period, POT method can be used with condition that at least records of two(2) continuous years are available. From the records, the peak flows exceeding an arbitrarily set thresholdd value q_0 are identified.

The threshold is set in such a way that on average between two(2) and five(5) peaks exceed the threshold value q_0. This results in M peak value with an average value q_0 over a total recording period of N years.

The mean annual flood is computed as published by DPMA, 1983 ;

$$MAF = q_0 + (q_p - q_0)x(0.58 \times I_n)$$

where, MAF : Mean annual flood in m^3/s
q_0 : Threshold discharge in m^3/s
q_p : Average peak discharge in m^3/s
I_n : M/N
M : Number of peak values
N : Number of years

The mean annual flood of the Rokan Kiri River at Lubuk Bendahara of which catchment area is about 3,076 Km^2 is computed.

The computation is made with the following conditions ;
- The latest continuous river discharge records at Lubuk Bendahara from 1985 to 1991 are used.

From an initial scan of the records, the threshold of 590 m^3/s seems to give a suitable number of floods for the POT series.

Thirty one(31) independent floods are abstracted as listed below;

Flood in Ranking (m^3/s)

Year	1	2	3	4	5	6	7	8	9
1985	669	616	599	599					
1986	864	776	709	669	647	646	646	641	599
1987	1,142	848	800						
1988	721	689	630						
1989	1,324	769	721	641					
1990	594								
1991	736	704	686	680	660	655	616		

In the notation given above ;

Threshold : q_0 = 590 m^3/s
Number of years of data : N = 7
Number of flood over the q_0 : M = 31

Therefore, q_p = 719 m^3/s and
In = M/N = 4.4 flood/year then
MAF = 590 + (719 - 590)x(0.58 x 4.4)
= 919 m^3/s

Thus, the mean annual flood for Rokan Kiri River at Lubuk Bendahara by using POT method is estimated to be 919 m^3/s.

The flood discharges are calculated by the following formula using MAF and Growth Factor(GF).

Q = GF x MAF

where, Q : Flood discharge
MAF : Mean annual flood
GF : Growth factors derived from the study on flood data in Jawa and Sumatra by IOH/DPMA shown in the following table.

Table of Growth Factor(GF)

Return Period T	Reduced Variation y	Catchment area(km^2)					
		180 or less	300	600	900	1,200	1,500 or more
1000	6.91	4.68	4.58	4.32	4.16	4.01	3.85
500	6.21	4.01	3.92	3.70	3.56	3.41	3.27
200	5.30	3.27	3.20	3.01	2.89	2.78	2.66
100	4.60	2.78	2.72	2.57	2.47	2.37	2.27
50	3.90	2.35	2.30	2.18	2.10	2.03	1.95
20	2.97	1.88	1.84	1.75	1.70	1.64	1.59
10	2.25	1.56	1.54	1.48	1.44	1.41	1.37
5	1.50	1.28	1.27	1.24	1.22	1.19	1.17

The probable flood discharges at Lubuk Bendahara and proposed weir site can be calculated as follows ;

Return Period	GF	MAF (m^3/s)	Probable flood discharge(m^3/s)	
			Lubuk B'hara 3,076 Km^2	Weir site 3,267 Km^2
1000	3.35	919	3,079	3,270
100	1.95	919	1,792	1,903
50	1.70	919	1,562	1,659
20	1.48	919	1,360	1,444
10	1.30	919	1,195	1,269
5	1.15	919	1,057	1,123

(6) Flood runoff by probability analysis of past records

The maximum daily discharges for 1978 to 1991 at Lubuk Bendahara are recorded as follows and converted discharges at the proposed weir site by applying the formula $Y = 1.075X - 10.035$ area also given in the following Table ;

Year	Maximum Discharge (m^3/s)	
	Lubuk B'hara (A=3,076)	Weir Site (A=3,267)
1978	854.2	908.2
1979	995.1	1,059.7
1980	518.6	547.5
1981	434.4	456.9
1982	680.3	721.3
1983	402.8	423.0
1984	632.3	669.7
1985	668.9	709.0
1986	863.9	918.7
1987	1,142.9	1,218.6
1988	721.2	765.3
1989	1,324.9	1,414.2
1990	594.0	628.5
1991	736.1	781.3

The probability analyses are carried out by Iwai's and Gumbel methods. The results are as follows ;

Probable flood discharge by past records

Probable year	Iwai (m^3/s)	Gumbel (m^3/s)
1,000	2,308	2,522
100	1,739	1,901
50	1,573	1,714
20	1,355	1,463
10	1,188	1,270
5	1,014	1,068

(7) Flood runoff at the proposed weir site

The flood runoff obtained by the various methods are summarized below ;

Probable year	Peak flood runoff (m^3/s)					
	Rational	Melchior	Hasper	Unit H.	POT	Past R.
1,000	3,365	2,412	1,192	3,100	3,270	2,522
100	2,156	1,553	836	1,996	1,903	1,901
50	1,895	1,354	739	1,740	1,659	1,714
20	1,568	1,126	616	1,448	1,444	1,463
10	1,372	978	527	1,258	1,269	1,270
5	1,176	848	437	1,090	1,123	1,068

As a results, the flood discharge with return period of 1/100 for designing of permanent weir and with 1/10 for designing of temporary works are decided to be 2,200 m^3/s and 1,400 m^3/s respectively.

Q_{100} = 2,200 m^3/s q_{100} = 0.67 $m^3/s/Km^2$
Q_{10} = 1,400 m^3/s q_{10} = 0.43 $m^3/s/Km^2$

2.3 Water Quality

In order to check whether water in the Rokan River is suitable for irrigation and drinking or not, water sampling and laboratory tests on the samples were carried out under entrusted work to the Indonesian Consultant.

The Indonesian Criteria for water quality categorized five(5) classes of water, i.e.

Class A : For drinking water without treatment
Class B : For drinking and domestic use but not applicable for Class A
Class C : Good for fishery & livestock as well as other purpose but not belong to Class A and B
Class D : Good for agriculture, industry, hydropower and navigation etc, but can not be used for Class A, B & C
Class E : Other than Class A, B, C, & D

The deatail of the Criteria are presented in Table 2.14.

Whereas, the WHO standard of water quality for drinking water and Scofield's standard for irrigation use are as follows:

Item	Unit	For city water	For irrigation
PH		7.0 - 8.5	6.0 - 7.5
Electric conductivity	$Kx10^5$	-	25
Ca	ppm	75	-
Mg	ppm	50	-
Cl	ppm	200	4 m.e/l
SO_4	ppm	200	4 m.e/l
(Nax100)/(Na+Ca+Mg+K)	m.e/l	-	20 %
$KMnO_4$	ppm	10	-
B	ppm	-	0.33 - 1.0

According to the laboratory test, as shown in Table 2.15, the river water in the Rokan Kiri river is categorized as Class D i.e. suitable for irrigation use and water taken from wells in the Project area is not suitable for drinking because of PH and high Mangan contents.

Table 1.1 Meteorological Condition in Project Area

Monthly Mean Rainfall — Unit : mm

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Remarks
Kota Lama	240.4	118.6	218.7	175.9	219.7	113.3	147.0	117.3	235.2	262.0	212.1	309.7	2369.9	
Ujung Batu	237.3	139.3	249.0	198.4	238.0	150.2	130.8	167.0	211.8	223.0	230.3	278.2	2453.3	
Lubuk Bendahara	236.2	98.4	207.4	231.3	180.7	75.9	149.7	141.4	263.5	224.6	279.4	301.4	2389.9	
Jamback	229.3	193.3	350.6	362.5	285.8	142.2	202.9	226.6	343.7	326.1	357.1	228.0	3248.1	
Sontang	172.7	172.1	215.7	191.1	179.1	110.9	94.9	115.1	227.5	183.8	279.6	241.6	2184.1	
Rao NT	413.3	285.9	318.2	260.5	250.9	83.2	161.4	207.7	501.9	369.9	385.2	415.8	3653.9	
Pasir Pangarayan	214.3	152.1	217.0	208.8	174.5	108.3	125.2	141.6	247.6	212.3	250.1	345.1	2396.9	Out of the area

Monthly Mean Evaporation — Unit : mm/day

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average	Remarks
Kota Lama	3.0	3.6	3.5	3.6	3.7	3.6	3.4	3.4	3.5	3.4	3.9	3.4	3.5	
Pasir Pangarayan	4.0	4.6	4.7	4.8	5.1	5.0	4.8	4.8	4.9	4.7	4.7	4.0	4.7	Out of the area

Monthly Mean Wind Velocity — Unit : Km/day

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average	Remarks
Kota Lama	11.8	14.6	17.7	15.2	13.7	15.8	18.6	15.8	18.2	18.4	20.1	18.8	16.6	
Pasir Pangarayan	32.1	34.7	34.6	30.7	31.8	30.8	32.4	34.1	34.2	33.7	31.6	29.6	32.5	Out of the area

Monthly Mean Air Temperature — Unit : °C

Station		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average	Remarks
Kota Lama	Max.	28.9	29.7	29.5	30.0	29.9	30.0	30.5	30.4	27.9	29.6	28.9	29.0	29.5	
	Min.	20.6	21.8	21.5	21.6	21.7	22.0	21.2	20.4	20.4	21.0	20.7	21.0	21.2	
	Mean	24.5	25.6	25.5	25.8	25.8	26.1	25.5	25.0	25.0	25.3	24.7	24.8	25.3	
Pasir	Max.	32.1	32.8	32.9	32.7	32.9	32.8	32.7	32.5	32.6	33.3	32.5	32.5	32.7	Out of the area
Pangarayan	Min.	20.9	21.4	21.0	22.6	23.0	22.6	23.0	22.0	22.8	21.4	21.4	20.9	21.9	Out of the area
	Mean	26.7	27.1	27.0	28.2	27.9	28.3	28.5	27.6	27.7	27.2	27.3	27.1	27.6	Out of the area

Monthly Mean Relative Humidity — Unit : %

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average	Remarks
Kota Lama	91.7	89.3	90.9	92.1	91.4	91.0	90.9	91.9	91.7	92.6	92.3	90.9	91.4	
Pasir Pangarayan	85.1	86.4	87.0	86.4	85.7	84.1	83.0	82.5	83.5	83.6	85.2	86.2	84.9	Out of the area

Monthly Mean Sunshine Ratio — Unit : %

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average	Remarks
Kota Lama	31.0	38.0	35.0	41.1	43.6	47.9	43.3	32.4	36.8	34.6	35.3	32.2	37.6	
Pasir Pangarayan	35.4	44.8	45.6	49.6	51.1	57.4	52.6	46.3	43.6	44.8	45.0	36.5	46.1	Out of the area

Monthly Solar Radiation — Unit : cal/cm²/day

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average	Remarks
Kota Lama	239	275	272	256	280	285	259	259	253	293	267	229	264	
Pasir Pangarayan	288	313	321	312	313	301	303	293	311	303	307	269	303	

Table 1.2 Observed Monthly Mean Discharge

MONTHLY MEAN DISCHARGE AT LUBUK BENDAHARA
(CATCHMENT AREA A = 3,076 Km2)

UNIT : m3/S

MONTH / YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVERAGE
1978	142.8	174.7	211.2	236.2	168.3	90.6	83.3	58.3	61.4	98.4	177.0	308.0	150.8
1979	194.0	122.7	95.0	132.3	106.2	132.7	68.4	57.7	104.7	70.2	283.0	210.1	131.4
1980	116.5	78.5	154.7	150.5	159.0	107.9	68.2	77.6	74.7	105.7	151.7	138.1	115.3
1981	130.0	103.5	137.8	157.6	169.2	119.1	69.0	48.6	88.0	126.8	89.6	102.8	111.8
1982	116.4	130.6	171.7	364.6	137.3	105.3	63.3	57.1	64.9	129.5	185.2	247.0	147.7
1983	214.3	94.3	92.7	92.4	126.1	98.8	88.6	78.6	163.9	119.7	73.6	159.9	116.9
1984	157.4	255.8	204.6	250.0	166.2	133.1	101.8	79.1	80.4	72.8	267.3	182.7	162.6
1985	156.3	273.7	165.6	140.8	179.2	66.2	44.2	63.6	150.3	108.8	281.3	180.0	150.8
1986	305.2	95.9	252.8	186.7	120.4	101.1	58.7	48.5	66.8	142.8	130.5	298.9	150.7
1987	173.1	102.8	138.0	159.1	284.1	86.5	66.0	159.6	134.4	280.6	274.4	244.5	175.3
1988	238.3	230.9	285.2	170.5	151.6	84.7	96.1	147.2	239.8	103.0	120.2	150.7	168.2
1989	341.4	97.5	97.8	112.5	98.7	50.5	49.8	50.4	140.6	127.9	192.9	218.7	131.6
1990	173.1	227.4	105.5	99.8	116.5	56.9	73.7	49.3	69.7	122.7	153.8	237.1	123.8
1991	163.4	156.5	170.5	332.5	166.9	130.3	74.1	57.9	74.9	114.4	257.3	414.2	176.1
MEAN	187.3	153.2	163.1	184.7	153.5	97.4	71.8	73.8	108.2	123.1	188.4	220.9	143.8

MONTHLY MEAN DISCHARGE AT KOTA LAMA
(CATCHMENT AREA A = 3,379 Km2)

UNIT : m3/S

MONTH / YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVERAGE
1991	-	-	-	-	-	92.3	113.5	96.0	94.4	150.9	269.9	405.1	
1992	210.1	159.1	-	-	-	-	-	-	-	-	-	-	

Remarks : AWLR was newly installed by JICA in 1991

Table 2.1 Reference Table for Moch Model(1)

CALCULATION OF REFERENCE EVAPOTRANSPIRATION(ETo) BY PENMAN METHOD

SCHEME : Rokan Kiri Irrigation Project
ELEVATION: EL.50 - EL.500 m
YEAR : 1985
CATCHMANT
AREA : 3,076 Km2
RAINFALL
STATIONS :Rao MT., Jamback and Sontang

Col. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Source	Data	Table 9	Data	Calc.	Calc.	Data	Calc.	Table 10	Table 11	Calc.	Calc.	Table 12	Table 13	Data	Table 14	Cal.	Calc.	Table 15	Data	Data	Data	Table 16	Calc.	Calc.
Symbol	T	ea	Rh	ed	ea-ed	U	f(U)	Ra	N	n	Rs	Rnl	Rnl	n/N	Rnl	Rnl	Rn	W	RHmax	U day	Ud/Un	c	ETO	ETO
	Mean Half Monthly temp. (deg C)	Saturate Vapour Pressure (mbar)	Mean Relative Humidity (%)	Actual Vapour Pressure (%)	Vapour Pressure Deficit (mbar)	Wind Run (Km/day)	Wind Function	Ex. Ter Rad. (mm/day)	Max. Sun Duration (hrs/day)	Mean Sun Duration (hrs/day)	Incom. Shortw. Rad. (mm/day)	Based on Mean Temp. (mm/day)	Based on ed (mm/day)		Based on n/N (mm/day)	Net Longw. Rad. (mm/day)	Total Net Rad. (mm/day)	Weight Factor Based on Temp. & Elevation	Max Relative Humidity (%)	Mean Wind Speed (m/s)	Ratio Uday/ Unight	Adjust Factor	Ref. Evapo. Trans. (mm/day)	Do (mm/ half mon.)
Jan. 1	26.8	35.3	74.8	26.5	9.0	35.8	0.37	14.9	11.96	5.5	7.2	16.1	0.12	0.46	0.52	1.00	4.4	0.77	100	0.41	2	1	4.1	61.8
Jan. 2	26.5	34.7	76.3	26.5	8.2	36.6	0.37	14.9	11.96	5.6	7.2	16	0.12	0.47	0.53	1.02	4.4	0.77	100	0.42	2	1	4.1	65.4
Feb. 1	27.0	35.7	90.1	32.2	3.5	28.6	0.35	15.4	11.98	5.4	7.3	16.1	0.09	0.45	0.51	0.74	4.7	0.77	100	0.33	2	1	3.9	59.1
Feb. 2	27.8	37.0	86.9	32.2	4.8	33.5	0.36	15.4	11.98	7.4	8.6	16.2	0.09	0.62	0.66	0.96	5.5	0.78	100	0.39	2	1	4.7	60.2
Mar. 1	27.0	35.7	87.2	31.1	4.6	34.4	0.36	15.7	12.00	5.0	7.2	16.1	0.09	0.42	0.48	0.70	4.7	0.77	100	0.40	2	1	4.0	63.2
Mar. 2	27.5	36.8	87.2	32.1	4.7	35.1	0.36	15.7	12.00	5.9	7.8	16.2	0.09	0.49	0.54	0.79	5.0	0.78	100	0.41	2	1	4.3	59.0
Apr. 1	28.2	38.3	84.3	32.3	6.0	32.8	0.36	15.3	12.04	6.3	7.8	16.3	0.09	0.52	0.57	0.84	5.0	0.78	100	0.38	2	1	4.4	65.8
Apr. 2	29.1	40.3	88.6	35.7	4.6	26.4	0.34	15.3	12.04	7.0	8.3	16.5	0.08	0.58	0.62	0.82	5.4	0.79	100	0.31	2	1	4.6	68.7
May 1	29.9	42.2	86.0	36.3	5.9	29.3	0.35	14.5	12.06	5.5	7.0	16.7	0.08	0.46	0.52	0.69	4.5	0.79	100	0.34	2	1	4.0	60.1
May 2	30.4	43.3	80.4	34.8	8.5	29.3	0.35	14.5	12.06	6.6	7.6	16.9	0.08	0.55	0.6	0.81	4.9	0.79	100	0.34	2	1	4.5	71.9
Jun. 1	29.4	41.0	83.5	34.2	6.8	30.1	0.35	14.1	12.08	6.3	7.2	16.6	0.08	0.52	0.57	0.76	4.6	0.79	100	0.35	2	1	4.2	62.4
Jun. 2	28.4	38.7	84.9	32.9	5.8	31.5	0.36	14.1	12.08	8.2	8.3	16.4	0.09	0.68	0.71	1.05	5.2	0.78	100	0.36	2	1	4.5	67.6
Jul. 1	29.8	41.9	84.4	35.4	6.5	23.5	0.33	14.2	12.06	6.3	7.2	16.7	0.08	0.52	0.57	0.76	4.7	0.79	100	0.27	2	1	4.1	62.2
Jul. 2	30.2	42.9	75.3	32.3	10.6	27.1	0.34	14.2	12.06	5.8	7.0	16.8	0.09	0.48	0.53	0.80	4.4	0.79	100	0.31	2	1	4.3	68.1
Aug. 1	27.8	37.4	76.9	28.8	8.6	44.7	0.39	14.8	12.06	5.8	7.3	16.2	0.1	0.48	0.53	0.86	4.6	0.78	100	0.52	2	1	4.3	64.7
Aug. 2	29.1	40.3	84.1	33.9	6.4	50.1	0.41	14.8	12.06	6.2	7.5	16.5	0.08	0.51	0.56	0.74	4.9	0.79	100	0.58	2	1	4.4	70.2
Sep. 1	28.6	39.2	79.8	31.3	7.9	39.5	0.38	15.3	12.02	6.3	7.8	16.4	0.09	0.52	0.57	0.84	5.0	0.79	100	0.46	2	1	4.6	68.8
Sep. 2	29.1	40.3	75.0	30.2	10.1	35.5	0.37	15.3	12.02	5.6	7.4	16.5	0.1	0.47	0.53	0.37	4.7	0.79	100	0.41	2	1	4.5	67.2
Oct. 1	29.3	41.5	92.5	38.4	3.1	35.8	0.37	15.4	12.00	5.3	7.2	16.6	0.07	0.44	0.5	0.58	4.8	0.79	100	0.41	2	1	4.1	61.0
Oct. 2	29.0	40.1	69.9	28.0	12.1	26.9	0.34	15.4	12.00	5.8	7.5	16.5	0.11	0.48	0.53	0.96	4.7	0.79	100	0.31	2	1	4.6	73.3
Nov. 1	27.2	36.1	96.7	34.9	1.2	40.5	0.38	15.0	11.08	4.7	6.9	16.1	0.08	0.42	0.48	0.62	4.6	0.77	100	0.47	2	1	3.6	54.2
Nov. 2	28.7	39.4	67.7	26.7	12.7	52.6	0.41	15.0	11.98	6.0	7.5	16.4	0.12	0.5	0.55	1.08	4.5	0.78	100	0.61	2	1	4.7	70.5
Dec. 1	28.9	39.9	93.6	37.3	2.6	27.1	0.34	14.6	11.96	4.5	6.4	16.5	0.07	0.38	0.44	0.51	4.3	0.78	100	0.31	2	1	3.6	53.3
Dec. 2	27.2	36.1	78.8	28.4	7.7	30.0	0.35	14.6	11.96	4.2	6.2	16.1	0.11	0.35	0.42	0.74	3.9	0.77	100	0.35	2	1	3.6	58.1

Colum 1 From MET Data
Colum 2 Read from Table 9 based on Mean Air ztemperstutre(Col.1)
Where Mean Air Temp is between two values in Table 9,
a linear relationship can be assumed
Colum 3 From MET Data
Colum 4 Calculated from : Col.3/100 x col.2
Colum 5 Calculated from : Col.2 - Col.4
Colum 6 From MET Data
Colum 7 Calculated from : 0.27 x(1+Col.6/100)

Colum 8 Read from Table 10 based on latitude and month
Colum 9 Read from Table 11 based on latitude and month
Colum 10 Calculated from : Col.14 x Col.9
Factor raw data by n = Z x 0.66 + 0.12
Colum 11 Calculated from : Col.8 x (0.25 + (0.5 x Col.10/Col.9))
Colum 12 Read from Table 12, based on Mean Air Temp.(Col.1)
Colum 13 Read from Table 13, based on ed, Col.4
where edis is between two values in Table 13,
a linear relationship can be assumed

Colum 14 From MET Data
Colum 15 Read from Table 14, based on Col.14
where n/N is between two values, alinear relationship can be assumed
Colum 16 Calculated from : Col.12 x Col.13 x Col.15
Colum 17 Calculated from : (0.75 x Col.11)-Col.16
Colum 18 Read from Table 15 based on a latitude and Mean Air Temp.
Colum 19 From Met Data
Colum 20 From Met Data
Colum 21 From Met Data
Colum 22 Read from Table 16 based on Col.19, Col.20 & Col.21
Colum 23 Calculated from : Col.22 x (Col.18 x Col.17 + (1-Col.18)x Col.7 X Col.5)

Table 2.2 Reference Table for Moch Model(2)

Saturated Vapour Pressure(ea) in mbar as Function of Mean Air Temperature(T) in C

Temp. (° C)	ea (mbar)	Temp. (° C)	ea (mbar)	Temp. (° C)	ea (mbar)	Temp. (° C)	ea (mbar)	Temp. (° C)	ea (mbar)
18.0	20.6	22.0	26.4	26.0	33.6	30.0	42.4	34.0	53.2
18.1	20.7	22.1	26.6	26.1	33.8	30.1	42.7	34.1	53.5
18.2	20.9	22.2	26.7	26.2	34.0	30.2	42.9	34.2	53.8
18.3	21.0	22.3	26.9	26.3	34.2	30.3	43.2	34.3	54.1
18.4	21.2	22.4	27.1	26.4	34.4	30.4	43.4	34.4	54.4
18.5	21.3	22.5	27.3	26.5	34.7	30.5	43.7	34.5	54.7
18.6	21.4	22.6	27.4	26.6	34.9	30.6	43.9	34.6	55.0
18.7	21.6	22.7	27.6	26.7	35.1	30.7	44.2	34.7	55.3
18.8	21.7	22.8	27.8	26.8	35.3	30.8	44.4	34.8	55.6
18.9	21.9	22.9	27.9	26.9	35.5	30.9	44.7	34.9	55.9
19.0	22.0	23.0	28.1	27.0	35.7	31.0	44.9	35.0	56.2
19.1	22.1	23.1	28.3	27.1	35.9	31.1	45.2	35.1	56.5
19.2	22.3	23.2	28.4	27.2	36.1	31.2	45.4	35.2	56.8
19.3	22.4	23.3	28.6	27.3	36.3	31.3	45.7	35.3	57.2
19.4	22.6	23.4	28.8	27.4	36.5	31.4	46.0	35.4	57.5
19.5	22.7	23.5	29.0	27.5	36.8	31.5	46.3	35.5	57.8
19.6	22.8	23.6	29.1	27.6	37.0	31.6	46.5	35.6	58.1
19.7	23.0	23.7	29.3	27.7	37.2	31.7	46.8	35.7	58.4
19.8	23.1	23.8	29.5	27.8	37.4	31.8	47.1	35.8	58.8
19.9	23.3	23.9	29.6	27.9	37.6	31.9	47.3	35.9	59.1
20.0	23.4	24.0	29.8	28.0	37.8	32.0	47.6	36.0	59.4
20.1	23.5	24.1	30.0	28.1	38.0	32.1	47.9	36.1	59.7
20.2	23.7	24.2	30.2	28.2	38.3	32.2	48.1	36.2	60.1
20.3	23.8	24.3	30.4	28.3	38.5	32.3	48.4	36.3	60.4
20.4	24.0	24.4	30.6	28.4	38.7	32.4	48.7	36.4	60.8
20.5	24.1	24.5	30.8	28.5	39.0	32.5	49.0	36.5	61.1
20.6	24.3	24.6	30.9	28.6	39.2	32.6	49.2	36.6	61.4
20.7	24.4	24.7	31.1	28.7	39.4	32.7	49.5	36.7	61.8
20.8	24.6	24.8	31.3	28.8	39.6	32.8	49.8	36.8	62.1
20.9	24.7	24.9	31.5	28.9	39.9	32.9	50.0	36.9	62.5
21.0	24.9	25.0	31.7	29.0	40.1	33.0	50.3	37.0	62.8
21.1	25.0	25.1	31.9	29.1	40.3	33.1	50.6		
21.2	25.2	25.2	32.1	29.2	40.6	33.2	50.9		
21.3	25.3	25.3	32.3	29.3	40.8	33.3	51.2		
21.4	25.5	25.4	32.5	29.4	41.0	33.4	51.5		
21.5	25.6	25.5	32.6	29.5	41.2	33.5	51.7		
21.6	25.8	25.6	32.8	29.6	41.5	33.6	52.0		
21.7	25.9	25.7	33.0	29.7	41.7	33.7	52.3		
21.8	26.1	25.8	33.2	29.8	41.9	33.8	52.6		
21.9	26.2	25.9	33.4	29.9	42.2	33.9	52.9		

Table 2.3 Reference Table for Moch Model(3)

Extra-terrestrial Radiation(Ra) expressed in equivalent evaporation in mm/day

Northern Hemisphere												Lat.	Southern Hemisphere											
Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	(°)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
6.4	8.6	11.4	14.3	16.4	17.3	16.7	15.2	12.5	9.6	7.0	5.7	40	17.9	15.7	12.5	9.2	6.6	5.3	5.9	7.9	11.0	14.2	16.9	18.3
6.9	9.0	11.8	14.5	16.4	17.2	16.7	15.3	12.8	10.0	7.5	6.1	38	17.9	15.8	12.8	9.6	7.1	5.8	6.3	8.3	11.4	14.4	17.0	18.3
7.4	9.4	12.1	14.7	16.4	17.2	16.7	15.4	13.1	10.6	8.0	6.6	36	17.9	16.0	13.2	10.1	7.5	6.3	6.8	8.8	11.7	14.6	17.0	18.2
7.9	9.8	12.4	14.8	16.5	17.1	16.8	15.5	13.4	10.8	8.5	7.2	34	17.8	16.1	13.5	10.5	8.0	6.8	7.2	9.2	12.0	14.9	17.1	18.2
8.3	10.2	12.8	15.0	16.5	17.0	16.8	15.6	13.6	11.2	9.0	7.8	32	17.8	16.2	13.8	10.9	8.5	7.3	7.7	9.6	12.4	15.1	17.2	18.1
8.8	10.7	13.1	15.2	16.5	17.0	16.8	15.7	13.9	11.6	9.5	8.3	30	17.8	16.4	14.0	11.3	8.9	7.8	8.1	10.1	12.7	15.3	17.3	18.1
9.3	11.1	13.4	15.3	16.5	16.8	16.7	15.7	14.1	12.0	9.9	8.8	28	17.7	16.4	14.3	11.6	9.3	8.2	8.6	10.4	13.0	15.4	17.2	17.9
9.8	11.5	13.7	15.3	16.4	16.7	16.6	15.7	14.3	12.3	10.3	9.3	26	17.6	16.4	14.4	12.0	9.7	8.7	9.1	10.9	13.2	15.5	17.2	17.8
10.2	11.9	13.9	15.4	16.4	16.6	16.5	15.8	14.5	12.6	10.7	9.7	24	17.5	16.5	14.6	12.3	10.2	9.1	9.5	11.2	13.4	15.6	17.1	17.7
10.7	12.3	14.2	15.5	16.3	16.4	16.4	15.8	14.6	13.0	11.1	10.2	22	17.4	16.5	14.8	12.6	10.6	9.6	10.0	11.6	13.7	15.7	17.0	17.5
11.2	12.7	14.4	15.6	16.3	16.4	16.3	15.9	14.8	13.3	11.6	10.7	20	17.3	16.5	15.0	13.0	11.0	10.0	10.4	12.0	13.9	15.8	17.0	17.4
11.6	13.0	14.6	15.6	16.1	16.1	16.1	15.8	14.9	13.6	12.0	11.1	18	17.1	16.5	15.1	13.2	11.4	10.4	10.8	12.3	14.1	15.8	16.8	17.1
12.0	13.3	14.7	15.6	16.0	15.9	15.9	15.7	15.0	13.9	12.4	11.6	16	16.9	16.4	15.2	13.5	11.7	10.8	11.2	12.6	14.3	15.8	16.7	16.8
12.4	13.6	14.9	15.7	15.8	15.7	15.7	15.7	15.1	14.1	12.8	12.0	14	16.7	16.4	15.3	13.7	12.1	11.2	11.6	12.9	14.5	15.8	16.5	16.6
12.8	13.9	15.1	15.7	15.7	15.5	15.5	15.6	15.2	14.4	13.3	12.5	12	16.6	16.3	15.4	14.0	12.5	11.6	12.0	13.2	14.7	15.8	16.4	16.5
13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9	10	16.4	16.3	15.5	14.2	12.8	12.0	12.4	13.5	14.8	15.9	16.2	16.2
13.6	14.5	15.3	15.6	15.3	15.0	15.1	15.4	15.3	14.8	13.9	13.3	8	16.1	16.1	15.5	14.4	13.1	12.4	12.7	13.7	14.9	15.8	16.0	16.0
13.9	14.8	15.4	15.4	15.1	14.7	14.9	15.2	15.3	15.0	14.2	13.7	6	15.8	16.0	15.6	14.7	13.4	12.8	13.1	14.0	15.0	15.7	15.8	15.7
14.3	15.0	15.5	15.5	14.9	14.4	14.6	15.1	15.3	15.1	14.5	14.1	4	15.5	15.8	15.6	14.9	13.8	13.2	13.4	14.3	15.1	15.6	15.5	15.4
14.7	15.3	15.6	15.3	14.6	14.2	14.3	14.9	15.3	15.3	14.8	14.4	2	15.3	15.7	15.7	15.1	14.1	13.5	13.7	14.5	15.2	15.5	15.3	15.1
15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8	0	15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8

Table 2.4 Reference Table for Moch Model(4)

Mean Daily Duration of Maximum Possible Sunshine Hours(N) for Different Months and Latitudes

Northern Latitude	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Southern Latitude (°)	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
40	9.60	10.70	11.90	13.30	14.40	15.00	14.70	13.70	12.50	11.20	10.00	9.30
39	9.70	10.76	11.90	13.26	14.32	14.90	14.62	13.66	12.48	11.22	10.06	9.40
38	9.80	10.82	11.90	13.22	14.24	14.80	14.54	13.62	12.46	11.24	10.12	9.50
37	9.90	10.88	11.90	13.18	14.16	14.70	14.46	13.58	12.44	11.26	10.18	9.60
36	10.00	10.94	11.90	13.14	14.08	14.60	14.38	13.54	12.42	11.28	10.24	9.70
35	10.10	11.00	11.90	13.10	14.00	14.50	14.30	13.50	12.40	11.30	10.30	9.80
34	10.16	11.02	11.92	13.06	13.92	14.40	14.22	13.44	12.40	11.34	10.36	9.88
33	10.22	11.04	11.94	13.02	13.84	14.30	14.14	13.38	12.40	11.38	10.42	9.96
32	10.28	11.06	11.96	12.98	13.76	14.20	14.06	13.32	12.40	11.42	10.48	10.04
31	10.34	11.08	11.98	12.94	13.68	14.10	13.98	13.26	12.40	11.46	10.54	10.12
30	10.40	11.10	12.00	12.90	13.60	14.00	13.90	13.20	12.40	11.50	10.60	10.20
29	10.46	11.14	12.00	12.86	13.54	13.94	13.82	13.16	12.38	11.52	10.66	10.28
28	10.52	11.18	12.00	12.82	13.48	13.88	13.74	13.12	12.36	11.54	10.72	10.36
27	10.58	11.22	12.00	12.78	13.42	13.82	13.66	13.08	12.34	11.56	10.78	10.44
26	10.64	11.26	12.00	12.74	13.36	13.76	13.58	13.04	12.32	11.58	10.84	10.52
25	10.70	11.30	12.00	12.70	13.30	13.70	13.50	13.00	12.30	11.60	10.90	10.60
24	10.76	11.34	12.00	12.68	13.26	13.62	13.44	12.96	12.30	11.62	10.96	10.66
23	10.82	11.38	12.00	12.66	13.22	13.54	13.38	12.92	12.30	11.64	11.02	10.72
22	10.88	11.42	12.00	12.64	13.18	13.46	13.32	12.88	12.30	11.66	11.08	10.78
21	10.94	11.46	12.00	12.62	13.14	13.38	13.26	12.84	12.30	11.68	11.14	10.84
20	11.00	11.50	12.00	12.60	13.10	13.30	13.20	12.80	12.30	11.70	11.20	10.90
19	11.06	11.52	12.00	12.58	13.04	13.24	13.14	12.76	12.28	11.72	11.24	10.96
18	11.12	11.54	12.00	12.56	12.98	13.18	13.08	12.72	12.26	11.74	11.28	11.02
17	11.18	11.56	12.00	12.54	12.92	13.12	13.02	12.68	12.24	11.76	11.32	11.08
16	11.24	11.58	12.00	12.52	12.86	13.06	12.96	12.64	12.22	11.78	11.36	11.14
15	11.30	11.60	12.00	12.50	12.80	13.00	12.90	12.60	12.20	11.80	11.40	11.20
14	11.36	11.64	12.00	12.46	12.76	12.94	12.84	12.56	12.18	11.80	11.44	11.26
13	11.42	11.68	12.00	12.42	12.72	12.88	12.78	12.52	12.16	11.80	11.48	11.32
12	11.48	11.72	12.00	12.38	12.68	12.82	12.72	12.48	12.14	11.80	11.52	11.38
11	11.54	11.76	12.00	12.34	12.64	12.76	12.66	12.44	12.12	11.80	11.56	11.44
10	11.60	11.80	12.00	12.30	12.60	12.70	12.60	12.40	12.10	11.80	11.60	11.50
9	11.64	11.82	12.00	12.28	12.54	12.64	12.54	12.38	12.10	11.84	11.66	11.56
8	11.68	11.84	12.00	12.26	12.48	12.58	12.48	12.36	12.10	11.88	11.72	11.62
7	11.72	11.86	12.00	12.24	12.42	12.52	12.42	12.34	12.10	11.92	11.78	11.68
6	11.76	11.88	12.00	12.22	12.36	12.46	12.36	12.32	12.10	11.96	11.84	11.74
5	11.80	11.90	12.00	12.20	12.30	12.40	12.30	12.30	12.10	12.00	11.90	11.80
4	11.84	11.92	12.00	12.16	12.24	12.32	12.24	12.24	12.08	12.00	11.92	11.84
3	11.88	11.94	12.00	12.12	12.18	12.24	12.18	12.18	12.06	12.00	11.94	11.88
2	11.92	11.96	12.00	12.08	12.12	12.16	12.12	12.12	12.04	12.00	11.96	11.92
1	11.96	11.98	12.00	12.04	12.06	12.08	12.06	12.06	12.02	12.00	11.98	11.96
0	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00

Table 2.5 Reference Table for Moch Model(5)

Effect of Temperature f(T) on Longwave Radiation(Rnl)

T° C	f(T)= δTK^4	T° C	f(T)= δTK^4	T° C	f(T)= δTK^4	T° C	f(T)= δTK^4	T° C	f(T)= δTK^4
18.0	14.20	22.0	15.00	26.0	15.90	30.0	16.70	34.0	17.70
18.1	14.22	22.1	15.02	26.1	15.92	30.1	16.72	34.1	17.72
18.2	14.24	22.2	15.04	26.2	15.94	30.2	16.75	34.2	17.74
18.3	14.26	22.3	15.06	26.3	15.96	30.3	16.77	34.3	17.76
18.4	14.28	22.4	15.08	26.4	15.98	30.4	16.80	34.4	17.78
18.5	14.30	22.5	15.10	26.5	16.00	30.5	16.82	34.5	17.80
18.6	14.32	22.6	15.12	26.6	16.02	30.6	16.85	34.6	17.82
18.7	14.34	22.7	15.14	26.7	16.04	30.7	16.87	34.7	17.84
18.8	14.36	22.8	15.16	26.8	16.06	30.8	16.90	34.8	17.86
18.9	14.38	22.9	15.18	26.9	16.08	30.9	16.92	34.9	17.88
19.0	14.40	23.0	15.20	27.0	16.10	31.0	16.95	35.0	17.90
19.1	14.42	23.1	15.22	27.1	16.12	31.1	16.97	35.1	17.92
19.2	14.44	23.2	15.24	27.2	16.14	31.2	17.00	35.2	17.94
19.3	14.46	23.3	15.26	27.3	16.16	31.3	17.02	35.3	17.96
19.4	14.48	23.4	15.28	27.4	16.18	31.4	17.05	35.4	17.98
19.5	14.50	23.5	15.30	27.5	16.20	31.5	17.07	35.5	18.00
19.6	14.52	23.6	15.32	27.6	16.22	31.6	17.10	35.6	18.02
19.7	14.54	23.7	15.34	27.7	16.24	31.7	17.12	35.7	18.04
19.8	14.56	23.8	15.36	27.8	16.26	31.8	17.15	35.8	18.06
19.9	14.58	23.9	15.38	27.9	16.28	31.9	17.17	35.9	18.08
20.0	14.60	24.0	15.40	28.0	16.30	32.0	17.20	36.0	18.10
20.1	14.62	24.1	15.43	28.1	16.32	32.1	17.22		
20.2	14.64	24.2	15.45	28.2	16.34	32.2	17.25		
20.3	14.66	24.3	15.48	28.3	16.36	32.3	17.27		
20.4	14.68	24.4	15.50	28.4	16.38	32.4	17.30		
20.5	14.70	24.5	15.53	28.5	16.40	32.5	17.32		
20.6	14.72	24.6	15.55	28.6	16.42	32.6	17.35		
20.7	14.74	24.7	15.58	28.7	16.44	32.7	17.37		
20.8	14.76	24.8	15.60	28.8	16.46	32.8	17.40		
20.9	14.78	24.9	15.63	28.9	16.48	32.9	17.42		
21.0	14.80	25.0	15.65	29.0	16.50	33.0	17.45		
21.1	14.82	25.1	15.68	29.1	16.52	33.1	17.47		
21.2	14.84	25.2	15.70	29.2	16.54	33.2	17.50		
21.3	14.86	25.3	15.73	29.3	16.56	33.3	17.52		
21.4	14.88	25.4	15.75	29.4	16.58	33.4	17.55		
21.5	14.90	25.5	15.78	29.5	16.60	33.5	17.57		
21.6	14.92	25.6	15.80	29.6	16.62	33.6	17.60		
21.7	14.94	25.7	15.83	29.7	16.64	33.7	17.62		
21.8	14.96	25.8	15.85	29.8	16.66	33.8	17.65		
21.9	14.98	25.9	15.88	29.9	16.68	33.9	17.67		

Table 2.6 Reference Table for Moch Model(6)

Effect of Vapour Pressure f(ed) on Longwave Radiation(Rnl)

ed (mbar)	f(ef)= Rnl	ed (mbar)	f(ef)= Rnl	ed (mbar)	f(ef)= Rnl	ed (mbar)	f(ef)= Rnl	ed (mbar)	f(ef)= Rnl
18.0	0.15	22.0	0.13	26.0	0.12	30.0	0.10	34.0	0.08
18.1	0.15	22.1	0.13	26.1	0.12	30.1	0.10	34.1	0.08
18.2	0.15	22.2	0.13	26.2	0.12	30.2	0.10	34.2	0.08
18.3	0.15	22.3	0.13	26.3	0.12	30.3	0.10	34.3	0.08
18.4	0.15	22.4	0.13	26.4	0.12	30.4	0.10	34.4	0.08
18.5	0.15	22.5	0.13	26.5	0.12	30.5	0.10	34.5	0.08
18.6	0.15	22.6	0.13	26.6	0.12	30.6	0.10	34.6	0.08
18.7	0.15	22.7	0.13	26.7	0.12	30.7	0.10	34.7	0.08
18.8	0.15	22.8	0.13	26.8	0.12	30.8	0.10	34.8	0.08
18.9	0.15	22.9	0.13	26.9	0.12	30.9	0.10	34.9	0.08
19.0	0.15	23.0	0.13	27.0	0.11	31.0	0.10	35.0	0.08
19.1	0.14	23.1	0.12	27.1	0.11	31.1	0.09	35.1	0.08
19.2	0.14	23.2	0.12	27.2	0.11	31.2	0.09	35.2	0.08
19.3	0.14	23.3	0.12	27.3	0.11	31.3	0.09	35.3	0.08
19.4	0.14	23.4	0.12	27.4	0.11	31.4	0.09	35.4	0.08
19.5	0.14	23.5	0.12	27.5	0.11	31.5	0.09	35.5	0.08
19.6	0.14	23.6	0.12	27.6	0.11	31.6	0.09	35.6	0.08
19.7	0.14	23.7	0.12	27.7	0.11	31.7	0.09	35.7	0.08
19.8	0.14	23.8	0.12	27.8	0.11	31.8	0.09	35.8	0.08
19.9	0.14	23.9	0.12	27.9	0.11	31.9	0.09	35.9	0.08
20.0	0.14	24.0	0.12	28.0	0.11	32.0	0.09	36.0	0.98
20.1	0.14	24.1	0.12	28.1	0.11	32.1	0.09	36.1	0.08
20.2	0.14	24.2	0.12	28.2	0.11	32.2	0.09	36.2	0.08
20.3	0.14	24.3	0.12	28.3	0.11	32.3	0.09	36.3	0.08
20.4	0.14	24.4	0.12	28.4	0.11	32.4	0.09	36.4	0.08
20.5	0.14	24.5	0.12	28.5	0.11	32.5	0.09	36.5	0.08
20.6	0.14	24.6	0.12	28.6	0.11	32.6	0.09	36.6	0.08
20.7	0.14	24.7	0.12	28.7	0.11	32.7	0.09	36.7	0.08
20.8	0.14	24.8	0.12	28.8	0.11	32.8	0.09	36.8	0.08
20.9	0.14	24.9	0.12	28.9	0.11	32.9	0.09	36.9	0.08
21.0	0.14	25.0	0.12	29.0	0.11	33.0	0.08	37.0	0.08
21.1	0.13	25.1	0.12	29.1	0.10	33.1	0.08	37.1	0.07
21.2	0.13	25.2	0.12	29.2	0.10	33.2	0.08	37.2	0.07
21.3	0.13	25.3	0.12	29.3	0.10	33.3	0.08	37.3	0.07
21.4	0.13	25.4	0.12	29.4	0.10	33.4	0.08	37.4	0.07
21.5	0.13	25.5	0.12	29.5	0.10	33.5	0.08	37.5	0.07
21.6	0.13	25.6	0.12	29.6	0.10	33.6	0.08	37.6	0.07
21.7	0.13	25.7	0.12	29.7	0.10	33.7	0.08	37.7	0.07
21.8	0.13	25.8	0.12	29.8	0.10	33.8	0.08	37.8	0.07
21.9	0.13	25.9	0.12	29.9	0.10	33.9	0.08	37.9	0.07

Table 2.7 Reference Table for Moch Model(7)

Effect of Ratio Actual and Maximum Bright Sunshine Hours f(n/N) on Longwave Radiation(Rnl)

n/N	f(n/N) =Rnl	n/N	f(n/N) =Rnl	n/N	f(n/N) =Rnl	n/N	f(n/N) =Rnl	n/N	f(n/N) =Rnl
0.00	0.10	0.20	0.28	0.40	0.46	0.60	0.64	0.80	0.82
0.01	0.11	0.21	0.29	0.41	0.47	0.61	0.65	0.81	0.83
0.02	0.12	0.22	0.30	0.42	0.48	0.62	0.66	0.82	0.84
0.03	0.13	0.23	0.31	0.43	0.49	0.63	0.67	0.83	0.85
0.04	0.14	0.24	0.32	0.44	0.50	0.64	0.68	0.84	0.86
0.05	0.15	0.25	0.33	0.45	0.51	0.65	0.69	0.85	0.87
0.06	0.16	0.26	0.34	0.46	0.52	0.66	0.70	0.86	0.88
0.07	0.16	0.27	0.34	0.47	0.52	0.67	0.70	0.87	0.88
0.08	0.17	0.28	0.35	0.48	0.53	0.68	0.71	0.88	0.89
0.09	0.17	0.29	0.35	0.49	0.53	0.69	0.71	0.89	0.89
0.10	0.19	0.30	0.37	0.50	0.55	0.70	0.73	0.90	0.91
0.11	0.20	0.31	0.38	0.51	0.56	0.71	0.74	0.91	0.92
0.12	0.21	0.32	0.39	0.52	0.57	0.72	0.75	0.92	0.93
0.13	0.22	0.33	0.40	0.53	0.58	0.73	0.76	0.93	0.94
0.14	0.23	0.34	0.41	0.54	0.59	0.74	0.77	0.94	0.95
0.15	0.24	0.35	0.42	0.55	0.60	0.75	0.78	0.95	0.96
0.16	0.25	0.36	0.43	0.56	0.61	0.76	0.79	0.96	0.97
0.17	0.26	0.37	0.44	0.57	0.62	0.77	0.80	0.97	0.98
0.18	0.26	0.38	0.44	0.58	0.62	0.78	0.80	0.98	0.98
0.19	0.27	0.39	0.45	0.59	0.63	0.79	0.81	0.99	0.99
0.20	0.28	0.40	0.46	0.60	0.64	0.80	0.82	1.00	1.00

Table 2.8 Reference Table for Moch Model(8)

Values of Weighting Factor(W) for Effect of Radiation on ETo at Different Temperaturea and Altitude

Temp. (° C)	Altitude in meter 0	500	1000	2000	3000
18.00	0.66	0.67	0.69	0.71	0.73
18.10	0.66	0.67	0.69	0.71	0.73
18.20	0.66	0.67	0.69	0.71	0.73
18.30	0.66	0.67	0.69	0.71	0.73
18.40	0.67	0.68	0.69	0.71	0.73
18.50	0.67	0.68	0.70	0.72	0.74
18.60	0.67	0.68	0.70	0.72	0.74
18.70	0.67	0.68	0.70	0.72	0.74
18.80	0.67	0.68	0.70	0.72	0.74
18.90	0.67	0.68	0.70	0.72	0.74
19.00	0.67	0.68	0.70	0.72	0.74
19.10	0.68	0.69	0.70	0.72	0.74
19.20	0.68	0.69	0.70	0.72	0.74
19.30	0.68	0.69	0.70	0.72	0.74
19.40	0.68	0.69	0.70	0.72	0.74
19.50	0.68	0.69	0.71	0.73	0.75
19.60	0.68	0.69	0.71	0.73	0.75
19.70	0.69	0.70	0.71	0.73	0.75
19.80	0.69	0.70	0.71	0.73	0.75
19.90	0.69	0.70	0.71	0.73	0.75
20.00	0.69	0.70	0.71	0.73	0.75
20.10	0.69	0.70	0.71	0.73	0.75
20.20	0.69	0.70	0.71	0.73	0.75
20.30	0.69	0.70	0.71	0.73	0.75
20.40	0.69	0.70	0.71	0.73	0.75
20.50	0.70	0.71	0.72	0.74	0.76
20.60	0.70	0.71	0.72	0.74	0.76
20.70	0.70	0.71	0.72	0.74	0.76
20.80	0.70	0.71	0.72	0.74	0.76
20.90	0.70	0.71	0.72	0.74	0.76
21.00	0.70	0.71	0.72	0.74	0.76
21.10	0.70	0.71	0.72	0.74	0.76
21.20	0.70	0.71	0.72	0.74	0.76
21.30	0.70	0.71	0.72	0.74	0.76
21.40	0.70	0.71	0.72	0.74	0.76
21.50	0.71	0.72	0.73	0.75	0.77
21.60	0.71	0.72	0.73	0.75	0.77
21.70	0.71	0.72	0.73	0.75	0.77
21.80	0.71	0.72	0.73	0.75	0.77
21.90	0.71	0.72	0.73	0.75	0.77
22.00	0.71	0.72	0.73	0.75	0.77

Temp. (° C)	Altitude in meter 0	500	1000	2000	3000
22.00	0.71	0.72	0.73	0.75	0.77
22.10	0.71	0.72	0.73	0.75	0.77
22.20	0.71	0.72	0.73	0.75	0.77
22.30	0.71	0.72	0.73	0.75	0.77
22.40	0.71	0.72	0.73	0.75	0.77
22.50	0.72	0.73	0.74	0.76	0.78
22.60	0.72	0.73	0.74	0.76	0.78
22.70	0.72	0.73	0.74	0.76	0.78
22.80	0.72	0.73	0.74	0.76	0.78
22.90	0.72	0.73	0.74	0.76	0.78
23.00	0.72	0.73	0.74	0.76	0.78
23.10	0.72	0.73	0.74	0.76	0.78
23.20	0.72	0.73	0.74	0.76	0.78
23.30	0.72	0.73	0.74	0.76	0.78
23.40	0.72	0.73	0.74	0.76	0.78
23.50	0.73	0.74	0.75	0.77	0.79
23.60	0.73	0.74	0.75	0.77	0.79
23.70	0.73	0.74	0.75	0.77	0.79
23.80	0.73	0.74	0.75	0.77	0.79
23.90	0.73	0.74	0.75	0.77	0.79
24.00	0.73	0.74	0.75	0.77	0.79
24.10	0.73	0.74	0.75	0.77	0.79
24.20	0.73	0.74	0.75	0.77	0.79
24.30	0.73	0.74	0.75	0.77	0.79
24.40	0.73	0.74	0.75	0.77	0.79
24.50	0.74	0.75	0.76	0.78	0.80
24.60	0.74	0.75	0.76	0.78	0.80
24.70	0.74	0.75	0.76	0.78	0.80
24.80	0.74	0.75	0.76	0.78	0.80
24.90	0.74	0.75	0.76	0.78	0.80
25.00	0.74	0.75	0.76	0.78	0.80
25.10	0.74	0.75	0.76	0.78	0.80
25.20	0.74	0.75	0.76	0.78	0.80
25.30	0.74	0.75	0.76	0.78	0.80
25.40	0.74	0.75	0.76	0.78	0.80
25.50	0.75	0.76	0.77	0.79	0.81
25.60	0.75	0.76	0.77	0.79	0.81
25.70	0.75	0.76	0.77	0.79	0.81
25.80	0.75	0.76	0.77	0.79	0.81
25.90	0.75	0.76	0.77	0.79	0.81
26.00	0.75	0.76	0.77	0.79	0.81

Temp. (° C)	Altitude in meter 0	500	1000	2000	3000
26.00	0.75	0.76	0.77	0.79	0.81
26.10	0.75	0.76	0.77	0.79	0.81
26.20	0.75	0.76	0.77	0.79	0.81
26.30	0.75	0.76	0.77	0.79	0.81
26.40	0.75	0.76	0.77	0.79	0.81
26.50	0.76	0.77	0.78	0.80	0.81
26.60	0.76	0.77	0.78	0.80	0.81
26.70	0.76	0.77	0.78	0.80	0.81
26.80	0.76	0.77	0.78	0.80	0.81
26.90	0.76	0.77	0.78	0.80	0.81
27.00	0.76	0.77	0.78	0.80	0.81
27.10	0.76	0.77	0.78	0.80	0.82
27.20	0.76	0.77	0.78	0.80	0.82
27.30	0.76	0.77	0.78	0.80	0.82
27.40	0.76	0.77	0.78	0.80	0.82
27.50	0.77	0.78	0.79	0.81	0.82
27.60	0.77	0.78	0.79	0.81	0.82
27.70	0.77	0.78	0.79	0.81	0.82
27.80	0.77	0.78	0.79	0.81	0.82
27.90	0.77	0.78	0.79	0.81	0.82
28.00	0.77	0.78	0.79	0.81	0.82
28.10	0.77	0.78	0.79	0.81	0.82
28.20	0.77	0.78	0.79	0.81	0.82
28.30	0.77	0.78	0.79	0.81	0.82
28.40	0.77	0.78	0.79	0.81	0.82
28.50	0.77	0.78	0.79	0.81	0.83
28.60	0.77	0.78	0.79	0.81	0.83
28.70	0.77	0.78	0.79	0.81	0.83
28.80	0.77	0.78	0.79	0.81	0.83
28.90	0.77	0.78	0.79	0.81	0.83
29.00	0.78	0.79	0.80	0.81	0.83
29.10	0.78	0.79	0.80	0.82	0.83
29.20	0.78	0.79	0.80	0.82	0.83
29.30	0.78	0.79	0.80	0.82	0.83
29.40	0.78	0.79	0.80	0.82	0.83
29.50	0.78	0.79	0.80	0.82	0.84
29.60	0.78	0.79	0.80	0.82	0.84
29.70	0.78	0.79	0.80	0.82	0.84
29.80	0.78	0.79	0.80	0.82	0.84
29.90	0.78	0.79	0.80	0.82	0.84
30.00	0.78	0.79	0.80	0.82	0.84

Table 2.9 Reference Table for Moch Model(9)

CALCULATION OF HALF MONTHLY FLOW BY MOCK MODAL

SCHEME : Rokan Kiri Irrigation Project
YEAR : 1985
CATCHMANT
AREA : 3,076 Km2

Col. No.	1	2	3	4	5	6	7	8	9	10			11	12	13	14
Source	Data	Data	Data	Data	Calc.	Calc.	Calc.	Calc.	Calc.	Calc.	Calc.	Calc.	Calc.	Calc.	Calc.	Calc.
Symbol	P	ETo	n	m	e	AEto	EP	SMSe	WS	INFIL			Vn	GSTOR	BF	DR
	Total Rainfall (mm)	Evapo-transp. (mm)	Raindays (no.)	Area not Covered by Vegetation (%)	ETox (m/20)x (18-n)	Actual Evap. (ETo-e) (mm)	Effective Rainfall (mm)	Soil Moist Storage end Half Month (mm)	Water Surplus end Half Month (mm)	Percol. to GW (mm)	(1+K)/2 x INFIL	K x V(n-1)	Storage Volume (mm)	GW Balance (mm)	Base Flow (mm)	Direct Runoff (mm)
								150.0					55			
Sep. 1	136.1	68.8	12	20	4.1	64.8	71.5	150.0	71.5	28.6	22.9	33.0	55.9	0.9	27.7	42.9
Sep. 2	221.9	67.2	15	20	2.0	65.2	156.7	150.0	156.7	62.7	50.1	33.5	83.7	27.8	34.9	94.0
Oct. 1	110.6	61.0	11	20	4.3	56.8	53.8	150.0	53.8	21.5	17.2	50.2	67.4	-16.2	37.8	32.3
Oct. 2	187.1	73.3	15	20	2.2	71.1	116.0	150.0	116.0	46.4	37.1	40.5	77.6	10.2	36.3	69.6
Nov. 1	265.7	54.2	15	20	1.6	52.6	213.1	150.0	213.1	85.3	68.2	46.6	114.8	37.2	48.1	127.9
Nov. 2	123.0	70.5	13	20	3.5	66.9	56.1	150.0	56.1	22.4	17.9	68.9	86.8	-28.0	50.4	33.6
Dec. 1	205.0	53.3	15	20	1.6	51.7	153.3	150.0	153.3	61.3	49.1	52.1	101.1	14.3	47.0	92.0
Dec. 2	50.9	58.1	10	20	4.7	53.5	-2.6	147.4	0.0	0.0	0.0	60.7	60.7	-40.5	40.5	0.0
Jan. 1	100.2	61.8	11	20	4.3	57.4	42.8	150.0	40.2	16.1	12.9	36.4	49.3	-11.4	27.5	24.1
Jan. 2	99.4	65.4	10	20	5.2	60.2	39.2	150.0	39.2	15.7	12.6	29.6	42.1	-7.1	22.8	23.5
Feb. 1	255.2	59.1	14	20	2.4	56.7	198.5	150.0	198.5	79.4	63.5	25.3	88.8	46.7	32.7	119.1
Feb. 2	9.4	60.8	2	20	9.7	51.1	-41.7	108.3	0.0	0.0	0.0	53.3	53.3	-35.5	35.5	0.0
Mar. 1	174.8	60.2	14	20	2.4	57.8	117.0	150.0	75.3	30.1	24.1	32.0	56.0	2.8	27.3	45.2
Mar. 2	149.3	69.0	15	20	2.1	66.9	82.4	150.0	82.4	33.0	26.4	33.6	60.0	4.0	29.0	49.4
Apr. 1	77.0	65.8	13	20	3.3	62.5	14.5	150.0	14.5	5.8	4.6	36.0	40.6	-19.4	25.2	8.7
Apr. 2	82.5	68.7	11	20	4.8	63.9	18.6	150.0	18.6	7.5	6.0	24.4	30.3	-10.3	17.7	11.2
May 1	145.0	60.1	12	20	3.6	56.5	88.5	150.0	88.5	35.4	28.3	18.2	46.5	16.2	19.2	53.1
May 2	126.2	71.9	12	20	4.3	67.6	58.6	150.0	58.6	23.4	18.7	27.9	46.7	0.1	23.3	35.2
Jun. 1	33.4	62.4	7	20	6.9	55.6	-22.2	127.8	0.0	0.0	0.0	28.0	28.0	-18.7	18.7	0.0
Jun. 2	14.5	67.6	4	20	9.5	58.1	-43.6	84.2	0.0	0.0	0.0	16.8	16.8	-11.2	11.2	0.0
Jul. 1	20.8	62.2	6	20	7.5	54.7	-33.9	50.3	0.0	0.0	0.0	10.1	10.1	-6.7	6.7	0.0
Jul. 2	92.0	68.1	12	20	4.1	64.0	28.0	78.3	0.0	0.0	0.0	6.0	6.0	-4.0	4.0	0.0
Aug. 1	81.4	64.7	11	20	4.5	60.2	21.2	99.5	0.0	0.0	0.0	3.6	3.6	-2.4	2.4	0.0
Aug. 2	134.2	70.2	11	20	4.9	65.3	68.9	150.0	18.4	7.4	5.9	2.2	8.1	4.4	2.9	11.0
Total	2895.6	1544.4							1454.7	581.9				-46.9	528.8	872.8

REMARKS : SMC : 150 mm (Soil Moisture Capacity)
INF : 0.4 (Infiltration Factor)
IGS : 55 mm (Initial Groundwater Storage)
K : 0.6 (Groundwater Recession Coefficient)
PF : 0.10 (Dry Season Storm Runoff Factor)

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Calc.	Calc.	Recalc.	Recalc.	Recalc.	Recalc.	Recalc.	Recalc.	Recalc.	Recalc.	Recalc.	Calc.	Calc.	Data	Calc.
TR	Qs	SMSe	WS	INFIL			Vn	GSTOR	BF	DR	TR	TR	Qo	TR-Qo
Total Runoff (mm)	Storm Runoff (mm)	Recalc. SMSe (mm)	Recalc. Water Surplus (mm)	Percol. to GW (mm)	(1+K)/2 x INFIL	K x V(n-1)	Storage Volume (mm)	GW Balance (mm)	Base Flow (mm)	Direct Runoff (mm)	Total Runoff (mm)	Total Runoff (m3/s)	Observed Flow (m3/s)	Diff. TR & Qo (%)
		150.0					55							
70.6	0.0	150.0	71.5	28.6	22.9	33.0	55.9	0.9	27.7	42.9	70.6	167.5	-	-
128.9	0.0	150.0	156.7	62.7	50.1	33.5	83.7	27.8	34.9	94.0	128.9	306.0	150.3	51
70.1	0.0	150.0	53.8	21.5	17.2	50.2	67.4	-16.2	37.8	32.3	70.1	166.3	124.8	25
105.9	0.0	150.0	116.0	46.4	37.1	40.5	77.6	10.2	36.3	69.6	105.9	235.6	93.6	60
176.0	0.0	150.0	213.1	85.3	68.2	46.6	114.8	37.2	48.1	127.9	176.0	417.7	425.1	-2
84.0	0.0	150.0	56.1	22.4	17.9	68.9	86.8	-28.0	50.4	33.6	84.0	199.4	137.4	31
139.0	0.0	150.0	153.3	61.3	49.1	52.1	101.1	14.3	47.0	92.0	139.0	329.8	196.4	40
40.5	5.1	142.3	0.0	0.0	0.0	60.7	60.7	-40.5	40.5	5.1	45.5	101.3	159.5	-57
51.6	0.0	150.0	35.1	14.0	11.2	36.4	47.6	-13.0	27.1	21.0	48.1	114.2	206.3	-81
46.4	0.0	150.0	39.2	15.7	12.6	28.6	41.1	-6.5	22.2	23.5	45.7	101.8	115.6	-14
151.8	0.0	150.0	198.5	79.4	63.5	24.7	88.2	47.1	32.3	119.1	151.4	359.4	398.4	-11
35.5	0.5	107.8	0.0	0.0	0.0	52.9	52.9	-35.3	35.3	0.5	35.7	97.9	129.8	-33
72.5	0.0	150.0	74.8	29.9	23.9	31.8	55.7	2.8	27.2	44.9	72.0	171.0	131.9	23
78.5	0.0	150.0	82.4	33.0	26.4	33.4	59.8	4.1	28.9	49.4	78.3	174.3	197.1	-13
33.9	0.0	150.0	14.5	5.8	4.6	35.9	40.5	-19.3	25.1	8.7	33.8	80.1	164.1	-105
28.9	0.0	150.0	18.6	7.5	6.0	24.3	30.3	-10.2	17.7	11.2	28.9	68.5	108.5	-58
72.3	0.0	150.0	88.5	35.4	28.3	18.2	46.5	16.2	19.2	53.1	72.3	171.5	123.7	28
58.4	0.0	150.0	58.6	23.4	18.7	27.9	46.6	0.2	23.3	35.2	58.4	130.0	231.2	-78
18.7	3.3	124.5	0.0	0.0	0.0	28.0	28.0	-18.7	18.7	3.3	22.0	52.2	74.8	-43
11.2	1.5	79.4	0.0	0.0	0.0	16.8	16.8	-11.2	11.2	1.5	12.6	30.0	61.3	-104
6.7	2.1	43.4	0.0	0.0	0.0	10.1	10.1	-6.7	6.7	2.1	8.8	20.9	51.2	-145
4.0	9.2	62.2	0.0	0.0	0.0	6.0	6.0	-4.0	4.0	9.2	13.2	29.4	58.1	-97
2.4	8.1	75.3	0.0	0.0	0.0	3.6	3.6	-2.4	2.4	8.1	10.6	25.1	63.6	-154
14.0	0.0	144.2	0.0	0.0	0.0	2.2	2.2	-1.5	1.5	0.0	14.0	33.2	-	-
1501.6	29.8		1430.7						625.1	888.2	1525.9	149.3 (Average)	141.8 (Average	5 (Average

Table 2.10 Monthly River Discharge at Proposed Weir Site

(UNIT : m3/s)

MONTH	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	AVG.
JAN.	145.5	198.7	118.2	132.2	112.9	219.8	160.6	164.7	314.2	177.0	244.8	351.9	176.9	166.9	191.7
FEB.	178.6	124.6	78.6	104.6	144.1	95.1	262.9	281.5	96.7	103.9	237.1	98.4	233.4	159.8	157.1
MAR.	216.6	95.8	157.8	140.3	175.5	93.5	209.7	169.2	259.8	140.4	293.5	98.7	106.8	174.3	166.6
APR.	242.6	134.6	153.5	160.8	376.0	93.1	257.0	138.7	191.1	162.4	174.2	114.0	100.8	342.7	188.7
MAY	172.0	107.4	162.3	172.9	173.5	128.2	169.8	183.3	122.2	292.4	154.6	99.7	118.2	170.5	159.1
JUN.	91.3	135.0	109.2	120.9	106.5	99.8	135.4	67.8	102.1	87.0	85.1	49.6	56.2	132.5	98.4
JUL.	83.6	68.2	68.0	68.8	62.8	89.2	102.9	54.8	58.1	65.7	97.0	48.8	73.7	74.1	72.6
AUG.	57.6	62.0	69.9	53.4	58.7	75.5	77.5	61.8	47.5	156.0	131.2	74.2	51.1	53.8	73.6
SEP.	60.8	105.9	74.7	88.6	64.5	167.4	80.6	122.3	66.5	136.8	246.3	143.2	69.6	74.9	107.3
OCT.	99.3	70.0	107.0	128.9	131.7	121.5	72.7	110.1	145.5	288.8	104.2	130.0	124.6	115.9	125.0
NOV.	181.0	291.2	154.7	90.2	189.6	73.6	274.9	289.4	132.7	282.3	122.0	197.6	156.9	264.5	192.9
DEC.	317.2	215.5	140.6	103.9	253.8	163.2	186.9	181.2	315.2	249.5	155.6	225.7	248.3	428.0	227.5
MEAN	153.9	134.1	116.2	113.8	154.1	118.3	165.9	152.1	154.3	178.5	170.5	136.0	126.4	179.8	146.7

Table 2.11 Estimated 10-day Discharge for 1978 to 1991 and 80% dependable Discharge at Proposed Weir Site

(UNIT : m3/s)

PERIOD/YEAR	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	AVG.	80% DEPENDABLE DISCHARGE
JAN. 1-10	153.2	297.3	132.2	211.0	186.4	256.9	98.9	240.1	474.2	187.7	185.7	174.9	136.3	191.47	209.0	140.0
11-20	166.1	151.2	83.4	92.1	91.6	256.1	205.7	132.2	339.9	209.5	148.6	609.8	194.1	134.53	201.1	108.0
21-31	119.8	152.4	137.0	96.9	65.4	153.0	175.7	125.6	145.5	137.7	386.0	278.3	198.3	173.90	167.5	106.7
FEB. 1-10	150.8	141.0	66.5	93.1	211.6	107.2	402.3	378.9	115.8	104.9	238.4	97.7	247.3	176.26	180.8	99.6
11-20	171.9	117.3	65.8	90.4	99.3	75.4	205.9	327.0	96.2	107.5	170.2	77.0	279.2	195.00	148.4	85.2
21-29	221.9	113.0	106.4	136.8	115.6	104.6	171.4	103.0	73.5	98.3	309.9	126.1	158.9	95.08	138.2	94.2
MAR. 1-10	206.3	88.1	166.4	230.1	173.5	105.8	262.6	102.4	195.0	139.3	438.8	132.9	100.3	122.50	176.0	109.7
11-20	211.7	79.2	161.8	97.0	147.0	102.1	176.5	232.6	469.9	156.2	217.5	75.7	119.8	110.52	168.4	97.0
21-31	230.3	117.9	146.4	98.1	203.3	74.5	191.8	172.2	127.8	127.2	230.4	88.6	100.8	279.24	156.3	103.3
APR. 1-10	163.7	133.9	191.8	165.0	354.4	84.1	241.7	169.5	173.9	141.6	152.8	156.4	119.9	503.93	196.6	122.0
11-20	240.9	98.1	146.7	166.0	490.4	74.3	277.7	157.3	215.0	193.1	205.6	116.7	89.8	312.11	198.8	111.8
21-30	323.3	171.8	121.9	151.6	283.1	120.8	251.4	89.4	184.5	152.5	164.4	68.8	92.7	212.04	170.6	107.4
MAY 1-10	219.2	179.1	230.7	169.5	188.9	148.8	206.3	91.7	171.0	403.3	145.8	112.8	165.8	196.57	187.8	131.7
11-20	197.6	67.1	164.7	158.5	150.9	139.0	152.3	252.6	96.0	332.7	236.6	114.0	127.0	102.94	163.7	106.0
21-31	105.9	79.0	98.0	189.0	180.0	99.5	152.5	203.6	101.6	154.9	88.2	74.8	66.8	208.34	128.7	86.0
JUN. 1-10	133.1	191.4	171.2	200.9	144.4	72.6	178.9	76.7	134.9	114.6	88.0	53.4	55.9	224.33	131.4	81.4
11-20	76.5	131.3	92.7	94.0	88.8	157.2	145.1	67.0	108.2	74.9	81.8	44.7	51.3	96.16	93.5	65.7
21-30	64.2	82.3	63.6	67.8	86.3	69.5	82.1	59.6	63.3	71.4	85.5	50.6	61.4	76.89	70.3	60.9
JUL. 1-10	67.0	67.0	65.7	67.8	67.1	67.6	87.4	54.0	62.0	57.7	120.1	58.1	58.5	103.34	71.7	58.5
11-20	85.1	71.6	74.5	81.7	62.5	76.0	117.7	49.6	55.9	56.9	74.4	49.8	91.0	67.02	72.4	57.1
21-31	97.4	66.2	64.1	58.0	59.2	120.8	103.5	60.3	56.5	81.0	96.5	39.5	71.7	53.90	73.5	54.4
AUG. 1-10	59.2	54.1	83.1	49.7	59.2	103.9	100.6	63.2	53.5	129.2	104.9	38.6	61.8	52.81	72.4	50.7
11-20	60.9	60.9	60.9	60.9	60.9	60.9	60.9	60.9	42.7	281.7	149.0	56.8	47.6	62.81	80.6	49.5
21-31	53.3	70.3	66.0	50.0	56.3	62.9	71.7	61.5	46.3	66.0	138.9	122.3	44.7	46.49	68.3	49.3
SEP. 1-10	81.2	119.9	66.6	70.1	78.7	136.8	63.6	88.1	50.2	115.3	270.2	73.6	50.7	52.63	94.1	57.3
11-20	50.7	131.7	79.8	114.6	59.5	265.5	84.3	97.6	45.8	114.0	270.9	142.8	68.9	68.32	113.9	61.7
21-30	50.6	66.1	77.8	81.1	55.4	99.9	94.0	181.1	103.5	180.9	197.8	213.2	89.1	103.88	113.9	69.2
OCT. 1-10	46.4	47.0	120.7	77.1	100.1	107.2	63.7	152.0	171.2	183.9	136.9	105.0	94.5	68.79	105.3	67.4
11-20	53.9	56.0	138.4	134.2	197.0	135.6	62.9	74.7	160.4	325.5	86.3	128.1	114.4	131.07	128.5	72.6
21-31	188.7	103.6	65.9	171.1	101.0	121.6	89.8	104.2	108.6	350.7	90.6	154.4	161.1	145.02	139.7	90.2
NOV. 1-10	279.3	170.6	74.5	140.7	236.7	82.3	304.0	493.0	123.8	536.3	123.8	155.2	176.0	203.59	221.4	113.6
11-20	139.2	236.8	118.6	65.6	148.7	63.4	256.1	255.2	61.7	185.0	107.3	231.4	90.5	250.74	157.9	90.9
21-30	124.5	466.3	271.0	64.2	163.3	75.0	264.7	120.0	212.6	125.7	135.0	206.0	204.1	339.24	199.4	108.9
DEC. 1-10	371.0	252.1	158.5	87.0	248.4	140.5	210.7	203.1	270.8	233.5	197.4	299.3	240.1	392.95	236.1	165.6
11-20	389.2	250.9	116.4	147.3	233.7	196.4	97.9	192.7	456.6	231.0	166.3	212.4	329.7	452.50	246.1	151.8
21-31	202.9	150.0	146.3	79.9	276.9	153.7	246.3	150.9	227.0	281.0	107.9	171.0	181.8	437.68	200.9	128.4

Table 2.12 Comparison of Probable Rainfall by Iwai and Gumbel Methods

(Unit : mm)

PROBABLE	RAO MT.		JAMBACK		SONTANG		LUBUK B'HARA		UJUNG BATU		KATA LAMA	
YEAR	IWAI	GUMBEL	IWAI	GUMBEL	IWAI	GUMBEL	IWAI	GUMBEL	IWAI	GUMBEL	IWAI	GUMBEL
1,000	487.0	535.5	144.3	164.4	334.1	319.6	361.9	303.0	287.7	317.0	390.1	274.0
500	448.9	495.1	137.9	155.7	297.3	294.5	317.8	282.5	264.6	292.9	356.9	257.4
200	399.9	441.5	129.4	144.2	252.6	261.3	266.8	255.3	235.0	260.9	314.6	235.3
100	363.4	400.9	123.0	135.5	221.5	236.1	233.0	234.8	213.1	236.8	283.6	218.6
50	327.3	360.2	116.5	126.7	192.5	210.8	203.1	214.1	191.6	212.5	253.4	201.8
20	279.8	305.8	107.8	115.0	157.2	177.1	169.0	186.6	163.6	180.1	214.3	179.5
10	243.5	263.8	101.0	106.0	132.5	151.1	146.8	165.3	142.3	155.1	184.9	162.2
5	205.7	220.0	93.7	96.6	109.2	123.9	127.3	143.2	120.4	129.0	154.9	144.2
2	149.0	153.9	82.3	82.3	78.8	82.9	104.8	109.7	88.1	89.6	111.4	116.9

Table 2.13 Calculation of Flood Discharge by Unit Hydrograph

(IN CASE OF PROBABLE RAINFALL OF 1/100)

Time (hr)	Unit Dis. (mm/hr)	Rain (mm)	Effec.R (mm)	Runoff by every 1 hr rainfall (m3/s)									Total Dis. (m3/s)
1	0.000	88.5	20.6	2.2									2
2	0.000	67.1	20.1	11.6	1.7								13
3	0.001	27.7	8.3	30.8	8.8	0.7							40
4	0.003	21.7	6.5	61.4	23.3	3.6	0.5						89
5	0.004	12.6	3.8	104.9	46.5	9.6	2.8	0.3					164
6	0.007	7.7	2.3	162.5	79.5	19.2	7.5	1.7	0.2				271
7	0.010	4.7	1.4	235.2	123.1	32.8	15.0	4.4	1.0	0.1			412
8	0.013	1.9	0.6	324.0	178.2	50.9	25.7	8.7	2.7	0.6	0.0		591
9	0.018	1.4	0.4	429.9	245.6	73.7	39.8	14.9	5.3	1.6	0.2	0.0	811
10	0.023			553.6	325.8	101.5	57.6	23.1	9.1	3.2	0.6	0.2	1,075
11	0.029			695.9	419.6	134.6	79.3	33.4	14.1	5.5	1.3	0.5	1,384
12	0.036			857.5	527.4	173.4	105.2	46.0	20.4	8.6	2.2	1.0	1,742
13	0.034			828.1	649.9	217.9	135.5	61.1	28.1	12.4	3.4	1.7	1,938
14	0.033			787.9	627.6	268.5	170.3	78.7	37.3	17.1	5.0	2.6	1,995
15	0.031			749.6	597.1	259.3	209.9	98.9	48.1	22.6	6.8	3.7	1,996
16	0.030			713.2	568.1	246.7	202.7	121.8	60.4	29.1	9.1	5.1	1,956
17	0.028			678.6	540.5	234.7	192.8	117.7	74.5	36.6	11.7	6.8	1,894
18	0.027			645.6	514.3	223.3	183.5	112.0	71.9	45.1	14.6	8.7	1,819
19	0.025			614.2	489.3	212.5	174.5	106.5	68.4	43.6	18.1	11.0	1,738
20	0.024			584.4	465.5	202.2	166.1	101.3	65.1	41.5	17.4	13.5	1,657
21	0.023			556.0	442.9	192.4	158.0	96.4	61.9	39.5	16.6	13.1	1,577
22	0.022			529.0	421.4	183.0	150.3	91.7	58.9	37.5	15.8	12.4	1,500
23	0.021			503.3	400.9	174.1	143.0	87.3	56.1	35.7	15.0	11.8	1,427
24	0.020			478.9	381.5	165.7	136.1	83.0	53.3	34.0	14.3	11.3	1,358
25	0.019			455.6	362.9	157.6	129.5	79.0	50.8	32.3	13.6	10.7	1,292
26	0.018			433.5	345.3	150.0	123.2	75.2	48.3	30.8	12.9	10.2	1,229
27	0.017			412.4	328.5	142.7	117.2	71.5	45.9	29.3	12.3	9.7	1,170
28	0.016			392.4	312.6	135.7	111.5	68.0	43.7	27.8	11.7	9.2	1,113
29	0.015			373.3	297.4	129.2	106.1	64.7	41.6	26.5	11.1	8.8	1,059
30	0.015			355.2	282.9	122.9	100.9	61.6	39.6	25.2	10.6	8.4	1,007
31	0.014			337.9	269.2	116.9	96.0	58.6	37.6	24.0	10.1	7.9	958
32	0.013			321.5	256.1	111.2	91.4	55.8	35.8	22.8	9.6	7.6	912
33	0.013			305.9	243.7	105.8	86.9	53.1	34.1	21.7	9.1	7.2	868
34	0.012			291.1	231.8	100.7	82.7	50.5	32.4	20.7	8.7	6.8	825
35	0.011			276.9	220.6	95.8	78.7	48.0	30.8	19.6	8.3	6.5	785
36	0.011			263.5	209.9	91.1	74.9	45.7	29.3	18.7	7.9	6.2	747
37	0.011			253.8	199.7	86.7	71.2	43.5	27.9	17.8	7.5	5.9	714
38	0.010			245.6	192.4	82.5	67.8	41.4	26.6	16.9	7.1	5.6	686
39	0.010			237.5	186.1	79.5	64.5	39.4	25.3	16.1	6.8	5.3	660
40	0.010			229.8	180.0	76.9	62.1	37.4	24.0	15.3	6.4	5.1	637
41	0.009			222.3	174.2	74.4	60.1	36.1	22.9	14.6	6.1	4.8	615
42	0.009			215.0	168.5	72.0	58.1	34.9	22.0	13.9	5.8	4.6	595
43	0.009			208.0	163.0	69.6	56.2	33.8	21.3	13.4	5.5	4.4	575
44	0.008			201.2	157.6	67.3	54.4	32.7	20.6	12.9	5.3	4.2	556
45	0.008			194.6	152.5	65.1	52.6	31.6	20.0	12.5	5.2	4.0	538
46	0.008			188.3	147.5	63.0	50.9	30.6	19.3	12.1	5.0	3.9	521
47	0.008			182.1	142.7	61.0	49.2	29.6	18.7	11.7	4.8	3.8	504
48	0.007			176.2	138.0	59.0	47.6	28.6	18.1	11.3	4.7	3.6	487
49	0.007			170.4	133.5	57.0	46.1	27.7	17.5	10.9	4.5	3.5	471
50	0.007			164.9	129.2	55.2	44.6	26.8	16.9	10.6	4.4	3.4	456
51	0.007			159.5	125.0	53.4	43.1	25.9	16.4	10.2	4.2	3.3	441
52	0.006			154.3	120.9	51.6	41.7	25.0	15.8	9.9	4.1	3.2	427
53	0.006			149.2	116.9	49.9	40.4	24.2	15.3	9.6	4.0	3.1	413
54	0.006			144.4	113.1	48.3	39.0	23.4	14.8	9.3	3.8	3.0	399
55	0.006			139.7	109.4	46.7	37.8	22.7	14.3	9.0	3.7	2.9	386
56	0.006			135.1	105.8	45.2	36.5	21.9	13.9	8.7	3.6	2.8	374
57	0.005			130.7	102.4	43.7	35.3	21.2	13.4	8.4	3.5	2.7	361
58	0.005			126.4	99.1	42.3	34.2	20.5	13.0	8.1	3.4	2.6	350
59	0.005			122.3	95.8	40.9	33.1	19.8	12.5	7.9	3.2	2.5	338
60	0.005			118.3	92.7	39.6	32.0	19.2	12.1	7.6	3.1	2.4	327
61	0.005			114.4	89.7	38.3	30.9	18.6	11.7	7.4	3.0	2.4	316
62	0.005			110.7	86.7	37.0	29.9	18.0	11.3	7.1	2.9	2.3	306
63	0.004			107.1	83.9	35.8	29.0	17.4	11.0	6.9	2.8	2.2	296
64	0.004			103.8	81.2	34.7	28.0	16.8	10.6	6.7	2.8	2.1	286
65	0.004			100.2	78.5	33.5	27.1	16.3	10.3	6.4	2.7	2.1	277
66	0.004			96.9	75.9	32.4	26.2	15.7	9.9	6.2	2.6	2.0	268
67	0.004			93.8	73.5	31.4	25.4	15.2	9.6	6.0	2.5	1.9	259
68	0.004			90.7	71.1	30.4	24.5	14.7	9.3	5.8	2.4	1.9	251
69	0.004			87.8	68.8	29.4	23.7	14.2	9.0	5.6	2.3	1.8	243
70	0.004			84.9	66.5	28.4	23.0	13.8	8.7	5.5	2.3	1.7	235
71	0.003			82.1	64.3	27.5	22.2	13.3	8.4	5.3	2.2	1.7	227
72	0.003			79.4	62.2	26.6	21.5	12.9	8.1	5.1	2.1	1.6	220
73	0.003			77.2	60.2	25.7	20.8	12.5	7.9	4.9	2.0	1.6	213
74	0.003			75.3	58.5	24.9	20.1	12.1	7.6	4.8	2.0	1.5	207
75	0.003			73.4	57.0	24.2	19.4	11.7	7.4	4.6	1.9	1.5	201
76	0.003			71.6	55.6	23.6	18.9	11.3	7.1	4.5	1.8	1.4	196
77	0.003			69.8	54.3	23.0	18.4	11.0	6.9	4.3	1.8	1.4	191
78	0.003			68.1	52.9	22.4	18.0	10.7	6.7	4.2	1.7	1.3	186
79	0.003			66.4	51.6	21.9	17.5	10.4	6.5	4.1	1.7	1.3	181
80	0.003			64.8	50.4	21.3	17.1	10.2	6.4	4.0	1.6	1.3	177
81	0.003			63.2	49.1	20.8	16.7	9.9	6.2	3.9	1.6	1.2	173
82	0.003			61.7	47.9	20.3	16.3	9.7	6.1	3.8	1.5	1.2	168
83	0.002			60.1	46.7	19.8	15.9	9.4	5.9	3.7	1.5	1.2	164
84	0.002			58.7	45.6	19.3	15.5	9.2	5.8	3.6	1.5	1.1	160
85	0.002			57.2	44.5	18.8	15.1	9.0	5.6	3.5	1.4	1.1	156
Total		233.2	70.0										

Table 2.14(1) Water Quality Criteria(Class A)

Class A : For drinking without treatment

Parameter		Unit	Maximum suggestion	Maximum Allowance	Remarks
1. Physics					
Temperature		° C	normal water temperature	normal water temperature	
Color		Unit	5	50	
Smell		-	no smell	no smell	
Taste		-	no taste	no taste	
Turbidity		mg/t, Sio2	5	25	
Disssolved redidue		mg/l	500	1,500	
2. Chemistry					
pH			6.5 - 8.5	6.5 - 8.5	
Calcium	(Ca)	mg/l	75	200	
Magnesium	(Mg)	mg/l	30	150	
Barrium	(Ba)	mg/l	nil	0.05	
Iron	(Fe)	mg/l	0.1	1	
Manganese	(Mn)	mg/l	0.05	0.5	
Copper	(Cu)	mg/l	nil	1	
Zinc	(Zn)	mg/l	1	15	
Chromium	(Cr)	mg/l	nil	0.05	
Cadmium	(Cd)	mg/l	nil	0.01	
Mercury	(Hg)	mg/l	0.0005	0.001	
Lead	(Pb)	mg/l	0.05	0.1	
Aresemic	(As)	mg/l	nil	0.05	
Selenium	(Se)	mg/l	nil	0.01	
Cyanide	(CN)	mg/l	nil	0.05	
Sulfur	(S)	mg/l	nil	nil	
Fluorine	(F)	mg/l	-	1.5	min. :1.5
Chlorine	(Cl)	mg/l	200	600	
Sulfate	(SO4)	mg/l	200	400	
Ammonia	(NH3-N)	mg/l	nil	nil	
Nitrate	(NO3-N)	mg/l	5	10	
Nitrate	(NO2-N)	mg/l	nil	nil	
Permangnate	(KMnO4)	mg/l	nil	10	
Blue methyl active compound		mg/l	nil	0.5	
Phenol		mg/l	0.001	0.002	
Oil and Grease		mg/l	nil	nil	
Extract Chloroform Carbon		mg/l	0.04	0.5	
PCB		mg/l	nil	nil	
3. Bacteriology					
Coliform group		MPN/100ml	nil	nil	
Parasitic Bacteria			nil	nil	
Pathogenic Bacteria			nil	nil	
4. Radioactivity					
Total Beta activity		pCi/l	-	100	
Strontium 90		pCi/l	-	2	
Radium 226		pCi/l	-	1	
Pestiside		mg/l	nil	nil	

Table 2.14(2) Water Quality Criteria(Class B)

Class B : For drinking and domestic use but not applicable for Class A

Parameter		Unit	Maximum Allowance	Remarks
1. Physics				
Temperature		° C	normal water temperature	
Disssolved redidue		mg/l	1,500	
2. Chemistry				
pH			5 - 9	
Barrium	(Ba)	mg/l	1	
Iron	(Fe)	mg/l	5	
Manganese	(Mn)	mg/l	0.5	
Copper	(Cu)	mg/l	1	
Zinc	(Zn)	mg/l	15	
Chromium	(Cr)	mg/l	0.05	
Cadmium	(Cd)	mg/l	0.01	
Mercury	(Hg)	mg/l	0.001	
Lead	(Pb)	mg/l	0.1	
Aresemic	(As)	mg/l	0.05	
Selenium	(Se)	mg/l	0.01	
Cyanide	(CN)	mg/l	0.05	
Sulfur	(S)	mg/l	nil	
Fluorine	(F)	mg/i	1.5	min.:1.5
Chlorine	(Cl)	mg/l	600	
Sulfate	(SO4)	mg/l	400	
Ammonia	(NH3-N)	mg/l	nil	
Nitrate	(NO3-N)	mg/l	10	
Nitrate	(NO2-N)	mg/l	nil	
Dissolved Oxygen	(DO)	mg/l		1/
BOD		mg/l	-	
COD		mg/l	-	
3. Bacteriology				
Coliform group		MPN/100ml	-	
Feces			-	
4. Radioactivity				
Total Beta activity		pCi/l	100	
Strontium 90		pCi/l	2	
Radium 226		pCi/l	1	
5. Pestiside				
Aldrin			0.017	
Chlordane			0.003	
DOT			0.042	
Dieldrin			0.017	
Endrin			0.001	
Heptachlor			0.018	
Heptachlor epoxide			0.018	
Lindane			0.056	
Methexy chlor			0.035	
Organic phophate & carnonate		mg/l	0.1	
Toxaphane			0.005	

1/ To be ≧6 for surface water

Table 2.14(3) Water Quality Criteria(Class C)

Class C : Good for fishery & livestock as well as other purpose but not belong to Class A and B

Parameter		Unit	Maximum Value	Remarks
1. Physics				
Temperature		° C	normal water temperature±4° C	
Disssolved redidue		mg/l	2,000	
2. Chemistry				
pH			6 - 9	
Copper	(Cu)	mg/l	0.02	
Zinc	(Zn)	mg/l	0.02	
Chromium	(Cr)	mg/l	0.05	
Cadmium	(Cd)	mg/l	0.01	
Mercury	(Hg)	mg/l	0.002	
Lead	(Pb)	mg/l	0.03	
Aresemic	(As)	mg/l	1	
Selenium	(Se)	mg/l	0.05	
Cyanide	(CN)	mg/l	0.02	
Sulfur	(S)	mg/l	0.002	
Fluorine	(F)	mg/l	1.5	
Ammonia	(NH3-N)	mg/l	0.016	
Nitrate	(NO2-N)	mg/l	0.06	
Chloride	(Cl2)	mg/l	0.003	
Dissolved Oxygen	(DO)	mg/l	-	1/
Blue methyl active compound			0.2	
Phenol		mg/l	0.001	
Oil and Grease		mg/l	1	
3. Radioactivity				
Total Beta activity		pCi/l	1,000	
Strontium 90		pCi/l	10	2/
Radium 226		pCi/l	3	
4. Pestiside				
DDT		mg/l	0.002	
Endrin		mg/l	0.004	
BHC		mg/l	0.21	
Methyl Parathion		mg/l	0.1	
Malathion		mg/l	0.16	

1/ to be >3 and allowance DO=3, maximum 8 hrs/day
2/ activities without Sr-90 and Ra-226

Table 2.14(4) Water Quality Criteria(Class D)

Class D : Good for agriculture, industry, hydropower and navigation etc, but can not be used for Class A, B &C

Parameter		Unit	Maximum Value	Remarks
1. Physics				
Temperature		° C	normal water temperature	
Disssolved redidue		mg/l	1,000 - 2,000	1/
Electric conductivity		μ Ω/cm (25° C)	1,750 - 2,250	2/
2. Chemistry				
pH			5 - 9	
Manganese	(Mn)	mg/l	2	
Copper	(Cu)	mg/l	0.2	
Zinc	(Zn)	mg/l	2	
Chromium	(Cr)	mg/l	1	
Cadmium	(Cd)	mg/l	0	
Mercury	(Hg)	mg/l	0.005	
Lead	(Pb)	mg/l	1	
Aresemic	(As)	mg/l	1	
Selenium	(Se)	mg/l	0.005	
Nichel	(Ni)	mg/l	0.5	
Cobalt	(Co)	mg/l	0.2	
Boron	(B)	mg/l	1	
Sodium	(Na)	%	60	
Sodium Absorption Ratio			10 -18	3/
Residual Sodium Carbonate			1.25 - 2.5	4/
3. Radioactivity				
Total Beta activity		pCi/l	1,000	5/
Strontium 90		pCi/l	10	
Radium 226		pCi/l	3	

1/ According to local condition
2/ 1,750 for sensitive plant
2,250 for medium sensitive plant
3/ maximum 10 for sensitive plant
maximum 18 for low sensitive plant
4/ maximum 1.25 for sensitive plant
maximum 2.5 for low sensitive plant
5/ activities without Sr-90 and Ra-226

Table 2.15 Water Quality Tests Results

PUSAT PENELITIAN DAN PENGEMBANGAN PENGAIRAN
LAB. KUALITAS LINGKUNGAN TATA AIR
Jalan Ir. H. Juanda No. 193 Bandung - Tlp. 84553 - 84554 - 81067

Lab. No. : PKA 92/1
Lokasi : R I A U

Form : P K A 2
Air minum

HASIL ANALISA KUALITAS AIR

Parameter		Satuan	Hasil Analisa 1	Hasil Analisa 2		
FISIKA :						
Temperatur		oC				
Warna		Unit PtCo	2,5	160		
Bau			-	-		
Rasa			-	-		
Kekeruhan		NTU	40	6,5		
Residu terlarut		mg/l	38	-		
Daya Hantar Listrik	(DHL)	µmho/cm	55	35		
KIMIA :						
PH			7,2	5,2		
Kalsium	(Ca)	mg/l	5,8	2,3		
Magnesium	(Mg)	"	1,4	1,0		
Kesadahan		mg/l CaCO3	20	10		
Natrium	(Na)	mg/l	2,0	1,1		
Kalium	(K)	"	0,50	0,60		
Nikel	(Ni)	"	tt	tt		
Besi	(Fe)	"	0,66	0,07		
Mangan	(Mn)	"	0,02	0,05		
Tembaga	(Cu)	"	tt	tt		
Seng	(Zn)	"	tt	tt		
Krom	(Cr)	"	tt	tt		
Kadmium	(Cd)	"	tt	tt		
Raksa total	(Hg)	"	-	-		
Timbal	(Pb)	"	tt	tt		
Sianida	(CN)	"	-	-		
Sulfida	(S)	"	-	-		
Fluorida	(F)	"	0,10	*)		
Khlorida	(Cl)	"	3,8	2,0		
Sulfat	(SO_4)	"	1,7	*)		
Amonium	(NH_4-N)	"	0,05	0,03		
Nitrat	(NO_3-N)	"	0,25	*)		
Nitrit	(NO_2-N)	"	tt	*)		
Bikarbonat	(HCO_3)	mg/l	22	16		
Senyawa aktif birumetilen		mg/l	-	-		
Fenol		"	-	-		
Minyak & Lemak		"	-	-		
Boron	(B)	"	0,03	0,02		
Nilai Permanganat		mg/l KMnO4	12	46		
BAKTERIOLOGI :						
Coliform group		MPN / 100ml				
Coli tinja						
Kuman - kuman parasitik						
Kuman - kuman patogenik						
% Na			17	15		
SAR			0,20	0,15		
RSC			-	0,06		

Keterangan : tt = tidak teramati
1. S. Rokan (11-12-1991)
2. Air rawa/SKP-F (13-12-1991)
*) tidak diperiksa karena terganggu oleh warna contoh air
Penerimaan contoh air tanggal 3-1-1992
Pemeriksaan con[illegible] air tanggal 3-1-1992

PUSAT PENELITIAN DAN PENGEMBANGAN PENGAIRAN
LAB. KUALITAS LINGKUNGAN TATA AIR
Jalan Ir. H. Juanda No. 193 Bandung - Tilp. 84553 - 84554 - 81067

Lab. No. : PKA 92/4
Lokasi : Daerah Riau

Form : P K A 2
Air minum

HASIL ANALISA KUALITAS AIR

Parameter		Satuan	Hasil Analisa			
			5			
FISIKA :						
Temperatur		oC				
Warna		Unit PtCo	10			
Bau			–			
Rasa			–			
Kekeruhan		NTU	26			
Residu terlarut		mg/l	–			
Daya Hantar Listrik	(DHL)	umho/cm	36			
KIMIA :						
PH			5,7			
Kalsium	(Ca)	mg/l	3,0			
Magnesium	(Mg)	,,	2,1			
Kesadahan		mg/l $CaCO_3$	16			
Natrium	(Na)	mg/l	1,0			
Kalium	(K)	,,	0,50			
Nikel	(Ni)	,,	tt			
Besi	(Fe)	,,	tt			
Mangan	(Mn)	,,	0,01			
Tembaga	(Cu)	,,	tt			
Seng	(Zn)	,,	0,01			
Krom	(Cr)	,,	tt			
Kadmium	(Cd)	,,	tt			
Raksa total	(Hg)	,,	–			
Timbal	(Pb)	,,	tt			
Sianida	(CN)	,,	–			
Sulfida	(S)	,,	–			
Fluorida	(F)	,,	0,05			
Khlorida	(Cl)	,,	1,5			
Sulfat	(SO^4)	,,	0,50			
Amonium	(NH^4-N)	,,	0,02			
Nitrat	(NO^3-N)	,,	1,6			
Nitrit	(NO^2-N)	,,	tt			
Bikarbonat	(HCO3)	mg/l	12			
Senyawa aktif birumetilen		mg/l				
Fenol		,,				
Minyak & Lemak		,,				
Boron	(B)	,,	0,02			
Nilai Permanganat		mg/l KMnO4	19			
BAKTERIOLOGI :						
Coliform group Coli tinja		MPN / 100ml				
Kuman - kuman parasitik						
Kuman - kuman patogenik						
% Na			12			
SAR			0,11			
RSC			–			

Keterangan : 5. S. Mandino

PUSAT PENELITIAN DAN PENGEMBANGAN PENGAIRAN
LAB. KUALITAS LINGKUNGAN TATA AIR
Jalan Ir. H. Juanda No. 193 Bandung - Tlp. 84553 - 84554 - 81067

Lab. No. : PKA 92/4
Lokasi : Daerah Riau

Form : P K A 2
Air minum

HASIL ANALISA KUALITAS AIR

Parameter		Satuan	Hasil Analisa			
			1	2	3	4
FISIKA :						
Temperatur		oC				
Warna		Unit PtCo	1,5	1,5	2,0	1,5
Bau			-	-	-	-
Rasa			-	-	-	-
Kekeruhan		NTU	3,0	1,6	15	2,7
Residu terlarut		mg/l	230	220	-	172
Daya Hantar Listrik	(DHL)	μmho/cm	343	298	28	250
KIMIA :						
PH			6,1	6,4	5,0	5,2
Kalsium	(Ca)	mg/l	22	40	2,3	16
Magnesium	(Mg)	"	13	6,8	1,3	3,4
Kesadahan		mg/l $CaCO_3$	109	128	11	54
Natrium	(Na)	mg/l	30	5,7	1,5	20
Kalium	(K)	"	16	3,8	1,0	6,9
Nikel	(Ni)	"	tt	tt	tt	tt
Besi	(Fe)	"	tt	tt	1,0	tt
Mangan	(Mn)	"	0,06	0,01	0,01	0,34
Tembaga	(Cu)	"	tt	tt	tt	tt
Seng	(Zn)	"	0,01	0,01	0,01	0,01
Krom	(Cr)	"	tt	tt	tt	tt
Kadmium	(Cd)	"	tt	tt	tt	tt
Raksa total	(Hg)	"	-	-	-	-
Timbal	(Pb)	"	tt	tt	tt	tt
Sianida	(CN)	"	-	-	-	-
Sulfida	(S)	"	-	-	-	-
Fluorida	(F)	"	0,10	0,10	0,05	0,10
Khlorida	(Cl)	"	51	8,5	1,5	30
Sulfat	(SO^4)	"	0,50	0,50	0,50	3,5
Amonium	(NH^4-N)	"	0,02	0,02	0,04	0,02
Nitrat	(NO^3-N)	"	4,0	2,6	0,48	5,4
Nitrit	(NO^2-N)	"	0,152	tt	tt	0,002
Bikarbonat	(HCO_3)	mg/l	90	162	6,4	60
Senyawa aktif birumetilen		mg/l				
Fenol		"				
Minyak & Lemak		"				
Boron	(B)	"				
Nilai Permanganat		mg/l $KMnO_4$	8,6	8,0	9,6	19
BAKTERIOLOGI :						
Coliform group		MPN / 100ml				
Coli tinja						
Kuman - kuman parasitik						
Kuman - kuman patogenik						

Keterangan : tt = tidak teramati
Penerimaan contoh air tanggal 6-1-1992
Pemeriksaan contoh air tanggal 6-1-1992
1. Sumur Kunto Darussalam
2. Sumur Musa Dilam
3. Sumur SP-1
4. Sumur Ujungbatu
5. S. Mandino

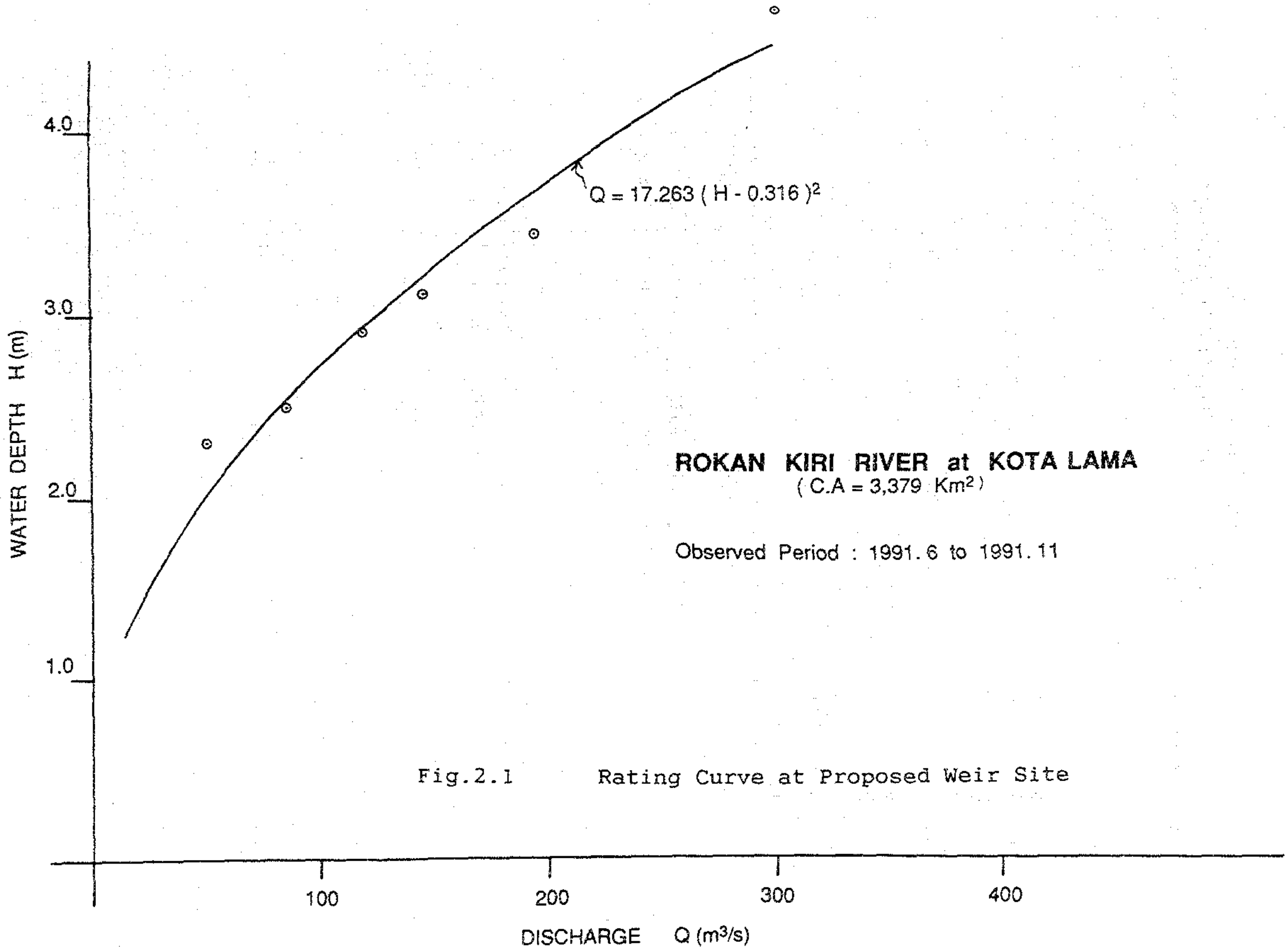

Fig.2.1 Rating Curve at Proposed Weir Site

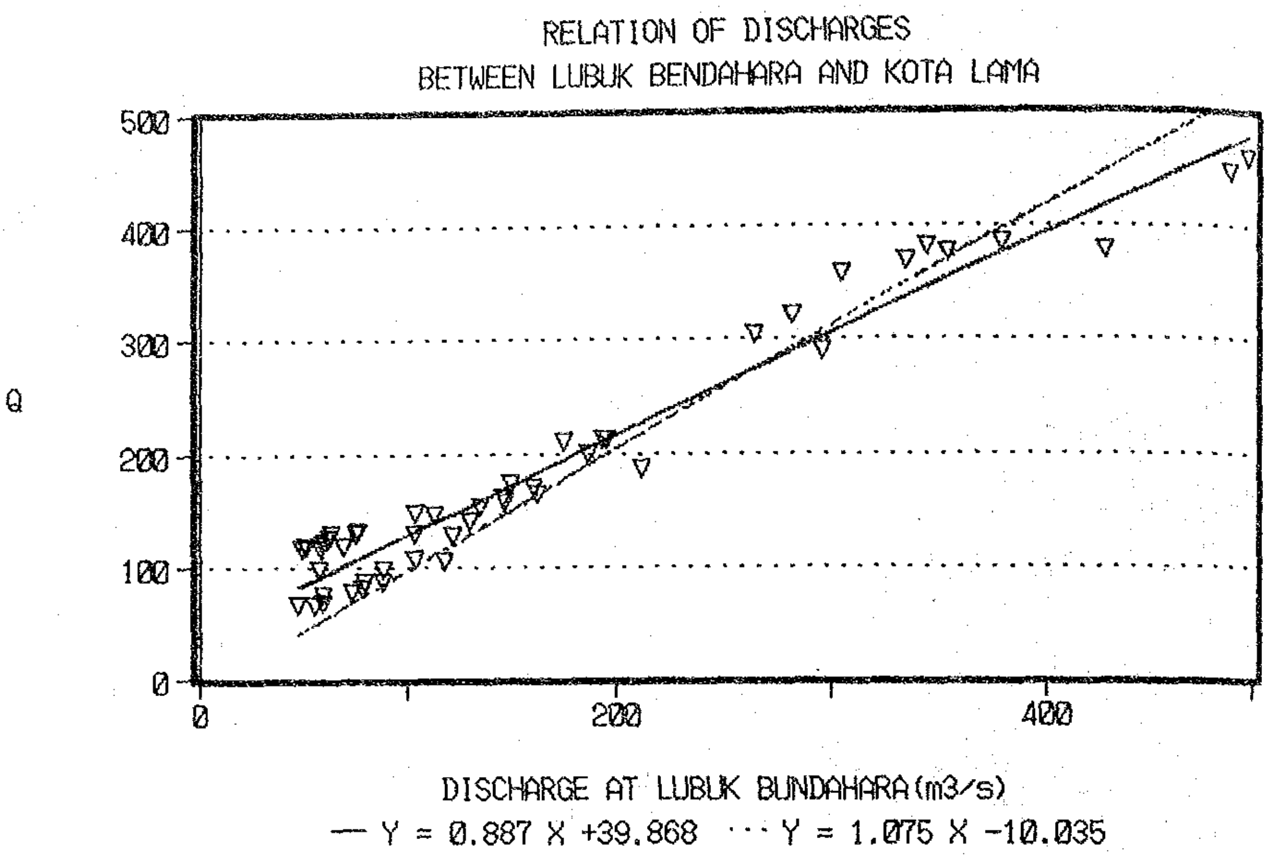

Fig.2.2 Relation of Discharges between Lubuk Bendahara and Kota Lama

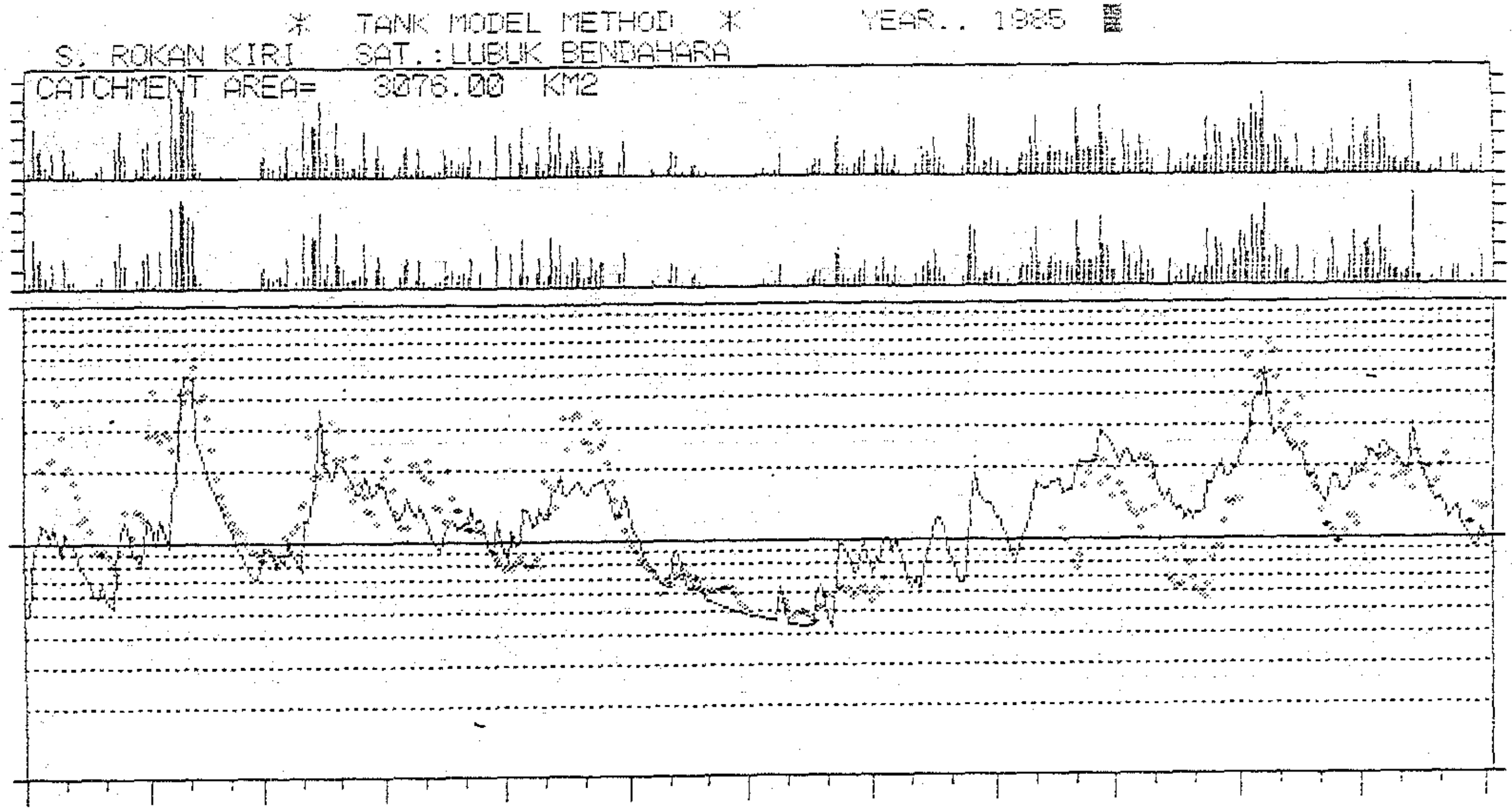

Fig.2.3 Comparison of Estimated and Observed River Discharges by Tank Model in 1985

RMAX= 46.2 MM
RDOT= 10.0 MM

QMAX= 1000.000 M3/S
QMIN= 10.000 M3/S

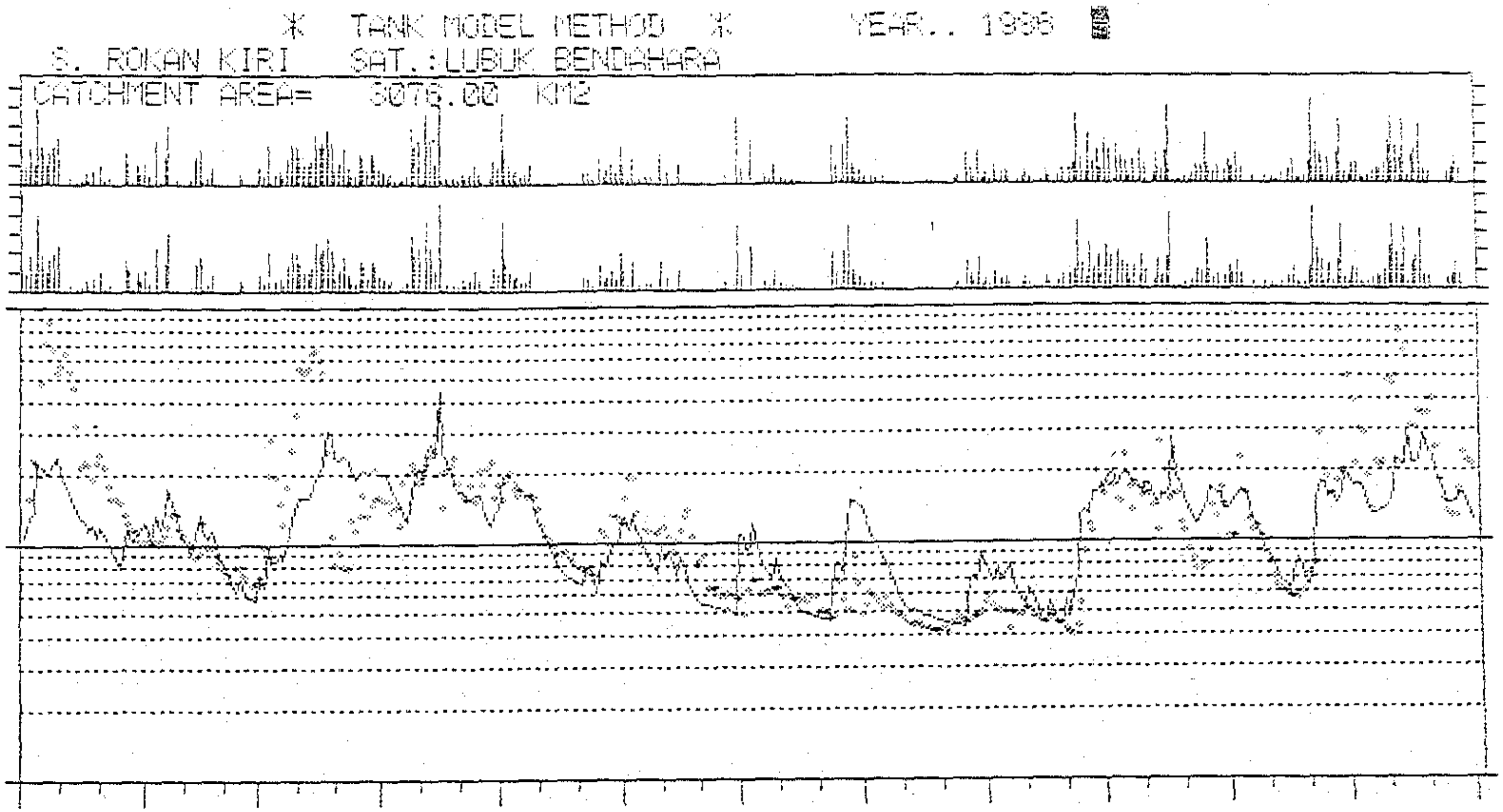

Fig.2.4 Comparison of Estimated and Observed River Discharges by Tank Model in 1986

RMAX= 46.5 MM
RDOT= 10.0 MM

QMAX= 1000.000 M3/S
QMIN= 10.000 M3/S

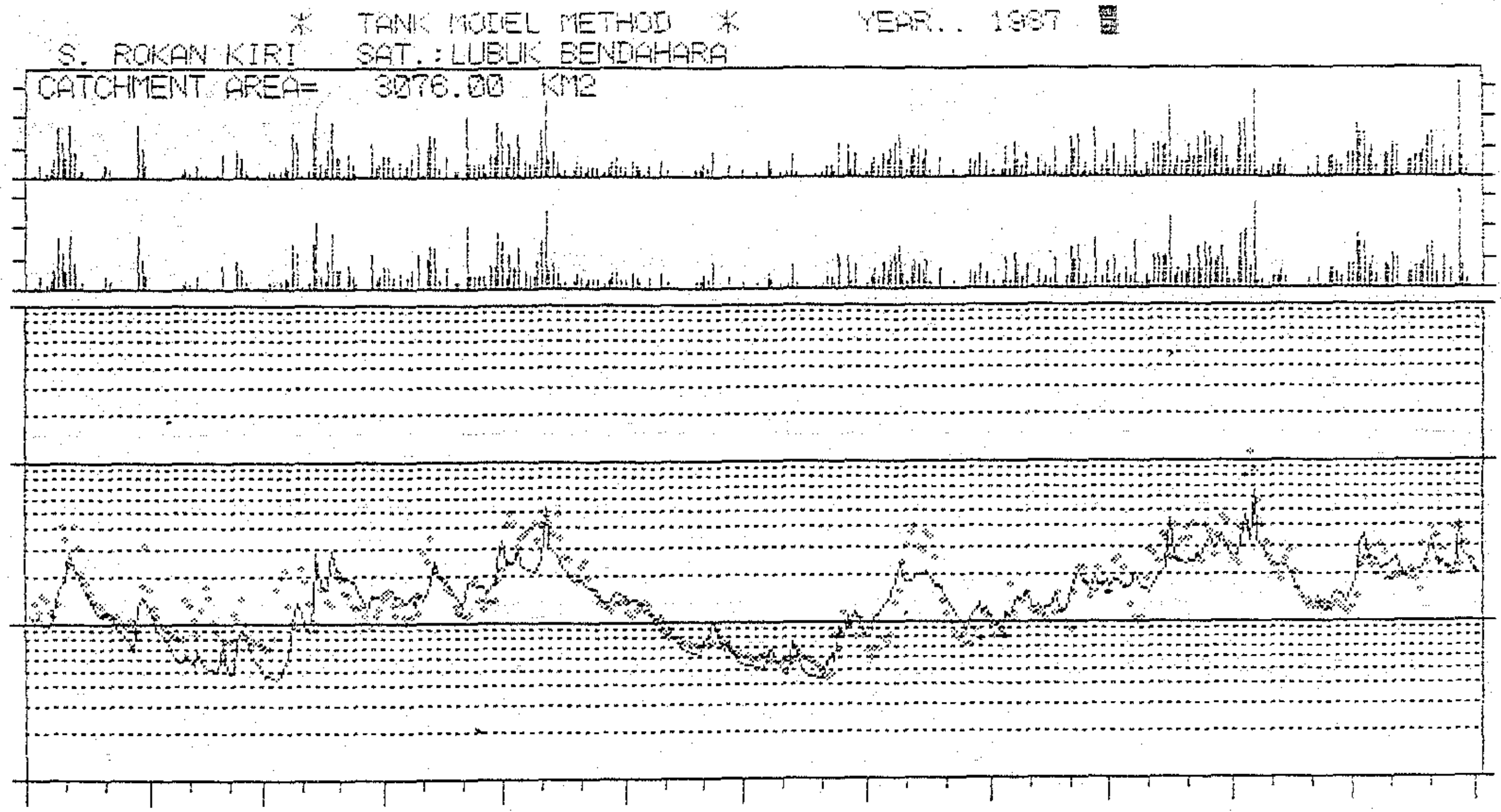

Fig.2.5 Comparison of Estimated and Observed River Discharges by Tank Model in 1987

RMAX= 62.4 MM
RDOT= 20.0 MM

QMAX= 10000.000 M3/S
QMIN= 10.000 M3/S

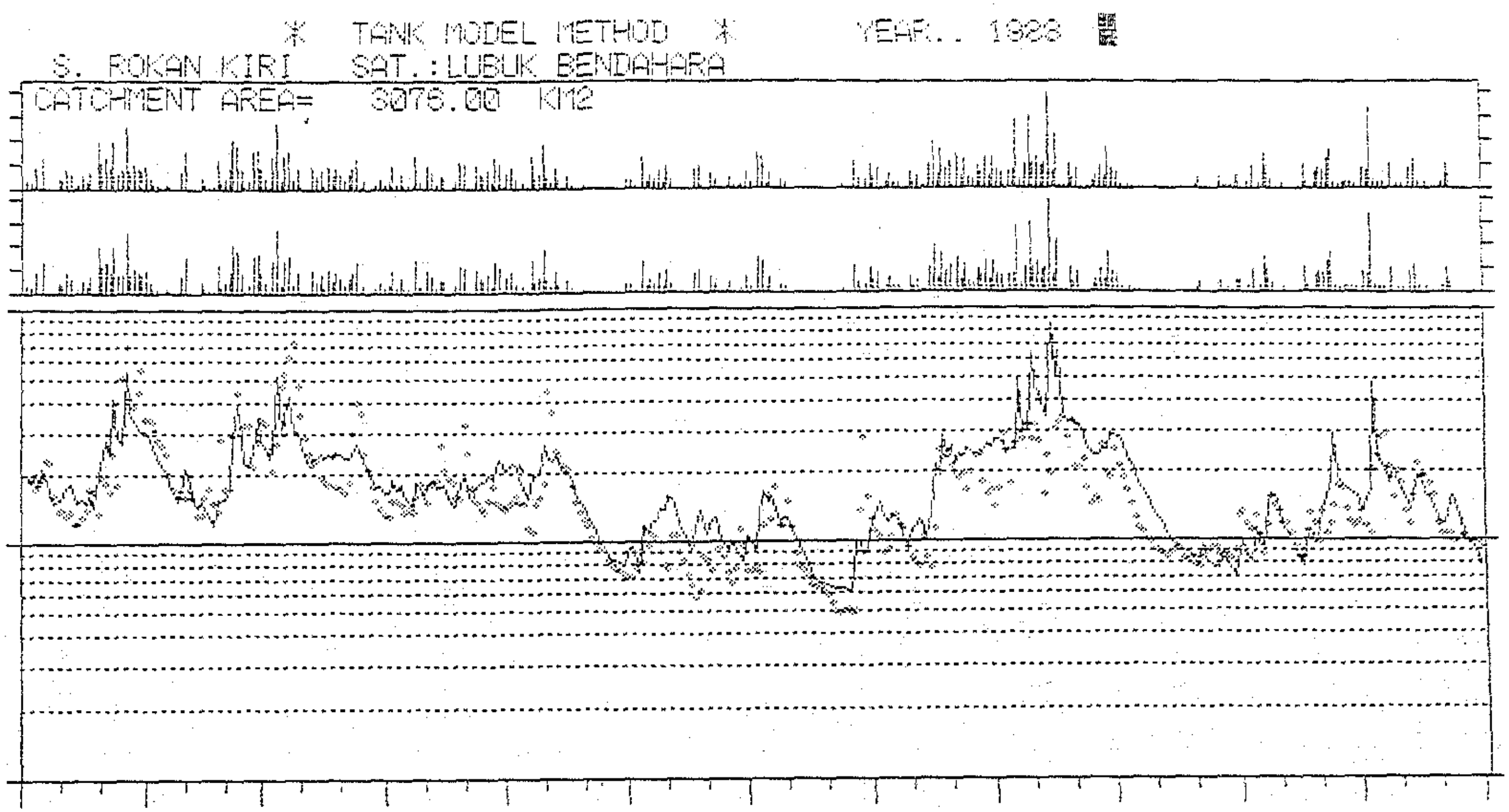

Fig.2.6 Comparison of Estimated and Observed River Discharges by Tank Model in 1988

RMAX= 78.5 MM
RDOT= 20.0 MM

QMAX= 1000.000 M3/S
QMIN= 10.000 M3/S

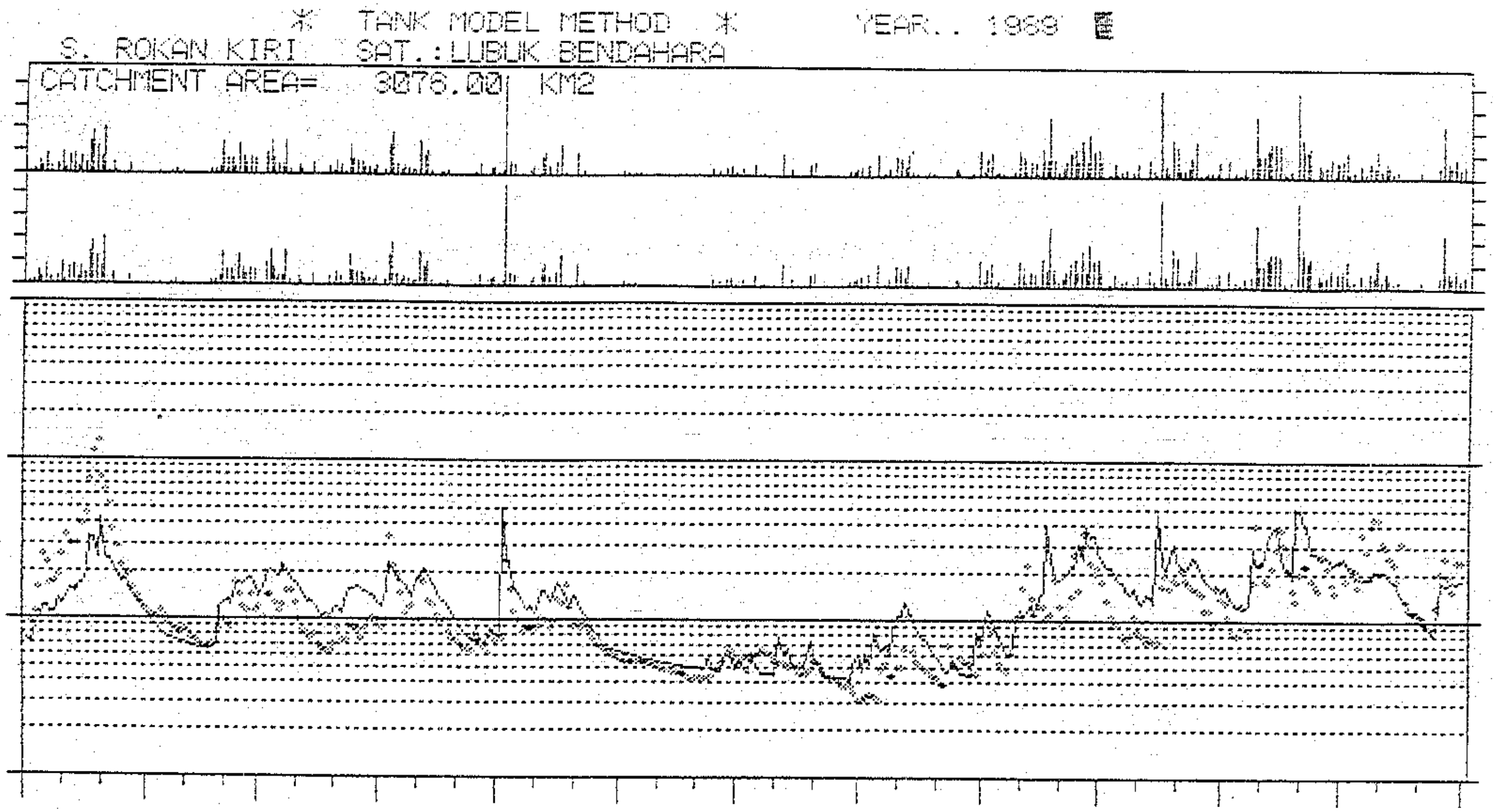

Fig.2.7 Comparison of Estimated and Observed River Discharges by Tank Model in 1989

RMAX= 86.3 MM
RDOT= 20.0 MM

QMAX= 10000.000 M3/S
QMIN= 10.000 M3/S

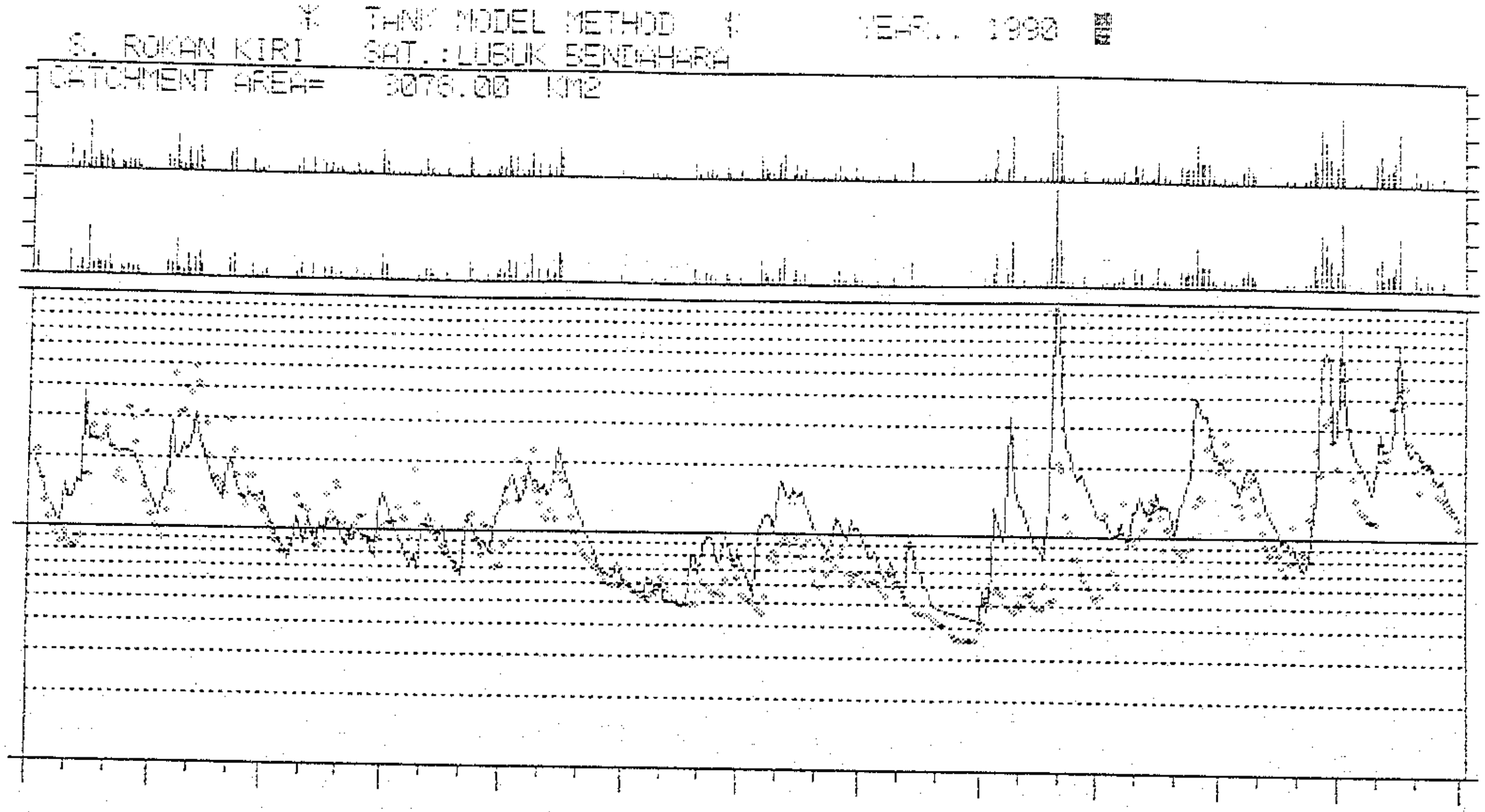

Fig.2.8 Comparison of Estimated and Observed River Discharges by Tank Model in 1990

RMAX= 119.2 MM
RDOT= 30.0 MM

QMAX= 1000.000 M3/S
QMIN= 10.000 M3/S

ANNEX B

GEOLOGY AND SOIL MECHANICS

ANNEX B GEOLOGY AND SOIL MECHANICS

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ANNEX B GEOLOGY AND SOIL MECHANICS

1. General

The JICA Study Team, during its survey period, conducted the following investigations (i) to grasp stratum conditions and soil mechanics properties in the project area sa well as at the site of the proposed bridge-type aqueduct for project construction works use and (ii) to check the property of embankment materials for canals and as foundation for the proposed related structures.

Investigation Conducted

Items	Quantities
(a)Mechanical boring	20 m (per hole) x 5 = 100 m
(b)Standard penetration test	At an interval of every 1.0 m, in total 100 m
(c)Permeability test in boreholes	15 nos.
(d)Collection of undisturbed soil samples	Non.
(e)Test pits	15 nos.
(f)Collection of disturbed soil samples	15 nos.
(g)Laboratory test	Physical and mechanical properties test, lumpsum.
(h)Cone penetrometer test	45 nos.
(i)Field permeability test	21 nos.
(j)Slaking test	2 samples.

* Note : Locations where the investigations were made are shown on Fig.1.

2. General Description of Geology of Sumatra Island

Sumatra Island is located on the Great Sunda Islands plate on which almost all of East-South Asia stretches. The island spans about 1,650 km from northwest to southeast and belongs to the Indo-Australian Plate which slips even now along the Manda Trench, resulting in rise of volcanos on the island originated in the Mesozoic era.

Riau Province lies on the eastern side of central part of Sumatra Island, adjoining to North Sumatra Province on the west and to South Sumatra Province on the south. Low-lying swamps, which face Malacca Strait, are extensive and numbers of lakes of different sizes are seen in the Province. The Barisan mountain ranges, influenced by active faults, consist of hills of different sizes formed by lateral slippage, and depressed portions form small rivers which flow from mountain ranges and hills, gradually changing into big rivers that flow into the Malacca Strait.

The S.Rokan Kiri, which flows through the project area, joins the Rokan Kanan at its lower reaches and flows into the Malacca sea, gathering another 3 rivers together on the way. The Minas Hills which run parallel with the Barisan mountain ranges are seen in the west of the S.Rokan Kiri near Duri, and in the southern foot of the Barisan mountain ranges. The hills are composed of Duri Kampar anticlinal structures.

The geology of the Rokan Kiri basin consists of sedimentary rocks formed in the Tertiary period, such as mudstones, sandstones, limestones and conglomerates. The surface layer of the terraces in the basin consists of volcanic and tufaceous sediments formed in the Pleistocene of the Quaternary period. The lower and swampy area within the S.Rokan basin consists of alluvial deposits, lower layer of soft sand and surface layer of peat developed in the back slough. The property of the geology around the project area is shown on the geological map in Fig.2.

3. Geology of the Project Area

The Barisan mountain ranges, which compose the basin of the S.Rokan, mainly consist of volcanic rocks, such as amphibolites and granitic magmas formed in later Palaeozoic and Mesozoic era.

The foundation of the project area, located on the middle reaches of the S.Rokan, consists of sandstones, conglomerates and mudstones. Terraced portion of the project area are covered with red-brownish tuff clay and its lower layer includes weathered quartzitic gravel. The tuff clay is thickly distributed and its bottom layer forms foundation composed of sandstones, conglomerates and mudstones formed in the Pliocene era.

The surface layer of the project area consists of tuff clay, peat, sands and weathered limestones as shown in Fig.3. Namely, tuff clay with the thickness of 3 to 5 m formed in the Pleistocene of Quaternary period is seen at the terraces and platforms located on both sides of the S.Rokan along the proposed weir site upto K.P. Kota Lama. Clay mixed with gravel formed in the early Pleistocene is also seen under the said tuff clay. Gravel, the sedimentary soils, formed by floods, is thickly distributed under the tuff clay within the reach of 300 m from the S.Rokan.

Peat with the thickness of 0.5 to 1.6 m is seen at the swampy area located downstream of the S.Rokan. Clay and/or sand layers are observed beneath the peat. The sand layer which partially covers the project area is often seen at the left side of the S.Rokan, and the sandstones, locally outcropped, are seen at K.P. Kota Intan. Weathered sandstones and/or soft sands are widely observed in the north of Kota Intan and to SP-1 and SP-2 in the north-east, and to the plantation area. Weathered siliciferous limestones, secondarily and narrowly deposited in the area of SKP-F and SKP-G and in the vicinity 15 km north from Kota Lama, are observed.

Dolomite with characteristics of quartz is widely deposited outside the said area, and forms a surface layer mixed with white gravels and sands. In the swampy area, the dolomite is distributed as lower foundation of the peat. Extent of its distribution is within N.0°56' - 1°01' to E.103°39' - 103°41'.

4. Topography and Geology At the Proposed Weir Site

The proposed weir site is located on the old floodplain, 2 km upstream of KP. Kota Intan, where the S.Rokan turns leftwards. The proposed weir site is flat with elevation of 45 to 46 m and 3 to 5 m higher than the existing river bed at the proposed weir site of 42 m. The water surface slope at the proposed weir site is about 1/2,100 at normal condition, thus resulting in relatively slow velocity of the river flow. Aggregates, as construction materials, such as boulders with the size of 10 to 15 cm, sands and gravels are fully available at the proposed weir site. Bigger boulders are available at 20 to 30 km upstream from the proposed weir site.

The foundation at the proposed weir site consists of mudstones formed in the Miocene of Neogene period. The Upper layer of the foundation is semisolid and has the thickness of 4.0 to 4.8 m and contains gravels deposited in the early Pleistocene of Quaternary period. The top of the layer consists of dark-brownish silty sand and silty clay formed in the Pleistocene of Quaternary period. The layer also includes cohesive tuff soil with thickness of 0.8 to 2.3 m, gradually increasing its depth in the direction of the existing river channel, forming a deposit gradient of 1/5,000.

The ground water level at the proposed weir site is between GL.(-)1.15 to (-)1.50 m, which is the same as the river water level. This suggests that the sand and gravel layers under the cohesive soil are continuous to the gravel layer of the river.

The boring data obtained at the proposed weir site show that the soil layer, from upper to lower, consists of tuff clay, sand, gravel and mudstones. The first layer consists of silty sand and silty clay with N values of 10 to 12, and it has highly cohesive characteristics of $C=0.6$ kg/cm², estimated by Terzaghi-Peck equation, assuming $\Phi=0°$. The expected bearing capacity of the layer is estimated at 11.4 t/m² using the said equation. The permeability (K) of the layer is 4.13×10^{-5} cm/sec, which shows that the layer is impervious.

The second layer consists of fine sands with the thickness of 0.5 to 1.0 m and has relative density of N= 12 to 18. Permeability is $K= 4.72 \times 10^{-4}$ cm/sec, which shows that the layer is pervious.

The third layer consists of sands and gravels with the thickness of 4.0 to 4.8 m, reducing its depth in the direction of the river channel.

The lower part of the layer is semisolid, on the other hand, the upper layer has relatively loose density of N= 0 to 30 and thickness of about 1.0 m. The lower layer consists of semi-rounded conglomerate with diameter of 2 to 40 mm and includes much gravels composed of quartz andesite with maximum diameter of 100 mm.

The N values are of N= 50 or less, which shows that the lower layer is very dense. Permeability of the lower layer obtained through the field test is $K= 4.6 \times 10^{-2}$ cm/sec, which is considered relatively high. But, it is estimated that overall K of the lower layer ranges between 10^{0} to 10^{-1} cm/sec considering that the upper layer, consisting of gravels, is loose. The proposed weir will be sited on this lower layer with N values of 30 to 50, which is considered stable as foundation for the weir. The allowable bearing capacity(qd) of the layer as direct foundation computed by Meyerhof and Terzaghi-Peck equation ranges between 33 to 50 t/m², assuming that overall N value of the layer is 50.

Generally, when a weir is constructed on sand or gravel layer whose permeability is high, measures to extend seepage length must be taken to protect the structure from failure. The fourth layer consists of mudstones formed in the Miocene of Neogene period with N values of more than 50. More than 15 m of the layer consists of impervious rock foundation with permeability of K= 7.7×10^{-7} cm/sec. The rock foundation has RQD of more than 40% and has less cracks and is uniformly composed. It is judged that the rock foundation consists of soft rock with compressive strength of quf= 30 to 50 kgf/cm².

5. Geology of the Planned Irrigation Area and Along the Planned Irrigation Canal

The planned irrigation area includes transmigrated area of SP-1, SP-2, SP-3 on the left bank of S.Rokan, and Kota Lama.
It also includes SKP-F, G, B located on Muara Dilam side and SKP-A located on the right bank of S.Rokan. These transmigrated areas other than SP-1, SP-2 and SP-3 lie along the S.Rokan and they extend in the swampy area as well as on the plateau.

As a whole, the planned irrigation area includes much swampy area. The terraces on which tuff clay deposits, stretch within 10 to 15 km from Kota Lama on the left bank of S.Rokan and at SKP-A.

The planned main irrigation canal, from Kota Lama to the weir site, passes through the area which mainly consists of tuff clay. The terraces within Plantation Area and SP-2 and 3 consists of weathered sandstones and their surface layers are covered with loose sands.

The area of SP-1 and low-lying cultivated area are covered with dark-green and grayish clay to a depth of 1.0 m and sandy soils with characteristics of weathered sandstones are observed in the lower layer. Distribution of the sandy soils which contain silicic limestones and grained quartz is observed in the narrow area along both sides of the road from 15 km north of Kota Lama to SKP-F and SKP-G.

The surface layer of the transmigrated area of SKP-F, G and B is covered with PT layer to a depth of 1.0 m and lower foundation beneath the PT layer consists of white sandy soil. At SKP-A, the transmigrated area, which is in the north-east of Kota Lama and lies on the terraces, brownish tuff clay covers the surface. The planned irrigation canal, diverting from Kota Lama, passes through low-lying swampy area on the right bank of S.Rokan, where dark-grayish tuff, which is loose and highly moist, covers the surface. Milky-white clay is seen below GL.(-)2.00 m in the area and sand layer as foundation seems to be in the lower layer according to observations.

6. Foundation and Soil Properties Under the Planned Irrigation Canal

To grasp the bearing capacity and soil properties, as banking materials, of the planned irrigation area and near the main and secondary irrigation canals, soil samples were taken from test pits at representative places and laboratory tests were made on the samples. The locations of test pits are shown in Fig.1 and test results are given on Fig.4.

From the proposed weir site to Kota Lama, the planned main irrigation canal passes through terraces covered with tuff clay. The tuff clay is considered stable as foundation of canal structures and it has allowable bearing capacity of more than $qa'=7.5\ t/m^2$ at the surface and $qa'=15\ t/m^2$ at around GL.(-)1.00 m.

Test results show that the tuff clay is 60 to 65% cohesive soil and 35 to 40% sand, and is highly plastic. It has soil mechanic properties of C= 1.10 to 1.60 t/m^2, internal shearing angle of 18° to 20° and compressive index of Cc= 0.25 to 0.33, which is relatively low, and it is lowly compressive soil subjected to excessive consolidation. Permeability of the tuff soil (K) ranges between 10^{-4} to 10^{-5} cm/sec and moisture ratio (Wn) ranges between 30 to 40%. Compaction tests also show that the tuff soil has Wopt of 22 to 30% and $\gamma dmax$ of 1.4 to 1.6 t/m^3, which suggests that the tuff clay is suitable for canal banking materials and can be handled in wet condition.

The foundation under the planned irrigation canals, diverting from Mura Dilam, Carrying water to SP-1, 2 and 3 from the Plantation Area consists of weathered sandstones or soft sands. Weathered sandstones are also observed at the surface near TP-10. The foundation lower than GL.(-)1.00 m consists of fine-grained soil with 55% cohesive soil content.

The compaction tests on the soil show that it has Wopt of 20.9%, γdmax of 1.83 t/m^3. The soil mechanical properties of the foundation show that the foundation has cohesion of C= 0.7 t/m^2, internal shearing angle of Φ= 21° and permeability of K=1.74 x 10^{-5} cm/sec, and consists of a finesand layer which contains silt.

Judging from this, the soil under GL.(-)1.00 m is not fully suitable for canal banking materials. It has expected allowable bearing capacity of qa= 10.0 to 15.0 t/m^2, but it is not suitable for canal banking materials due to its insufficient resistance against erosion. Thus, it is recommended that the planned irrigation canals which pass through the said section be lined with proper materials such as concrete etc.

The planned irrigation canals for SPK-F, G and B, all of which are in the north of the diversion point at Mura Dilam pass through the low-lying swampy area and partially through weathered sandy soil and ciliceous limestones which have enough bearing capacity at qa= 15 to 20 t/m^2. The soil tests on the samples taken from the test pits show that the sandy soil and ciliceous limestones consist of fine-grained soil which contains 45 to 50% sand with Wn= 27 to 37%, Gs= 2.56 to 2.57, Pt= 1.57 to 1.68 g/cm^2, Wopt= 29%, γdmax= 1.45 g/cm^3, C= 0.7 to 1.6 t/m^2, internal shearing angle of Φ= 17°, compressive index of 0.22 to 0.29 and permeability of K= 2.45 x 10^{-5} cm/sec, which suggests that the samples have characteristics of tuff soil. It is recommended, however, since the tuff soil is narrowly distributed along the said canals, that the canals be lined with suitable materials.

The PT layer which covers the surface of the low-lying area at SPK-B has thickness of 1.50 to 2.00 m, which is relatively deep, on the other hand, PT layer at SPK-F and G is shallow with depth of 0.8 to 1.00 m. The allowable bearing capacity of the PT Layer (qa) is estimated at less than 2.5 t/m^2, which suggests need of foundation improvement by replacement.

The foundation under the planned irrigation canals, heading for SKP-A from Kota Lama on the right bank of S.Rokan, consists of tuff clay composed of deposits on the terraces. This suggests that the foundation soil poses no problems in terms of bearing capacity and use as banking materials, except for that of low-lying swampy area.

The soil foundation has cohesion of C= 2.30 to 2.60 t/m², and internal shearing angle of Φ= 21° to 22°, which suggests that the foundation soil is highly cohesive due to ill-drainage even under normal conditions. The foundation soil has compressibility of Cc= 0.30 to 0.37, which suggests that the foundation soil is less compressive. However, the foundation soil can be used as canal banking materials by lowering the present value of Wn by 3 to 5%.

7. Seismic Feature in the Proposed Project Area

1) Historic records of earthquakes around the project area

The seismic events more than magnitude five(5) on the Richer Scale within a radius of 300 Km centering around the downstream of the proposed weir site are reported as shown Table 3 and Fig.14, during the past 62 years(1920-1981).

2) Maximum acceleration(2 max)

The maximum accelerations caused by the above earthquakes are estimated as shown in Table 3 as well.

3) Design intensity

(i) Method by the use of 2 max

The coefficient of earthquake computed based on the by-gone maximum 2 max is derived by the following formula.

$$Kh = 0.5 \times \beta \times (2\ max)/g$$

where, β : compensation coefficient on ground propensity
Alluvium, Diluvium = 1.2
Tertiary soft rock = 1.0
Tertiary hard rock = 0.9
g : gravity acceleration
Kh : coefficient of earthquakes
0.5 : constant coefficient

Therefore,

$$Kh = 0.5 \times 1.0 \times (230/980) = 0.12$$

(ii) Method of DPMA

The coefficient of earthquake is obtained by the following formula.

$$Kh = ad/g = (1/g) \times b1 \times (ac * z)$$

where, Kh : coefficient of earthquake
ad : design earthquake acceleration
g : gravity acceleration
b1,b2 : coefficient for soil or rock
z : coefficient of zone
ac : basal acceleration

If the basal period is 100 years, ac is 160, then Kh can be calculated as follow;

$b1 = 2.76$ and $b2 = 0.71$ for rock foundation
$z = 0.56$,
$Kh = 2.76 \times (160 \times 0.56) / 980 = 0.07$

(iii) Design intensity(K)

The value calculated by the method(i), Kh=0.12, is based on the maximum record which occurred on July 1953.

Taking the length of the observation period(62 years) and the value obtained by DPMA's method(Kh=0.07) into consideration, the design intensity is set up as K=0.10.

Table 1 Time Stratigraphy

GEOLOGICAL TIME					THE VEGETAB LE KING DOM	THE ANIMAL KING DOM
ERA / ERATHEM	(x 10^6 T)	PERIODE / SYSTEM		EPOCH / SERIES		
CENO ZOIC		QUATERNARY		HOLECENE	ANGIOSPERM TIME	THE MAMMALIA TIME
	1,7			PLEISTECENS		
	5	TERTIARY	NEOGENE	PLIOCENE		
	34			MEOCENE		
	37		PALEOGENE	OLIGOCENE		
	54			EOCENE		
	64			PALEOCENE		
MESO ZOIC	140	CRETACEONS			AGYMNOSPERM TIME	THE REPTILES TIME
	208	JURASSIE				
	242	TRIARSIC				
PALEOZOIC	284	PERMIAN			PTERIDO PHYTA	THE AMPHIBIA
	360	CARBONIFEROUS				
	409	DEVONIAN				
	436	SILURIAN				

Table 2 Permeability Test Results at Test Pits

TEST PIT No.	DEPTH (m)	SOIL NAME	K (cm/sec)
TP－1	1.00 ～ 1.40	Silty Clay	1.723×10^{-4}
TP－2	1.00 ～ 1.40	Clayey Silt	1.638×10^{-5}
TP－3	2.00 ～ 2.40	Sandy Clay	1.870×10^{-4}
TP－4	0.40 ～ 0.80	Clayey Silt	7.111×10^{-6}
TP－5	0.40 ～ 0.80	Silty Clay	2.116×10^{-7}
TP－6	1.00 ～ 1.40	Clayey Silt	2.851×10^{-7}
TP－7	1.60 ～ 2.00	Silty Sands	2.453×10^{-5}
TP－8	1.60 ～ 2.00	Silty Sands	4.906×10^{-6}
TP－9	2.00 ～ 2.40	Sandy Silt	1.413×10^{-5}
TP－10	1.10 ～ 1.50	Silty Sands	1.740×10^{-5}
TP－11	0.40 ～ 0.80	Silty Sands	1.226×10^{-5}
TP－12	1.00 ～ 1.40	Silty Sands	1.701×10^{-6}
TP－13	1.60 ～ 2.00	Silty Clay	8.464×10^{-7}
TP－14	1.60 ～ 2.00	Silty Sands	1.880×10^{-5}
TP－15	1.60 ～ 2.00	Silty Sands	1.514×10^{-4}

Table 3 Records of Major Earthquakes in Indonesia

* Distance within 300 Km

* More than magritude of 5.0

No.	Date	Epicenter		Magritude	Distance	2 max
		Latitude	Longitude	(M)	(Km)	(Gal)
1	Jun.28,1926	1.0 S	99.5 E	6.7	200	5.9
2	Dec.28,1935	0.0	98.2 E	7.9	220	44.1
3	Oct.31,1951	1.0 N	98.25E	6.5～6.75	260	5.7
4	May 24,1952	1.0 S	98.8 E	6.5～6.75	290	3.5
5	Jul.07,1953	1.0 N	100.0 E	6.5～6.75	25	229.9
6	Aug.15,1956	0.0	101.5 E	6.4	200	7.2
7	Oct.26,1961	0.4 S	98.6 E	6.0	245	1.0
8	Dec.31,1965	0.8 N	100.2 E	5.2	35	53.4
9	May 21,1967	1.0 S	101.5 E	6.3	285	1.1
10	Oct.15,1968	0.5 S	100.6 E	5.6	190	1.1
11	Feb.04,1971	0.6 N	98.8 E	6.3	160	12.7
12	Nov.05,1971	0.1 S	100.2 E	5.0	140	0.9
13	Mar.09,1971	0.4N	99.7 E	6.0	100	26.5

Source:Earthquakes in Indonesia, Ministry of Communication
Meteorological and Geophysical Institute, Jakarta

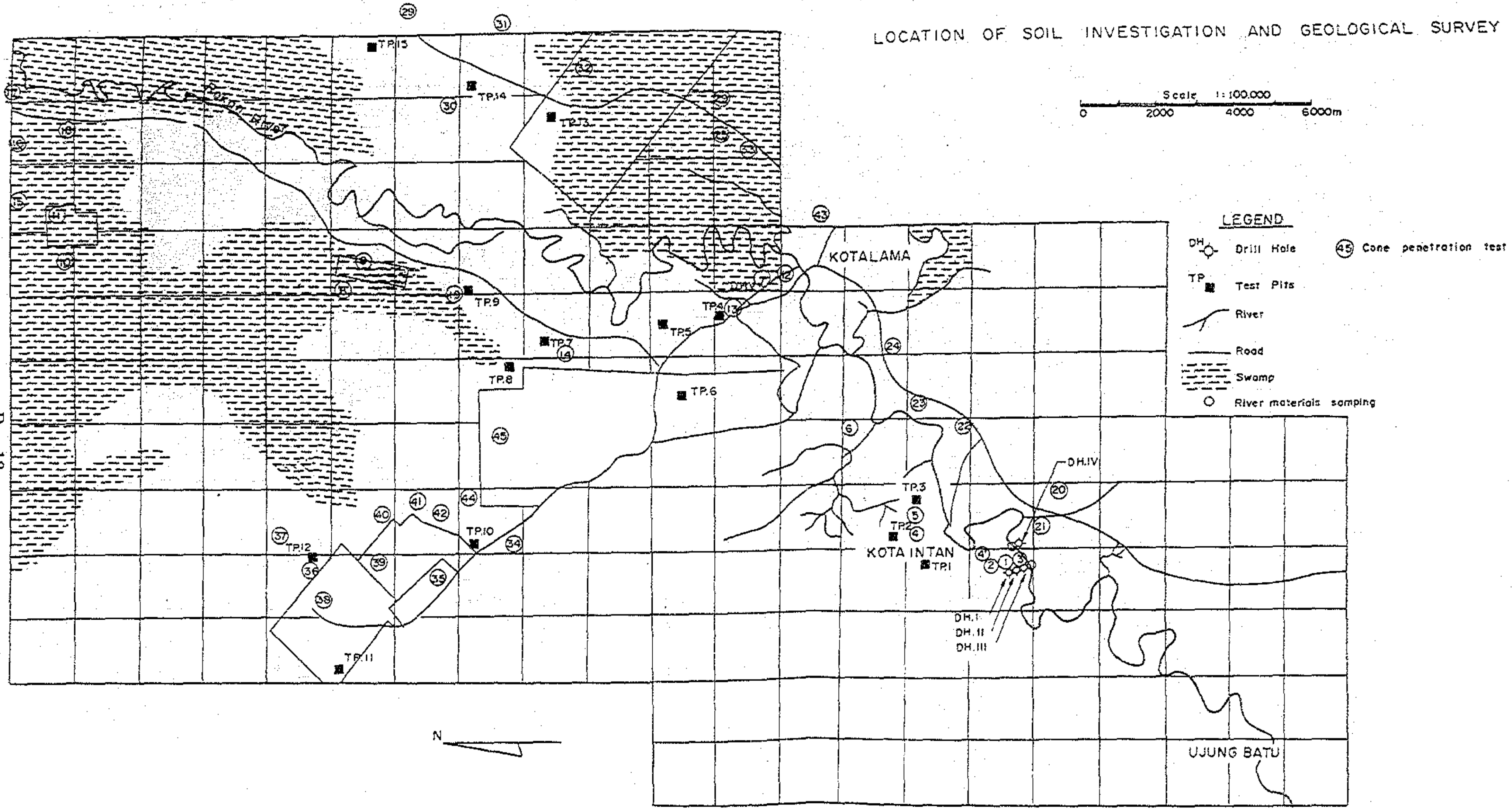


Fig. 1 Location of Soil Investigation and Geological Survey

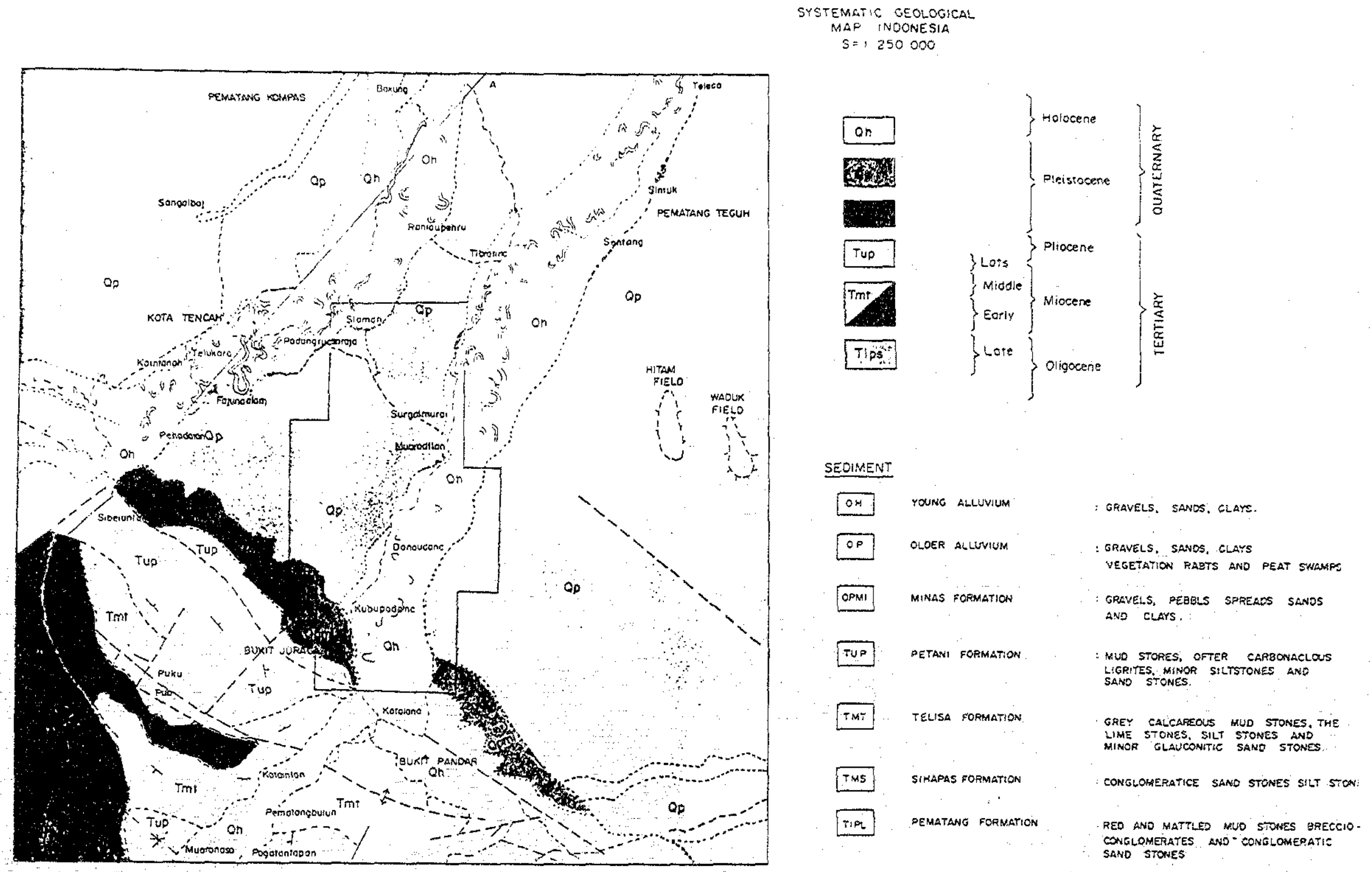
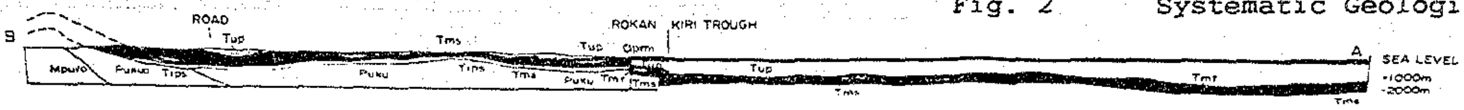


Fig. 2 Systematic Geological Map in Survey Area



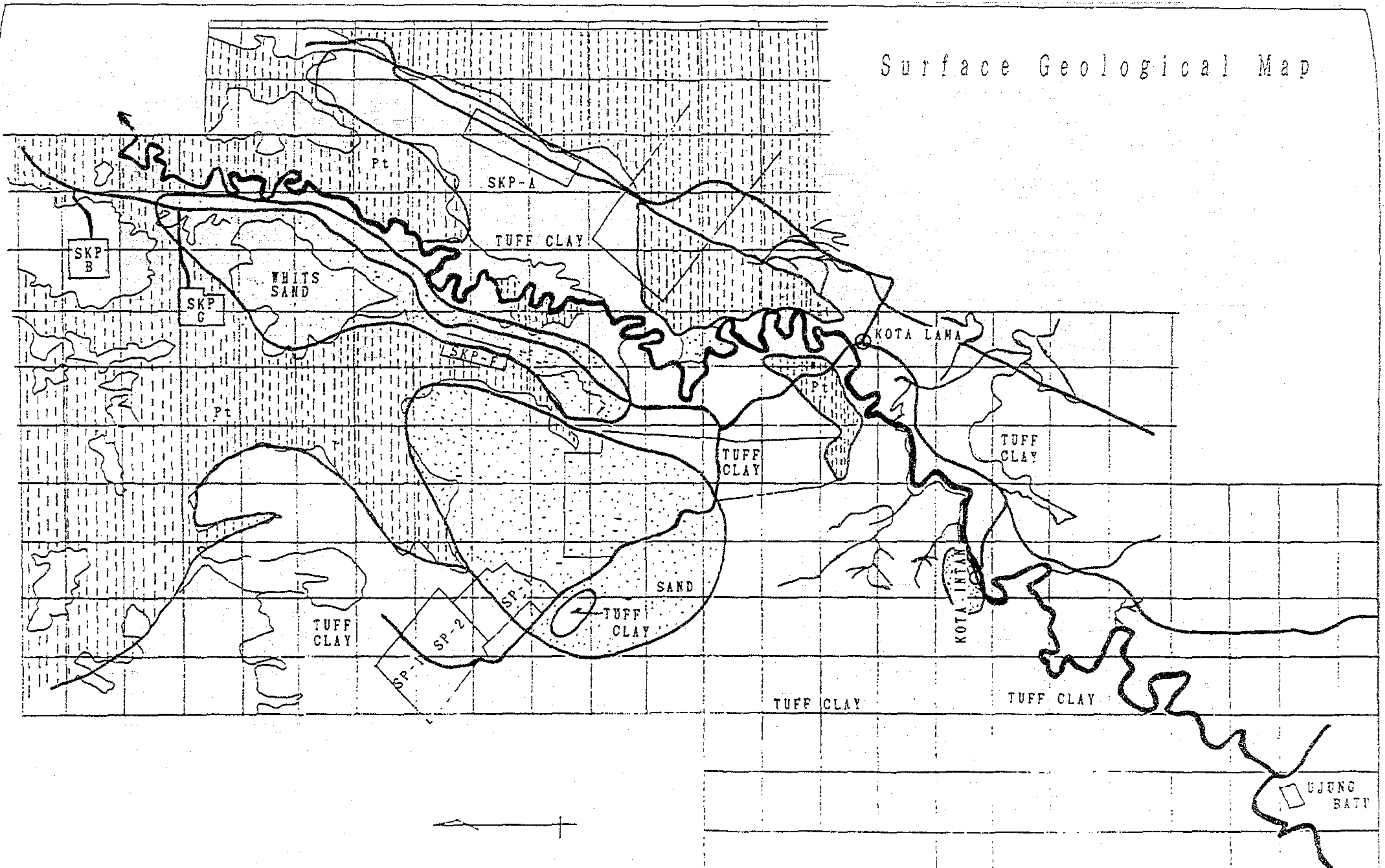


Fig. 3   Surface Geological Map in the Project Area

Fig. 4(1) Geological Profile in Test Pits(1)

APPENDIX 7.f

TP.1
Location : Kota Lama

TEST PIT LOG	EXCAVATION METHOD	LOG BY
PROJECT	ELEVATION	CHECKED BY
LOCATION	SCALE	APPROVED BY

DEPTH	DESCRIPTION	GWL (m)	SAMPLES TYPE	SAMPLES DIAMETER	REMARKS
0.10	Top soil clay, brown dark with some roots				undisturbed sample
1.60	Silty sands, clayey, red soft				0.40–0.80m
2.00	Silty sands, clayey bright brown, greyey rather loose				100–1.40

APPENDIX 7.g

TP.2
Location : Kota Lama

TEST PIT LOG	EXCAVATION METHOD	LOG BY
PROJECT	ELEVATION	CHECKED BY
LOCATION	SCALE	APPROVED BY

DEPTH	DESCRIPTION	GWL (m)	SAMPLES TYPE	SAMPLES DIAMETER	REMARKS
0.20	Top soil sandy clay, yelloish with some roots				undisturbed sample
1.80	Clayey silt, sandy, red soft				100–1.40
2.00	Clayey silt, sandy, greyey, rather loose				

APPENDIX 7.h

TP.3
Location : Kota Lama

TEST PIT LOG	EXCAVATION METHOD	LOG BY
PROJECT	ELEVATION	CHECKED BY
LOCATION	SCALE	APPROVED BY

DEPTH	DESCRIPTION	GWL (m)	SAMPLES TYPE	SAMPLES DIAMETER	REMARKS
0.10	Top soil sandy silt, brown dark, soft with some roots				undisturbed sample
1.60	Sandy siltr, clayey, brown soft				100–1.40
2.30	Silty sands, clayey, brown soft				200 – 240

APPENDIX 7.i

TP.4
Location : Kota Lama

TEST PIT LOG	EXCAVATION METHOD	LOG BY
PROJECT	ELEVATION	CHECKED BY
LOCATION	SCALE	APPROVED BY

DEPTH	DESCRIPTION	GWL (m)	SAMPLES TYPE	SAMPLES DIAMETER	REMARKS
0.15	Top soil silty clay, brown dark with some roots				undisturbed sample
1.20	Clayey silt, yellow, sticky				0.40–0.80
1.50	Clay stone, brownish, grey brittle				

Fig. 4(2) Geological Profile in Test Pits(2)

APPENDIX 7.j

T.P.5

Location : Kota Lintan

TEST PIT LOG	EXCAVATION METHOD	LOG BY
PROJECT	ELEVATION	CHECKED BY
LOCATION	SCALE	APPROVED BY

DEPTH	DESCRIPTION	REMARKS
0.15	Top soil silty clay, brown dark with some roots	
1.30	Silty clay, redish, yellow, sticky	undisturbed sample 0,40–0,80
1.50	Silt stone, grey dark, brittle	

APPENDIX 7.k

T.P.6

TEST PIT LOG	EXCAVATION METHOD	LOG BY
PROJECT	ELEVATION	CHECKED BY
LOCATION	SCALE	APPROVED BY

DEPTH	DESCRIPTION	REMARKS
0.15	Top soil silty, clay, blackish brown, contain plan roots	0,40–0,20
0.20	Clayey sitl, redish yellow stickyu	100–1,40
1.30	Clayey silt, whiteish yellow soft	

APPENDIX 7.l

T.P.7

Location : Muara Dilam,

TEST PIT LOG	EXCAVATION METHOD	LOG BY
PROJECT	ELEVATION	CHECKED BY
LOCATION	SCALE	APPROVED BY

DEPTH	DESCRIPTION	REMARKS
0.10	Top soil sandy silt, brown with some roots	undisturbed
1.00	Silty sands, clayey, dark brown	0,60–1,00
2.00	Silty sands, white	1,60–2,00

APPENDIX 7.m

T.P.8

Location : Muara Dilam

TEST PIT LOG	EXCAVATION METHOD	LOG BY
PROJECT	ELEVATION	CHECKED BY
LOCATION	SCALE	APPROVED BY

DEPTH	DESCRIPTION	REMARKS
0.05	Top soil sandy silt, brown with some roots	undisturbed sample
1.00	Silty sands, clayey, brown soft	
2.00	Silty sand, clayey, yellow ish white	

Fig. 4(3) Geological Profile in Test Pits(3)

APPENDIX 7.n

TP.9	TEST PIT LOG	EXCAVATION METHOD	LOG BY
tion , Muara Dilam	PROJECT	ELEVATION	CHECKED BY
	LOCATION	SCALE	APPROVED BY

CLASSIFICATION LOG (SECT 1, SECT 2, SECT 3, SECT 4)	DEPTH	DESCRIPTION	GWL (m)	SAMPLES TYPE	SAMPLES DIA-METER	REMARKS
	0.10	Top soil silt, brown dark with some roots				undisturbed sample
	1.50	Sandy silt clayey, grey, soft				1,00-1,40
	2.00	Sandy silt, clayey soft and rather loose				2,00-2,40

APPENDIX 7.o

TP.10	TEST PIT LOG	EXCAVATION METHOD	LOG BY
ation , SP.1	PROJECT	ELEVATION	CHECKED BY
	LOCATION	SCALE	APPROVED BY

CLASSIFICATION LOG (SECT 1, SECT 2, SECT 3, SECT 4)	DEPTH	DESCRIPTION	GWL (m)	SAMPLES TYPE	SAMPLES DIA-METER	REMARKS
	0.10	Top soil sandy silt brown dark with some roots				▽ 0,80 m undisturbed sample
	0.80	Silty sands, whiteish yellow				0,40-0,80
	1.50	Silty sands, yellowish, white, soft rather sticky				1,00-1,50m

APPENDIX 7.p

TP.11	TEST PIT LOG	EXCAVATION METHOD	LOG BY
sition , SP.2	PROJECT	ELEVATION	CHECKED BY
	LOCATION	SCALE	APPROVED BY

CLASSIFICATION LOG (SECT 1, SECT 2, SECT 3, SECT 4)	DEPTH	DESCRIPTION	GWL (m)	SAMPLES TYPE	SAMPLES DIA-METER	REMARKS
	0.10	Top soil sandyy silt, black with some roots				▽ Gwt=1,10
	0.80	Silty sand, brown, dark				undisturbed sample 0,40-0,80
	1.50	Fine sand, owhite, loose				

APPENDIX 7.r

TP.12	TEST PIT LOG	EXCAVATION METHOD	LOG BY
cation SP.3	PROJECT	ELEVATION	CHECKED BY
	LOCATION	SCALE	APPROVED BY

CLASSIFICATION LOG (SECT 1, SECT 2, SECT 3, SECT 4)	DEPTH	DESCRIPTION	GWL (m)	SAMPLES TYPE	SAMPLES DIA-METER	REMARKS
	0.10	Top soil sandy silt, brown with some roots				▽ Gwt 1,20 undisturbed sample
	1.40	Silty sand, clayey, grey				1,00-140m
	2.00	Fine sand, grey, rather loo se				

Fig. 4(4) Geological Profile in Test Pits(4)

APPENDIX 7.r

TP.13

ation : SKP.A

TEST PIT LOG	EXCAVATION METHOD	LOG BY
PROJECT	ELEVATION	CHECKED BY
LOCATION	SCALE	APPROVED BY

DEPTH	DESCRIPTION	GWL (m)	SAMPLES TYPE	SAMPLES DIAMETER	REMARKS
0.15	Top soil, clay, brown with some roots, soft				undisturbed sample
2.50	Silty clay, whiteish grey and redish, rather stiff				0,60-1,00 1,60-200

APPENDIX 7.s

TP.14

ation : SKPA

TEST PIT LOG	EXCAVATION METHOD	LOG BY
PROJECT	ELEVATION	CHECKED BY
LOCATION	SCALE	APPROVED BY

DEPTH	DESCRIPTION	GWL (m)	SAMPLES TYPE	SAMPLES DIAMETER	REMARKS
0.10	Top soil clay, brown with some roots				undisturbed sample
1.60	Silty clay, brown				0,60-1,00m
2.00	Silt ysands, whiteish grey rather sticky				1,60-2,00m

APPENDIX 7.t.

TP.15

ation : SKPA

TEST PIT LOG	EXCAVATION METHOD	LOG BY
PROJECT	ELEVATION	CHECKED BY
LOCATION	SCALE	APPROVED BY

DEPTH	DESCRIPTION	GWL (m)	SAMPLES TYPE	SAMPLES DIAMETER	REMARKS
0.10	Top soil, silty clay, brown dark with some roots				gwt 0,50m undisturbed sample
1.60	Silty clay, whiteish grey				0,60-1,00
2.00	Silty sand, greyey, yellow rather sticky				1,60-2,00

Fig. 5(1) Bore Hole Log(1)

Project	: ROKAN RIVER BASIN OVERALL IRR DEV. PLAN STUDY	Depth	: 0,00 - 20,00 m
Location	: RIAU Province	Inclinational	:
Boring No	: DB.I	Started / Finished	:
Elev of groundsurface	: +46.207	Drilled by	: Nana. R
Bed rock elevation	:	Logged by	: Ahmad. S
		Approved by	:

DATE	ELEVATION (m)	DEPTH (m)	CORE RECOVERY GRAFIC	CORE RECOVERY %	Profil		DESCRIPTION	DRILLING WATER SMITEL COLOR	%	MATERIAL	DRILL SPEED	PERMEABILITY TEST	S P T	REMARK
	+46.207	0,00		100	//////	Young Alluvial	Top soil, Sandy silt with some roots, Softy brown						12/30	
	+46.007	0,20		100	-.-.-	Young Alluvial	Sandy silt, Clayey, Brown,soft rather sticly						22/30	
													11/30	
	+45.007	1,20		45	......	Young Alluvial	Fine sand up to medium sands, silty, brownish white, loose					K=3,433x10-4	> 50	
	+44.207	2,00		60	:::::	Old Alluvium	Fine sand up to coarse, gravelly and cobble stone, well sorted sub angular rounded, brownish white, loose						> 50	
													> 50	
													> 50	
	+42.957	3,25		60	:::::	Old Alluvium	Conglomeratic sand, fine sand up to coarse, gravely and coblle stone, well sorted, sub angular rounded, brownish white, dense						> 50	
												K=5,42x10-2	> 50	
													> 50	
													> 50	
													> 50	
	+39.407	6,80		100	-.-.-	Clay stone calcareous	Clay stones calcareous, contain foramini fera fossil, greenest grey, dense						> 50	
													> 50	
													> 50	
													> 50	
												K=7,492x10-7	> 50	
													> 50	
													> 50	
													> 50	
	+26.207	20,00												

Fig. 5(2) Bore Hole Log(2)

Project	: ROKAN RIVER BASIN OVERALL IRR DEV. PLAN STUDY	Depth	: 0,00 - 20,00 m	Logged by	: Ahmad. S
Location	: RIAU Province	Inclinational	:	Approved by	:
Boring No	: DR.11	Started / Finished	:		
Elev of groundsurface	: +45.123	Drilled by	: Nana. R		
Bed rock elevation	:				

DATE	ELEVATION (m)	DEPTH (m)	CORE RECOVERY %	Geology	DISCRIPTION	DRILING WATER SHIFTL (COLOR / % / MATERIAL)	DRILL SPEED	PERMEABIABILITY TEST	S P T	REMARK
	+45.123	0,00	100	Young Alluvial	Top soil, Sandy silt with some roots, Softy brown					
	+44.923	0,20	100	Young Alluvial	Sandy silt, Clayey, Brown,soft rather sticly				> 50 40/30	
	+43.623	1,50	80	Young Alluvial	Fine sand up to medium sands, silty, brownish white, loose			$K=5,53 \times 10^{-4}$	> 50 30/30	
	+43.123	2,00	75	Old Alluvial	Fine sand up to coarse, gravelly and cobble stone, well sorted sub angular rounded, brownish white, loose				> 50 > 50	
	+42.123	3,00	75	Old Alluvial	Conglomeratic sand, fine sand up to coarse, gravely and coblle stone, well sorted, sub angular rounded, brownish white, dense			$K=3,91 \times 10^{-2}$	> 50 > 50 > 50 > 50 > 50 > 50	
	+38.623	6,50	100	Clay stones calcareous	Clay stones calcareous, contain foraminifera fossil, greenest grey, dense			$K=8,721 \times 10^{-7}$	> 50 > 50 > 50 > 50 > 50 > 50 > 50	
	+25.123	20,00								

Fig. 5(3) Bore Hole Log(3)

Project : ROKAN RIVER BASIN OVERALL IRR DEV. PLAN STUDY
Location : RIAU Province
Boring No : DH.III
Elev of groundsurface : +45.072
Bed rock elevation :

Depth : 0,00 - 20,00 m
Inclinational :
Started / Finished :
Drilled by : Nana. R

Logged by : Ahmad. S
Approved by :

DATE	ELEVATION (m)	DEPTH (m)	CORE RECOVERY GRAFIC	CORE RECOVERY %	Profil		DESCRIPTION	DRILLING WATER COLOR	DRILLING WATER %	DRILLING WATER MATERIAL	DRILL SPEED	PERMEABILITY TEST	S P T	REMARK
	+45.072	0,00		100	//////	Young Alluvial	Top soil, Sandy silt with some roots, Softy brown					K=4,13x10^{-5}	19/30	
	+44.812	0,20		100		Young Alluvial	Sandy silt, Clayey, Brown, soft rather sticky						33/30 > 50	
	+44.072	1,00		60		Young Alluvial	Fine sand up to medium sands, silty, brownish white, loose					K=5,20x10^{-4}	> 50 > 50	
	+43.072	2,00		55		Old Alluvium	Fine sand up to coarse, gravelly and cobble stone, well sorted sub angular rounded, brownish white, loose						> 50 > 50	
	+42.072	3,00		55		Old Alluvium	Conglomeratic sand, fine sand up to coarse, gravely and coblle stone, well sorted, sub angular rounded, brownish white, dense					K=4,50x10^{-2}	> 50 > 50 > 50 > 50 > 50 > 50	
	+39.072	6,00		100		Clay stones Calcareous	Clay stones calcareous, contain foramini fera fossil, greenest grey, dense					K=6,981x10^{-7}	> 50 > 50 > 50 > 50 > 50 > 50 > 50	
	+25.072	20,00												

Fig. 5(4) Bore Hole Log(4)

Project	: ROKAN RIVER BASIN OVERALL IRR DEV. PLAN STUDY	Depth	: 0,00 - 20,00 m	Logged by	: Ahmad. S
Location	: RIAU Province	Inclinational	:	Approved by	:
Boring No	: DH.IV	Started / Finished	:		
Elev of groundsurface	: +46.01	Drilled by	: Nana. R		
Bed rock elevation	:				

DATE	ELEVATION (m)	DEPTH (m)	CORE RECOVERY %	Profil		DESCRIPTION	DRILLING WATER SHIFEL COLOR	%	MATERIAL	DRILL SPEED	PERMEABIABILITY TEST	S P T	REMARK
	+46.01	0,00	100		Young Alluvial	Top soil, Sandy silt with some roots, Softy brown						20/30	
	+45.76	0,25	100		Young Alluvial	Sandy silt, Clayey, Brown, soft rather sticky						38/30 > 50	
	+43.51	2,50	85		Young Alluvial	Fine sand up to medium sands, silty, brownish white, loose.					K=4,44x10⁻⁶	> 50	
	+43.01	3,00	60		Old Alluvium	Fine sand up to coarse, gravelly and cobble stone, well sorted sub angular rounded, brownish white, loose						> 50 > 50 > 50	
	+42.01	4,00	75		Old Alluvium	Conglomeratic sand, fine sand up to coarse, gravely and coblle stone, well sorted, sub angular rounded, brownish white, dense					K=3,27x10⁻²	> 50 > 50 > 50 > 50 > 50	
	+38.71	7,30	100		Claystones Calcareous	Clay stones calcareous, contain foramini fera fossil, greenest grey, dense					K=6,289x10⁻⁷	> 50 > 50 > 50 > 50 > 50 > 50 > 50 > 50	
	+26.01	20,00											

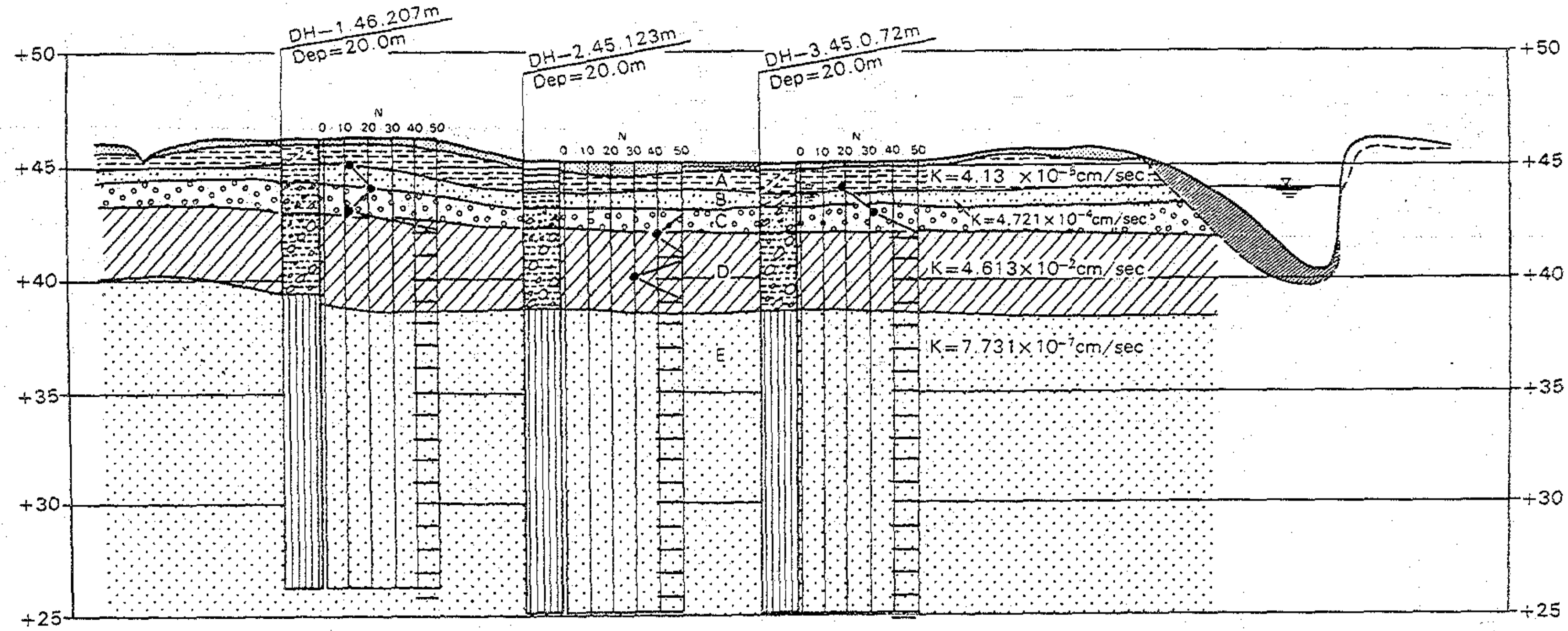
Fig. 5(5) Bore Hole Log(5)

Project : ROKAN RIVER BASIN OVERALL IRR DEV. PLAN STUDY
Location : RIAU Province
Boring No : DH. V
Elev of groundsurface : +38.591
Bed rock elevation :

Depth : 0,00 - 20,00 m
Inclinational :
Started / Finished :
Drilled by : Nana. R

Logged by : Ahmad. S
Approved by :

DATE	ELEVATION (m)	DEPTH (m)	CORE RECOVERY GRAFIC	CORE RECOVERY %	Profil		DESCRIPTION	DRILING WATER SHIFEL COLOR	DRILING WATER SHIFEL %	DRILING WATER SHIFEL MATERIAL	DRILL SPEED	PERMEABILITY TEST	S P T	REMARK
	+38.591	0,00		100		Young Alluvial	Top soil, Sandy silt with some roots, Softy brown						22/30	
	+38.341	0,25		90		Young Alluvial	Sandy silt, Clayey, Brown, soft rather sticky						41/30 39/30	
	+37.491	1,10		90		Young Alluvial	Fine sand up to medium sands, silty, brownish white, loose					K=4,21x10-4	> 50 > 50	
	+36.591	2,00		70		Old Alluvium	Fine sand up to coarse, gravelly and cobble stone, well sorted sub angular rounded, brownish white, loose						> 50 > 50	
	+35.091	3,50		70 70		Old Alluvium	Conglomeratic sand, fine sand up to coarse, gravely and cobble stone, well sorted, sub angular rounded, brownish white, dense					K=3,489x10-7	> 50 > 50 > 50 > 50 > 50 > 50 > 50 > 50 > 50 > 50 > 50 > 50 > 50	
	+18.591	20,00												



EXPLANATION

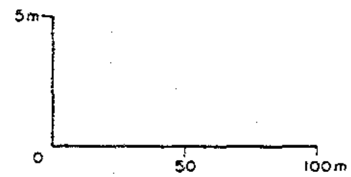
Young Alluvium
- River deposit Sands and gravels.
- Top soil, sandy silts, mixed roots soft brawns.

Old Alluvium
- Sandy silt clayey , brawn soft rather sticky.
- Fine sand up to medium sand silty-brawn-white loose.
- Fine sand up to coase, gravels and cobblestone, well sorted subangular subrounded, brawn white loose.
- Conglomeratic Sands fine sands up to coarse, gravely and cobblestone, well sorted subangular subrounded brawnish whit, dense.

Uncontormity

Claystones calcareous
- Clay stones calcareous contain foraminitera fossil, greenest grey, dense.

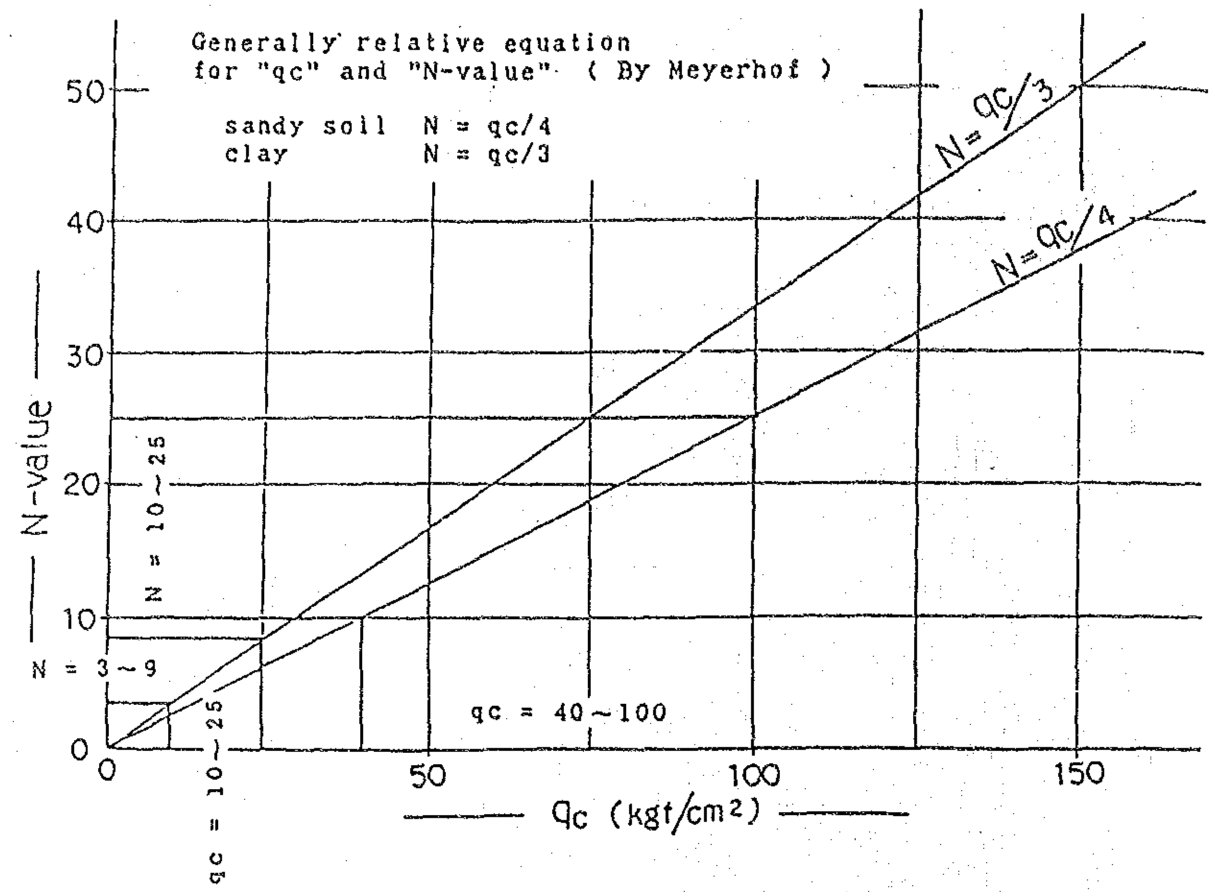
Undisturbed Sample



REPUBLIC OF INDONESIA MINISTRY OF PUBLIC WORKS
DIRECTORATE GENERAL OF WATER RESOURCES DEVELOPMENT
FEASIBILITY STUDY ON LOWER ROKAN KIRI IRRIGATION PROJECT

GEOLOGICAL PROFILE AT PROPOSED WEIR SITE

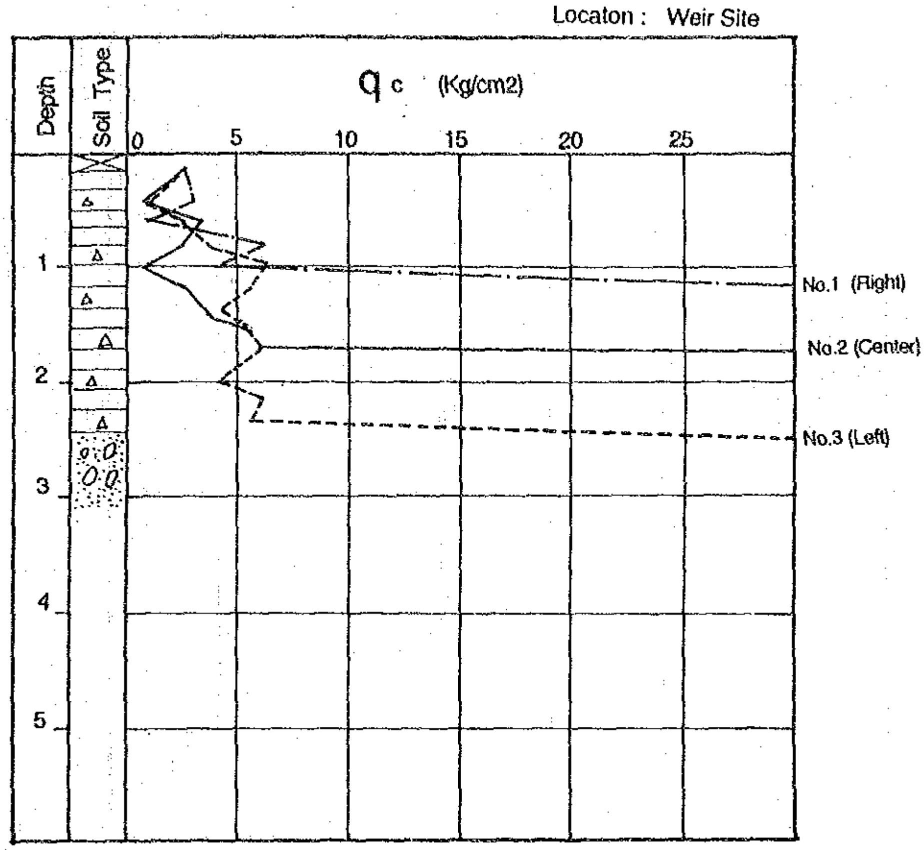
JAPAN INTERNATIONAL COOPERATION AGENCY TOKYO (JICA)	DWG NO. 11



Relation Between Cone Bearing Capacity(qc) and N-Value

Fig. 7 Relation between Cone Bearing Capacity(qc) and N-Value

Fig. 8(1) Cone-Penetration Test Results(1)



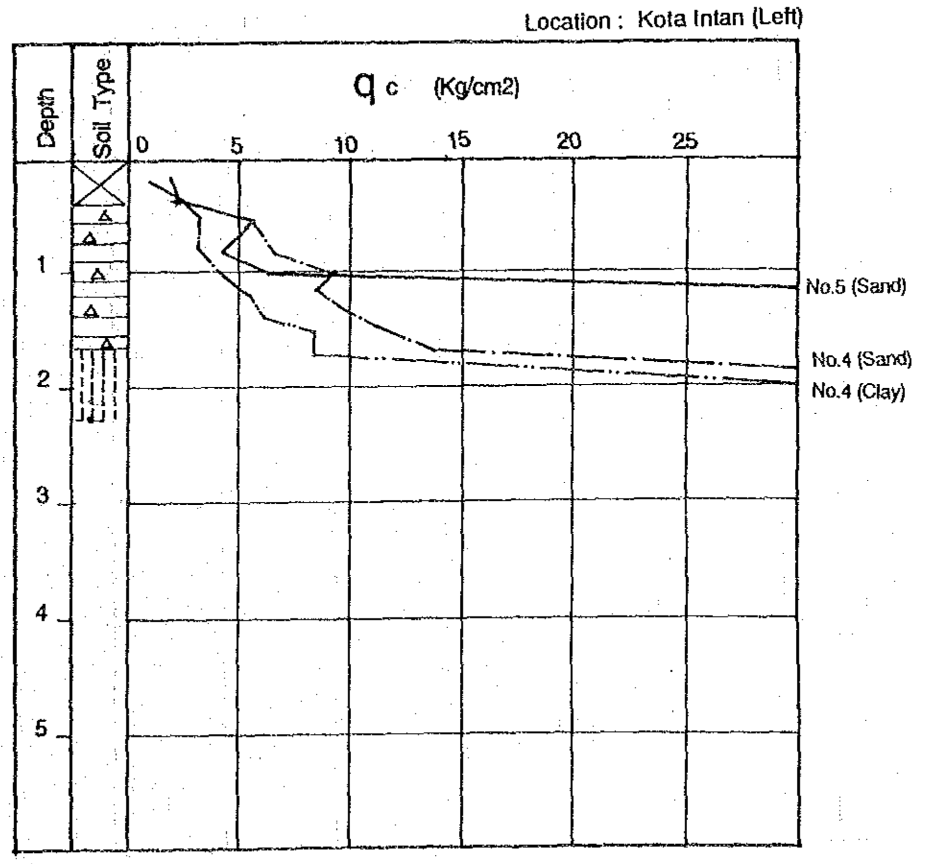
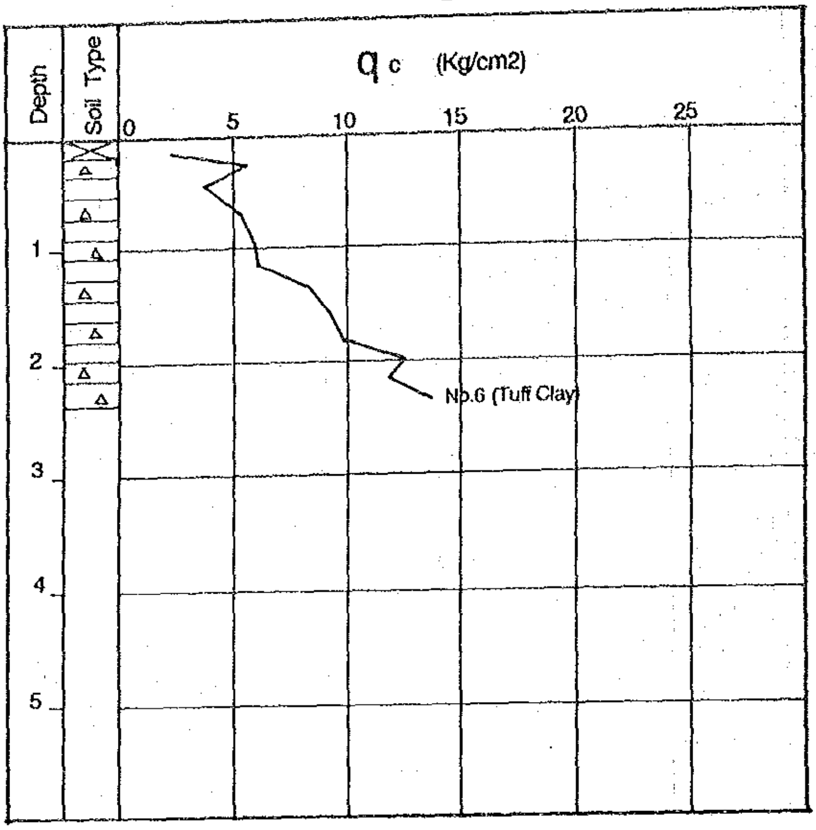


Fig. 8(2)   Cone-Penetration Test Results(2)

Location : Kota Lama (Upstream)



Location : SKP-F

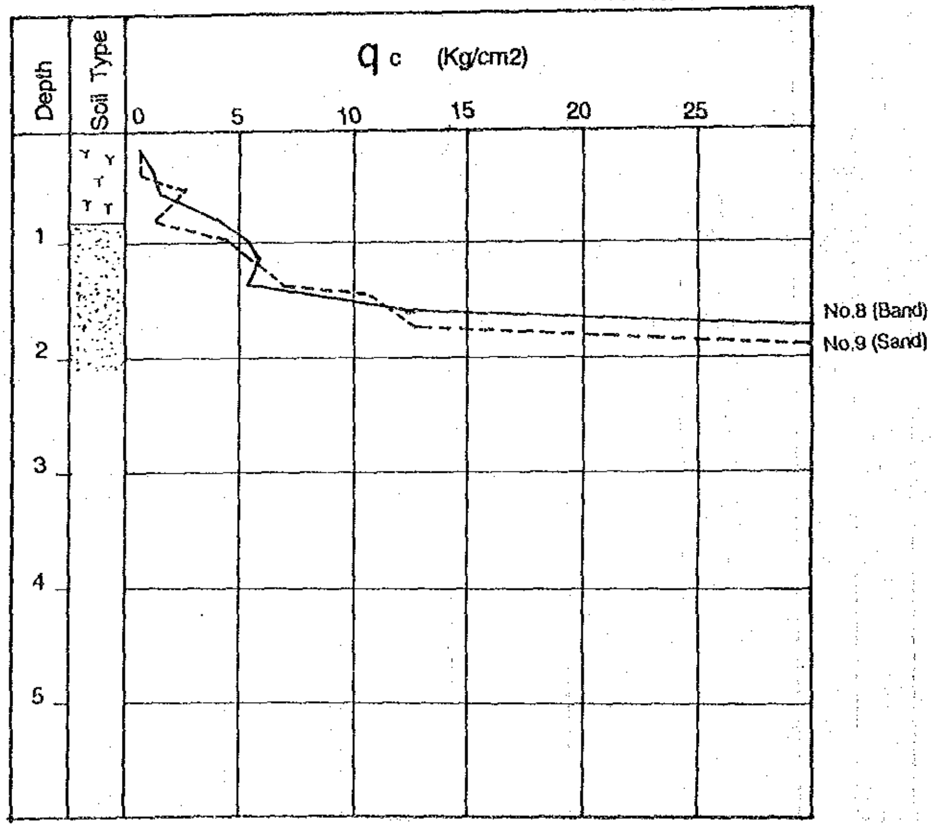
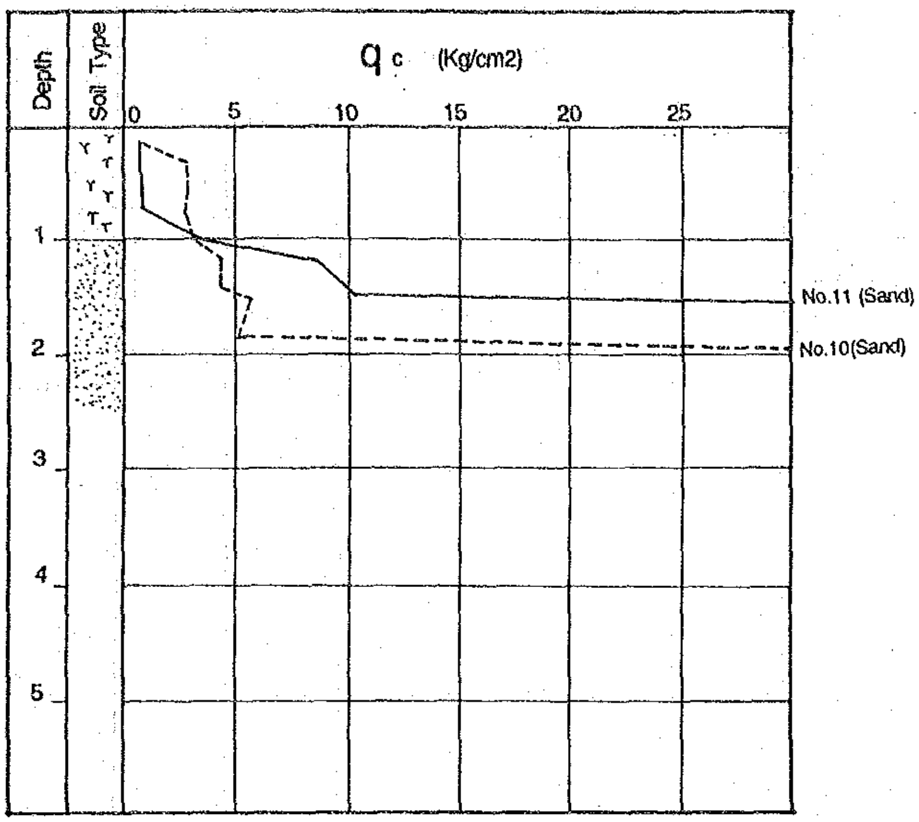


Fig. 8(3) Cone-Penetration Test Results(3)

Location : SKP-G



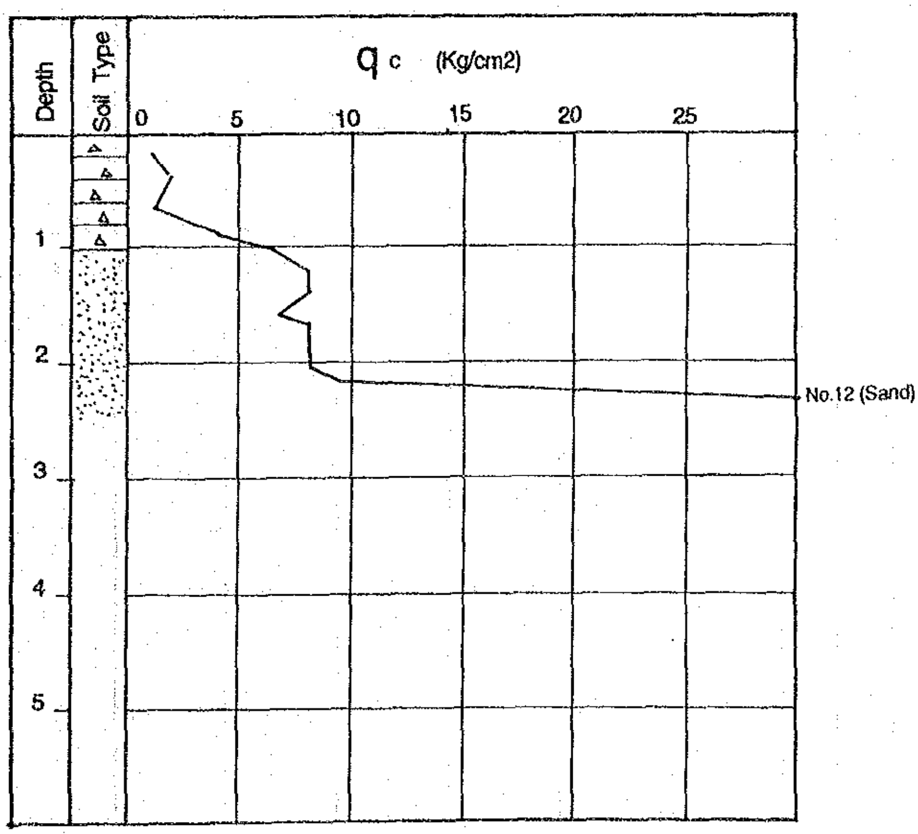
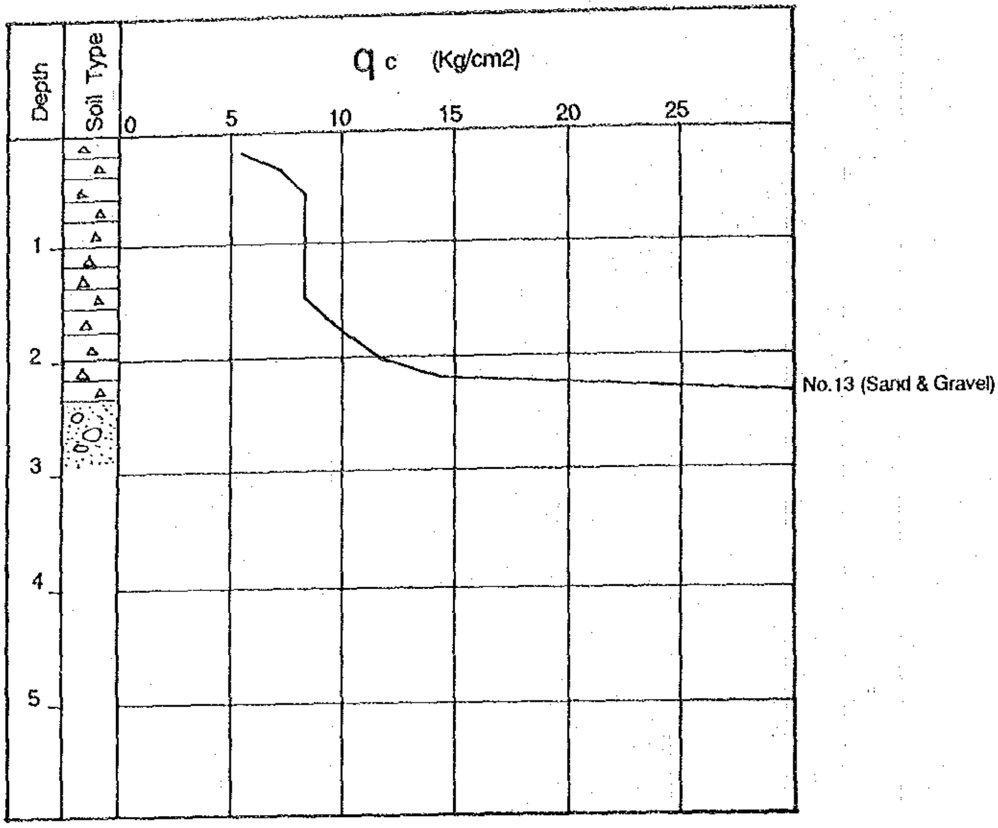


Fig. 8(4) Cone-Penetration Test Results(4)



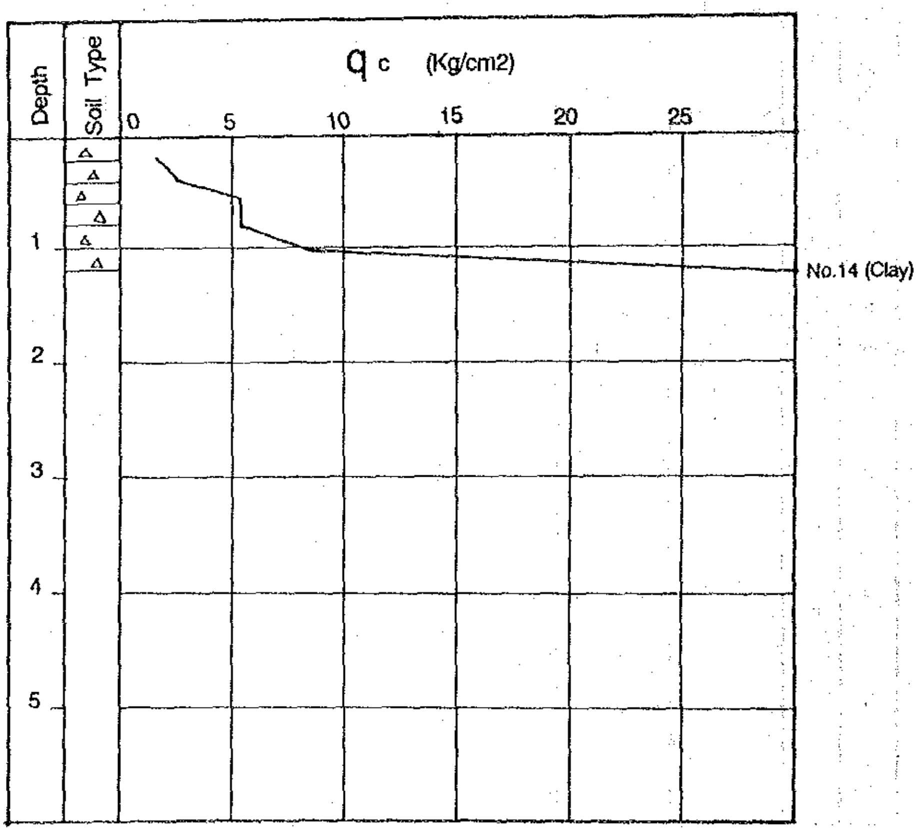
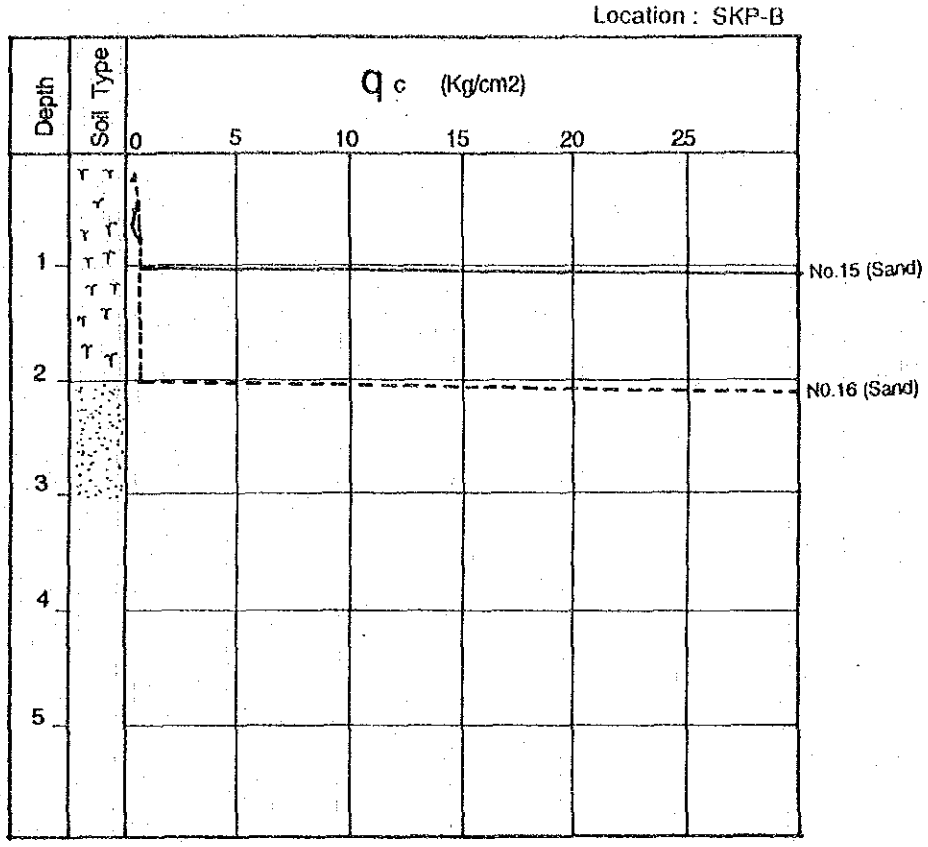


Fig. 8(5) Cone-Penetration Test Results(5)



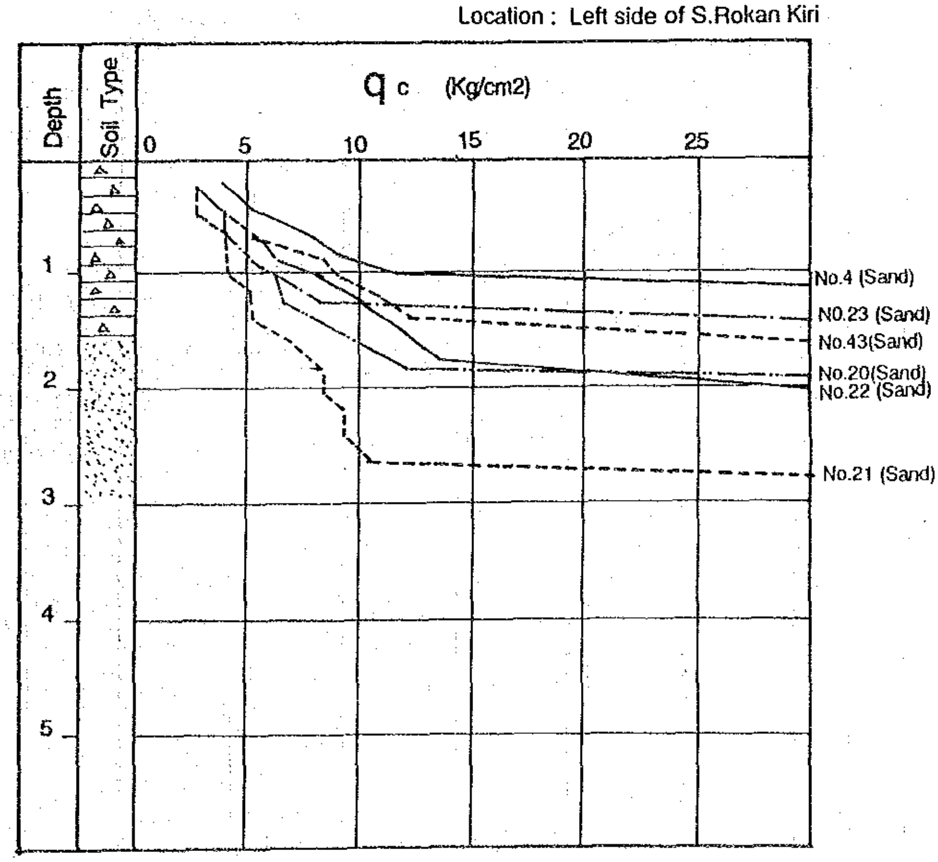
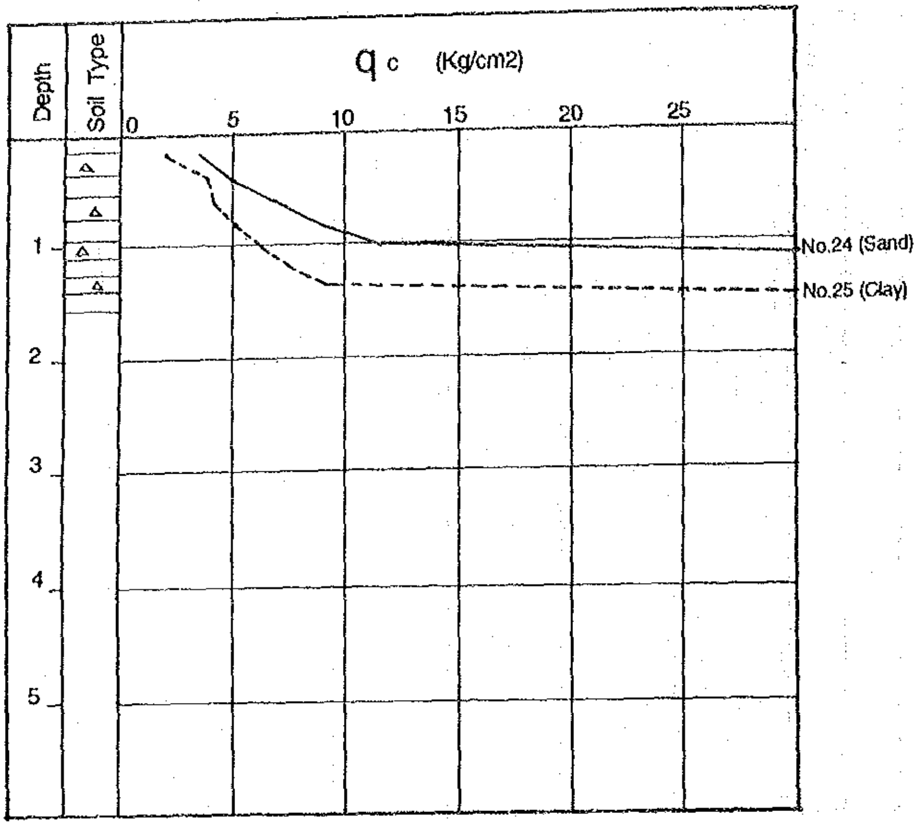


Fig. 8(6)   Cone-Penetration Test Results(6)



Location : SKP-A

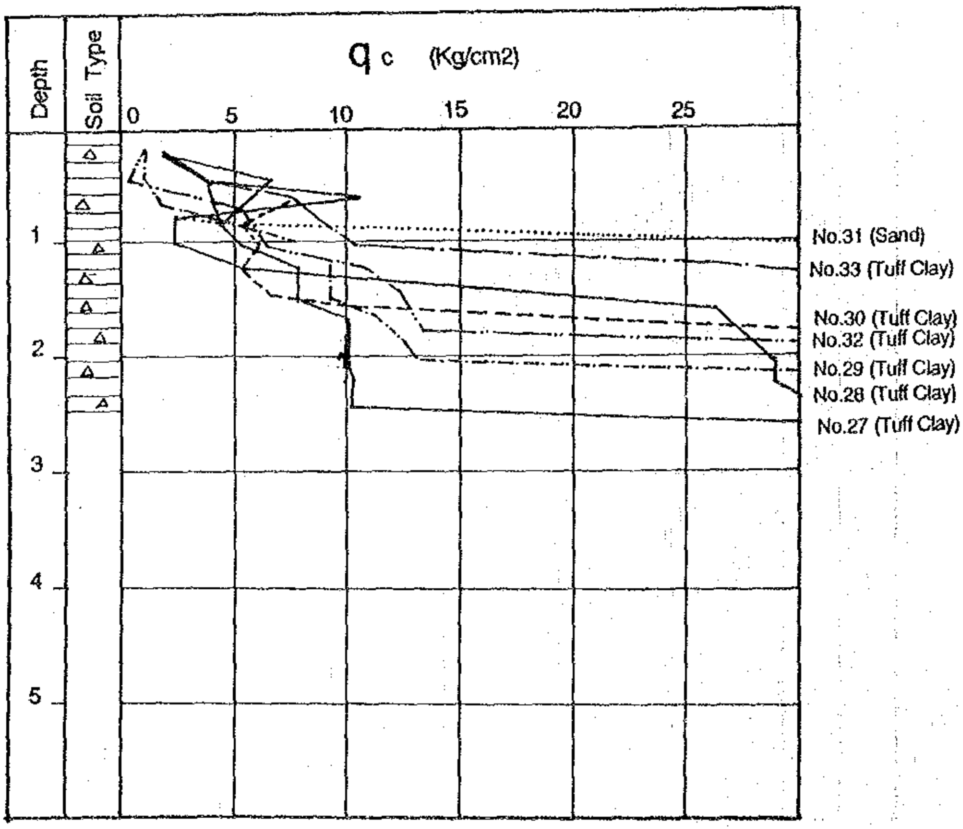
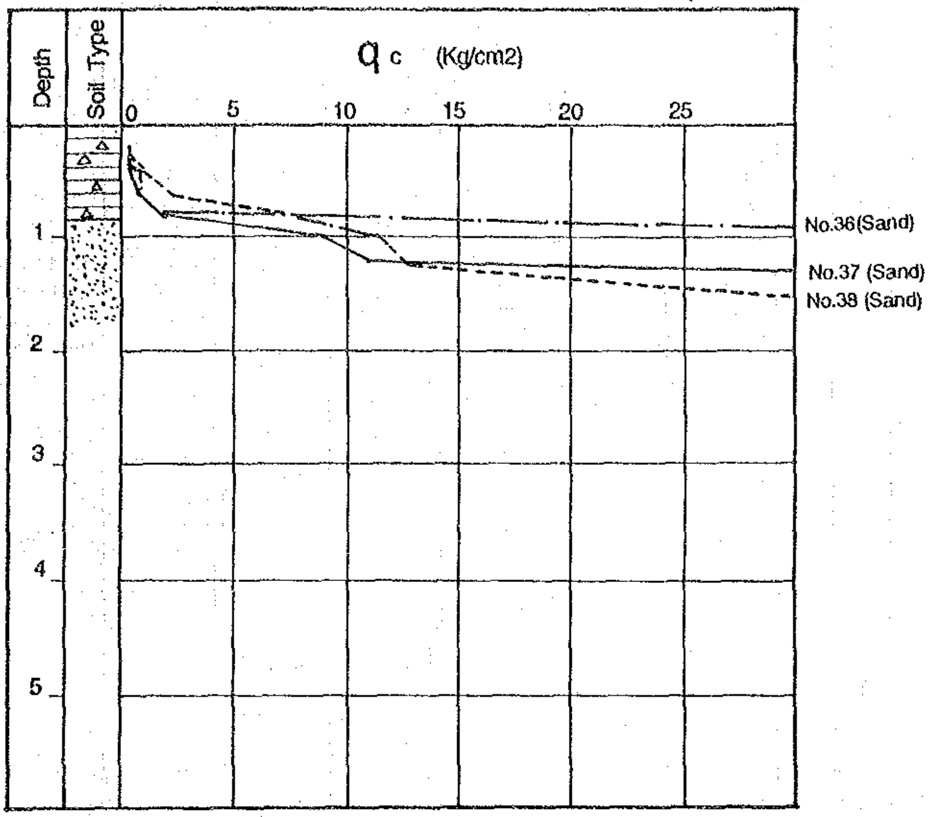


Fig. 8(7) Cone-Penetration Test Results(7)

Location : SP-1 (Near BM 9)



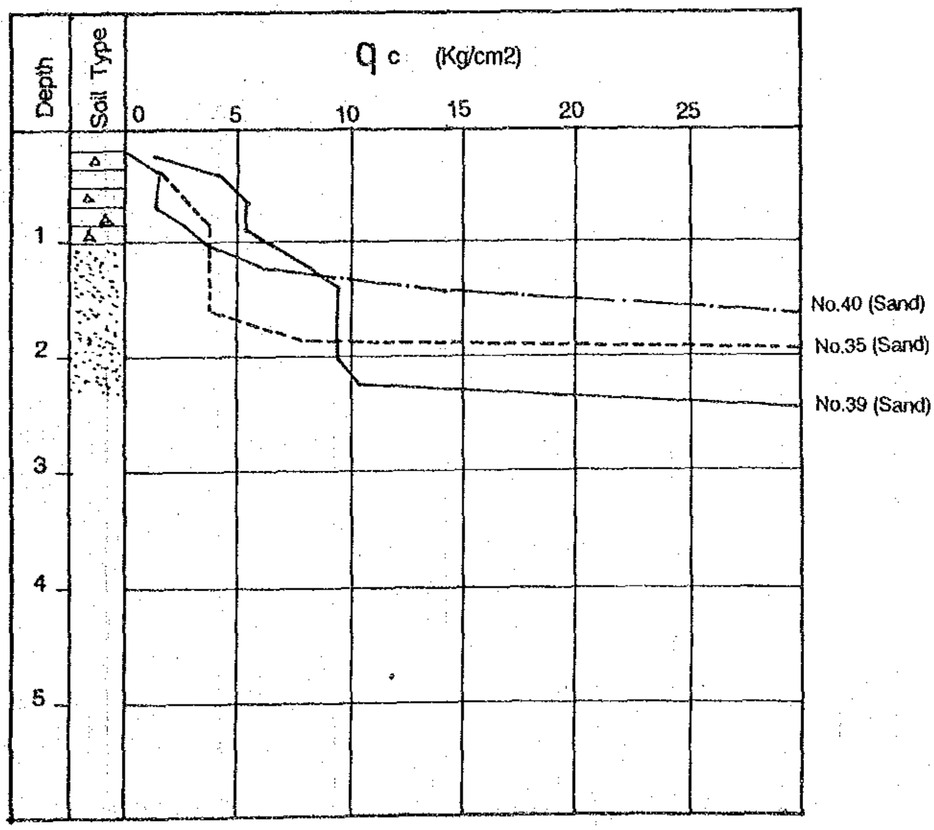
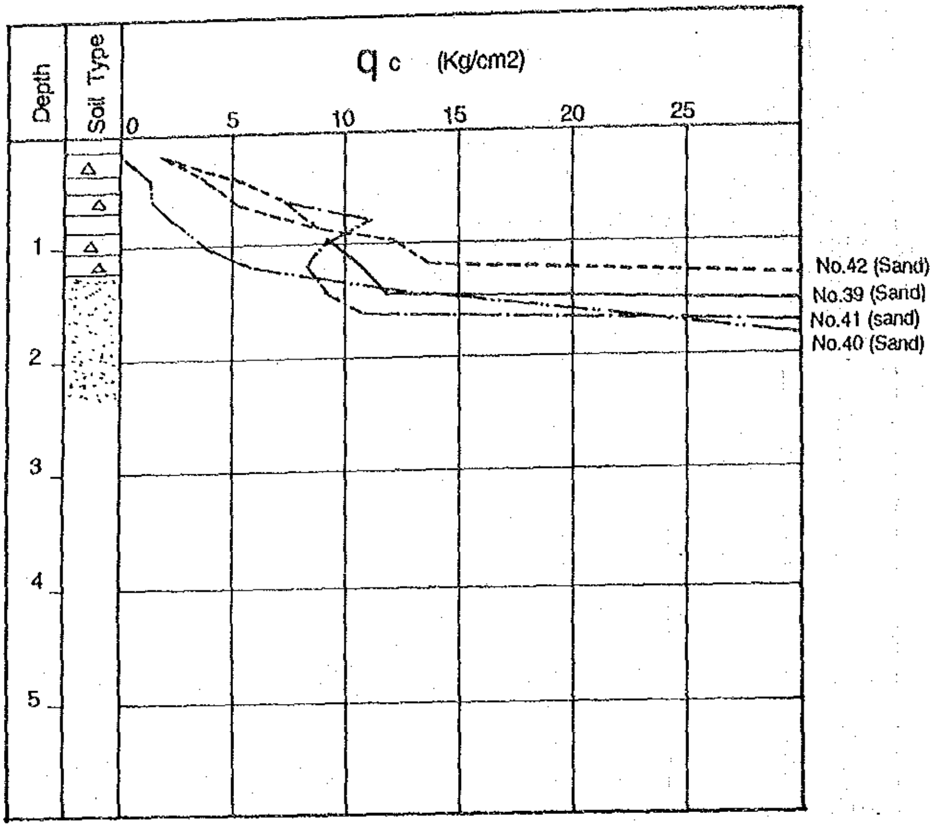
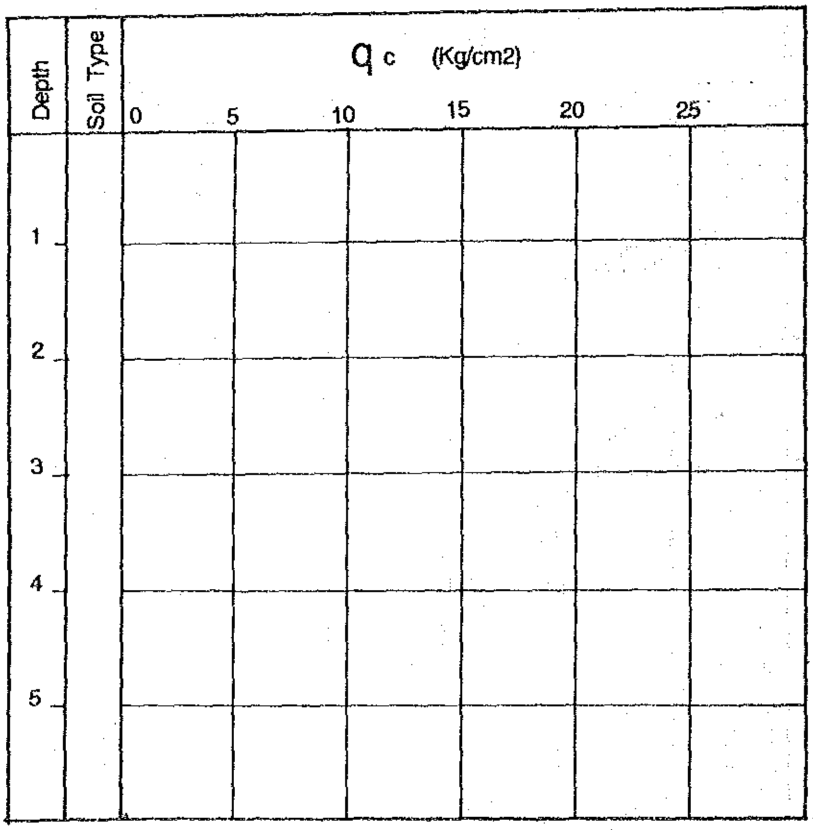


Fig. 8(8) Cone-Penetration Test Results(8)

Location : SP-1 & 2





SUMMARY OF LABORATORY TEST RESULTS

	Sample No. (Depth)	TP－1 0.40～0.80	TP－1 1.00～1.40	TP－2 1.00～1.40	TP－3 1.00～1.40	TP－3 2.00～2.40
	Unit Weight ρ_t g/cm³	1.675	1.518	1.701	1.746	1.741
	Dry Density ρ_d g/cm³					
	Gs ρ_s g/cm³	2.570	2.590	2.630	2.600	2.550
	Wn %	27.88	50.20	23.66	24.45	25.59
	l					
	Sr %					
Gradation	Gravel 2～75mm %	—	—	—	—	—
	Sand 75μm～2mm %	34.00	39.00	57.00	44.00	40.00
	Silt 5～75μm %	52.00	39.00	32.00	38.00	32.00
	Clay 5μm未満 %	14.00	22.00	11.00	18.00	28.00
	U_c					
	U_c'					
Consistency	WL %	60.55	60.55	—	45.55	48.20
	WP %	29.21	32.33	—	12.59	36.20
	IP	31.34	28.32	—	32.96	12.00
	Index Property	CH	C'H	SF	CL	ML
Compaction Test	I:	100	100	100	100	100
	Wopt (%)	—	26.55	20.91	—	19.67
	γd (g/cm³)	—	1.475	1.632	—	1.691
Direct Shear Test	c kgf/cm²	0.114	0.112	0.160	0.150	0.126
	ϕ	19°	18°	19°	21°	24°
	c' kgf/cm²					
	ϕ'					
Consolidation	C_c	—	0.335	0.318	0.246	0.235
	Cv (cm²/sec)					
	Mv (cm²/kg)					
	Permeblility Test					
	k (cm/sec)	—	1.723×10^{-4}	1.638×10^{-5}	—	1.870×10^{-4}

Fig. 9(1) Summary of Laboratory Test Results(1)

	Sample No. (Depth)	TP−4 0.40〜0.80	TP−5 0.40〜0.80
	Unit Weight ρ_t g/cm³	1.693	1.592
	Dry Density ρ_d g/cm³		
	Gs ρ_s g/cm³	2.560	2.540
	Wn %	30.04	42.74
	e		
	Sr %		
Gradation	Gravel 2〜75mm %	—	—
Gradation	Sand 75μm〜2mm %	7.00	25.00
Gradation	Silt 5〜75μm %	68.00	57.00
Gradation	Clay 5μm未満 %	25.00	18.00
Gradation	U_c		
Gradation	U_c'		
Consistency	WL %	78.85	75.90
Consistency	WP %	27.46	28.69
Consistency	IP	51.39	47.21
	Index Property	CH	CH
Compaction Test	E	100	100
Compaction Test	Wopt (%)	22.87	27.39
Compaction Test	γd (g/cm³)	1.539	1.402
Direct Shear Test	c kgf/cm²	0.200	0.200
Direct Shear Test	φ	19°	19°
Direct Shear Test	c' kgf/cm²		
Direct Shear Test	φ'		
Consolidation	C_c	0.302	0.420
Consolidation	Cv (cm²/sec)		
Consolidation	Mv (cm²/kg)		
	Permeability Test		
	k (cm/sec)	7.111×10^{-8}	2.116×10^{-7}

Fig. 9(2) Summary of Laboratory Test Results(2)

	Sample No. (Depth)	TP−6 0.40~0.80	TP−6 1.00~1.40	TP−7 0.60~1.00	TP−7 1.60~2.00		
	Unit Weight ρ_t g/cm³	1.615	1.632	1.571	1.679		
	Dry Density ρ_d g/cm³						
	Gs ρ_s g/cm³	2.550	2.570	2.570	2.560		
	Wn %	37.02	30.52	37.37	27.14		
	e						
	Sr %						
Gradation	Gravel 2~75mm %	−	−	−	−		
	Sand 75μm~2mm %	20.00	37.50	50.00	45.00		
	Silt 5~75μm %	41.00	48.00	34.00	39.00		
	Clay 5μm未満 %	39.00	15.00	16.00	16.50		
	U_c						
	U_c'						
Consistency	WL %	60.00	48.85	−	48.45		
	WP %	26.46	24.31	−	22.30		
	IP	33.54	24.54	−	26.55		
	Index Property	CH	CL	F	CL		
Compaction Test	E	100	100	100	100		
	Wopt (%)	−	30.404	−	29.370		
	γd (g/cm³)	−	1.404	−	1.450		
Direct Shear Test							
	c kgf/cm²	0.252	0.114	0.072	0.162		
	φ	22°	21°	17°	17°		
	c' kgf/cm²						
	φ'						
Consolidation	C_c	0.328	0.316	0.226	0.293		
	Cv (cm²/sec)						
	Mv (cm²/kg)						
	Permeblility Test						
	k (cm/sec)	−	2.851×10^{-4}	−	2.453×10^{-6}		

Fig. 9(3) Summary of Laboratory Test Results(3)

	Sample No. (Depth)	TP−8 0.60〜1.00	TP−8 1.60〜2.00	TP−9 1.00〜1.40			
	Unit Weight ρ_t g/cm³	1.826	−	1.713			
	Dry Density ρ_d g/cm³						
	Gs ρ_s g/cm³	2.590	2.600	2.580			
	Wn %	17.30	−	25.71			
	e						
	Sr %						
Gradation	Gravel 2〜75mm %	−	−	−			
	Sand 75μm〜2mm %	55.00	52.50	40.00			
	Silt 5〜75μm %	30.00	31.50	41.00			
	Clay 5μm未満 %	15.00	16.00	19.00			
	U_c						
	U_c'						
Consistency	WL %	27.00	29.25	36.30			
	WP %	16.44	16.26	19.93			
	IP	10.56	12.99	16.37			
	Index Property	CL	CL	CL			
Compaction Test	E	100	100	100			
	Wopt (%)	−	22.90	−			
	γd (g/cm³)	−	1.553	−			
Direct Shear Test							
	c kgf/cm²	0.080	0.138	0.200			
	ϕ	25°	19°	21°			
	c' kgf/cm²						
	ϕ'						
Consolidation	C_c	0.373	−	0.282			
	Cv (cm²/sec)						
	Mv (cm²/kg)						
	Permebility Test						
	k (cm/sec)	−	4.906X10⁻⁵	−			

Fig. 9(4) Summary of Laboratory Test Results(4)

SUMMARY OF LABORATORY TEST RESULTS

	Sample No. (Depth)	TP－9 2.00～2.40	TP－10 0.40～0.80	TP－10 1.10～1.50	TP－11 0.40～0.80		
	Unit Weight ρ_t g/cm³	1.734	1.726	1.698	1.426		
	Dry Density ρ_d g/cm³						
	Gs ρ_s g/cm³	2.570	2.600	2.580	2.550		
	Wn %	28.46	23.49	30.11	60.90		
	e						
	Sr %						
Gradation	Gravel 2～75mm %	—	—	—	—		
	Sand 75μm～2mm %	25.00	60.00	45.00	50.00		
	Silt 5～75μm %	52.50	26.00	37.00	37.50		
	Clay 5μm未満 %	22.50	14.00	17.00	12.50		
	U_c						
	U_c'						
Consistency	WL %	45.35	—	39.85	—		
	WP %	21.95	—	16.70	—		
	IP	23.40	—	23.85	—		
	Index Property	CL	SF	CL	SF		
Compaction Test	E	100	100	100	100		
	Wopt (%)	23.66	—	21.39	23.38		
	γd (g/cm³)	1.510	—	1.620	1.560		
Direct Shear Test	c kgf/cm²	0.250	0.108	0.075	0.080		
	φ	22°	25°	21°	20°		
	c' kgf/cm²						
	φ'						
Consolidation	C_c	0.339	0.288	0.282	0.336		
	Cv (cm²/sec)						
	Mv (cm²/kg)						
	Permebility Test						
	k (cm/sec)	1.413×10^{-6}	—	1.740×10^{-6}	1.226×10^{-6}		

Fig. 9(5) Summary of Laboratory Test Results(5)