NO. 15

FEASIBILITY REPORT
ON
BUKIT BAUK PILOT PROJECT
FOR
TRENGGANU TENGAH SWAMP AREA
AGRICULTURAL DEVELOPMENT
MALAYSIA

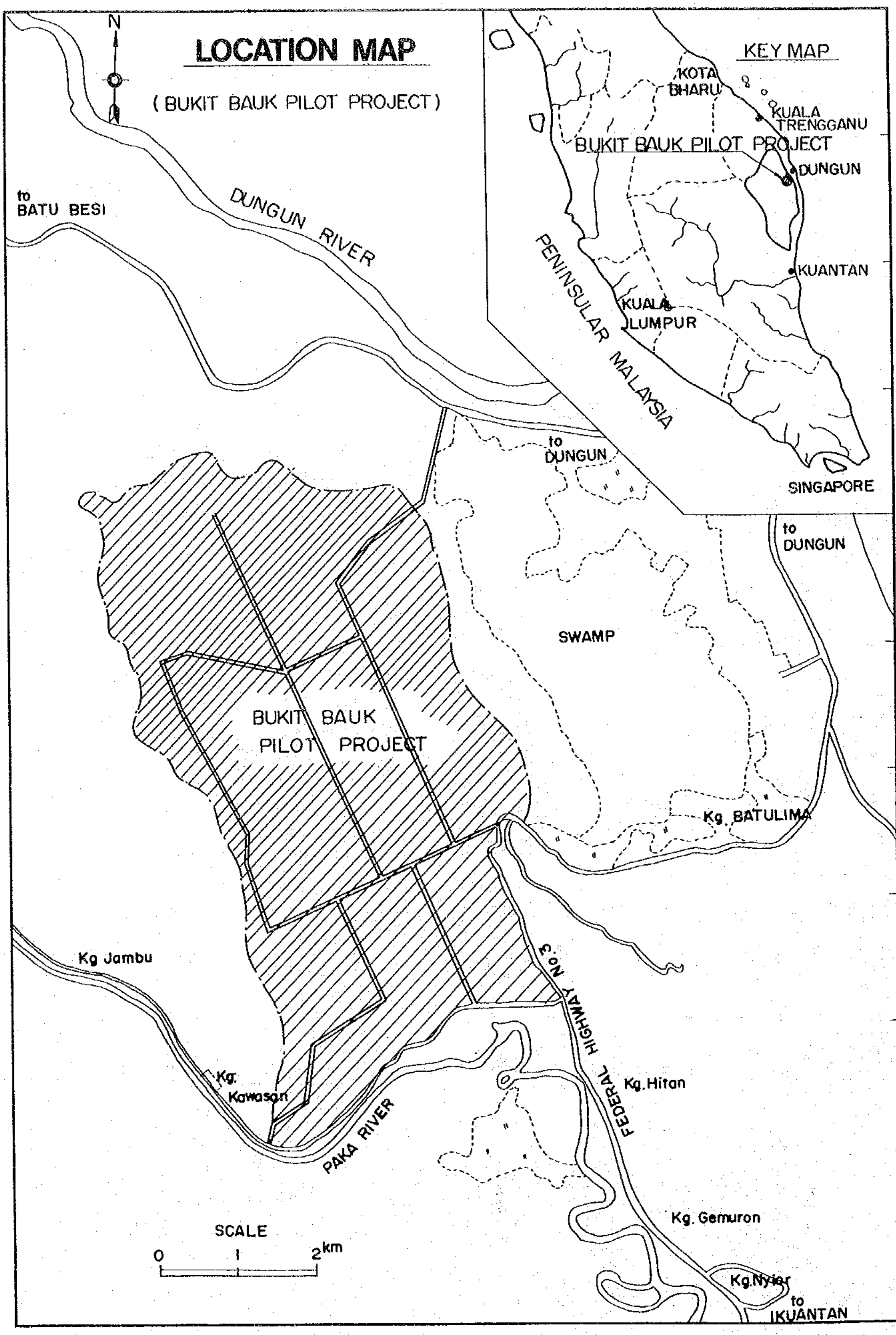
FEASIBILITY REPORT
ON
BUKIT BAUK PILOT PROJECT
FOR
TRENGGANU TENGAH SWAMP AREA
AGRICULTURAL DEVELOPMENT

MALAYSIA

STUDY REPORT

MARCH 1979

JAPAN INTERNATIONAL COOPERATION AGENCY



N
LOCATION MAP
(BUKIT BAUK PILOT PROJECT)
to
BATU BESI
DUNGUN RIVER
KEY MAP
KOTA
BHARU
KUALA
TRENGGANU
BUKIT BAUK PILOT PROJECT
DUNGUN
KUANTAN
KUALA
LUMPUR
PENINSULAR MALAYSIA
SINGAPORE
to
DUNGUN
to
DUNGUN
SWAMP
BUKIT BAUK
PILOT PROJECT
Kg. BATULIMA
Kg Jambu
Kg.
Kawasan
PAKA RIVER
FEDERAL HIGHWAY No.3
Kg. Hitan
Kg. Gemuron
Kg.Nyior
to
KUANTAN
SCALE
0 1 2km

CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF DRAWINGS

ABBREVIATIONS AND DEFINITION OF TERMS

km	kilometer	ha	hectare
cm	centimeter	kl	kilometer
t	ton	m^3/sec	cubic meter per second
g	gram	l/sec/ha	liter per second per ha
m^2	square meter	l/ha	liter per hectare
m^3	cubic meter	hr(s)	hour(s)
l	liter	mm/day	millimeter per day
l/sec	liter per second	%	percent
t/ha	ton per hectare	ft	foot
kg/ha	kilogram per hectare	Fig.	Figure
t/hr	ton per hour	U.S.$	U.S. Dollar
$mile^2$	square mile	M$	Malaysian Dollar
°C	degree Centigrade	M$/ha	Malaysian Dollar per ha
°F	degree Fahrenheit	U.S.$/ha	U.S. Dollar per hectare
m	meter	M$$10^3$	M$1,000
mm	millimeter	U.S.$$10^3$	U.S. $1,000
kg	kilogram	M$/kati	Malaysian Dollar
km^2	square kilometer		per kati
L	length	inch/month	inch per month
Q	quantity	ft^3/sec	cubic feet per second
φ	diameter	N	Nitrogen
H	head	P	Phosphorus
KW	kilowatt	K	Potassium
		wt.	weight

GDP	Gross Domestic Product
GNP	Gross National Product
c.i.f.	cost, insurance, freight
f.o.b.	free on board
TOL	Temporary Occupation License
IBRD	International Bank for Reconstruction and Development
FAO	Food and Agriculture Organization of the United Nations
KETENGAH	Trengganu Tengah Development Authority
EPU	Economic Planning Unit
MARDI	Malaysia Agricultural Research Development Institute
DID	Drainage and Irrigation Department

FAMA	Federal Agricultural Marketing Authority
FELCRA	Federal Land Consolidation and Rehabilitation Authority
FELDA	Federal Land Development Authority
KADA	Kamubu Agricultural Development Authority
MAJUIKAN	Fisheries Development Authority
RISDA	Rubber Industry Smallholders Development Authority

CONVERSION TABLE OF MEASURES

(1) Gantang = I Imperial gallon = 4.546 ℓ or
= 2.54 Kg

(2) Kati = 1.33 pounds = 0.606 Kg

(3) Picul = 133 pounds = 60.55 Kg

CURRENT EQUIVALENT

M$1.00 = US$0.45

I. ALTERNATIVE STUDIES

A. ALTERNATIVE STUDIES

1. Comparison of three plans

The Pilot Project is a guideline for the development of the whole swamp of the Trengganu State. It is an experiment on a practical scale to solve unknown technology. At the same time, its economic activities are to be conducted by introducing settlers of 700 farming families. Therefore, the Pilot Plan must be successful. Taking its various conditions into consideration, the construction plan which would incur the lowest cost is not necessarily suitable for the purpose. For your reference, however, the construction costs of the following three plans are compared.

Under the First Plan all construction work including the embankment for flood protection of the Paka river and the pumping station is to be completed. This includes land reclamation, removed of free stumps and roots and land clearing. The total area to be developed in Bukit Bauk is 2,835 hectares.

Under the Second Plan in the total scale and the area to be developed are the same as under the first plan. In the Second Plan, the construction period is divided into the First and the Second Phases. It is planned that the embankment is to be built, the pumping station installed, and trees of 16 inches or more in the diameter uprooted in the Second Phase. In the First Phase, namely, within 10 years after settlement, the land will be developed by farm workers and draft animals. In the Second Phase, namely 10 years after the First Phase, agricultural machinery will be introduced. During this period, the embankment will be built and the pumping station will be installed.

Under the Third Plan the area excluding the flood plain of the Paka River for a 10-year return period is to be developed. Therefore, in this plan, an area of 2,141 hectares where water can be drain naturally will be developed, excluding the construction of the embankment and the installation of the pumping station.

The table below shows the comparison of the construction costs of these 3 plans.

Items	1st Plan	2nd Plan			3rd Plan
		1st Phase	2nd Phase	Total	
Farmland area (ha)	2,622	2,622			2,141
Total project cost ($M\$10^3$)	35,525	27,937	(12,411)	(40,348)	23,673
Unit cost per ha (M$/ha)	13,548	10,654	(4,733)	(15,387)	11,056

The total respective project costs of these 3 plans is M$35,525,000, M$27,937,000 (First Phase), and M$23,673,000. The total cost of the First Plan is clearly the highest. On the other hand, the unit cost of these 3 plans is M$13,548/ha, M$10,654/ha, and M$11,056/ha. So in terms of the unit cost, the First Plan ranks first, the Second Plan ranks third, and the Third Plan ranks second. It is natural the unit cost of the First Plan should be the highest, because this plan includes the construction of the embankment, the installation of the pumping station, and the introduction of agricultural machinery. It is also natural that the unit cost of the Third Plan should be higher than that of the Second Plan, because the development area of the Third Plan is smaller than that of the Second Plan, though the Third Plan includes a demonstration farm and public facilities like the other plans.

The unit cost of the Second Plan including the Second Phase for the construction of the embankment and the installation of the pumping station becomes higher than that of the First Plan, because of its larger price contingency. However, the unit cost of the Second Plan including only the First Phase is lower than that of the Third Plan, because the development area of the Second Plan is larger than that of the Third Plan.

It has been decided that the agricultural machinery is not to be introduced from the beginning, since most of the settlers would be unskilled agricultural workers and fishermen. On the low land where flooding often occurs, paddy fields are to be developed and water buffaloes raised. The Second Plan is recommended to those concerned.

Table I-1 Cost Estimate for Alternative Study

(Unit: M$$10^3$)

	First plan	Second plan			Third plan
		First phase	Second phase	Total	
[Drainage]					
Driving channel	8	8		8	8
Main drainage canal	217	217		217	217
Secondary canal	891	891		891	561
Embankment	1,351				
Pump station	1,301		1,301	1,301	
Boxculvert	191		191	191	
Sluice gates	243		243	243	
(Sub-total)	(4,202)	(1,116)	(1,735)	(2,851)	(786)
[Irrigation]					
Pipe line: Main	421	421		421	421
Pipe line: Secondary	369	369		369	369
Open canal: Secondary	407	407		407	-
Irrigation pump	671	671		671	671
(Sub-total)	(1,868)	(1.868)		(1,868)	(1,461)
[Road]					
Main road	228	228		228	228
Secondary road	653	653		653	587
Bridges, culverts	1,614	1,614		1,614	1,448
District road		521	830	1,351	
(Sub-total)	(2,495)	(3,016)	(830)	(3,846)	(2,263)

	First plan		Second plan		Third plan
		First phase	Second phase	Total	
[Demonstration farm]					
Site arrangement	706	706		706	663
Buildings and instruments	1,200	1,200		1,200	1,200
(Sub-total)	(1,906)	(1,906)		(1,906)	(1,863)
[Settlement]					
Site arrangement	285	285		285	190
Housing	3,173	3,173		3,173	2,728
Public buildings	2,493	720	1,773	2,493	720
(Sub-total)	(5,951)	(4,178)	(1,773)	(5,951)	(3,638)
[Land reclamation]					
Cutting	1,682	1,384	298	1,682	1,205
Transportation	841	692	149	841	603
Uprooting	2,652	2,076	576	2,652	1,808
Land clearing	2,103	1,731	372	2,103	1,508
Land grading	505	505		505	
Farm road	1,134	1,134		1,134	987
Farm drainage canal	1,134	1,134		1,134	987
(Sub-total)	(10,051)	(8,656)	(1,395)	(10,051)	(7,098)
[Engineering services]	1,323	1,036	287	1,323	959
[Physical contingency]	1,959	1,564	395	1,959	1,420

	First plan		Second plan		Third plan
		First phase	Second phase	Total	
[Price contingency]	5,770	4,597	5,996	10,593	4,185
(Sub-total)	(9,052)	(7,197)	(6,678)	(13,875)	(6,564)
Total	35,525	27,937	12,411	40,348	23,673
Unit cost per hectare	M$13,548	M$10,654	M$4,733	M$15,387	M$11,056
Farm land area (ha)	2622.2	2622.2	2622.2	2622.2	2141.2

Table I-2 Annual Cost for Alternative Study (First Plan) (Unit: M$$10^3$)

Items	Total	1st Year	2nd Year	3rd Year	4th Year	5th Year
Drainage	4,202	777	1,664	1,569	192	
Irrigation	1,868			504	890	474
Road	2,495		645	1,223	531	96
Demonstration farm	1,906				818	1,088
Settlement	5,951				2,736	3,215
Land reclamation	10,051		570	3,577	3,699	2,205
Engineering services	1,323	1,058	265			
Physical contingency	1,959	57	213	508	656	525
Price contingency	5,770	95	346	1,166	2,057	2,106
Total	35,525	1,987	3,703	8,547	11,579	9,709

Table I-3 Annual Cost for Alternative Study (Second Plan - First Phase)

(Unit: M$$10^3$)

Items	Total	1st Year	2nd Year	3rd Year	4th Year	5th Year
Drainage	1,116	225	383	316	192	
Irrigation	1,868		199	690	639	340
Road	3,016	213	847	1,329	531	96
Demonstration farm	1,906				859	1,047
Settlement	4,178				1,834	2,344
Land reclamation	8,656		468	3,218	3,118	1,852
Engineering services	1,036	828	206			
Physical contingency	1,564	33	143	418	541	429
Price contingency	4,597	65	231	943	1,666	1,692
Total	27,937	1,364	2,479	6,914	9,380	7,800

Table I-4 Annual Cost for Alternative Study (Second Plan - Second Phase)

(Unit: M$$10^3$)

Items	Total	1st Year	2nd Year	3rd Year	4th Year	5th Year	....	14th Year	15th Year
Drainage	2,851	225	383	316	192			801	934
Irrigation	1,868		199	690	639	340			
Road	3,846	213	847	1,329	531	96		415	415
Demonstration farm	1,906				859	1,047			
Settlement	5,951				1,834	2,344		886	887
Land reclamation	10,051		468	3,218	3,118	1,852		698	697
Engineering services	1,323	828	208					230	57
Physical contingency	1,959	33	143	418	541	429		193	202
Price contingency	10,593	65	231	943	1,666	1,692		2,862	3,134
Total	40,348	1,364	2,479	6,914	9,380	7,800		6,085	6,326

Table I-5 Annual Cost for Alternative Study (Third Plan) (Unit: M$$10^3$)

Items	Total	1st Year	2nd Year	3rd Year	4th Year	5th Year
Drainage	786	157	267	220	142	
Irrigation	1,461		161	541	497	262
Road	2,263	158	634	996	407	68
Demonstration farm	1,863				838	1,025
Settlement	3,638				1,600	2,038
Land reclamation	7,098		355	2,626	2,555	1,562
Engineering services	959	767	192			
Physical contingency	1,420	28	128	383	497	384
Price contingency	4,185	42	209	879	1,507	1,548
Total	23,673	1,152	1,946	5,645	8,043	6,887

II. METEOROLOGY AND HYDROLOGY

II. METEOROLOGY AND HYDROLOGY

CONTENTS

A. Meteorology

1. Rainfall

The rainfall data is obtained from the observation values of Klinik Bidan Paka (station No. 4634085). The observation period is 22 years between 1957 and 1978.

1.1 Probability calculation

Probabilities of the annual rainfall, maximum daily rainfall, 2 maximum daily rainfall, 3 maximum daily rainfall, available rainfall, and continuous drought days shall be calculated based on the daily rainfall data.
The results are as shown in Tables II-1 to II-13 and Figs. II-1 to II-6.

Table II-1 Probability Calculation Table

Return period (year)	Annual rain-fall	Maximum daily rainfall	2 maximum daily rainfall	3 maximum daily rainfall	Available rainfall	Continuous drought days
100	4,706.6mm	475.3mm	705.1mm	801.7mm	1,568.4mm	86 days
50	4,429.8	418.7	619.8	714.3	1,613.8	75
30	4,218.9	378.3	558.7	650.5	1,652.6	67
20	4,043.7	346.8	511.0	599.9	1,687.6	61
10	3,731.3	293.7	430.6	512.7	1,759.5	51
5	3,383.3	240.8	350.0	422.6	1,855.3	42
3	3,088.6	200.5	288.5	351.5	1,954.4	35
2	2,806.7	166.1	235.7	288.5	2,069.2	29

(See appendix I for daily rainfall, monthly rainfall, and available rainfall.)

2. Evaporation

The evaporation data is obtained from "Water Resources Publication No. 5, Evaporation in Peninsular Malaysia (1976)," DUNGUN.

Table II-14 shows the monthly evaporation data.

3. Water Level

The Paka River Water level observation is conducted at Durian Mentangau about 1 km upstream and at kg. Luit about 15 km upstream the Bukit Bauk

Pilot Project site.

At Durian Mentangau, the water level observation by the staff has been conducted since 1973 only at floods. At Kg. Liut, water level observation by recording level meter has been conducted since 1973. The water basin areas at observation points are 530.9 km^2 at Kg. Liut and 717.5 km^2 at Durian Mentangau. The gradient of the Paka River is 1/6000.

See Appendix I for water level of the Paka River.

Table II-2 Calculation of Probability of Annual Rainfall

(Station No. 4634085)

N	X	LOG X	X+B	Y=LOG(X+B)	Y**2
1	152.4	2.182984	152.4	2.182984	4.765423
2	140.9	2.148910	140.9	2.148910	4.617818
3	140.4	2.147367	140.4	2.147367	4.611185
4	133.9	2.126780	133.9	2.126780	4.523195
5	130.2	2.114610	130.2	2.114610	4.471579
6	128.0	2.107209	128.0	2.107209	4.440333
7	125.4	2.098297	125.4	2.098297	4.402852
8	118.5	2.073718	118.5	2.073718	4.300307
9	117.0	2.068185	117.0	2.068185	4.277392
10	113.6	2.055378	113.6	2.055378	4.224580
11	106.7	2.028164	106.7	2.028164	4.113450
12	104.8	2.020361	104.8	2.020361	4.081859
13	101.9	2.008174	101.9	2.008174	4.032763
14	96.1	1.982723	96.1	1.982723	3.931192
15	94.9	1.977266	94.9	1.977266	3.909581
16	85.7	1.932980	85.7	1.932980	2.736414
17	78.5	1.894869	78.5	1.894869	3.590531
18	65.5	1.816241	65.5	1.816241	3.298732
	113.0	2.043568 (XG = 110.55)		2.043568	4.184955

XL	XS	XL*XS	XL*XS-XG**2	XL+XS	2*XG-(XL+XS)	B
152.4	65.5	9982	-2239.1025	217.5	3.2000	-699.72
140.9	78.5	11060	-1160.6525	219.4	1.7000	-682.74
						0

LOG(X + 0) = 2.0435 + 0.1363*KSI

T	KSI	LOG(X+B)	X
100	1.6450	2.2679	185.3
50	1.4520	2.2416	174.4
30	1.2967	2.2204	166.1
20	1.1630	2.2021	159.2
10	0.9062	2.1671	146.9
5	0.5951	2.1247	133.2
3	0.3045	2.0850	121.6
2	0.0000	2.0435	110.5

Table II-3 Annual Rainfall (Staion No. 4634085)

n	Annual Rainfall	Year	$F_n=(1-\frac{2n-1}{2N})x100$	Remarks
1	152.4(inch)	1975	97.2(%)	
2	140.9	1973	91.7	
3	140.4	1966	86.2	
4	133.9	1961	80.6	
5	130.2	1974	75.0	
6	128.0	1971	69.4	
7	125.4	1967	63.9	
8	118.5	1969	58.3	
9	117.0	1968	52.8	
10	113.6	1970	47.2	
11	106.7	1976	41.7	
12	104.8	1959	36.1	
13	101.9	1960	30.6	
14	96.1	1965	25.0	
15	94.9	1962	19.4	
16	85.7	1964	13.9	
17	78.5	1977	8.3	
18	65.5	1963	2.8	
19				
20				
21				
22				

Fig. II-1 Probable Value of Annual Rainfall by Hazen - Plot

(Station No. 4634085)

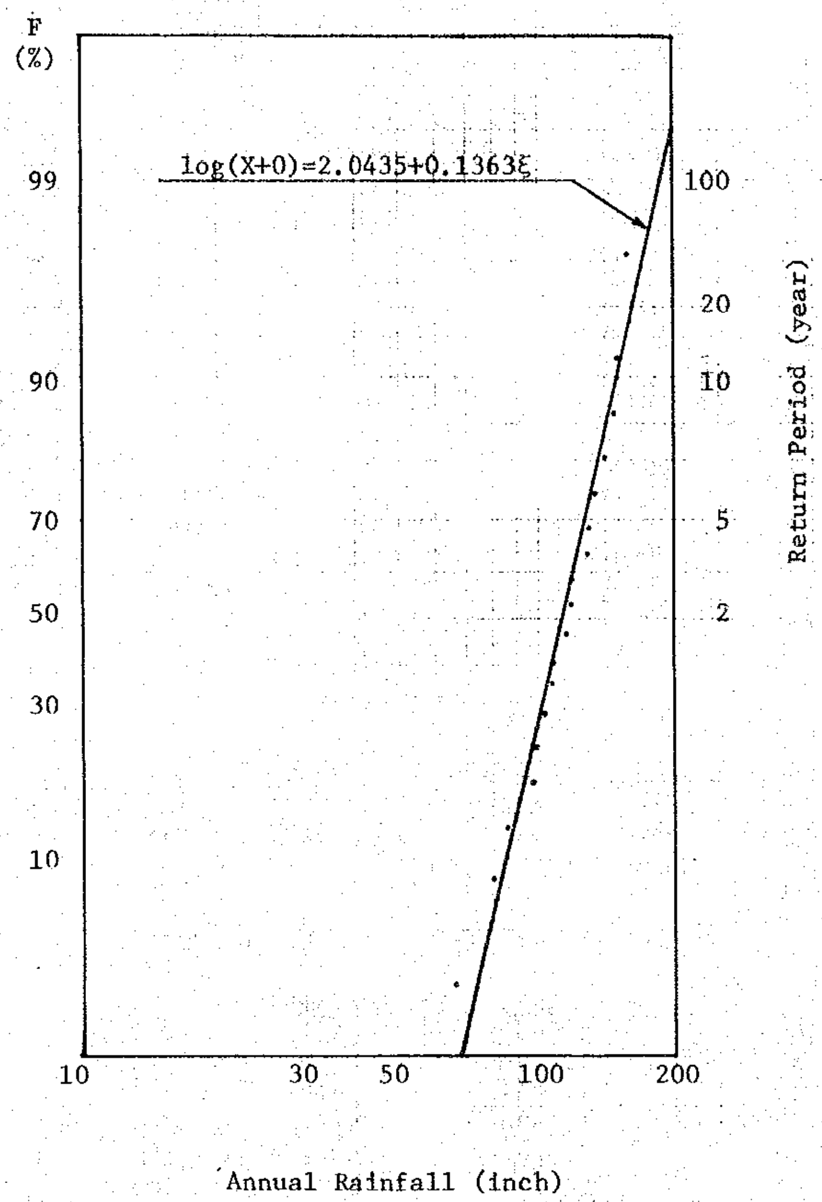


Table II-4 Calculation of Probability of Maximum Daily Rainfall

N	X	LOG X	X + B	Y=LOG(X + B)	Y**2
1	380.0	2.579783	363.0	2.449906	6.553121
2	340.0	2.531478	323.0	2.509202	6.296097
3	282.0	2.450249	265.0	2.423245	5.872120
4	262.0	2.418301	245.0	2.389166	5.708114
5	212.0	2.326335	195.0	2.290034	5.244258
6	205.0	2.311753	188.0	2.274157	5.171793
7	187.0	2.271841	170.0	2.230448	3.974902
8	187.0	2.271841	170.0	2.230448	4.974902
9	178.0	2.250420	161.0	2.206825	4.870080
10	170.0	2.230448	153.0	2.184691	4.772876
11	170.0	2.230448	153.0	2.184691	4.772876
12	169.0	2.227886	152.0	2.181843	4.760441
13	168.0	2.225309	151.0	2.178976	4.747940
14	167.0	2.222716	150.0	2.176091	4.735373
15	161.0	2.206825	144.0	2.158362	4.658528
16	143.0	2.155336	126.0	2.100370	4.411556
17	104.0	2.017033	87.0	1.939519	3.761734
18	98.0	1.991226	81.0	1.908485	3.642315
19	93.0	1.968482	76.0	1.880813	3.537459
20	93.0	1.968482	76.0	1.880813	3.537359
21	74.0	1.869231	57.0	1.755874	3.083096
	183.0	2.225021 (XG = 167.89)		2.173523	4.766050

XL	XS	XL*XS	XL*XS-XG**2	XL+XS	2*XG-(XL+XS)	B
380.0	74.0	28120	-67.0521	454.0	-118.2200	0.57
340.0	93.0	31620	3432.9479	433.0	-97.2200	-35.31
						-17

LOG (X -17) = 2.1735 + 0.2964*KSI

T	KSI	LOG(X+B)	X
100	1.6450	2.6611	475.3
50	1.4520	2.4039	418.7
30	1.2967	2.5579	378.3
20	1.1630	2.5182	346.8
10	0.9062	2.4421	293.7
5	0.5951	2.3499	240.8
3	0.3045	2.2637	200.5
2	0.0000	2.1735	166.1

Table II-5 Maximum Daily Rainfall (Station No. 4634085)

Order	Maximum Daily Rainfall	Date	$F_n=(1-\frac{2n-1}{2N})\times100$	Remarks
1	380 mm	1967.1.6	97.6%	
2	340	1976.11.27	92.9	
3	282	1966.12.28	88.1	
4	262	1970.12.29	83.3	
5	212	1971.3.16	78.6	
6	205	1973.12.9	73.8	
7	187	1958.11.8	69.0	
8	187	1961.12.26	64.3	
9	178	1957.11.30	59.5	
10	170	1974.12.4	54.8	
11	170	1975.12.15	50.0	
12	169	1969.12.13	45.2	
13	168	1960.12.9	40.5	
14	167	1963.1.2	35.7	
15	161	1959.11.22	31.0	
16	143	1968.12.9	26.2	
17	104	1964.6.28	21.4	
18	98	1962.12.18	16.7	
19	93	1965.12.29	11.9	
20	93	1977.12.10	7.1	
21	74	1972.9.16	2.4	

Fig. II-2 Probable Value of Maximum Daily Rainfall by Hazen-Plot

(Station No. 4634085)

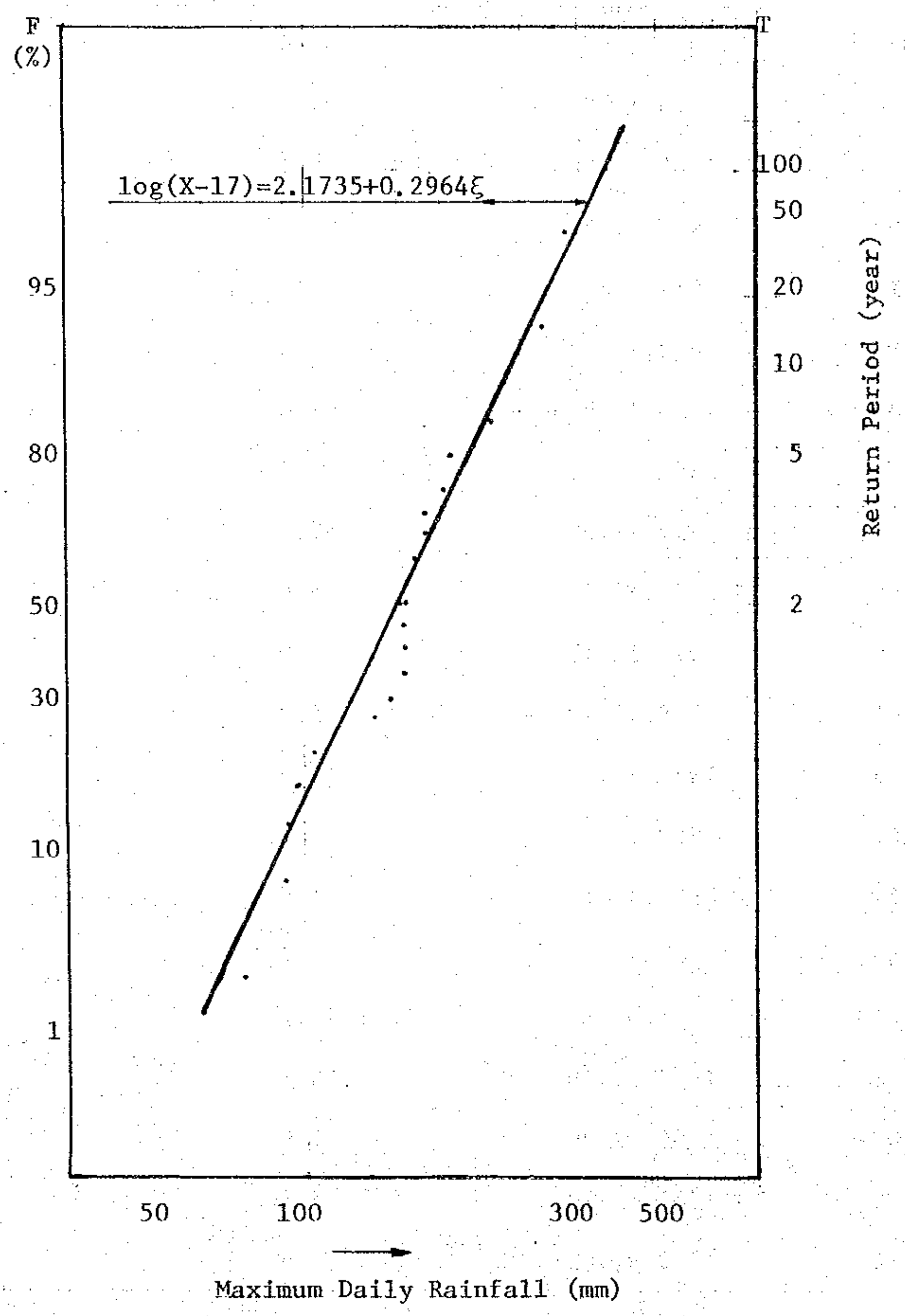


Table II-6 Calculation of Probability of 2 Maximum Daily Rainfall

N	X	LOG X	X+B	Y=LOG(X+B)	Y**2
1	526.0	2.720985	523.0	2.718501	7.390251
2	483.0	2.683947	480.0	2.681241	7.189054
3	449.0	2.652246	446.0	2.649334	7.018975
4	415.0	2.618048	412.0	2.614897	6.837687
5	343.0	2.535294	340.0	2.531478	6.408385
6	313.0	2.495544	310.0	2.491361	6.206883
7	300.0	2.477121	297.0	2.472756	6.114524
8	281.0	2.448706	278.0	2.444044	5.973354
9	280.0	2.447158	277.0	2.442479	5.965707
10	236.0	2.372912	233.0	2.367355	5.604374
11	229.0	2.359835	226.0	2.354108	5.541826
12	222.0	2.346352	219.0	2.340444	5.477678
13	218.0	2.338456	215.0	2.332438	5.440269
14	197.0	2.294466	194.0	2.287801	5.234036
15	194.0	2.287801	191.0	2.281033	5.203113
16	170.0	2.230448	167.0	2.222716	4.940468
17	147.0	2.167317	144.0	2.158362	4.658528
18	136.0	2.133538	133.0	2.123851	4.510745
19	135.0	2.130333	132.0	2.120573	4.496833
20	116.0	2.064457	113.0	2.053078	4.215131
21	107.0	2.029383	104.0	2.017033	4.068423
	261.7	2.373065 (XG = 236.08)		2.366900	5.642678

XL	XS	XL*XS	XL*XS-XG**2	XL+XS	2*XG-(XL+XS)	B
526.0	107.0	56282	548.2336	633.0	-160.8400	-3.41
483.0	116.0	56028	294.2336	599.0	-126.8400	-2.32
						-3

LOG (X - 3) = 2.3669 + 0.2914*KSI

T	KSI	LOG(X+B)	X
100	1.6450	2.8464	705.1
50	1.4520	2.7901	619.8
30	1.2967	2.7448	558.7
20	1.1630	2.7059	511.0
10	0.9062	2.6310	430.6
5	0.5951	2.5403	350.0
3	0.3045	2.4556	288.5
2	0.0000	2.3669	235.7

Table II-7 2 Maximum Daily Rainfall (Station No. 4634085)

Order	2 Maximum Daily Rainfall	Date	$F_n = (1 - \frac{2n-1}{2N})x100$	Remarks
1	526 mm	1976.11.27-28	97.6%	340+186 mm
2	483	1966.12.28-29	92.9	282+201
3	449	1967.1.5-6	88.1	69+380
4	415	1971.3.15-16	83.3	203+212
5	343	1973.12.9-10	78.6	205+138
6	313	1970.12.29-30	73.8	262+51
7	300	1975.12.14-15	69.0	130+170
8	281	1969.11.29-30	64.3	155+126
9	280	1974.12.4-5	59.5	170+110
10	236	1960.12.8-9	54.8	68+168
11	229	1957.11.29-30	50.0	51+178
12	222	1961.12.25-26	45.2	35+187
13	218	1959.11.22-23	40.5	161+57
14	197	1958.11.8-9	35.7	187+10
15	194	1963.12.4-5	31.0	90+104
16	170	1965.12.28-29	26.2	77+93
17	147	1968.12.8-9	21.4	4+143
18	136	1964.11.20-21	16.7	52+84
19	135	1962.12.5-6	11.9	64+71
20	116	1977.12.10-11	7.1	93+23
21	107	1972.9.15-16	2.4	64+71

Fig, II-3 Probable Value of 2 Maximum Daily Rainfall by Hazen-Plot

(Station No. 4634085)

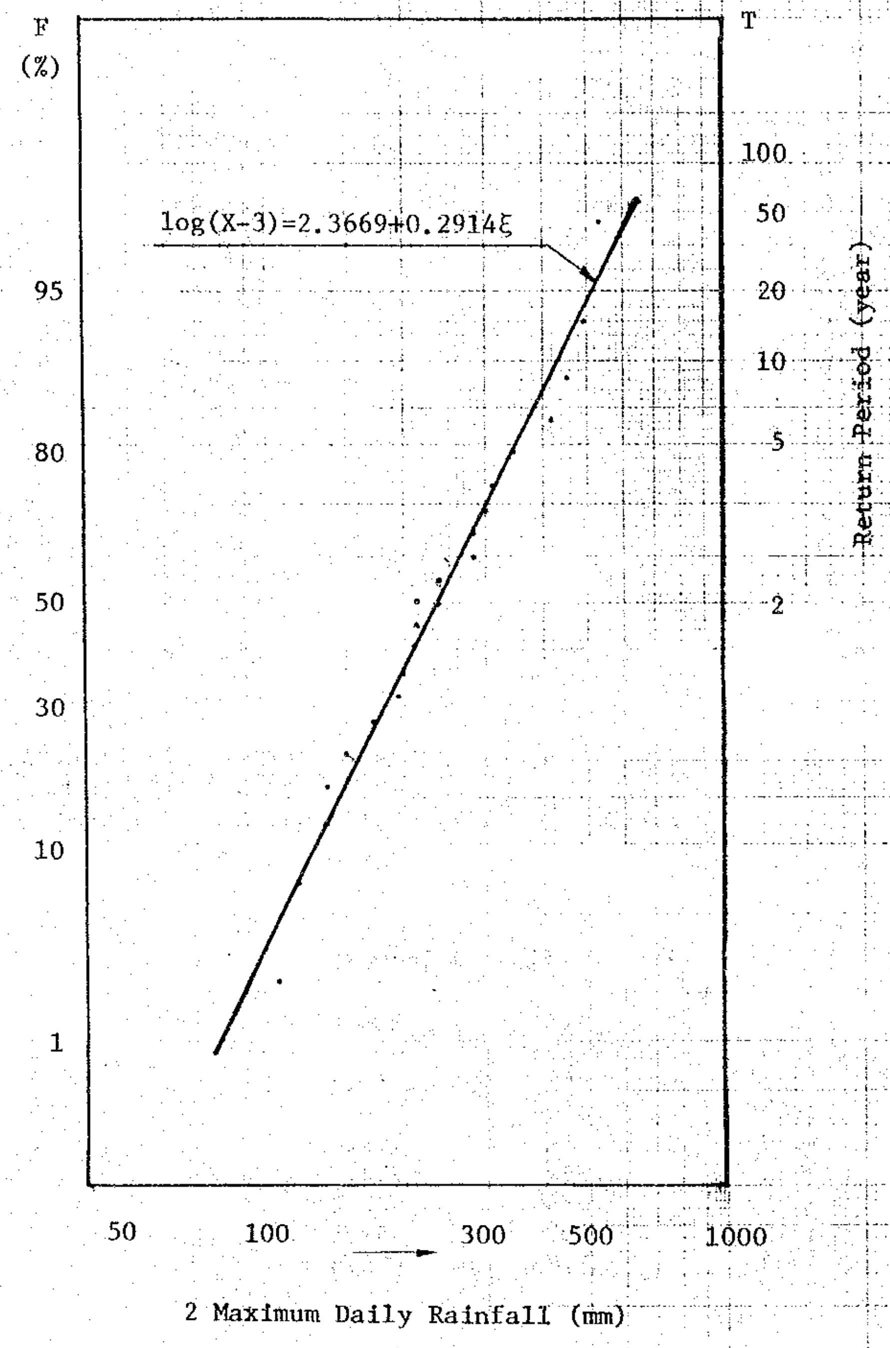


Table II-8 Calculation of Probability of 3 Maximum Daily Rainfall

N	X	LOG X	X+B	Y=LOG(X+B)	Y**2
1	601.0	2.778874	650.0	2.812913	7.912481
2	555.0	2.744292	604.0	2.781036	7.734166
3	519.0	2.715167	568.0	2.754348	7.586434
4	438.0	2.641474	487.0	2.687528	7.222811
5	427.0	2.630427	476.0	2.677606	7.169578
6	419.0	2.622214	468.0	2.670245	7.130212
7	419.0	2.622214	468.0	2.670245	7.130212
8	350.0	2.544068	399.0	2.600972	6.765060
9	326.0	2.513217	375.0	2.574031	6.625636
10	315.0	2.498310	364.0	2.561101	6.559240
11	281.0	2.448706	330.0	2.518513	6.342912
12	275.0	2.439332	324.0	2.510545	6.302836
13	258.0	2.411619	307.0	2.487138	6.185857
14	243.0	2.385606	292.0	2.465382	6.078112
15	214.0	2.330413	263.0	2.419955	5.856185
16	197.0	2.294466	246.0	2.390935	5.716570
17	184.0	2.264817	233.0	2.367355	5.604374
18	165.0	2.217483	214.0	2.330413	5.430828
19	160.0	2.204119	209.0	2.320146	5.383078
20	135.0	2.130333	184.0	2.264817	5.129399
21	121.0	2.082785	170.0	2.230448	4.974902
	314.3	2.453331 (XG = 284.01)		2.528366	6.420995

XL	XS	XL*XS	XL*XS-XG**2	XL+XS	2*XG-(XL+XS)	B
601.0	121.0	72721	-7940.6801	722.0	-153.9800	51.57
555.0	135.0	74925	-5736.6801	690.0	-121.9800	47.03
						49

LOG (X + 49) = 2.5283 + 0.2440*KSI

T	KSI	LOG(X+B)	X
100	1.6450	2.9298	801.7
50	1.4520	2.8827	714.3
30	1.2967	2.8448	650.5
20	1.1630	2.8121	599.9
10	0.9062	2.7495	512.7
5	0.5951	2.6735	422.6
3	0.3045	2.6026	351.5
2	0.0000	2.5283	288.5

Table II-9 3 Maximum Daily Rainfall (Station No. 4634085)

Order	3 Maximum Daily Rainfall	Date	$F_n = (1 - \frac{2n-1}{2N})x100$	Remarks
1	601mm	1976.11.27-29	97.6%	75+340+186mm
2	555	1966.12.27-29	92.9	72+282+201
3	519	1967.1.4-6	88.1	70+69+380
4	438	1970.12.29-31	83.3	262+51+125
5	427	1969.11.29-12.1	78.6	155+126+146
6	419	1971.3.15-17	73.8	203+212+4
7	419	1973.12.8-10	69.0	76+205+138
8	350	1975.12.13-15	64.3	50+130+170
9	326	1960.12.7-9	59.5	90+68+168
10	315	1974.12.7-9	54.8	150+90+75
11	281	1961.12.24-26	50.0	59+35+187
12	275	1959.11.22-24	45.2	161+57+57
13	258	1957.11.28-30	40.5	29+51+178
14	243	1963.12.4-6	35.7	90+104+49
15	214	1968.10.28-30	31.0	44+119+51
16	197	1958.11.7-9	26.2	0+187+10
17	184	1965.12.12-14	21.4	70+67+47
18	165	1962.10.20-22	16.7	85+0+80
19	160	1964.2.10-12	11.9	64+66+30
20	135	1972.9.14-16	7.1	28+33+74
21	121	1977.2.7-9	2.4	48+65+8

Fig. II-4 Probable Value of 3 Maximum Daily Rainfall by Hazen-Plot.

(Station No. 4634085)

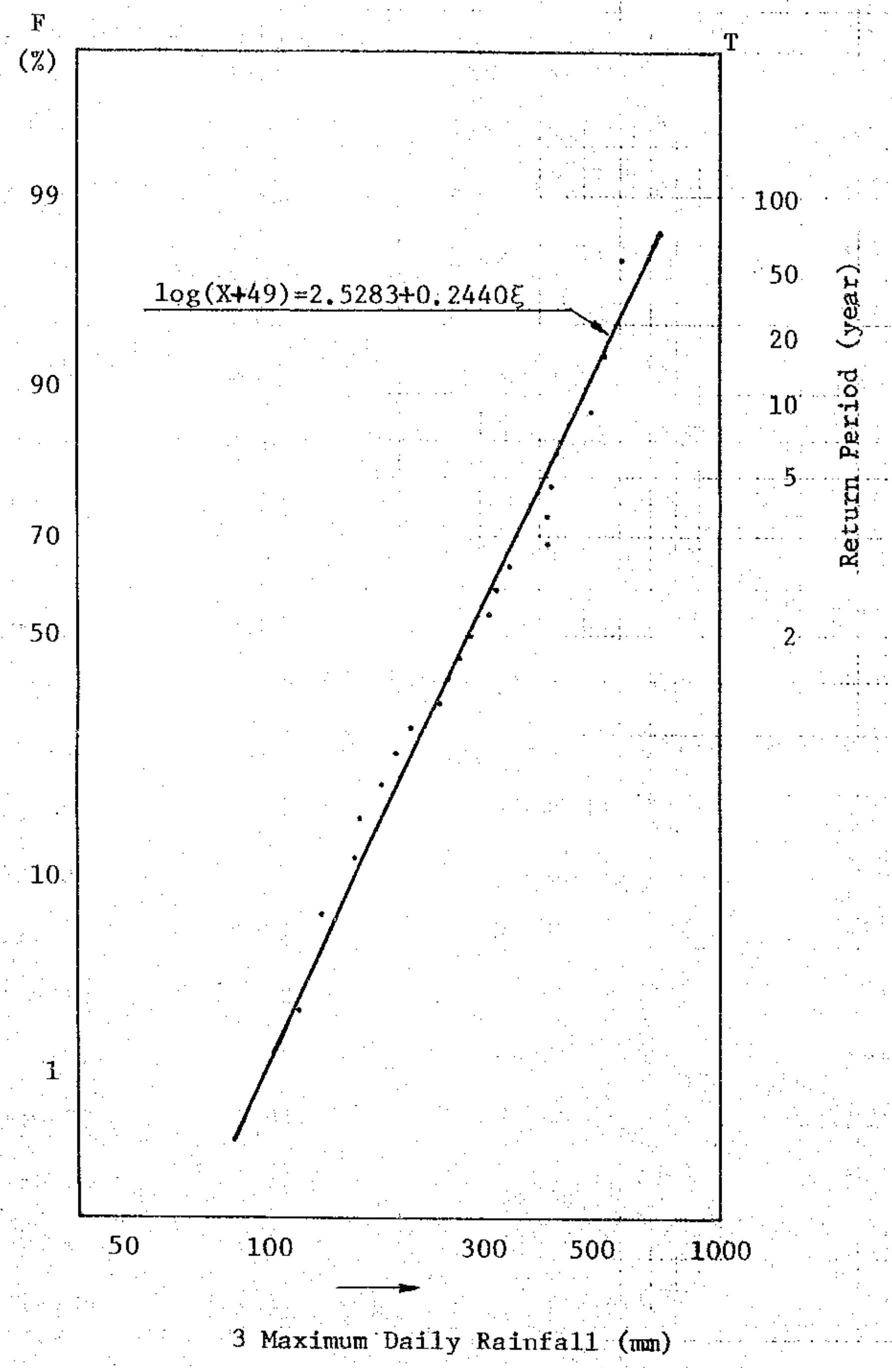


Table II-10 Calculation of Probability of Available Rainfall

N	X	LOG X	X + B	Y=LOG(X + B)	Y**2
1	2773.0	3.442949	1879.0	3.273926	10.718596
2	2389.0	3.378216	1495.0	3.174641	10.078346
3	2354.0	3.371806	1460.0	3.164352	10.013128
4	2319.0	3.365300	1425.0	3.153814	9.946548
5	2297.0	3.361160	1403.0	3.147057	9.903971
6	2075.0	3.317018	1181.0	3.072249	9.438719
7	2043.0	3.310268	1149.0	3.060320	9.365558
8	2043.0	3.310268	1149.0	3.060320	9.365558
9	1995.0	3.299942	1101.0	3.041787	9.252470
10	1901.0	3.278982	1007.0	3.003029	9.018186
11	1891.0	3.276691	997.0	2.998695	8.992172
12	1867.0	3.271144	973.0	2.988112	8.928818
13	1822.0	3.260548	928.0	2.967547	8.806340
14	1646.0	3.216429	752.0	2.876217	8.272629
	2101.0	3.318623 (XG = 2082.68)		3.070148	9.435789

XL	XS	XL*XS	XL*XS-XG**2	XL+XS	2*XG-(XL+XS)	B
2773.0	1646.0	4564358	226802.0176	4419.0	-253.6400	-894.19
						-894

LOG (X - 894) = 3.0701 - 0.1466*KSI

T	KSI	LOG(X + B)	X
100	1.6450	2.8289	1568.4
50	1.4520	2.8572	1613.8
30	1.2967	2.8800	1652.6
20	1.1630	2.8996	1687.6
10	0.9062	2.9372	1759.5
5	0.5951	2.9828	1855.3
3	0.3045	3.0255	1954.4
2	0.0000	3.0701	2069.2

Table II-11 Available Rainfall

n	Available Rainfall	Year	F (%) = $(1-\frac{2n-1}{2N})\times 100$	Remarks
1	1646	1964	96.4	
2	1822	1959	89.2	
3	1867	1960	82.1	
4	1891	1970	75.0	
5	1901	1965	67.8	
6	1995	1969	60.7	
7	2043	1971	53.5	
8	2043	1968	46.4	
9	2075	1967	39.2	
10	2297	1974	32.1	
11	2319	1973	25.0	
12	2354	1966	17.8	
13	2389	1961	10.7	
14	2773	1975	3.5	

Fig. II-5 Probable Value of Available Rainfall by Hazen-Plot

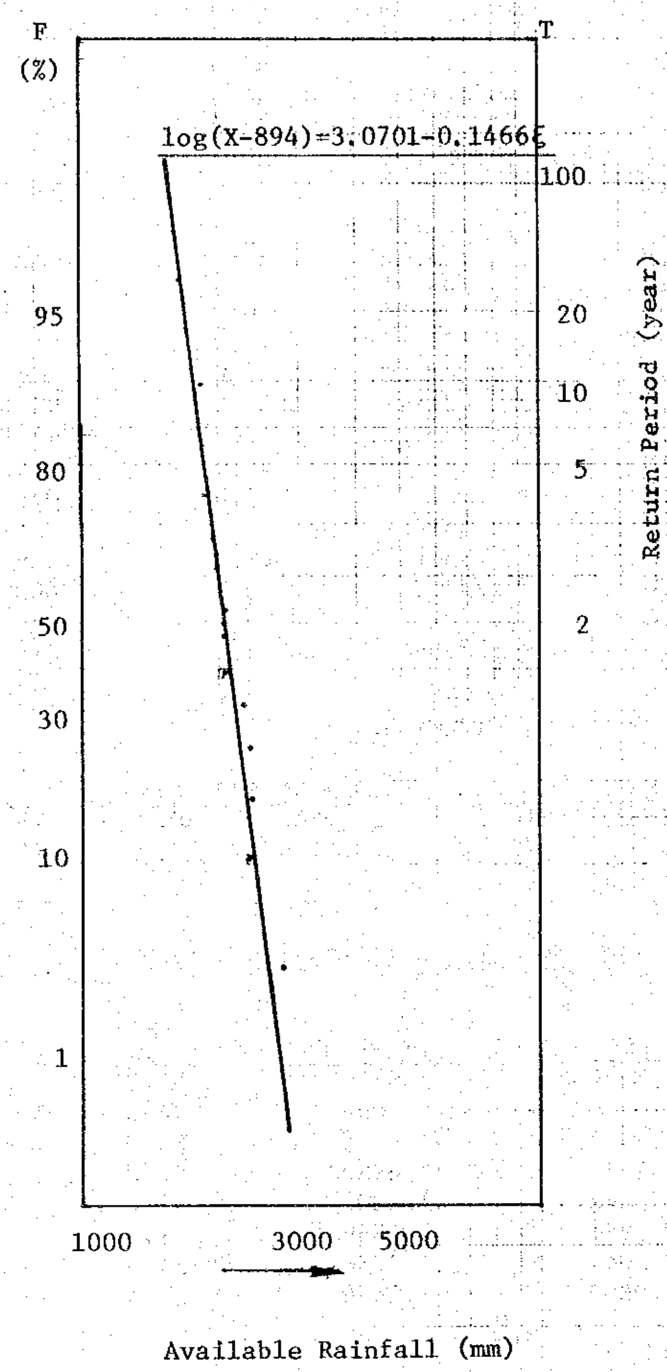


Table II-12 Calculation of Probability of Continuous Drought Days

N	X	LOG X	X + B	Y=LOG(X + B)	Y**2
1	63.0	1.799340	52.0	1.716003	2.944667
2	62.0	1.792391	51.0	1.707570	2.915795
3	58.0	1.763427	47.0	1.672097	2.795911
4	55.0	1.740362	44.0	1.643452	2.700936
5	43.0	1.633468	32.0	1.505149	2.265476
6	40.0	1.602059	29.0	1.462397	2.138607
7	37.0	1.568201	26.0	1.414973	2.002149
8	32.0	1.505149	21.0	1.322219	1.748263
9	31.0	1.491361	20.0	1.301029	1.692679
10	31.0	1.491361	20.0	1.301029	1.692679
11	27.0	1.431363	16.0	1.204119	1.449904
12	27.0	1.431363	16.0	1.204119	1.449904
13	24.0	1.380211	13.0	1.113943	1.240869
14	24.0	1.380211	13.0	1.113943	1.240869
15	24.0	1.380211	13.0	1.113943	1.240869
16	23.0	1.361727	12.0	1.079181	1.164632
17	23.0	1.361727	12.0	1.079181	1.164632
18	23.0	1.361727	12.0	1.079181	1.164632
19	23.0	1.361727	12.0	1.079181	1.164632
20	21.0	1.322219	10.0	1.000000	1.000000
21	20.0	1.301029	9.0	0.954242	0.910578
22	17.0	1.230448	6.0	0.778151	0.605519
	33.0	1.485959 (XG = 30.62)		1.265687	1.667919

XL	XS	XL*XS	XL*XS-XG**2	XL+XS	2*XG-(XL+XS)	B
63.0	17.0	1071	133.4156	80.0	-18.7600	-7.11
62.0	20.0	1240	302.4156	82.0	-20.7600	-14.57
						-11

LOG (X - 11) = 1.2656 + 0.3717*KSI

T	KSL	LOG(X + B)	X
100	1.6450	1.8772	86.3
50	1.4520	1.8054	74.8
30	1.2967	1.7477	66.9
20	1.1630	1.6980	60.8
10	0.9062	1.6025	51.0
5	0.5951	1.4869	41.6
3	0.3045	1.3788	34.9
2	0.0000	1.2656	29.4

Table II-13 Continuous Drought Days

n	Continuous Drought Days	Year	$Fn(\%) = (1- \frac{2n-1}{2N})x100$	Remarks
1	63	1957	97.7	31/3-1/6
2	62	1958	93.2	12/3-12/5
3	58	1963	88.6	17/3-13/5
4	55	1976	84.1	7/1-1/3
5	43	1968	79.6	6/2-20/3
6	40	1971	75.0	21/3-29/4
7	37	1977	70.4	26/3-1/5
8	32	1962	65.9	15/4-16/5
9	31	1969	61.3	11/4-11/5
10	31	1970	56.8	7/2-9/3
11	27	1960	52.2	8/3-3/4
12	27	1967	47.7	12/3-7/4
13	24	1961	43.1	15/5-7/6
14	24	1973	38.6	9/2-4/3
15	24	1978	34.1	2/3-25/3
16	23	1964	29.5	2/7-24/7
17	23	1966	25.0	29/3-20/4
18	23	1972	20.4	21/2-13/2
19	23	1975	16.0	4/9-26/9
20	21	1959	11.3	18/8-7/9
21	20	1965	6.8	17/1-5/2
22	17	1974	2.2	16/1-1/2

Fig. II-6 Probable Value of Continuous Drought Days by Hazen-Plot

(Station No. 4634085)

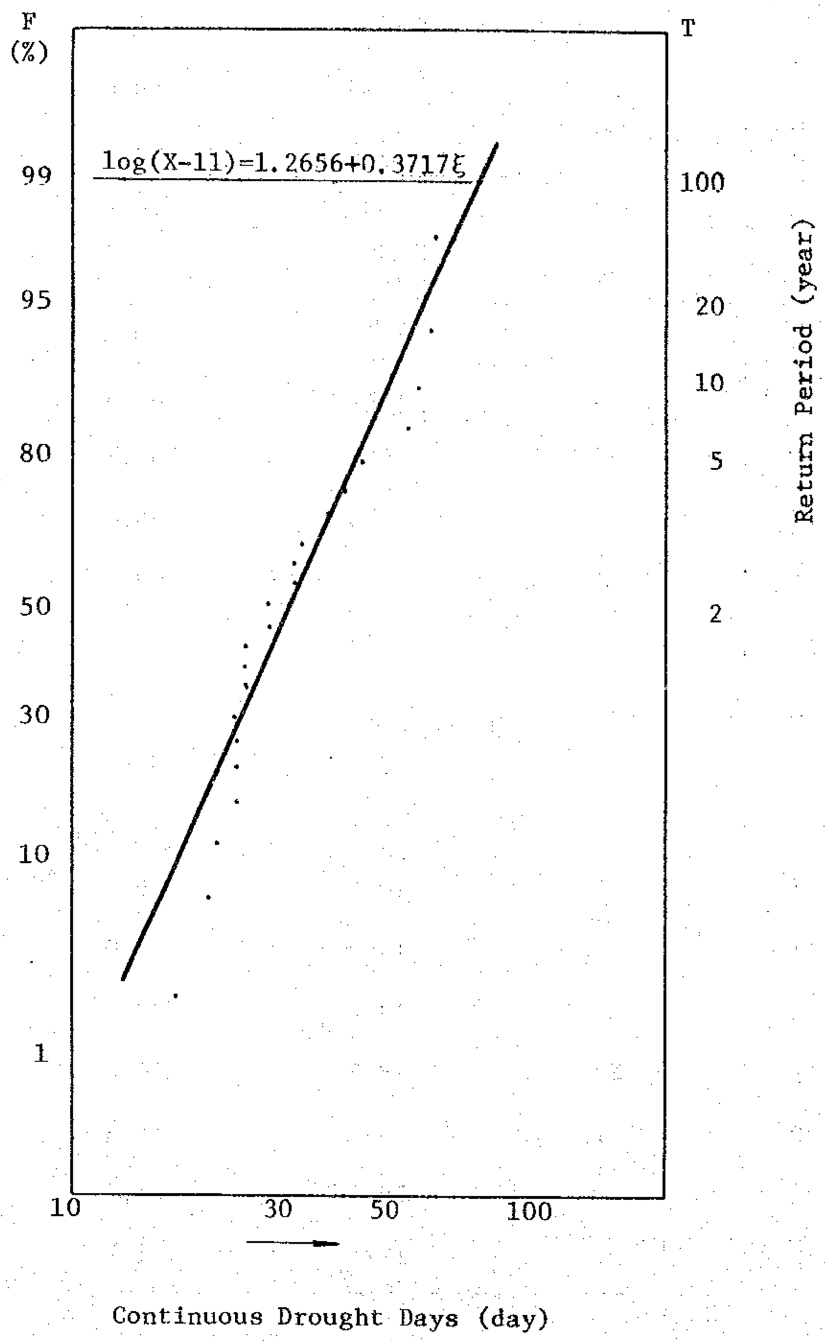


Table II-14 Evaporation

	Open Water Evaporation	Forest Evaporation	Grass Evaporation
JAN.	4.5 mm/day	3.9 mm/day	3.6 mm/day
FEB.	4.8	4.3	3.9
MAR.	5.5	4.8	4.5
APR.	5.3	4.7	4.3
MAY	5.0	4.4	4.1
JUN	4.7	4.1	3.8
JUL.	4.6	4.1	3.8
AUG.	4.9	4.3	3.9
SEPT.	4.8	4.2	3.9
OCT.	4.6	4.1	3.7
NOV.	4.0	3.5	3.2
DEC.	4.0	3.5	3.2
MEAN	4.7	4.2	3.8

B. Flood Protection

1. Design of Embankment

1.1 Determining the height of planned embankment

Water level measurements of the Paka river were conducted at a point in Durian Mentangau about 1 km upstream of the Bukit Bauk area and at a point in Kg. Luit about 15 kilometers in the upper reaches. Measurements at Durian Mentangau were conducted with staff at flood time only since 1973, while measurements at Kg. Luit were conducted by an automatic recording water gauge since 1973. The data obtained at Durian Mentangau will be incorporated in determining the height of the planned embankment.

Table II-5 shows the measurement results at Durian Mentangau. The measurement values were obtained from only the 8 floods occured during the 1973-1978 period.

The planned embankment height will be determined by obtaining the correlation between the peak water level at flood time and the daily precipitation as flood records are scarce, and then estimate the 1/10th probability daily precipitation and the 1/10th probability peak water level. The relationship between daily rainfall and peak water level is as shown in Fig. II-7. When the correlation between the two are to be obtained by the method of least squares, it will be as follows:

$$y = 0.0144x + 11.78$$

y: peak water level (feet)
x: daily precipitation (mm/day)

When the 1/10th probability daily precipitation (293.7 mm/day) is substituted in the above equation:

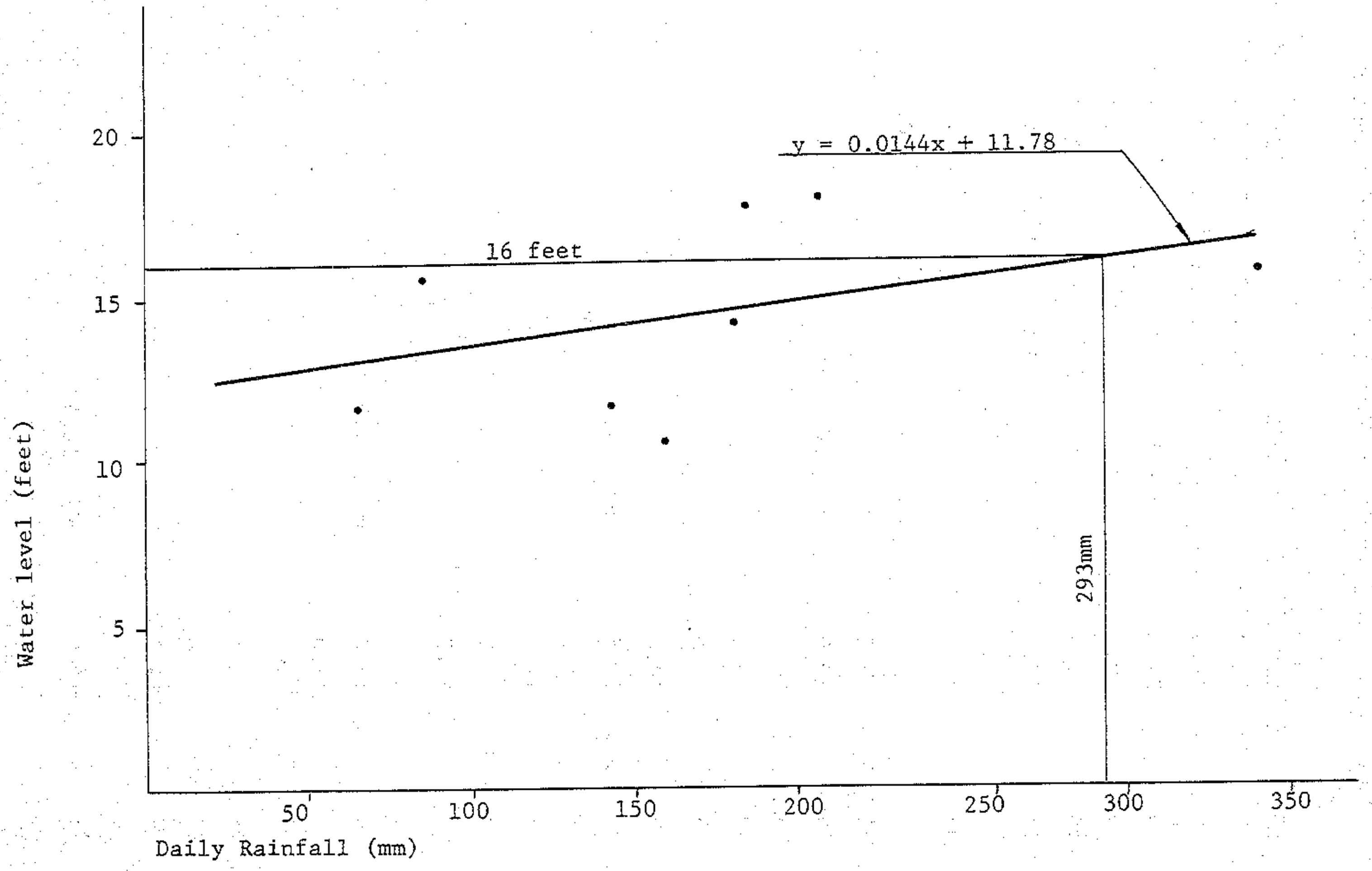
$$y + 0.0144 \times 293.7 + 11.78 = 16.0 \text{ feet.}$$

Thus, the 1/10th probability water level of the Paka river is 16 feet. Therefore, the height of the planned embankment will be 17 feet by giving one foot allowance over the probability peak water level.

Table II-15 Water Level of Paka River (at Durian Mentangau)

Date	Water level	Remarks	Date	Water level	Remarks
Dec. 1, 1973	8.0 feet		Dec. 1, 1975	12.0 feet	
2	10.0		Nov. 27, 1976	8.8	
3	11.2	max. 11.5	28	9.8	
9	9.5		29	12.6	
10	14.9		30	15.5	max. 15.5
11	17.2		Dec. 1, 1976	14.6	
12	17.6	max. 17.8	2	13.5	
22	11.0		3	12.0	
23	17.5	max. 17.5	4	10.0	
Nov. 24, 1974	8.0				
25	10.0	max. 10.5			
26	10.5				
27	9.5				
29	9.0				
30	10.6				
Dec. 31, 1974	11.5	max. 11.5			
Jan. 1, 1975	11.6				
2	11.8				
3	12.1				
4	12.0				
5	13.2				
6	14.0	max. 14.1			
7	14.0				
8	13.8				
Nov. 24, 1975	8.5				
25	9.8				
26	11.0				
27	14.0				
28	15.2	max. 15.4			
29	15.2				
30	14.8				

Fig. II-7 Relationship between Daily Rainfall and Peak Water Level



In Fig. II-8, the twice conducted actual measurement values exceeded the embankment height of E.L. 17 feet. Rainfalls at measurement time were 184 mm/day (average year) and 206 mm/day (return period: 3 years), therefore measurement errors according with the river improvement program in the future, the embankment height should be decided by setting the recurrence period to between 50 and 100 years. However, the return period in this instance was set at 10 years and the embankment height at 17 feet because the agricultural development program has just started.

1.2 Location of the planned embankment

The location of the planned embankment is to be united with the District Road based on the following reasons:

i. The foundation on the older District Road is found more reliable that of the Federal Highway.

ii. As the District Road is on the banking of 1 to 2 meters above the original ground level, the construction of the planned embankment on top of this road require less banking work than constructing the embankment newly along the Paka river.

iii. Soil survey tests have revealed that the foundation along the Paka river is weak and lacks strength.

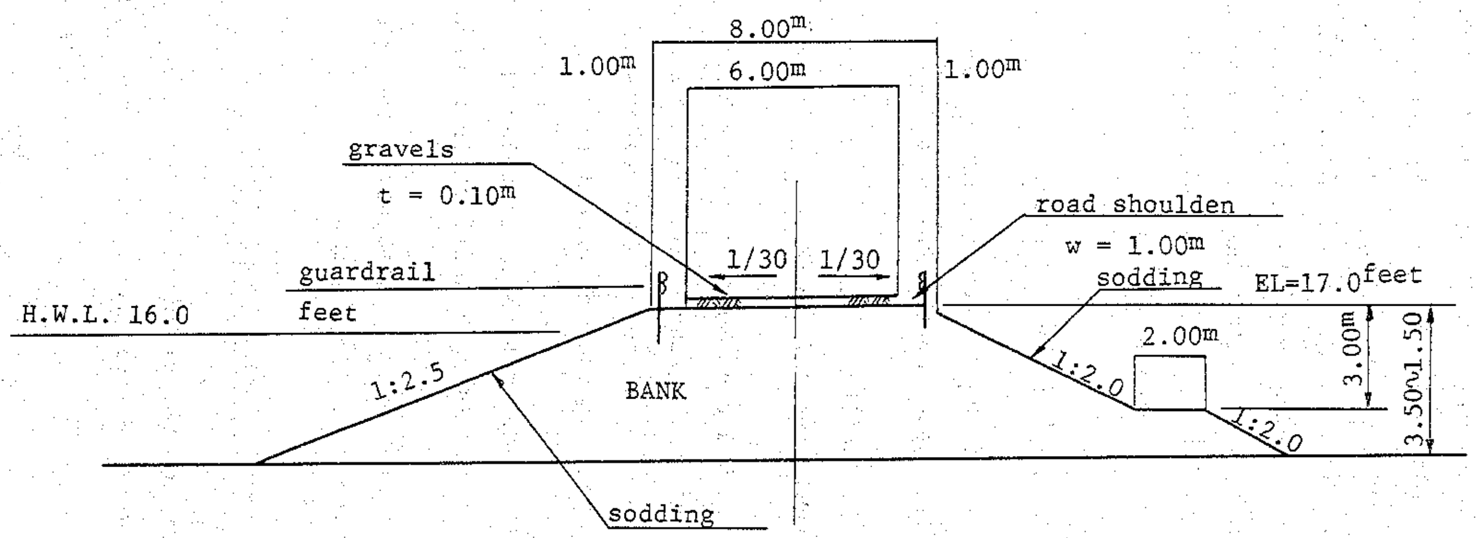
iv. The embankment can also serve as a part of the District Road linking Durian Mentangau.

1.3 Standard sectional view of embankment

Fig. II-8 shows the standard sectional view of the embankment which also serves as part of the district road that links Durian Mentangau.

Fig. II-8 Standard Sectional View of Embankment with Attached Road

SCALE ; 1/200



2. Design of Pumping Station

2.1 Computation of pump water delivery

The pump water delivery is to remove in 3 days the 1/10th probability daily precipitation volume of rainfalls in the district.

$$Q = \frac{A \times R \times 10 \times f}{86,400 \times m}$$

However, Q: pump water delivery (m^3/sec)

A: catchment area (ha) A = 1,911 ha

R: 1/10th probability daily precipitation

R = 293.7 mm/day

f: outflow rate f = 0.7

m: days of water removal m = 3

Therefore,

$$Q = \frac{1,911 \times 293.7 \times 10 \times 0.7}{86,400 \times 3} = 15.2 \ m^3/sec$$

The catchment area of the Paka river is 752.4 km^2, the water course 61 km, and the flood arrival time based on Rziha equation is about 13 hours. But as there are a number of swamps found along the Paka river, the actual flood arrival time is considered to be much longer than that obtained by computation. The catchment area of the river within the pilot project area is 19.1 km^2, the water course 4.8 km and the flood arrival time according to Rziha equation about 2 hours.

As there is a difference in arrival time of the Paka river and the pilot project area, 70% of the pump water delivery obtained from the above equation should be considered as natural outflow. Therefore if the pump is to deliver the remaining 30%, it will be:

$$Q = 15.2 \times 0.3 = 4.6 \ m^3/s = 276 \ m^3/min.$$

2.2 Number of pumps

Two pumps of the same capacity will be used. The amount of water delivery by each pump is:

$$qp = \frac{276}{2} = 138\ m^3/min.$$

2.3 Type of pumps

The pumps will be longitudinal axial diagonal flow types, φ 1,000 m/m.

2.4 Output of prime mover

The output of prime mover is obtained as follows:

$$P = \frac{K.r.Q.H.}{p, q}\ (1 + R)$$

However,
- P: output of prime mover (kw) (PS)
- K: in case of kw 0.163
  in case of PS 0.222
- r: specific gravity of water r = 1.0
- Q: pump discharge volume Q = 138 m^3/min.
- H: total lift of pump H = 5 m
- p: pump efficienty p = 0.80
- q: conductivity when using a reduction gear q = 0.95
- R: marginal coefficient of prime mover
  in case of diesel engine R = 0.2
  in case of electric motor R = 0.15

$$P = \frac{0.163x1.0x138x5}{0.8x0.95}x(1+0.15) = 170kw \text{ or } = 180kw \text{ (by motor)}$$

$$P = \frac{0.222x1.0x138x5}{0.8x0.95}x(1+0.2) = 242PS \text{ or } = 250PS \text{ (by diesel engine)}$$

3. Planning of Driving Canal

A driving canal between the pump site and the Paka river of L = 250 meters will convey water for irrigation and flood drainage. The bed slope of the channel will be level.
As the control reservoir and its surrounding lowlands serve as a flood regulator, the estimated rate of discharge of the driving canal is computed on a daily rainfall daily discharge basis:

$$R = \frac{10\ ARf}{86,400} = \frac{10 \times 1911 \times 293.7 \times 0.7}{86,400} = 45.5\ m^3/sec$$

Checking of water conveyance capacity of the section in Para.

However, $d = 2.0$ meters

$$A = \frac{10 + 18}{2} \times 2.0 = 28.00\ m^2$$

$P = 18.94$ m and

Surface slope $I = 1/500$

$$V = \frac{1}{n} I^{1/2} R^{2/3} = \frac{1}{0.03} \times 0.002^{1/2} \times \left(\frac{28.00}{18.94}\right)^{2/3} = 1.93\ m/sec.$$

$$Q = AV = 28.00 \times 1.93 = 54.04\ m^3/sec$$

The section can sufficiently convey water despite head loss by box calvert.

4. Planning of Control Reservoir

The control reservoir has a dual purpose of controlling irrigation water and pump discharge water. During the flood time, the water peak level can reach 16 feet (E.L. 4.88 meters) within the pilot project area, and the control reservoir regulates the remaining area (below E.L. 2.00 m) of the low marsh land and 835 acres of paddy fields. Therefore, it is not necessary to newly construct a control reservoir for floods.

On the other hand, when planning the irrigation water systems, it was feared that the salt wedge would reach the intake point to make water intake impossible at full tide during the dry season before conducting the survey. However, our survey results revealed that nothing would be affilicted by the salt wedge, and therefore there is no need to build a large scale control reservoir.

From the above reason, the control reservoir will be prepared as a part of the pumping station facility with an area of 80 m x 80 m and the bottom reaching E.L. - 1.50 meters. The reservoir will hold 100 x 100 x 2.00 (20,000 m^3) of water to facilitate smooth pump operation. This volume is equal to the pump's one-hour water delivery capacity.

III. SOIL AND GEOLOGY

A. Soil

1. Introduction

Soil surveying in Malaysia has a history of 50 years. Therefore, the accumulated data on soils is abundant[1]. However, acomprehensive survey of the inland swamp area that occupies the major part of the Pilot Project area has not been attempted to date.

With regard to the Bukit Bauk area that includes the Pilot Project area, a semi-detailed soil survey was conducted after 1973, and in 1976 a survey report containing two maps - a Soil Terrain Classification Map and a Soil-Crop Suitability Map - was issued[2]. With regard to the swamp area in the Pilot Project area, in the report the peat terrain class was classified as 1, and the soil suitability class as 4Do(n) in the soil series. The report indicates that poor drainage and thick organic piles are the important factors restricting crop cultivation, and of the 25 kinds of crops identified, the report says that Kacang Tanah (Groundnut) alone is "margible" while the rest is "unsuitable". But neither a detailed survey nor an actual test on cultivation was conducted.

Also the Hunting Report on Regional Planning and the Development Study in Trengganu Tengah which were commissioned[3], excluded the swamp area because it was and is considered to have a low possibility of agricultural development. In this manner, this swamp area hitherto remained untouched. Therefore the soil map uses Great Soil Units. For example, in the Generalized Soil Map of West Malaysia (1970), the Soil Units are Organic Soils with Gley Soils and Alluvial Soils & Gley Soils on Recent Riverine Alluvium. In the semi-detailed soil survey of the Bukit Bauk area mentioned above, the soil units are divided into Peat and Riverine Alluvium. These soil units, according to FAO/UNESCO[1], [2] correspond to Histosols and Gleysols.

---

1): J.K. Coulter; Soils of Malaysia, Soils and Fertilizer 35, 475-498 (1972)

2): Lim Jit Sai and S. Paramananthan; Semi-Detailed Soil Survey of Bukit Bauk Area, Ministry of Agriculture, Malaysia (1976)

3): Hunting Technical Services Ltd.; Final Report Vol. I-IV (1974)

The objective of this feasibility study is to formulate an overall agricultural development project leading to irrigation and drainage development of the Bukit Bauk area which comprises about 7,000 acres in the southern part of the Trengganu Tengah, Dungun District, Trengganu State. It likewise aims to assess the technical feasibility and economic viability of such a pilot project.

Therefore the accuracy of the soil survey should be assessed accordingly. On the other hand, bearing the following conditions in mind, this survey was conducted to a level to classify the Great Soil Units.

i. The greater portion of the survey site occupied an unexplored jungle formed atop peat swamp. Therefore, felling work preceded the soil survey.

ii. Especially at the Deep Woody Peat (Histosols) portion, drainage is necessary after felling, otherwise execution of detailed profile surveying observing the soil profile is impossible.

iii. Despite lack of personnel, the survey period was short.

iv. After deforestation, drastic soil changes in both the Gleysols and Histosols areas are anticipated as drainage proceeds in the future. Therefore, it is essential to conduct the detailed soil survey necessary for cultivation after project implementation.

---

1): FAO-UNESCO; Definitions of Soil Units for the Soil Map of the World (1968)

2): FAO/UNESCO; Soil Map of the World (1974)

2. Procedures of Soil Survey

Field and laboratory studies were conducted as the two major pillars of this soil survey.

2.1 Procedures of field studies and soil sampling

Boring sticks were employed in field studies for a rough survey. Also a soil profile survey and a water quality survey were conducted to comprise the three basic surveys.

2.1.1 Boring sticks were used to survey the types of major soils and the range of soil distribution. The stick surveys were conducted at 150 sites. The results of the survey roughly revealed that the major soils of the Pilot Project area are Histosols, Gleysols and Acrisols according to soil units designated by FAO/UNESCO.

2.1.2 Based on the stick survey results, 20 pits were designated for profile survey. The profile survey results revealed that there are 4 Histosols, 7 Gleysols, 8 Acrisols and 1 Fluvisol.

At each pit, the following items were determined: thickness of horizon and horizon boundary, color of matrix, mottles, texture, gravel, structure, clay coating, porosity, compactness, wetness, identifiable minerals, and rooting.
The survey was conducted by a method specified by the Japanese Government[1).]

As described above, in the deep woody peat portion immersed in water all the year round, it was impossible to observe the soil profile by the ordinary method employed in the other areas. Thus, a profile survey based on a soil profile was not conducted on the two pits associated with such areas of the four pits of Histosols.

---

1): Secretariat of Technical Conference on Agriculture, Forestry and Fisheries; Study on Productivity of Upland Soils. Technical Conference of Agriculture, Forestry and Fisheries, held in Tokyo, 1962.

Instead, various characteristics of the soil profile were estimated from peat specimens collected with the peat sampler[1] and boring core samples (peat and mineral soils) collected by Geotechnique (Malaysia) Sdn. Bhd.[2] (who was authorized to conduct boring tests by the Japanese Survey Team) using the Pilcon Wayfarer drilling machine. For the detailed results of the soil profiles of the 20 pits, refer to the Appendix.

2.1.3 Portable pH meters and portable EC meters were used in the water quality survey at 32 sites.

2.1.4 Soil sampling was conducted to prepare specimens for measurement of the physical properties of soils; to measure the dehydrating and shrinking curves of heavy clay soil (Gleysols) and peat (Histosols); to analyze the chemical properties of soils; to analyze the grading of soils (mechanical analysis) and to analyze the chemical nature of soils (chemical analysis) on consignment. The samples were collected at 10 profiles and 18 horizons, and the breakdown of samples was: Histosols - 2 profiles and 4 horizons, Gleysols - 5 profiles and 8 horizons, Acrisols 2 profiles and 4 horizons, and Fluvisols - 1 profile and 2 horizons. In sampling, more than 5 samples were collected at each horizon, for example, to measure only the physical properties of soils.

---

1): A kind of boring stick which is popular in Japan and made in Japan.

2): Contractor to the Japanese Survey Team for the boring test.

2.2 Procedures of laboratory studies

The following four basic studies were conducted in the laboratory: measurement of physical properties of soils with a volumenometer, measurement of dehydration and shrinkage curves of heavy clay soils (Gleysols) and peats (Histosols) changing from wet to dry conditions, analysis of chemical properties of soil with a soil test kit, and commissioning of mechanical and chemical analysis of soils to Miss I. Jogeswary[1)].

2.2.1 The measurement of the physical properties of soils was performed by employing the actual volumenometer made by Dr. S. Misono, the Soil scientist of the Japanese Feasibility Survey Team. The measured items were total weight W (g/100cc wet soil), actual volume V (cm^3/100 cc wet soil), true density d (g/cm^3), air ratio Av (%), water ratio Mv (%), solid ratio Sv (%), porosity P (%), volume weight S (g/100 cc oven dried soil), saturation percentage (H %) and moisture percentage Mo (%).

2.2.2 The measurement of dehydration and shrinkage curves of heavy clay soils and peat was conducted continuously on soils taken under field moisture conditions until they had reached an air dried soil condition by leaving them intact in the laboratory to clarify the dehydration, drying and shrinkage conditions. The dehydration percentage of air dried soil was measured on a weight basis while the shrinkage percentage was measured on a volume basis.

The specimens were collected keeping the original structure as intact as possible. But with woody peat in wet conditions was measured after gauge dehydration. For heavy clay soil, remolded (rectangular prism) soils were added.

---

1): Agricultural Research and Advisory Bureau - Consultant in Tropical Agriculture, Kajang, Selangor, Malaysia