930	315	Sandy silt	light grey	silt with fine sand. soft.
-513	1100	170	Sand	light grey	coarse(10mm) to fine sand.
-663	1250	150	Clayey silt	light grey	medium to very stiff.
-758	1345	095	Sandy silt	light grey	silt with coarse sand.
-1113	1700	355	Silt	light grey with redish patches	very stiff. some fine sand.
-1538	2125	425	Sandy silt	light grey with redish patches	silt with fine sand.medium. 19-20m coarse sand rich.
-1613	2200	075	Silt	light grey to light brownish grey	silt with fine sand. medium.
-1713	2300	100	Sandy silt	light grey with redish patches	coarse sand with silt. dense.
-1853	2440	140	Sand	red to yellow	coarse sand. some gravel(5mm). medium.
-1913	2500	060	Clayey sand		
-2013	2600	100	Sand	light	quartz coarse sand. somegravel (10mm)
-2241	2828	228	Weatherd granite		look like a silty sand.

STANDARD PENETRATION TEST

Depth m	N / INTER-PENE cm
015–045	6/30
115–145	8/30
215–245	13/30
315–345	21/30
415–445	16/30
515–545	4/30
615–645	4/30
715–745	3/30
815–845	3/30
915–945	3/30
1015–1045	6/30
1115–1145	7/30
1215–1245	20/30
1315–1345	26/30
1415–1445	27/30
1515–1545	26/30
1615–1645	25/30
1715–1745	17/30
1815–1845	16/30
1915–1945	13/30
2015–2045	13/30
2115–2145	13/30
2215–2245	23/30
2315–2345	13/30
2415–2445	14/30
2515–2545	38/30
2615–2645	43/30
2715–2745	50/30
2800–2828	50/28

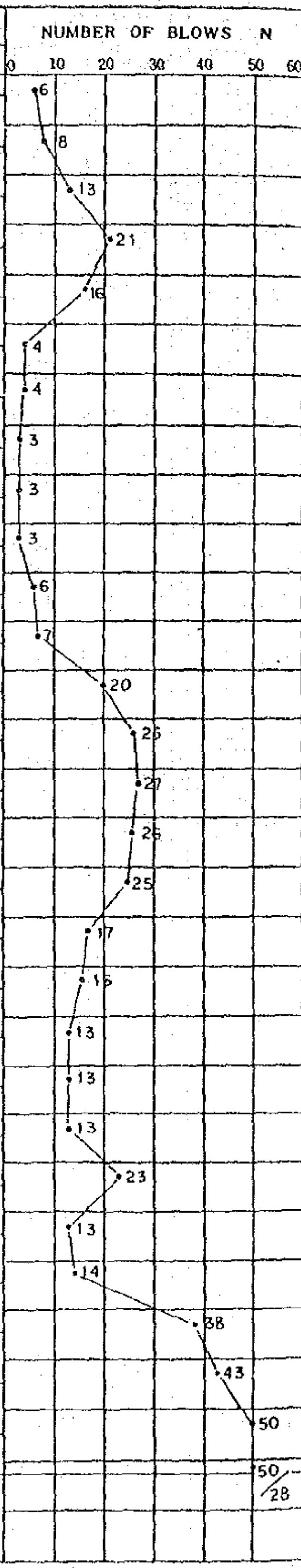


Figure IX-3-2 (5)

BORING LOG (Soil exploration)

PROJECT · LOCATION: Ban Khok Kraduk Mu Amphoe Tak Bai

GROUND ELEVATION: 2.260 m

DATE OF INVESTIGATION: Feb.7,1986

BORING HOLE No.: P-5

DEPTH TO GROUND WATER LEVEL IN HOLE: 0.300 m

INVESTIGATED BY: P.Chalearw

FIELD OBSERVATIONAL RECORD

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	Soil or Rock NAME OF CLASSIFICATION	COLOR TONE	DESCRIPTION
1.26	1.00	1.00	Organic clay	brackish brown	clay with unresolved organic matter. very soft.
0.26	2.00	1.00	Organic sand	grey	fine sand with unresolved organic matter. very soft.
-2.74	5.00	3.00	Sand	grey	fine to coarse sand, fine sand rich(quartz). some gravel(5mm). very loose.
-6.89	9.15	4.15	Sand	grey	coarse sand. some granel(3mm). medium to dense.
-7.74	10.00	0.85	Silt	grey	some fine sand and mica. very soft.
-9.74	12.00	2.00	Sand	light grey with light yellow	caorse sand. some quartz gravel(10mm). medium.
-12.74	15.00	3.00	Clay	dark grey	medium.
-14.74	17.00	2.00	Graveley clay	light grey with red patches	clay with gravel (5mm). very stiff.
-15.74	18.00	1.00	Sandy silt		silt with fine sand. stiff.
-16.74	19.00	1.00	Silt	light grey	stiff.
-17.74	20.00	1.00	Clayey silt	grey	some organic matter. medium.
-25.74	28.00	8.00	Clay	dark grey, light grey, dark grey	medium to very stiff. 21.0-22.0m some organic matter.
-26.74	29.00	1.00	Sand	dark grey	coarse sand. medium.some clay.
-28.19	30.45	1.45	Clay	light grey	very stiff.

STANDARD PENETRATION TEST

Depth (m)	N / INTER-PENE (cm)	15 cm	30 cm	NUMBER OF BLOWS N
0.15–0.45	1/30	0	1	1
1.15–1.45	1/30	0	1	1
2.15–2.45	0/30	0	0	0
3.15–3.45	0/30	0	0	0
4.15–4.45	0/30	0	0	0
5.15–5.45	0/30	0	0	0
6.15–6.45	15/30	5	10	15
7.15–7.45	27/30	11	16	27
8.15–8.45	18/30	9	9	18
9.15–9.45	2/30	1	1	2
10.15–10.45	19/30	8	11	19
11.15–11.45	22/30	11	11	22
12.15–12.45	6/30	2	4	6
13.15–13.45	5/30	1	4	5
14.15–14.45	29/30	13	16	29
15.15–15.45	19/30	7	12	19
16.15–16.45	17/30	7	10	17
17.15–17.45	11/30	5	6	11
18.15–18.45	12/30	5	7	12
19.15–19.45	7/30	3	4	7
20.15–20.45	7/30	3	4	7
21.15–21.45	9/30	4	5	9
22.15–22.45	11/30	5	6	11
23.15–23.45	15/30	6	9	15
24.15–24.45	16/30	7	9	16
25.15–25.45	10/30	4	6	10
26.15–26.45	13/30	6	7	13
27.15–27.45	10/30	5	5	10
28.15–28.45	14/30	6	8	14
29.15–29.45	15/30	6	9	15
30.15–30.45	17/30	7	10	17

SAMPLING

Sample No.	Depth m	Method

Figure IX-3-2 (6) | BORING LOG (Soil exploration)

PROJECT · LOCATION Ban Sala Mai Amphoe Tak Bai

GROUND ELEVATION 1.940 m

DATE OF INVESTIGATION Feb.5,1986

BORING HOLE No. P-6

DEPTH TO GROUND WATER LEVEL IN HOLE 0.750 m

INVESTIGATED BY P.Chalearw

FIELD OBSERVATIONAL RECORD

ELEVATION (m)	DEPTH (m)	THICKNESS (m)	Soil or Rock NAME OF CLASSIFICATION	COLOR TONE	DESCRIPTION
0.94	1.00	1.00	Sandy clay	light grey	clay with fine to coarse sand.
-1.06	3.00	2.00	Sand	light grey	quartz coarse sand. very loose to medium.
-4.06	6.00	3.00	Sand	light grey	fine sand, quartz rich. some organic matter. lower portion some coarse sand.
-9.06	11.00	5.00	Sand	light grey	6.0-7.0m coarse to fine sand, some gravel (5mm). dense. 7.0-8.5m fine sand, some mica. dense 8.5-9.5m coarse sand , some medium. gravel(5mm). 9.5-11.0m fine sand, medium.
-11.56	13.50	2.50	Silty sand	light grey	silt to fine sand. some shells and organic matter. medium.
-17.06	19.00	5.50	Silt	grey	contained very fine sand. medium. some shells and organic matter.
-25.31	27.25	8.25	Silty clay	grey	medium to stiff. some fine sand. some shells and organic matter.
-28.36	30.30	3.05	Sand	whitish grey	27.25-28.00m fine sand, medium. 28.00-29.00m medium sand, medium 29.00-29.50m coarse sand, dense. 29.50-30.30m fine sand, dense.

STANDARD PENETRATION TEST

Depth (m)	N / INTER-PENE (cm)	Num. of blows Every 10cm: 15 cm	30 cm	NUMBER OF BLOWS N
0.15-0.45	4/30	2	2	4
1.15-1.45	3/30	1	2	3
2.15-2.45	10/30	5	5	10
3.15-3.45	12/30	4	8	12
4.15-4.40	50/25			50
5.15-5.45	19/30	6	13	19
6.15-6.45	33/30	15	18	33
7.15-7.45	39/30			39
8.15-8.45	33/30			33
9.15-9.45	28/30	12	16	28
10.15-10.45	28/30	12	16	28
11.15-11.45	4/30	2	2	4
12.15-12.45	5/30	2	3	5
13.15-13.45	4/30	1	3	4
14.15-14.45	5/30	2	3	5
15.15-15.45	4/30	2	2	4
16.15-16.45	5/30	2	3	5
17.15-17.45	4/30	2	2	4
18.15-18.45	6/30	3	3	6
19.15-19.45	5/30	2	3	5
20.15-20.45	5/30	3	2	5
21.15-21.45	8/30	4	4	8
22.15-22.45	5/30	2	3	5
23.15-23.45	6/30	3	3	6
24.15-24.45	6/30	3	3	6
25.15-25.45	12/30	5	7	12
26.15-26.45	15/30	6	9	15
27.15-27.45	21/30	9	12	21
28.15-28.45	27/30	12	15	27
29.15-29.45	32/30			32
30.00-30.30	30/30			30

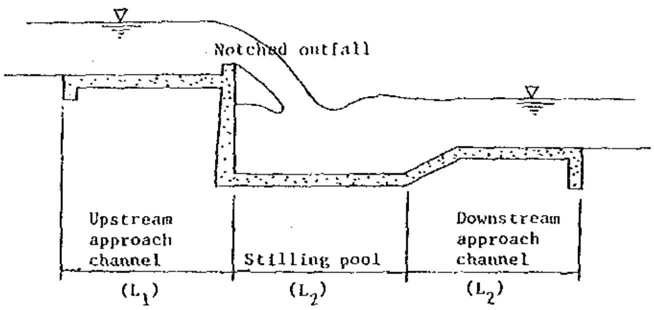
SAMPLING: Sample No. | Depth m | Method

IX-3-2 Design of Vertical Drop

The aim of the drop is to adjust the gradient of canal course, thereby, keep the canal flow velocity within the tolerable limit. Drops consist of vertical and inclined types. As a vertical drop seems suitable for this area in consideration of its topography, the following design has been made:

(1) Structure

As shown below, the vertical drop would consist of upstream approach channel, notched outfall, stilling pool, and downstream approach channel.



(2) Configuration dimensions

(a) Upstream approach channel

For the purpose of preventing the channel scouring on the upstream side of the drop, the upstream approach channel would be provided. The length of upstream approach channel would be obtained by the following two equations where the greater value is adopted:

$q<2 \quad \ell 1 = 1.2 + 3/2\ Q^{1/2}$

.... 1

$q>2 \quad \ell 1 = 2.1 + 3/2\ Q^{1/2}$

$\ell 2 = 4Hd$ 2

Where Q: Total discharge (m^3/sec), q: Unit-width discharge (m^3/sec/m), and Hd: Difference in water level between upstream and downstream (m).

Type of Drainage Canal	Q (m^3/sec)	b (m)	q (m^3/sec/m)	ℓ1 (m)	ℓ2 (m)	L1 (m)
I	5	3.95	1.3	4.6	6.0	6.0
II	10	5.70	1.8	6.0	6.0	6.0
III	15	7.15	2.1	7.9	6.0	8.0
IV	20	7.75	2.6	2.8	6.0	8.8
V	25	9.05	2.8	9.5	6.0	9.6
VI	30	9.50	3.2	10.3	6.0	10.3
VII	35	11.10	3.2	11.0	6.0	11.0
VIII	60	14.50	4.1	13.7	6.0	13.7
IX	80	19.00	4.2	15.5	6.0	15.5

(b) Notched outfall

The configuration of a notched outfall of the drop greatly affects the whole design of the drop. The reasons for selecting the configuration of an outfall are given below:

First, a conceivable cross-sectional configuration is rectangular or trapezoidal. Here, in order to equalize the flow distribution in the cross-section and to perfect the function of energy dissipator, rectangular cross-section would be adopted. Also, as the critical depth occur near the notched outfall and the upstream side is affected by a drop-down, the outfall is provided with the following configuration to prevent such influence:

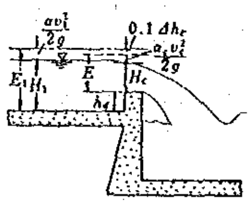
- o Narrow the width of the notched outfall.
- o Raise the height of the notched outfall.
- o Raise the height of and narrow the width of the notched outfall.

As it is considered disadvantageous if the configuration of the notched outfall provided within a drainage canal is of a reduced cross-section to allow the flood to flow down rapidly, a notched outfall of the raised height type is adopted. The width of the notched outfall is the average of all the widths of upstream canal courses, and the height of the notched outfall is raised to meet the specific energy of the upstream channel course. In this context, the raised height (hd) is obtained as follows:

$B = A/H1$ $\qquad q = Q/B$

$Hc = (\alpha q^2/g)^{1/3}$ $\qquad E = 1.5Hc$

$E1 = H1 + \alpha hv1$ $\qquad hd = E1 - E - 0.1\Delta hv$



B: width of notched outfall (m)

A: flow area of upstream channel (m^2)

q: unit width discharge of notched outfall (m^3/sec/m)

Q: total discharge (m^3/sec)

Hc: critical depth at notched outfall (m)

E: specific energy at notched outfall (m)

E1: specific energy of upstream channel (m)

H1: depth of uniform flow at upstream channel (m)

hv1: velocity head of upstream channel (m)

Δhv: difference in velocity head between upstream channel and notched outfall (m)

α: coefficient of correction (= 1.1)

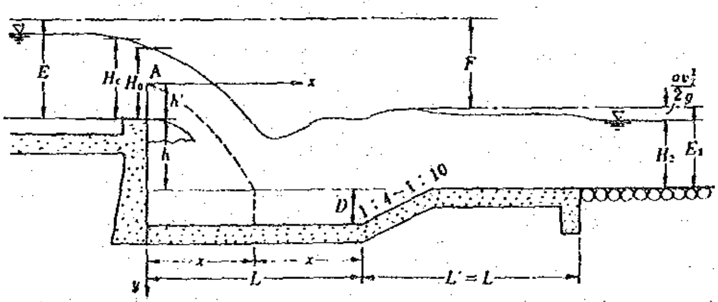
Type of chan-nel	Q (m^3/sec)	H1 (m)	V1 (m/sec)	B (m)	q (m^3/sec/m)	Hc (m)	E (m)	E1 (m)	0.1Δhv (m)	hd (m)
I	5	1.25	1.03	3.95	1.27	0.57	0.86	1.31	0.02	0.43
II	10	1.72	1.04	5.70	1.75	0.70	1.05	1.78	0.03	0.70
III	15	2.03	1.05	7.15	2.10	0.79	1.19	2.09	0.03	0.87
IV	20	2.47	1.05	7.75	2.58	0.91	1.37	2.53	0.04	1.12
V	25	2.66	1.05	9.05	2.76	0.95	1.43	2.72	0.04	1.25
VI	30	3.00	1.05	9.50	3.16	1.04	1.56	3.06	0.04	1.46
VII	35	3.10	1.06	10.80	3.24	1.06	1.59	3.16	0.04	1.53
VIII	60	3.97	1.05	14.50	4.14	1.24	1.86	4.03	0.05	2.12
IX	80	3.99	1.06	19.00	4.21	1.26	1.89	4.05	0.05	8.11

(c) Stilling basin

Stilling basins are provided to ease the impact caused by the falling water as well as to dissipate the energy. Energy dissipation method generally consists of a water cushion type or energy dissipator column type when a large water depth is available and of a hydraulic jump type when only a small water depth is available, depending on the magnitude of the water depth of the downstream channel. Since the water depth required is available on the downstream side or the water cushion type stilling basin is generally employed for a low drop, the water cushion type is adopted.

(i) Length of stilling basin

The length of a stilling basin is obtained in such manner that the vein of falling water enters the center of the stilling basin. As shown below, point A is the central point for the falling water vein in the outfold, and the vein of free falling water is obtained as follows:



$$L2 = 2X = 2v'\left\{\frac{2(h+\alpha \cdot Hc/2)}{g}\right\}^{1/2}$$

$$v' = \frac{Q}{\alpha' HcB} \quad (m/sec)$$

h : Drop height (=1.5 m)

v' : Water velocity at the Notched Outfall (m/sec.)

Hc : Critical depth at the Notched Outfall (m)

B : Width of the Notched Outfall (m)

Q : Discharge (m^3/sec)

α' : 0.656 - 0.72 (0.72 is adopted)

(ii) Depth of water cushion

In general, the depth of water cushion (D) is obtained by the following equation:

$$D = 1/2 \cdot \sqrt{EF}$$

E: Specific energy at the upstream of notched outfall (m)

F: Difference of total head of the up and downstream channel (m)

Type of Drainage Canal	Q (m^3/sec)	Hc (m)	B (m)	v' (m/sec)	$\left\{\frac{2(h + \alpha'.HC/2)}{g}\right\}^{1/2}$	L2 (m)	E (m)	F (m)	D (m)
I	5	0.91	2.0	3.82	0.61	4.7	1.36	1.5	0.72
II	10	1.24	2.5	4.48	0.63	5.7	1.86	1.5	0.84
III	15	1.44	2.9	4.99	0.64	6.4	2.16	1.5	0.90
IV	20	1.71	3.0	5.41	0.66	7.2	2.56	1.5	0.98
V	25	1.84	3.4	5.55	0.66	7.4	2.76	1.5	1.02
VI	30	2.04	3.5	5.84	0.68	8.0	3.06	1.5	1.07
VII	35	2.31	3.4	6.19	0.69	8.6	3.46	1.5	1.14
VIII	60	2.71	4.5	6.83	0.71	9.7	4.06	1.5	1.23
IX	80	2.71	6.0	6.83	0.71	9.7	4.06	1.5	1.23

(d) Downstream approach channel

An approach channel is provided so as not to damage the downstream channel. The length of approach channel is the same as that of stilling basin.

IX-3-3 Design of Inclined Drop

(1) Location

At those points in the improvement section of the drainage canal where the elevation of the drop's downstream approach channel is below the normal impounding water level of the Bang Nara storage and the downstream water depth is considerable, the inclined drop type would be taken.

Canal	Location
Khlong Na Ko	3 + 100
K. Chang	3 + 300
K. Ku Rong Ya Ma	5 + 400*
K. Ba Ngo Du Dung	3 + 650*
K. Sala Mai	1 + 300

* Figure represents the distance from the Bang Nara water storage.

(2) Basic dimensions

Canal	Type	Bottom Width (m)	Dis-charge (m^3/sec)	Canal bottom elevation: Up-stream (EL-m)	Canal bottom elevation: Down-stream (EL-m)	Head (m)
K. Na Ko	II	3.0	10	(+)2.1	(-)1.6	3.7
K. Chang	IV	4.0	20	(+)0.4	(-)1.5	1.9
K. Ya Ma	III	4.0	15	(+)1.4	(-)1.1	2.5
K. Ba Ngo Du Dung	VI	5.0	30	(-)0.4	(-)2.0	1.6
K. Sala Mai	II	5.5	10	(+)0.6	(-)1.1	1.7

(3) Structure

Since, depending on the conditions under which inclined drops are to be installed, the Bang Nara water storage situated on the downstream side plays the role of a stilling basin, provision of the stilling basin is omitted for a drop of this type. Also, as the head is more than 1.5 m and the standard gradient of a chute section is 1:2, the chute section in this case is constructed of wet masonry. The cross-sectional shape of inclined drop is trapezoid.

The length of the upstream approach channel (ℓ) is the same as that of vertical drop. This section is of riprap bed and revetment.

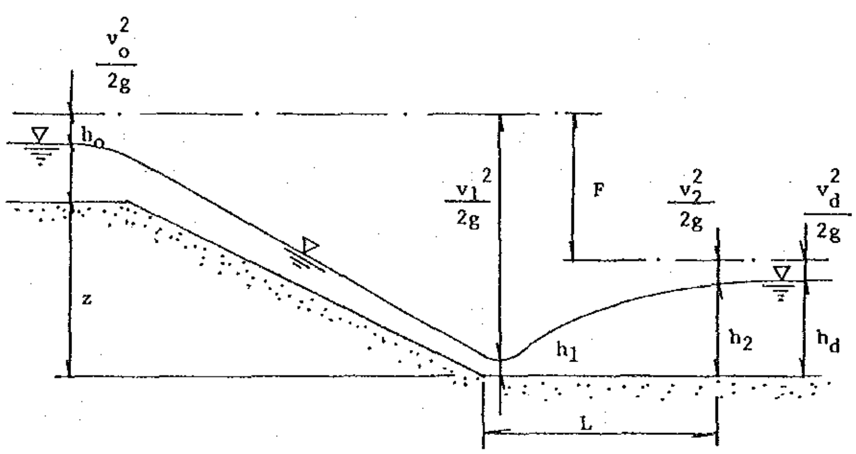
Channel type	(m)
II	6
III	8
IV	9
VI	10.5

The channelizing section is of the same wet masonry as that used for the chute section. Its length is equal to the length of jumping water. The length of jumping water (L) is calculated by applying the Smetana equation.

$L = b\ (h2 - h1)$

h1 : Water depth before water jumps.

h2 : Water depth after water has jumped.



$$F = (Z + ho + vo^2/2g) - (hd + vd^2/2g)$$
$$= Z + (ho - hd) + (vo^2/2g - vd^2/2g)$$

Khlong	Z (m)	ho (m)	Vo (m/s)	$\frac{vo^2}{2g}$	hd (m)	vd (m/s)	$\frac{vd^2}{2g}$	F (m)	A2 (m^2)
II K.Na ko	3.7	1.8	1.059	0.06	2.4	0.631	0.02	3.14	15.84
IV K.Chang	1.9	2.5	1.055	0.06	3.8	0.543	0.02	0.64	36.86
III K.Ku Rong Ya Ma	2.5	2.1	1.061	0.06	3.8	0.407	0.01	0.85	36.86
VI K.Ba Ngo Du Dung	1.6	3.0	1.053	0.06	4.0	0.682	0.02	0.64	44.0
II K. Sala Mai	1.7	1.7	0.759	0.03	1.9	0.630	0.02	1.51	15.865

The following relationship is established between the head loss of the energy by hydaulic jump in the channel with rectangular cross-section and the conjugate depths of the hydraulic jump, h1 and h2:

$$\frac{F}{h_1} = \frac{\left(h_2/h_1 - 1\right)^3}{4 \cdot h_2 \cdot h_1}$$

Also, assuming the unit-width discharge of the given discharge is q, the critical depth is obtained by the following equation:

$$h_c = \sqrt[3]{\frac{q^2}{g}}$$

and, the following relationship exists between h1 and h2.:

$$\frac{h_1}{h_c} = \left\{\frac{2}{h_2/h_1\left(h_2/h_1 + 1\right)}\right\}^{1/3}$$

$$\frac{F}{h_c} = \frac{F}{h_1} \cdot \frac{h_1}{h_c} = \frac{\left(h_2/h_1 - 1\right)^3}{4 \cdot h_2 \cdot h_1} \cdot \left\{\frac{2}{h_2/h_1\left(h_2/h_1 + 1\right)}\right\}^{1/3}$$

By obtaining hc and combining it with the previous F, the values for h1 and h2 are obtained.

Khlong	Q (m^3/S)	B (m)	q ($m^3/S/m$)	hc (m)	$\frac{F}{hc}$	$\frac{h1}{hc}$	$\frac{h2}{h1}$	h1 (m)	h2 (m)
K. Na ko	10	5.7	1.75	0.54	5.8	0.244	11.21	0.13	1.48<2.4
K. Chang	20	7.75	2.58	0.70	0.9	0.405	5.00	0.28	1.42<3.8
K. Ku Rong Ya Ma	15	7.15	2.10	0.61	1.4	0.362	6.02	0.22	1.33<3.8
K. Ba Ngo Du Dung	30	9.50	3.16	0.80	0.8	0.461	4.04	0.37	1.49<4.0
K. Sala Mai	10	8.05	1.24	0.43	3.5	0.276	9.26	0.12	1.10<1.9

When comparing the above h2 with the downstream water level (hd), h2 is considerably smaller than hd. This is because jump is indirect and the length of jump is shorter than in the case of direct jump. However, considering the effect on the downstream, the length of jump adopted is that of direct jump.

Khlong	L(m)
K. Na Ko	8
K. Chang	7
K. Ku Rong Ya Ma	7
K. Ba Ngo Du Dung	7
K. Sala Mai	6

As previously mentioned, because the channelizing section is designed to be longer than the required hydraulic length, it would be judged unnecessary to provide downstream approach channel. However, in order to prevent the scouring from the downstream side of the channelizing section, a riprap revetment with a length equal to half that of the channelizing section is provided.

IX-4 Irrigation Facilities

IX-4-1 Examination of Headrace

This covers the basic requirements governing the headrace scheme when utilizing the drainage canals for channelling irrigation water up to the respective pumping station. Examination has been made in the following sequence:

o Establish the elevation at headrace bed.

↓

o Calculate non-uniform flow to obtain the friction loss (h).

↓

o Obtain the water absorption level at each pump station.

↓

o Re-establish the elevation at headrace bed at a higher level, and move the location of pumping station for excavation height to be 5 m.

↓

o Again, obtain h.

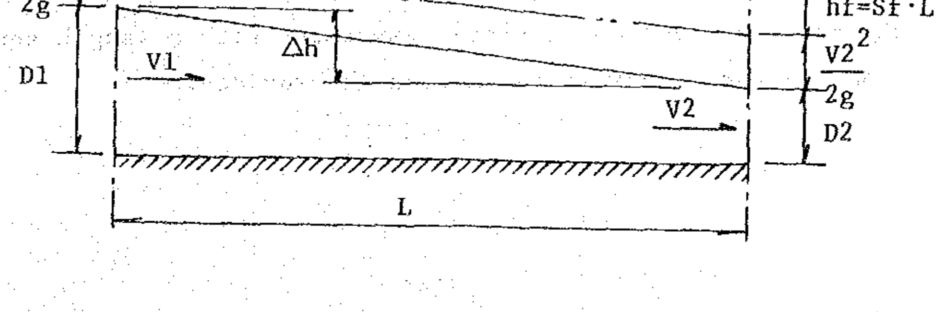
↓

o Repeat the above as far as a headrace bed elevation does not converge.

↓

o From the above, select a headrace bed elevation which can minimize the excavation height.

The head loss under non-uniform flow in the headrace would be obtained by the following equation:



The Bernoulli's theorem is applied.

$$D_1 + \frac{V_1^2}{2g} = D_2 + \frac{V_2^2}{2g} + hf$$

$$\Delta h = Sf \cdot L + \frac{V_2^2}{2g} - \frac{V_1^2}{2g} \qquad Sf = \frac{I_2 + I_1}{2}$$

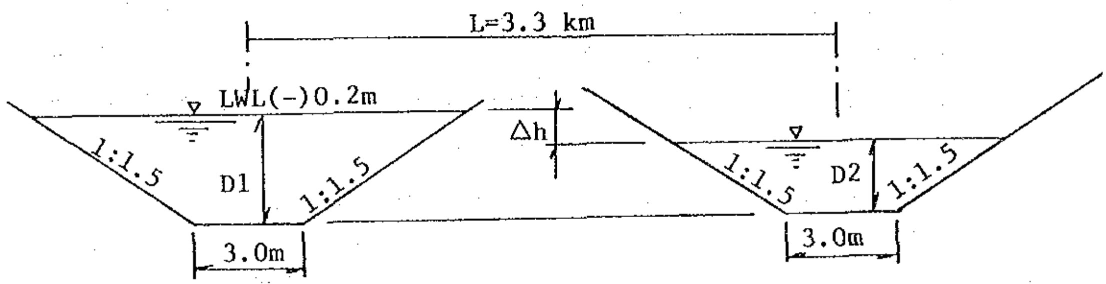
Calculate in advance the value of the left side vs. D1 which is established by the above equation, assume D2 of the right side. Then repeat trial calculations until the value of the right side becomes equal to that of the left side. By this method, obtain D2 at each pumping station.

(i) Du Song Pumping Station - Khlong Na Ko

The basic conditions for the examination of headrace are as follows:

- o Rate of discharge Q = 880 ha x 1.38 l/sec/ha = 1,214 l/sec
  = 1.2 m^3/sec

- o Cross-section of the improved drainage canal Type II (Bed width: 3.0 m and total length: 3.3 km)



At the Bang Nara Water Storage

At Pumping Station

From the results of above examination, the adequate plan for a headrace in the canal would be as follows:

Water depth at the Bang Nara Water Storage	D1 = 1.4 m
Elevation at headrace bed	EL - 1.6 m
Head loss due to water conveyance	Δh = 0.164 m
Water level at pumping station	EL - 0.364 m
Water depth at pumping station point	D2 = 1.236 m

(ii) Khok Ti Te Pumping Station - Khlong Chang

o Rate of discharge Q = 1,120 ha x 1.38 l/sec/ha = 1,546 l/sec.
= 1.6 m^3/sec.

o Cross-section of canal
Type IX (Bed width: 13.5 m and total length: 0.85 km)
Type IV (Bed width: 4.0 m and total length: 2.65 km)

Although in the Type IX section the rate of discharge (Q = 0.65 m^3/sec) to the Maru Bo Pumping Station is added, head loss in this section would be nearly zero because the cross-section is large. Therefore, with the downstream end of the Type IV section as the starting point, the results are as shown below:

Water depth at downstream end of Type IV section	D1 = 1.3 m
Elevation at headrace bed	EL - 1.5 m
Head loss due to water conduction	h = 0.218 m
Water level at pumping station point	EL - 0.418 m
Water depth at pumping station point	D2 = 1.082 m

(iii) Maru Bo Pumping Station - Khlong Ku Rong Ya Ma

o Rate of discharge Q = 470 ha x 1.38 l/sec/ha = 649 l/sec
= 0.65 m^3/sec.

o Cross-section of canal
Type IX (Bed width: 13.5 m and total length: 0.85 km)

Type VIII (Bed width: 8.5 m and total length : 2.5 km)
Type III (Bed width: 4.0 m and total length : 1.75 km)

The rate of discharge in the Type IX section is Q = 2.25 m^3/sec and that in the Type VIII section is Q = 0.65 m^3/sec. As both sections are large for the rates of discharge, head loss in this section would be very minor. With the downstream end of the Type III section as the starting point, the results of the examination are as shown below:

Water depth at downstream end of Type III section	D1 = 0.9 m
Elevation at headrace bed	EL - 1.1 m
Head loss due to water conduction	h = 0.087 m
Water level at pumping station point	EL - 0.287 m
Water depth at pumping station point	D2 = 0.813 m

(iv) Sala Mai Pumping Station

o Rate of discharge Q = 490 ha x 1.38 l/sec/ha = 676 l/sec
= 0.7 m^3/sec

o Cross-section of canal

Type II (Bed width: 3.0 m and total length: 1.3 km)

The results of similar examinations are as shown below:

Water depth at entrance point to the Bang Nara Water Storage	D1 = 0.9 m
Elevation at headrace bed	EL - 1.1 m
Head loss due to water conduction	h = 0.085 m
Water level at pumping station point	EL - 0.285 m
Water depth at pumping station point	D2 = 0.815 m

IX-4-2 Comparison between Types of Pumping Stations

The following three types of pumping stations can be considered:

1) Provide a reinforced concrete suction well and mount pumps thereon (well type).

2) Drive in piles within the headrace, construct a concrete slab on the driven pile heads, and mount pumps thereon (pile type).

3) Install the pumps inclined along the surface of the bank slope on one side of the headrace (inclined type).

Figures IX-4-1 to 3 show the state of each of the above pumping stations with reference to a ø400 mm pump which is an average size. Based on the estimated construction cost of the respective pumping station, the following comparison would be obtained:

Item		(1) Well type		(2) Pile type		(3) Inclined type	
Excavation	(m^3)	990	14,260฿	550	7,920฿	430	6,200฿
Filling	(m^3)	890	16,020	-	-	-	-
Soil disposal	(m^3)	100	1,100	550	6,050	430	4,730
Reinforced concrete	(m^3)	70	348,600	30	149,400	40	199,200
RC pile	(pc)	4 (ø400) (L=10m)	24,000	9 (ø500) (L=10m)	82,800	-	-
Pipe	(m)	10 (ø900) (RC)	12,000	10 (ø800) (PC)	24,000	-	-
Dry masonry	(m^3)	10	6,300	10	6,300	10	6,300
Wet masonry	(m^3)	40	34,000	200	170,000	80	68,000
Pump	(LS)		4,100,900		4,100,900		4,160,800
Total			฿4,557,180		฿4,547,370		฿4,445,230
			(1.000)		(0.998)		(0.975)

As far as the construction cost is concerned, the most economical is the type using the inclined pumps. The following are considered with respect to the operation and maintenance of pumps:

- o Well type:

  The height of the pump house is minimized and no crane or any other equipment is used to minimize the construction cost. A truck crane can take access to the pump house to hoist any of the pumps requiring maintenance or repairs with relative ease.

- o Pile type:

  As in the case of the well type, provision of the crane and other equipment is omitted in order to have the pump house of lower height. However, the pump house of this type is not accessible by a normal truck crane. Consequently, the use of a truck crane of a super long boom is inevitable, and the crane operation becomes more difficult.

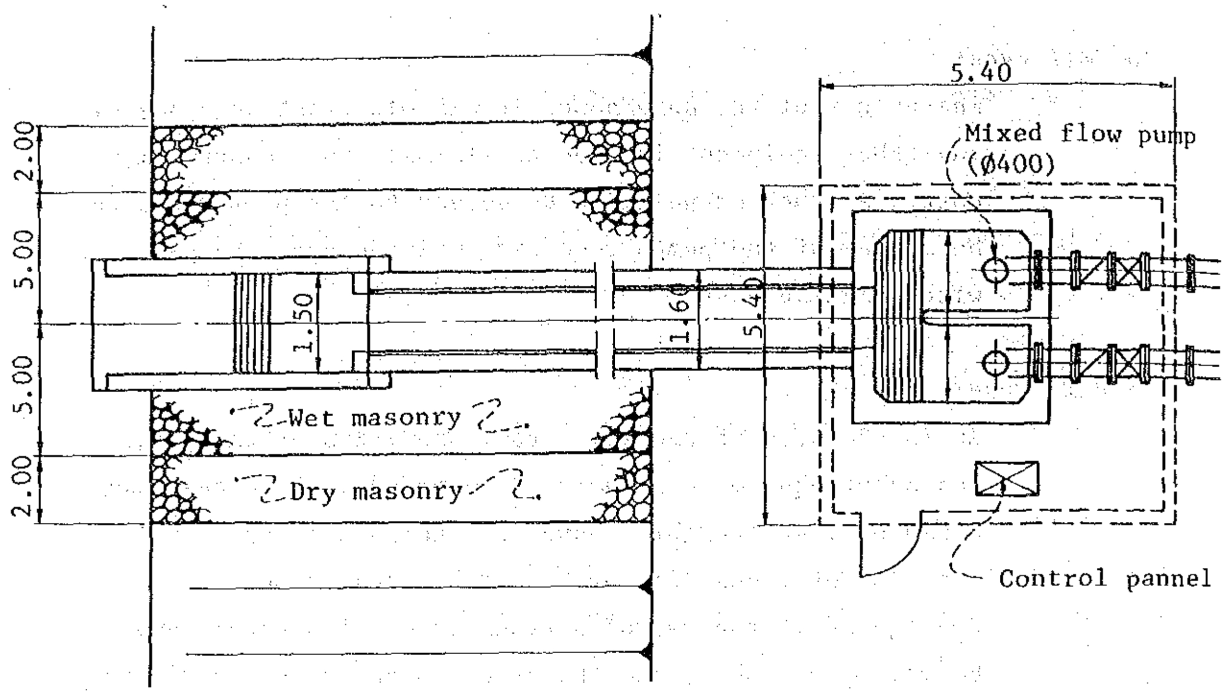
- o Inclined type:

  Embed a concrete base in the slope surface, install tracks thereon, and install a pump on the tracks. With the pump being in trouble, on-the-ground repair is possible by hoisting the pump by the tracks. In this case, a winch is the only device required and the types of equipment and tools needed during repairs and checking can be relatively simple.

By judging from the above items,the inclined pump would be the most viable particularly with regard to its repair and checking requirements.

Figure IX-4-1 Pumping Station Type-1 (Concrete Well Type)

Plan



Profile

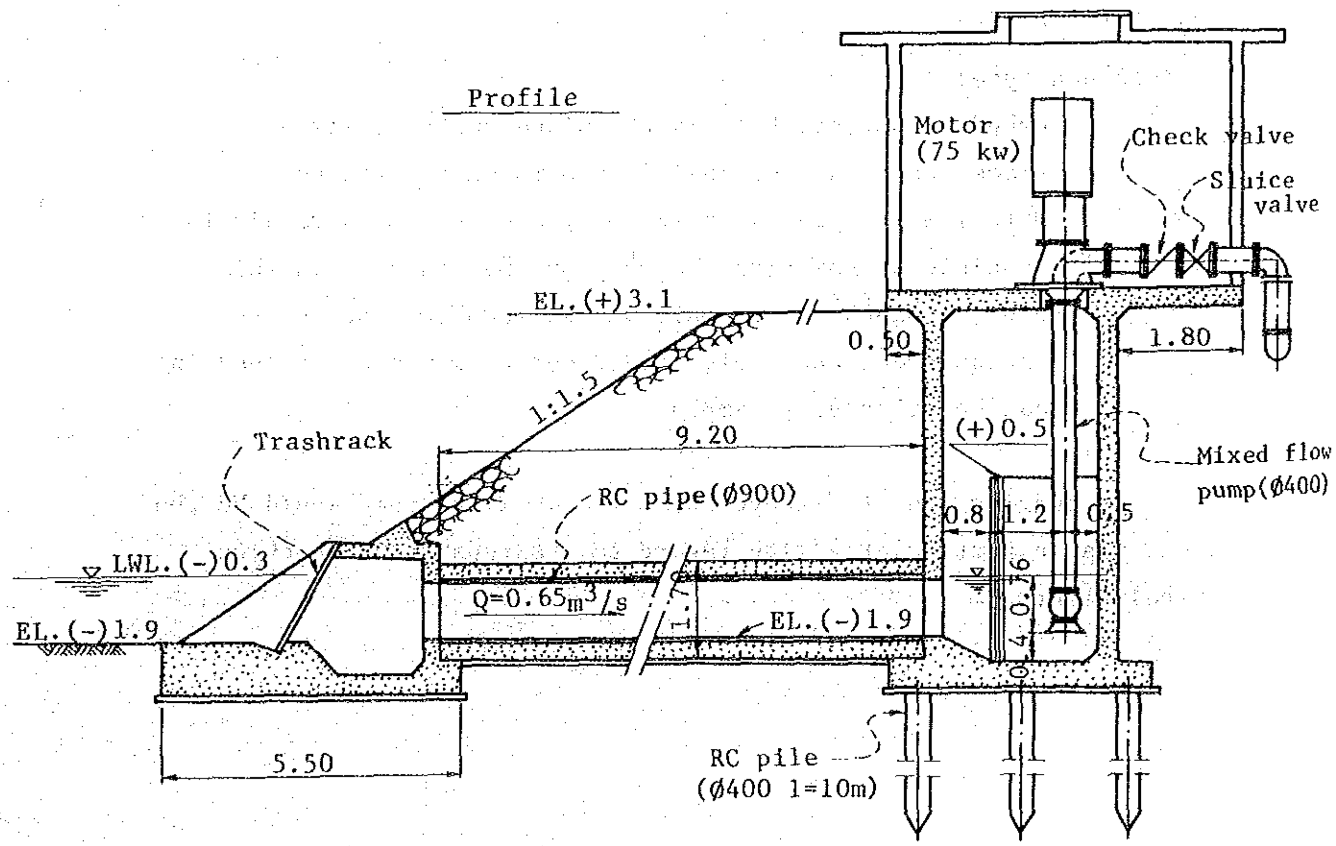


Figure IX-4-2 Pumping Station Type-2 (Pile Structure Type)

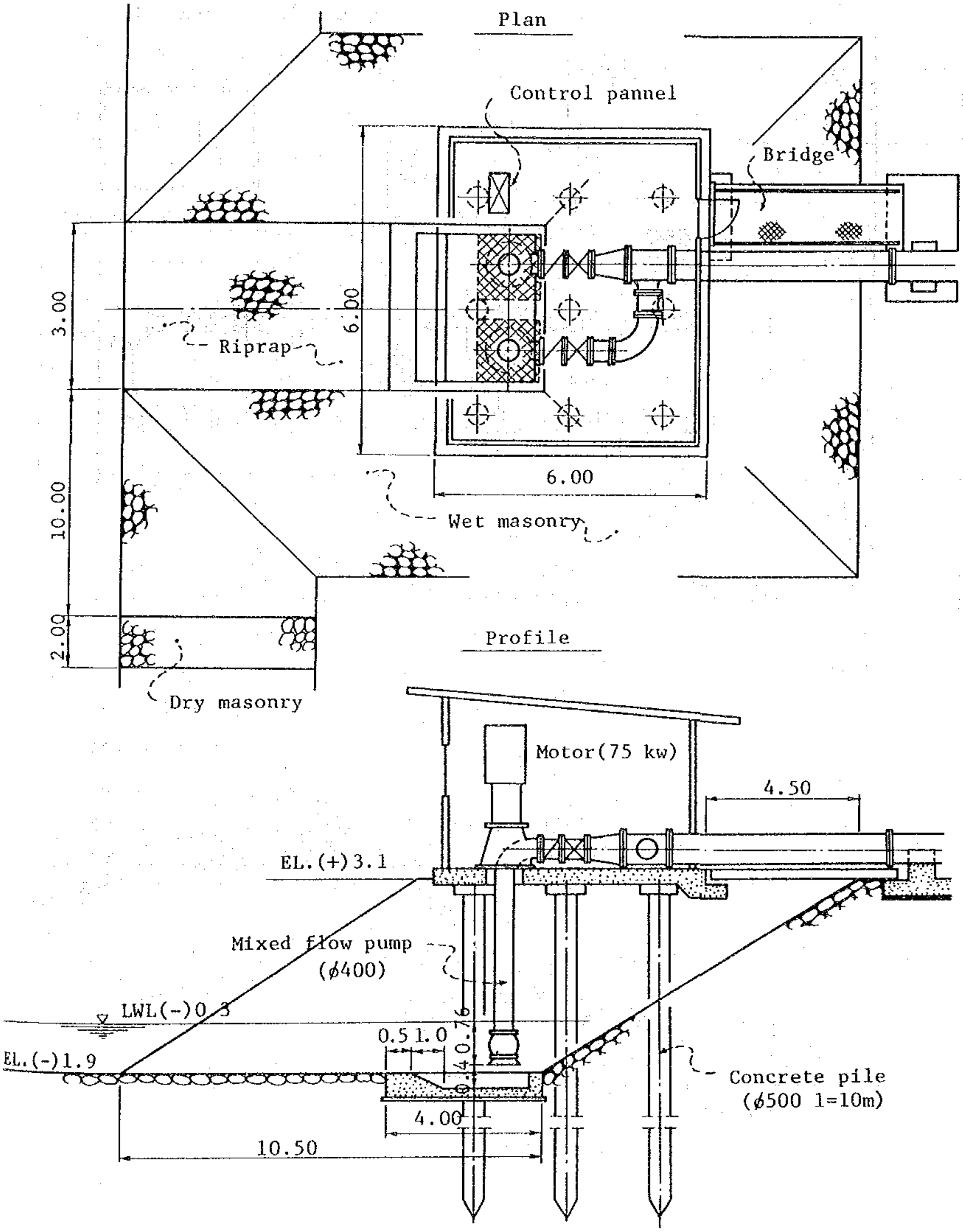
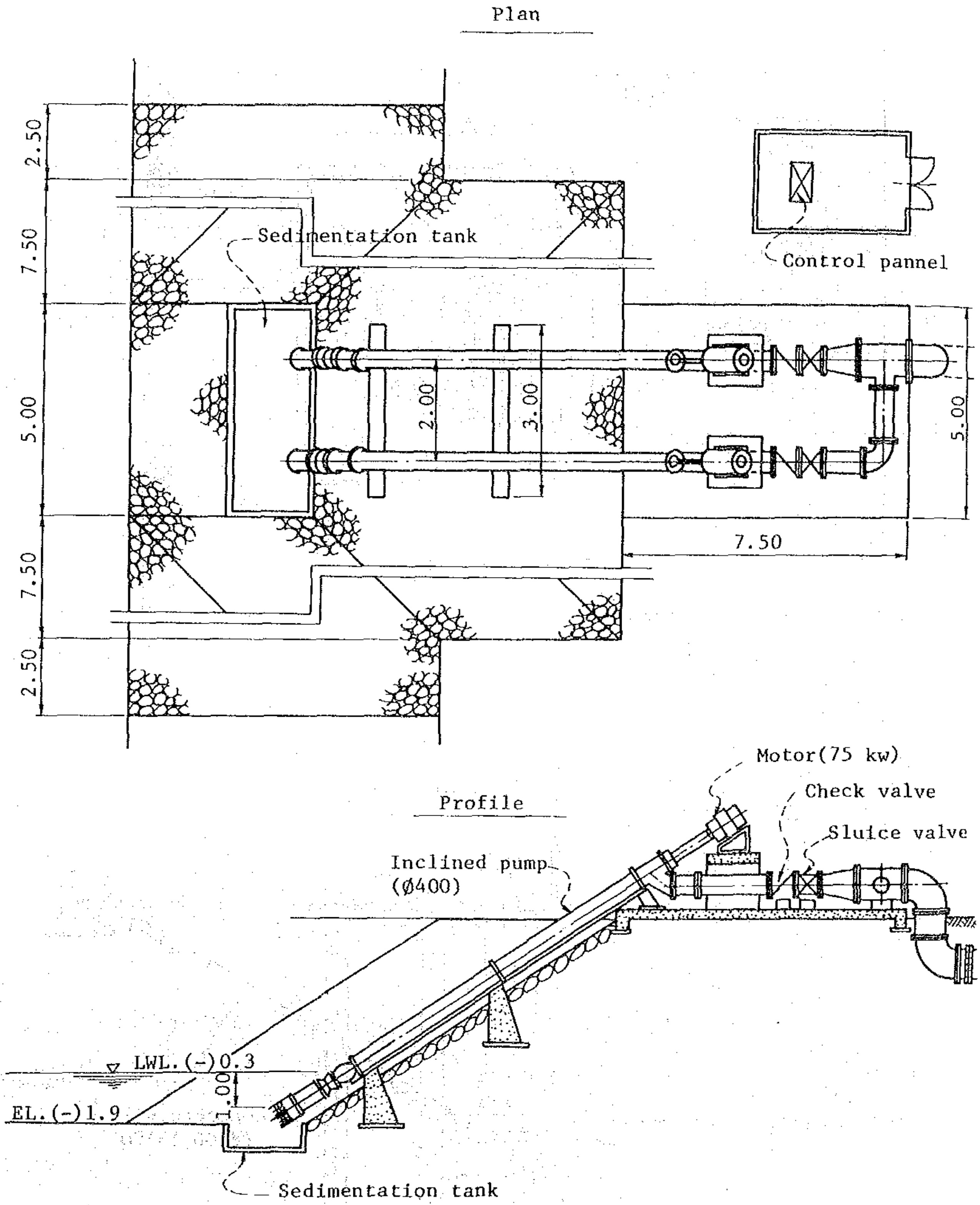


Figure IX-4-3 Pumping Station Type-3 (Inclined Type)



IX-4-3 Comparison between Types of Conveyance Channels

As a means of conveying water to the high paddy field from the pumping stations to be provided on the bank of the improved drainage canal running down to the Bang Nara water storage, the following two types of channel can be considered:

(i) Open channel type constructed of earth
(ii) Pipe channel type.

(1) Water conveyance capacity

1) Unit water requirement

The peak unit water requirement during the period of paddy cultivation is 1.38 litre per sec per ha.

2) Irrigation area

Examination has been made of the pumping irrigation in the vicinity of Khlong Sala Mai, which is a pumping irrigation scheme having an average size of the irrigation area. The irrigation area under the Pumping Station P7 is 490 ha.

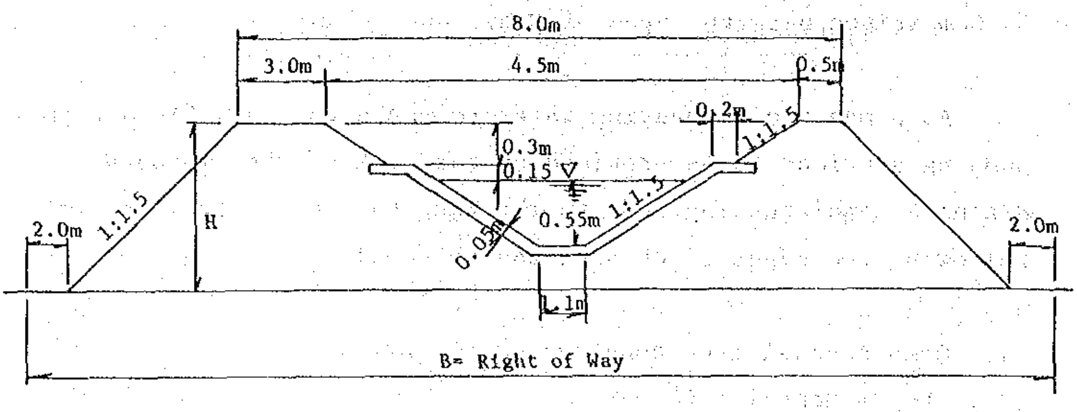
3) Water conveyance capacity

$$Q = 1.38 \text{ l/sec/ha} \times 490 \text{ ha} = 676.2 \text{ l/sec} = 0.68 \text{ m}^3\text{/sec}$$

(2) Cross-section of conveyance channel

The cross-section of conveyance channel required to convey the above discharge would be as shown below:

1) Open channel



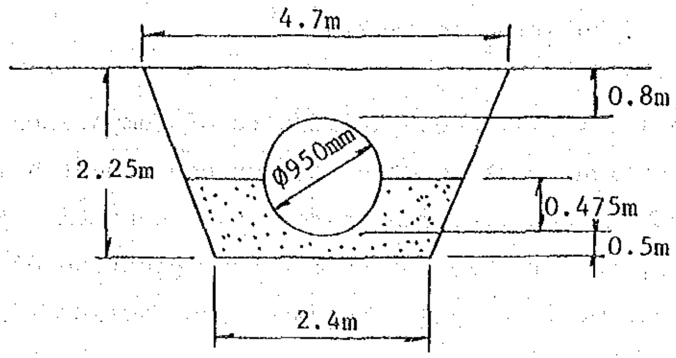
In the case of a channel with a thin concrete lining, the tolerable maximum flow velocity would be 1.5 m per sec. A channel with steep gradient needs considerably more embankment and is in no way economical, therefore, a tolerable minimum flow velocity of 0.7 m per sec to prevent silt from building up and underwater vegetation from growing has been used to minimize the scale of embankment.

2) Pipe channel

When determining the cross-section of a pipe channel, the general relationship between the pipe diameters and in-pipe flow velocities shown below has been used.

Pipe dia. (mm)	Design flow velocity (m/sec)
75 - 150	0.7 - 1.0
200 - 400	0.9 - 1.6
450 - 800	1.2 - 1.8
900 - 1,500	1.3 - 2.0

Based on the above figures, the pipe diameter at Q = 0.68 m^3/sec would be determined as ø800 mm. In consideration of the embedment in unstable ground, the cross-section of the pipe as embedded would be as shown below:



(3) Construction quantities

1) Open channel

The estimated quantities per meter vs. the various embankment heights (H) in the cross-section are as follows:

H (m)	Embankment (m3)	Excavation (m3)	Right-of-way width (m2)	Lining (m3)
1.0	8.1	1.4	15.0	0.184
2.0	20.6	1.4	18.0	0.184
2.5	28.0	1.4	19.5	0.184
3.0	36.1	1.4	21.0	0.184
3.5	45.0	1.4	22.5	0.184
4.0	54.6	1.4	24.0	0.184
3.25	40.5	1.4	21.75	0.184

2) Pipe channel

- o Excavation 8 m^3
- o Foundation sand 2.5 m^3
- o Pipe embedding (ø800 PC pipe) 1 m
- o Backfill 5 m^3
- o Surplus material to be disposed of 3 m^3

(4) Comparison of construction costs

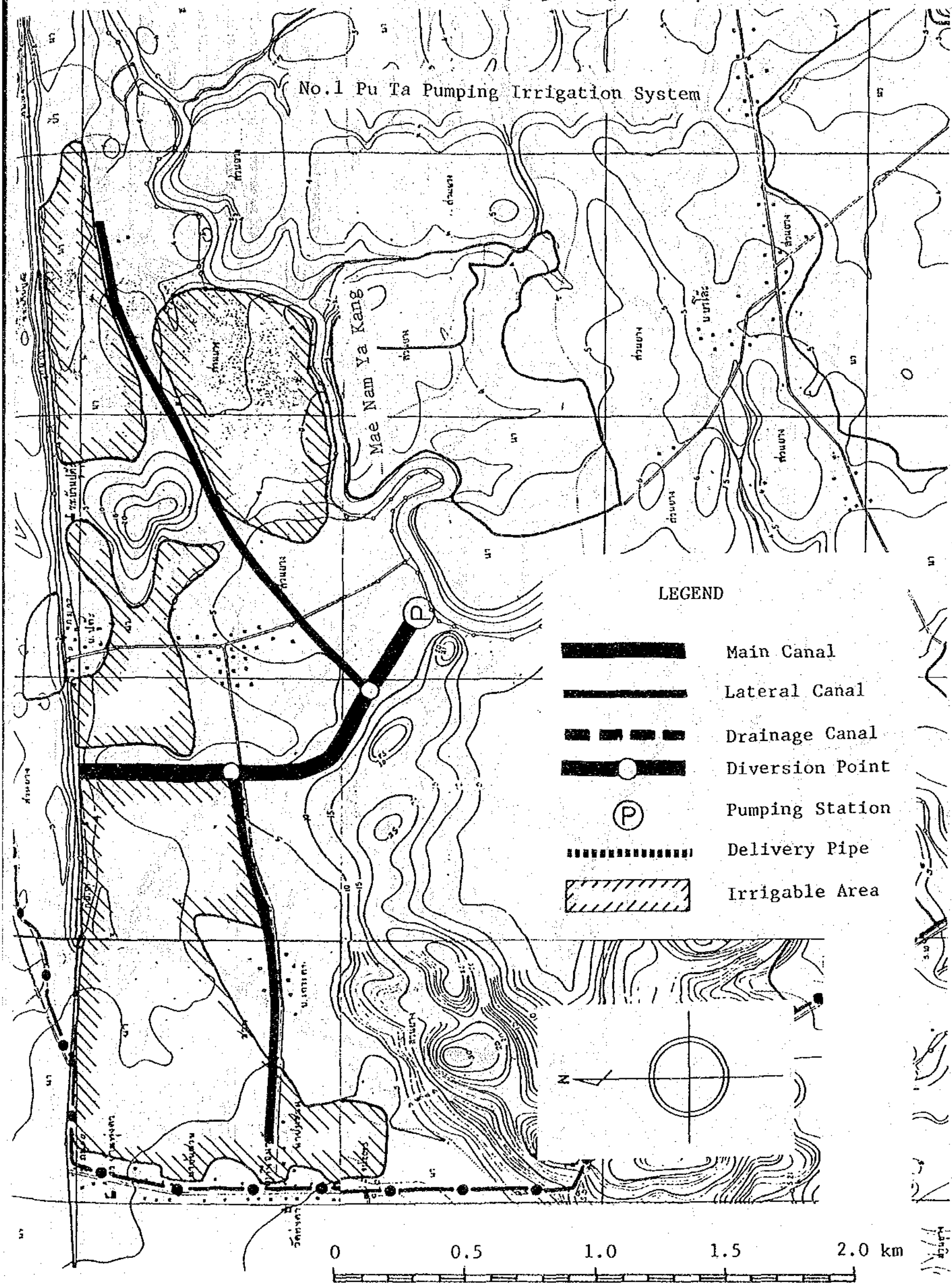
Table IX. 4-3-1 shows the results of comparison made between the construction costs vs. the various embankment heights of open channel and the construction cost of pipe channel. According to the results, the breaking point for the selection of open and pipe channel types would be near the embankment height (H) of 3 to 3.5 m of the open channel.

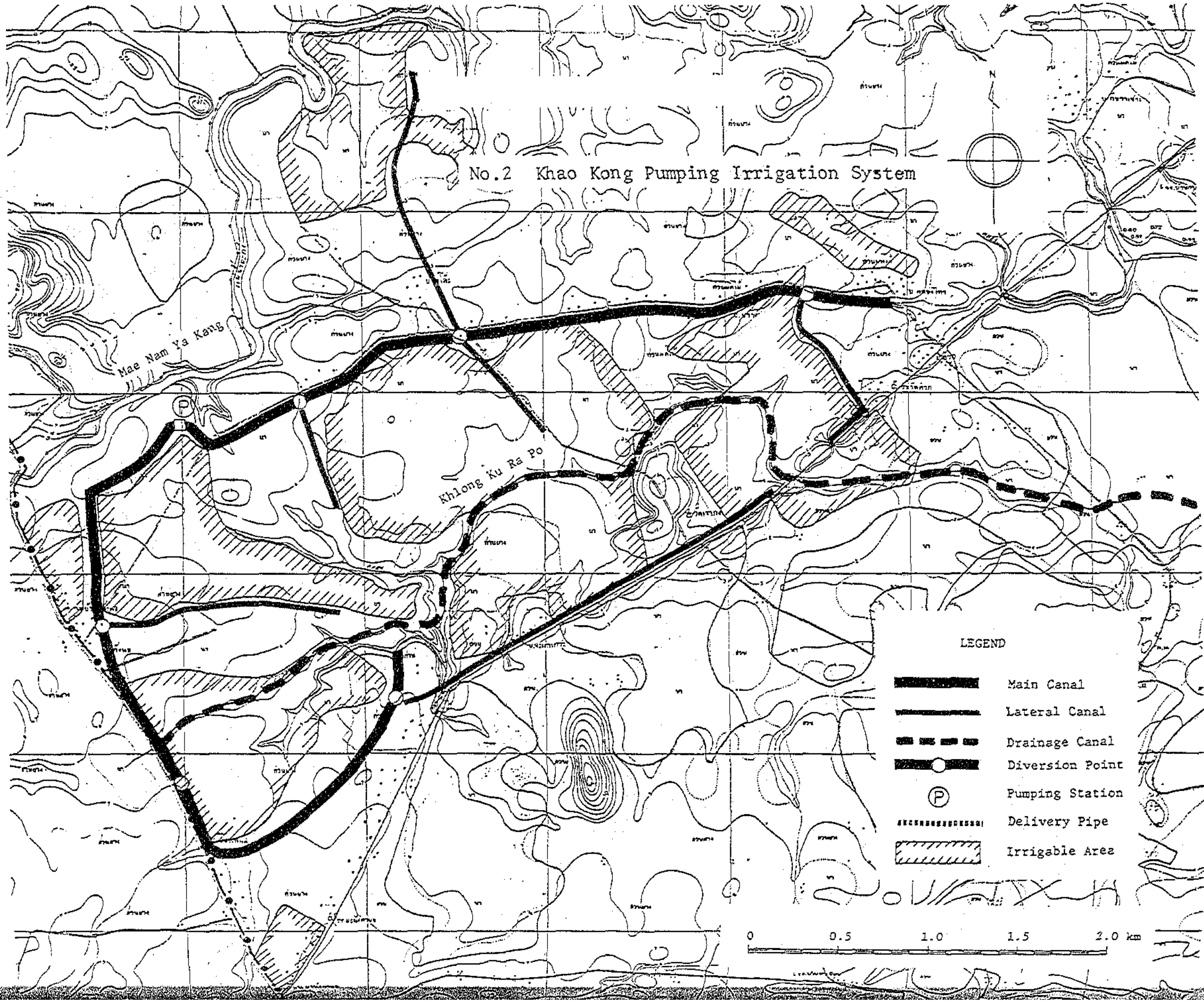
Table IX. 4-3-1 Construction Cost by Types of Conveyance Channels per meter

(Unit: ₱ per meter)

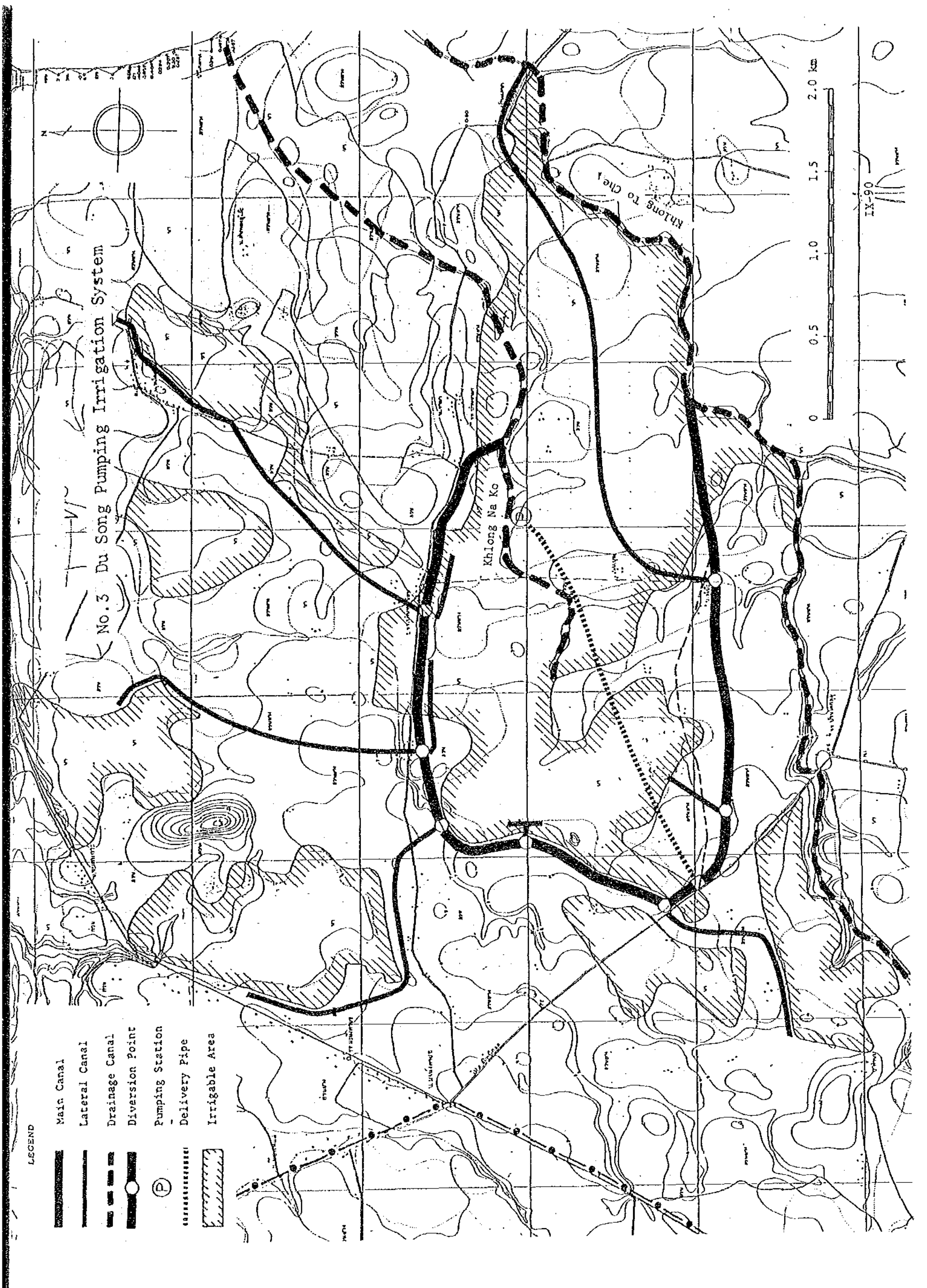
Item	Open canal						Pipe channel
Embankment height (m)	1.0	2.0	2.5	3.0	3.5	4.0	∅800 mm
Land acquisition	94	113	122	132	141	150	-
Embankment	438	1,112	1,512	1,950	2,430	2,949	-
Excavation	20	20	20	20	20	20	115
Filling	-	-	-	-	-	-	143
Soil disposal	-	-	-	-	-	-	33
Sand bed	-	-	-	-	-	-	45
Concrete lining	405	405	405	405	405	405	-
PC pipe	-	-	-	-	-	-	2,400
Cost total	957	1,650	2,059	2,507	2,996	3,524	2,756

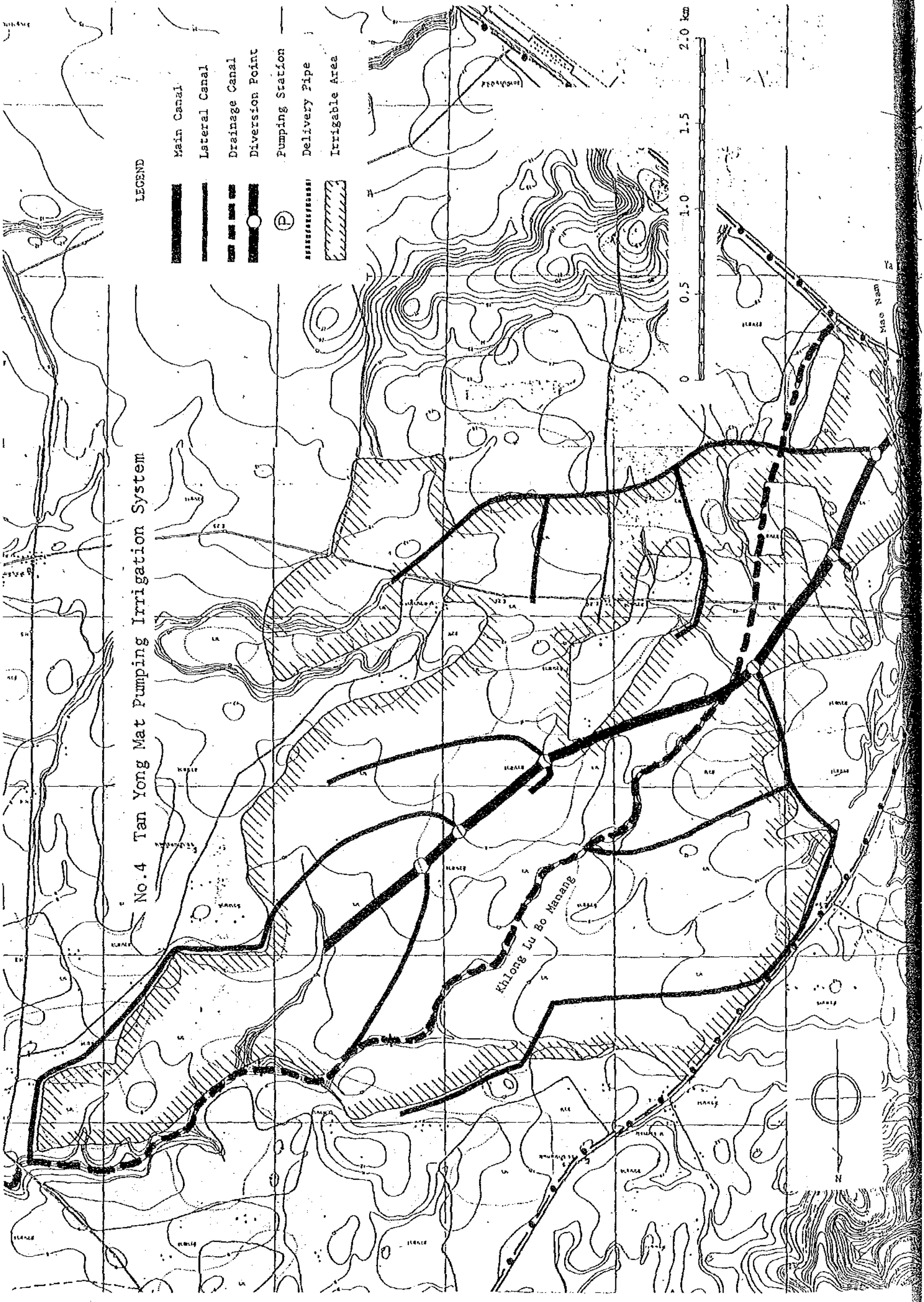
IX-4-4 RID Pumping Irrigation System



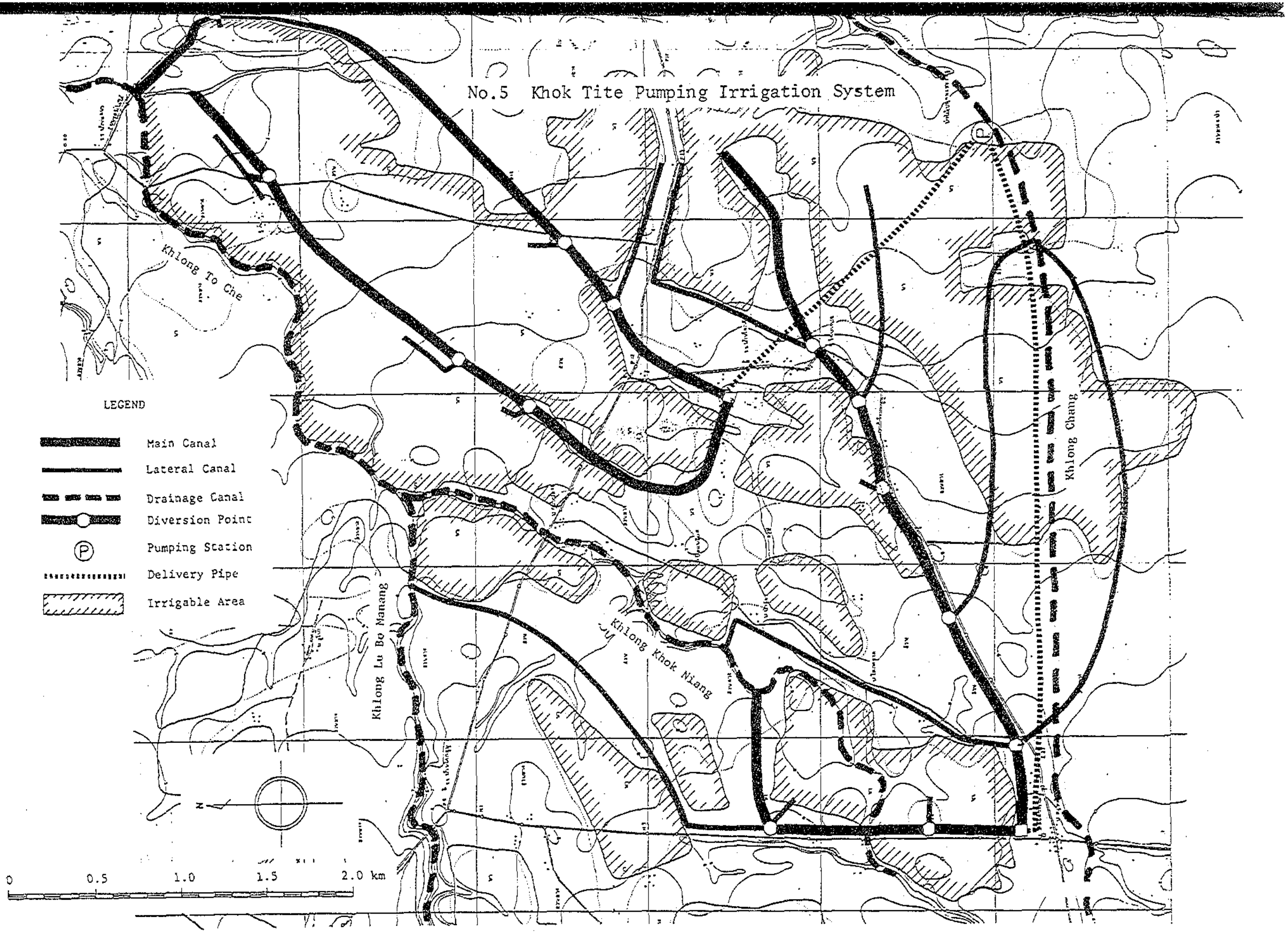


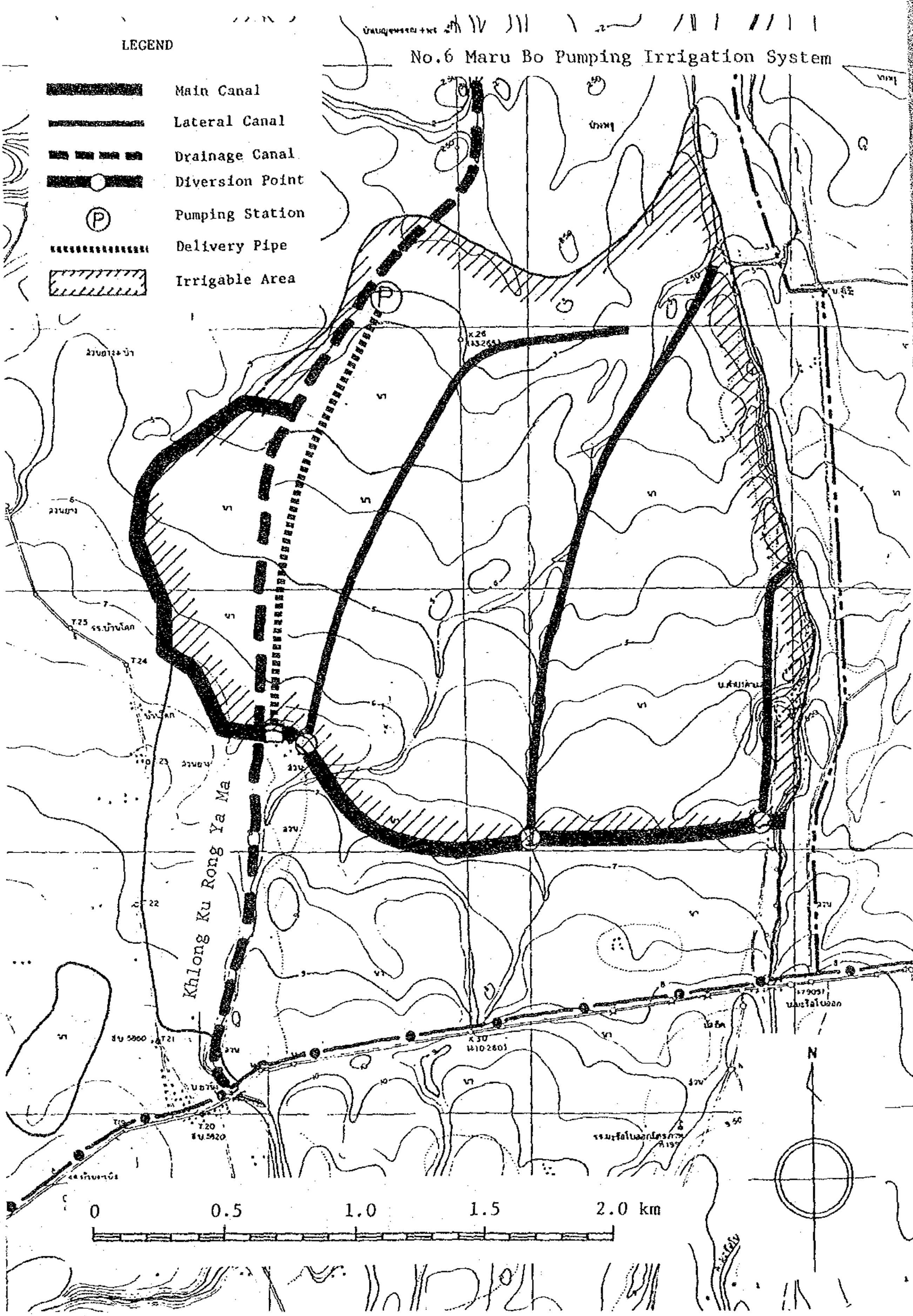
No.2 Khao Kong Pumping Irrigation System
N
Mae Nam Ya Kang
Khlong Ku Ra Po
LEGEND
Main Canal
Lateral Canal
Drainage Canal
Diversion Point
Pumping Station
Delivery Pipe
Irrigable Area
0
0.5
1.0
1.5
2.0 km


No.3 Du Song Pumping Irrigation System
LEGEND
Main Canal
Lateral Canal
Drainage Canal
Diversion Point
Pumping Station
Delivery Pipe
Irrigable Area
Khlong Na Ko
Khlong To Che
0
0.5
1.0
1.5
2.0 km
IX-90



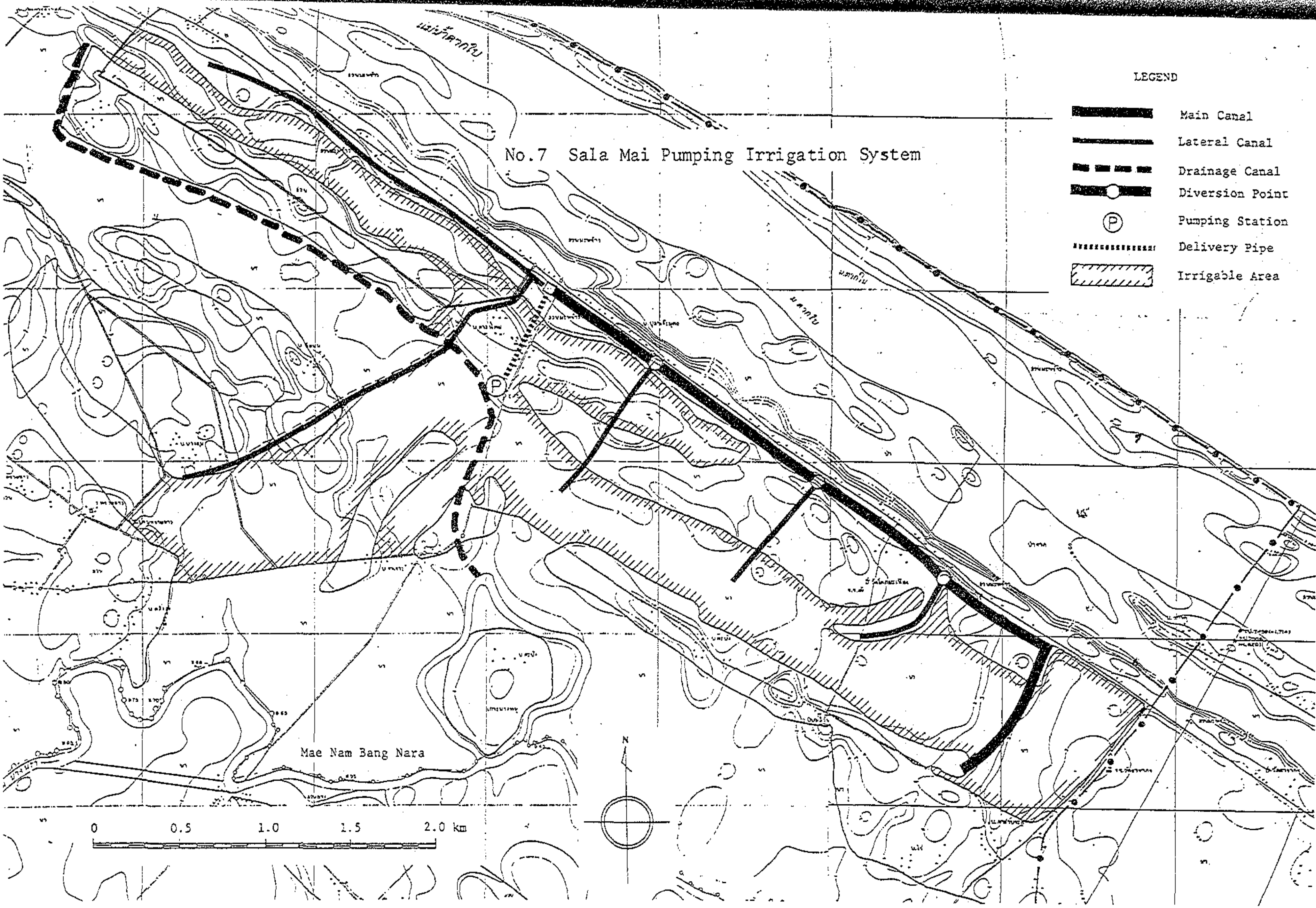
No.4 Tan Yong Mat Pumping Irrigation System
LEGEND
Main Canal
Lateral Canal
Drainage Canal
Diversion Point
Pumping Station
Delivery Pipe
Irrigable Area
0
0.5
1.0
1.5
2.0 km
Khlong Lu Bo Manang
Mae Nam
N


No.5 Khok Tite Pumping Irrigation System
Khlong To Che
Khlong Lu Bo Manang
Khlong Khok Niang
Khlong Chang
LEGEND
Main Canal
Lateral Canal
Drainage Canal
Diversion Point
Pumping Station
Delivery Pipe
Irrigable Area
N
0
0.5
1.0
1.5
2.0 km

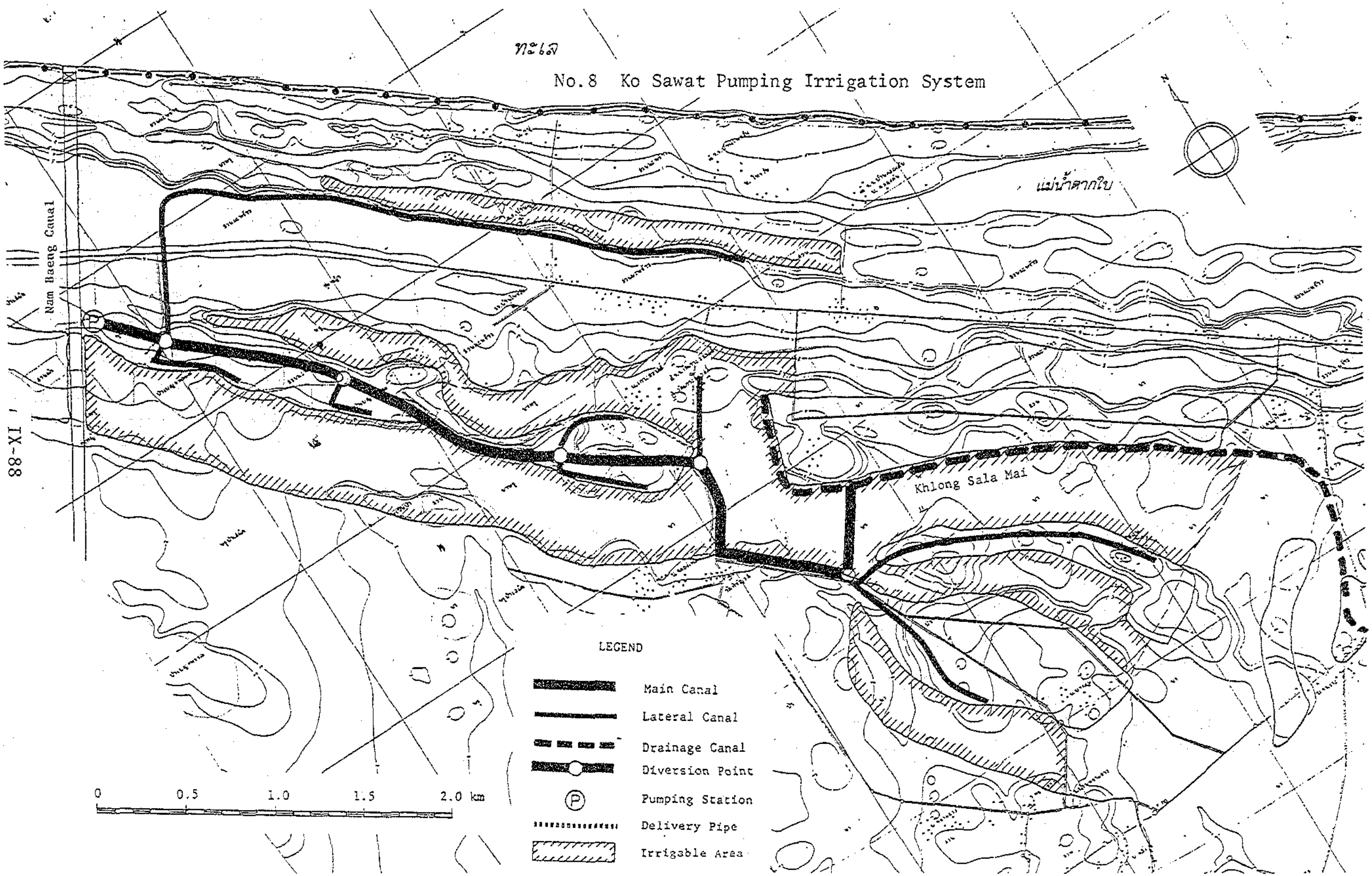


LEGEND
Main Canal
Lateral Canal
Drainage Canal
Diversion Point
Pumping Station
Delivery Pipe
Irrigable Area
No.6 Maru Bo Pumping Irrigation System
Khlong Ku Rong Ya Ma
0
0.5
1.0
1.5
2.0 km
N

No.7 Sala Mai Pumping Irrigation System



No.8 Ko Sawat Pumping Irrigation System



No.9 Phru Kap Daeng Pumping Irrigation System