4-2-3 Water levels of the Little Scarcies

Water level of the Little Scarcies has been influenced by tide level as far as Mange.

Levels to be considered for irrigation and drainage analysis are the highest and lowest high tide of the month and the highest and lowest low tide. These values are listed in Table 4-2-5 for the years 1960, 1961, 1962 and 1963.

Daily water level variations are reported in the following figures.

Fig. 4-2-5 Maximum Water Levels at 6 Places

Fig. 4-2-6 Relationship between Height of Tide and Max. Water Levels at Kagbulo

Fig. 4-2-7 Daily Water Level Variations on 8 Sept. 1982, at Kagbulo and Katik

Fig. 4-2-8 Daily Water Level Variations on 18 Sept. 1982 at Kagbulo, Katik and Konta

Fig. 4-2-9 Daily Water Level Variations on 2 Dec. 1982 at Kagbulo, Katik, Rhombe, Konta, Bomprokom and Katonga

Fig. 4-2-10 Daily Water Level Variations on 16 Dec. 1982 at Kagbulo, Katik and Konta

Fig. 4-2-11 Daily Water Level Variations on 31 Dec. 1982 and 1 Jan. 1983 at Kagbulo, Katik and Konta

Fig. 4-2-12 Daily Water Level Variations on 7 Jan. 1982 at Konta

Fig. 4-2-13 Daily Water Level Variations on 18 Jan. 1983 at Kagbulo, Katik and Konta

Table 4-2-5 Monthly Summary of Water Levels Measured for the Little Scarcies

	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
(Kagbulo)	1960				28.77	28.56	28.67	29.96	29.11	29.26	29.17	28.99	28.65
Maximum Hihg Tide	1961	28.71	28.71	28.99	28.77	28.77	28.77	29.26	29.26	29.26	29.14	29.14	28.80
Value for the Month	1962	28.65	28.80	29.02	28.86	28.80	28.83	29.14	29.35	29.29	29.05	29.05	29.20
	1963	28.83	28.83	28.83	28.99		28.90	29.29				29.29	29.08
	1982									29.39			
(Kagbulo)	1960				28.13	28.22	28.29	28.47	28.35	28.65	28.16	28.13	28.04
Minimum High Tide	1961	28.16	28.10	28.13	28.13	28.13	28.50	28.50	28.65	28.65	28.65	28.47	28.16
Value for the Month	1962	28.35	28.13	28.16	28.25	28.25	28.38	28.53	28.47	28.83	28.50	28.68	28.35
	1963	28.38	28.38	28.38	28.50		28.38	28.41				28.71	28.50
	1982									28.59			
(Kagbulo)	1960				27.25	27.25	27.34	27.74	28.35	28.77	28.38	27.80	27.16
Maximum Low Tide	1961	27.37	27.40	27.01	27.55	27.25	27.55	28.65	28.80	28.80	28.16	27.77	27.28
Value for the Month	1962	27.16	27.13	27.16	27.28	27.13	27.19	28.10	29.29	29.29	28.86	28.07	28.07
	1963	27.37	27.37	27.37	27.58		27.49	28.19				28.38	27.68
	1982												
(Kagbulo)	1960				26.76	26.85	26.85	27.28	26.91	27.77	27.46	26.94	26.82
Minimum Low Tide	1961	26.94	26.94	26.82	26.94	26.91	27.13	27.13	28.16	28.04	27.43	27.13	26.91
Value for the Month	1962	26.85	26.82	26.82	26.85	26.82	26.91	27.22	27.86	28.71	28.07	27.55	27.13
	1963	27.07	27.07	27.04	27.04		27.13	27.01				27.19	27.13
	1982												
(Konta)	1960				28.74	28.74					29.26	29.25	29.08
Maximum High Tide	1961	28.80	28.80	28.93	28.77	28.77	28.77	29.38	29.38	29.75	29.26	29.26	28.99
Value for the Month	1962	28.99	28.99	28.99	29.29	28.99	28.99	29.29	29.57	29.57	29.29	29.29	29.20
	1963			28.99			28.65	28.96					
	1982	28.06 (1983)											
(Konta)	1960				28.47	28.47					28.35	28.44	28.32
Minimum Hihg Tide	1961	28.32	28.32	28.22	28.35	28.13	28.35	28.65	28.96	28.77	28.44	28.35	28.35
Value for the Month	1962	28.50	28.38	28.38	28.38	28.38	28.38	28.71	28.71	28.99	28.68	28.68	28.38
	1963			28.35			28.32	28.41					
	1982	28.06 (1983)											
(Konta)	1960				27.89	27.89					28.62	27.32	27.55
Maximum Low Tide	1961	27.28	27.28	27.28	27.43	27.43	27.43	28.77	29.08	29.57	28.77	28.04	27.43
Value for the Month	1962	27.77	27.58	27.46	28.04	27.77	27.77	28.68	29.44	29.38	28.99	28.53	28.38
	1963			27.68			27.68	27.68					
	1982												
(Konta)	1960				27.68	27.71					27.74	27.22	27.91
Minimum Low Tide	1961	26.94	26.94	26.94	26.94	27.10	26.94	27.25	28.35	28.41	27.74	27.19	27.10
Value for the Month	1962	27.16	27.16	27.16	27.19	27.19	27.28	27.46	28.35	28.68	28.07	27.80	27.19
	1963			27.19		27.25	27.22						
	1982	27.00 (1983)											
(Kikam)	1960				27.65	27.65	27.65	27.40	27.74	28.80	28.04	27.68	27.61
Minimum Low Tide	1961	27.43	27.46	27.43	27.46	27.43	27.46	27.49	28.65	28.77	28.04	27.46	27.49
Value for the Month	1962	27.52	27.74	27.77	27.77	27.80	28.10	28.38	28.77	29.17	28.10	27.58	27.37
	1963		27.43	27.43									

Measured by Irrigation and Drainage Department of the Ministry of Agriculture.

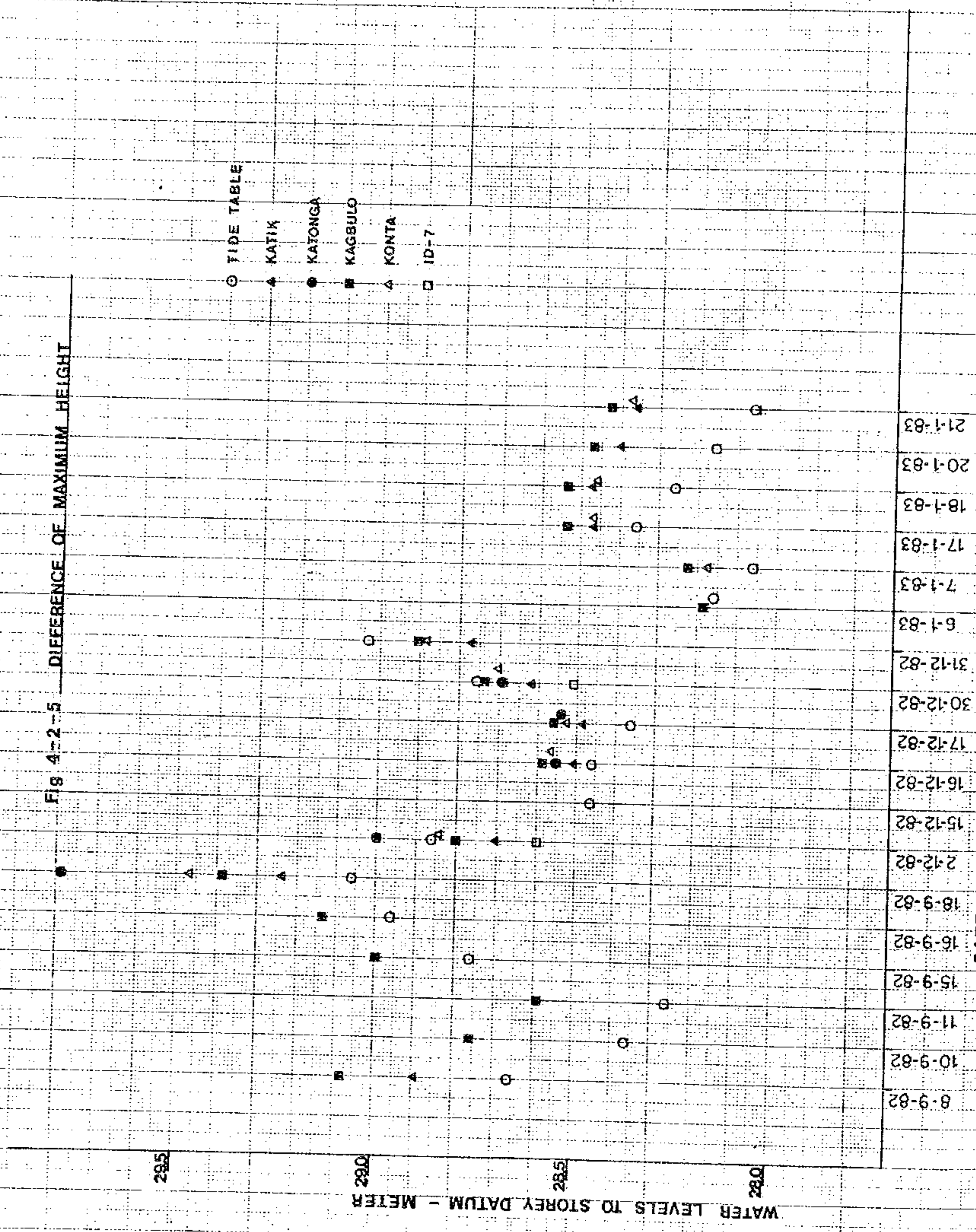
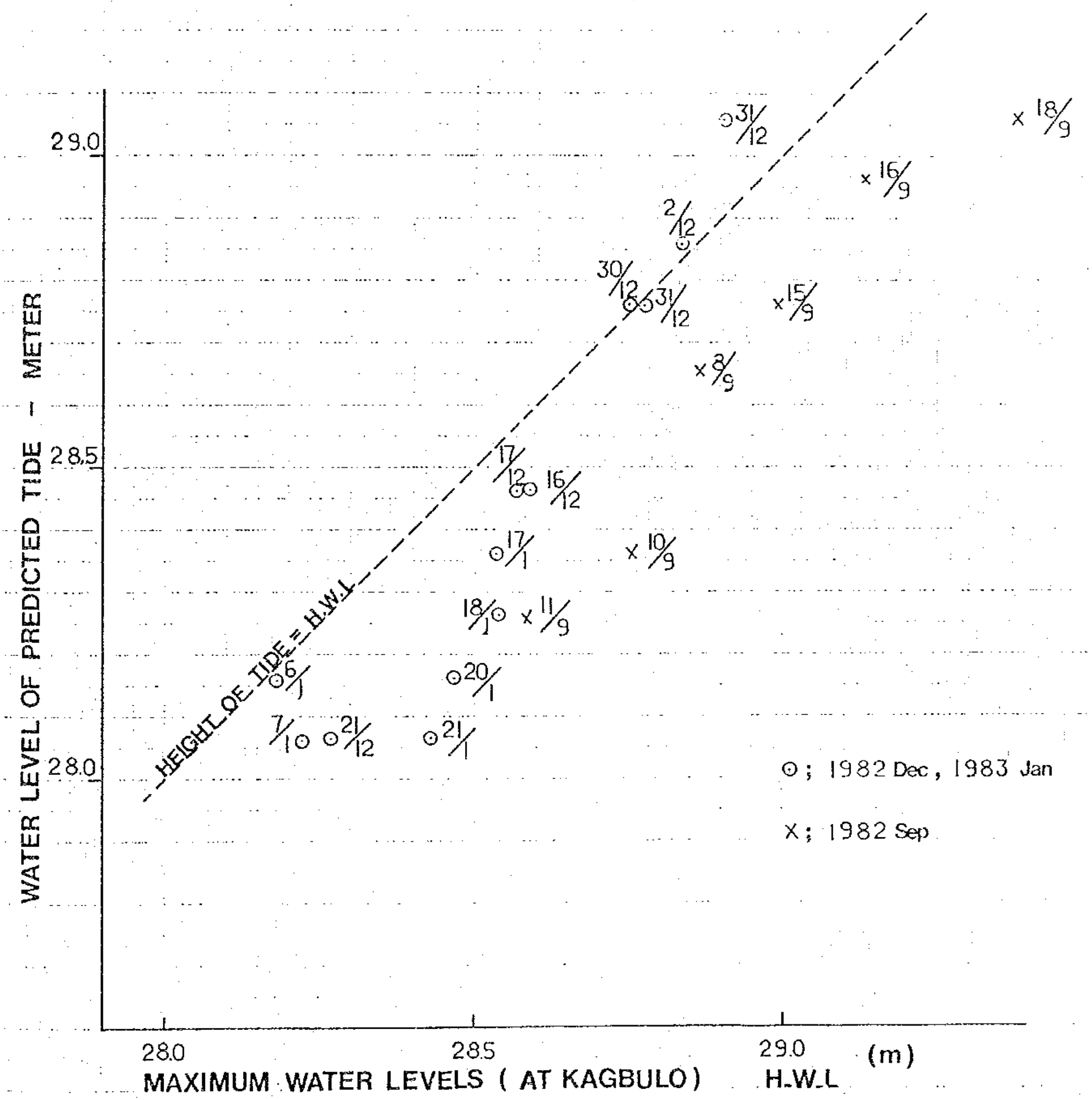


Fig 4-2-5 DIFFERENCE OF MAXIMUM HEIGHT

Fig 4-2-6 RELATIONSHIP BETWEEN HEIGHT OF TIDE AND MAX WATER LEVEL (AT KAGBULO)



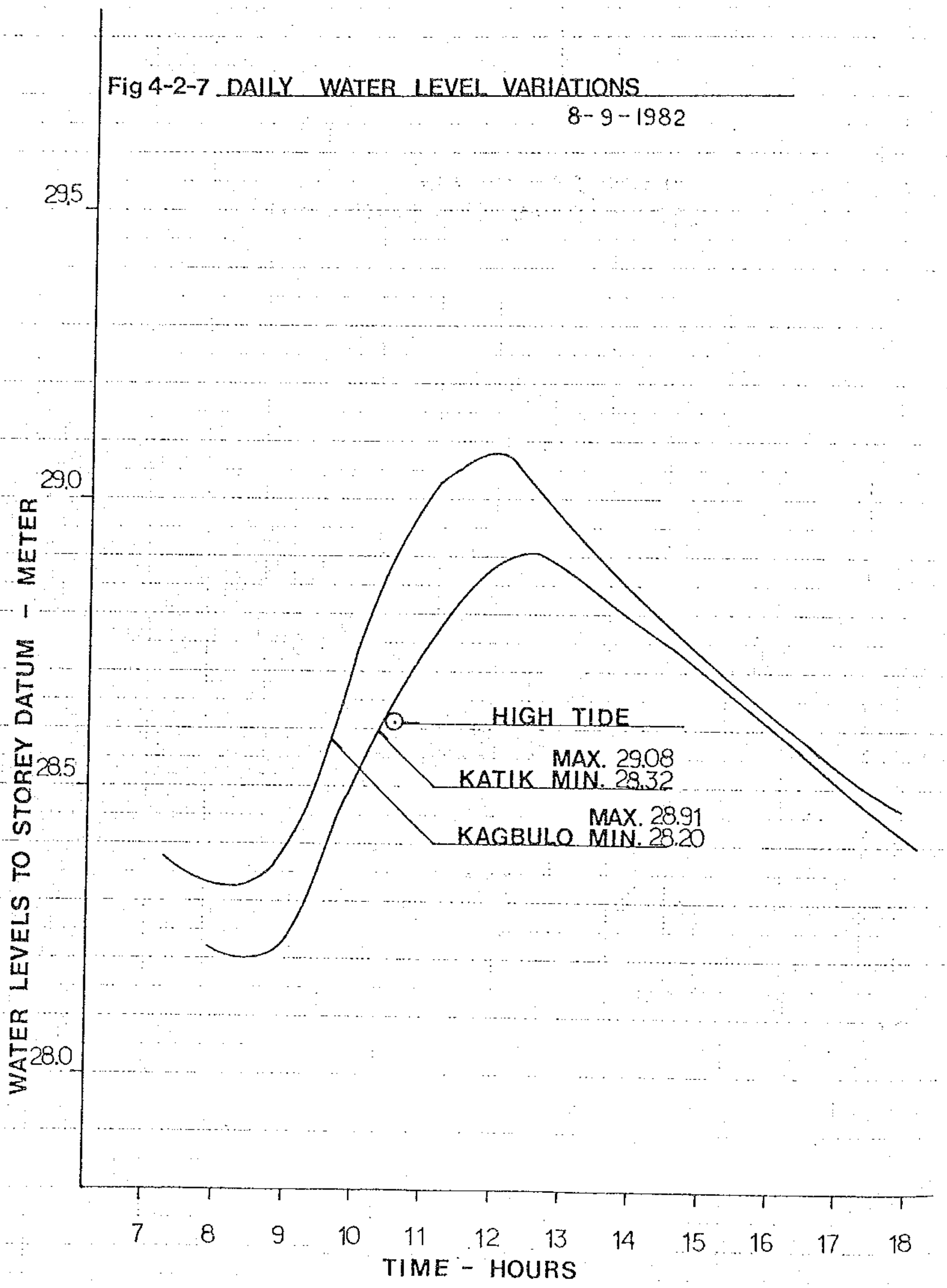


Fig 4-2-7 DAILY WATER LEVEL VARIATIONS
8-9-1982
29.5
29.0
28.5
28.0
WATER LEVELS TO STOREY DATUM - METER
HIGH TIDE
MAX. 29.08
KATIK MIN. 28.32
MAX. 28.91
KAGBULO MIN. 28.20
7
8
9
10
11
12
13
14
15
16
17
18
TIME - HOURS

Fig 4-2-8 DAILY WATER LEVEL VARIATIONS
18-9-1982

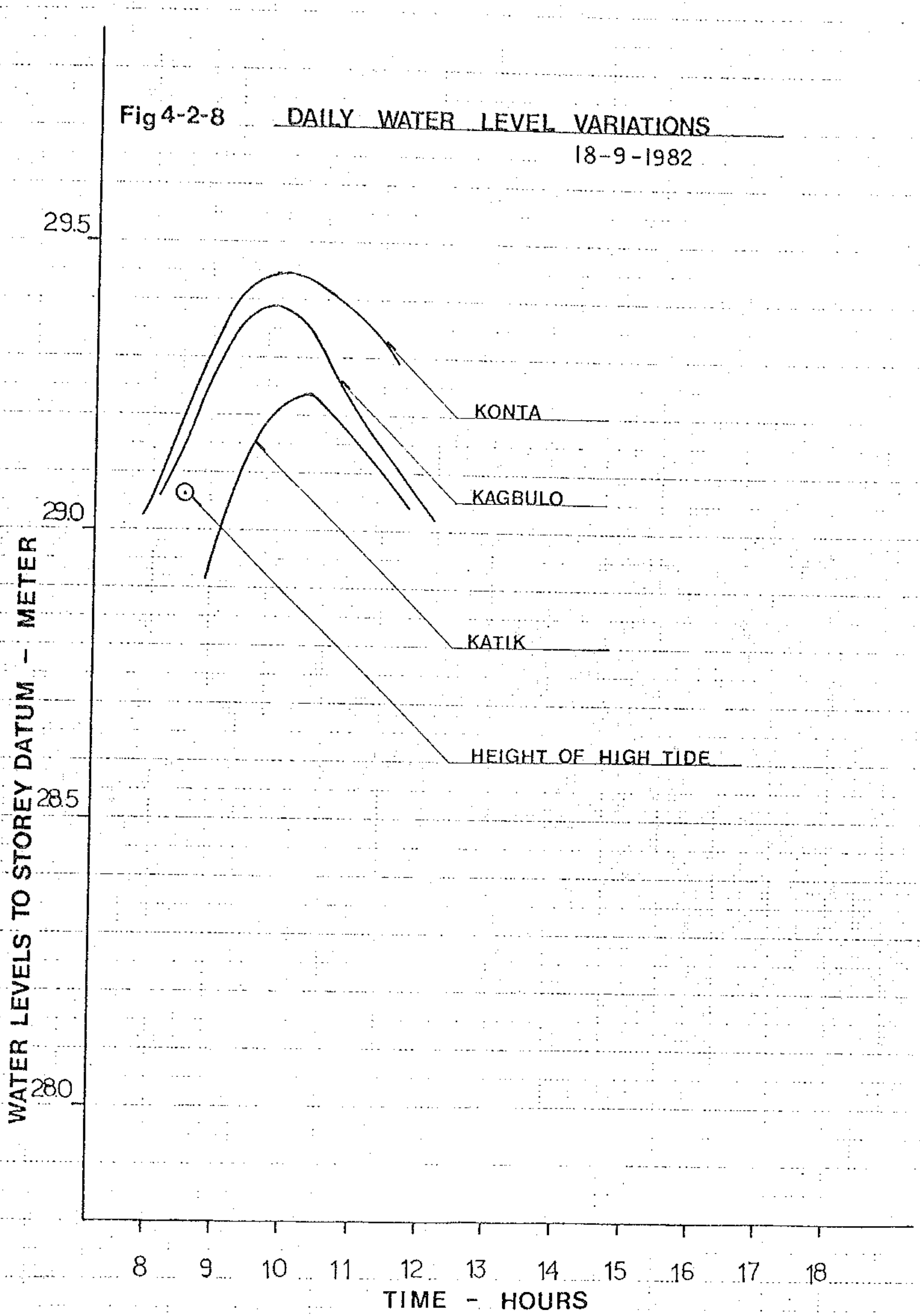
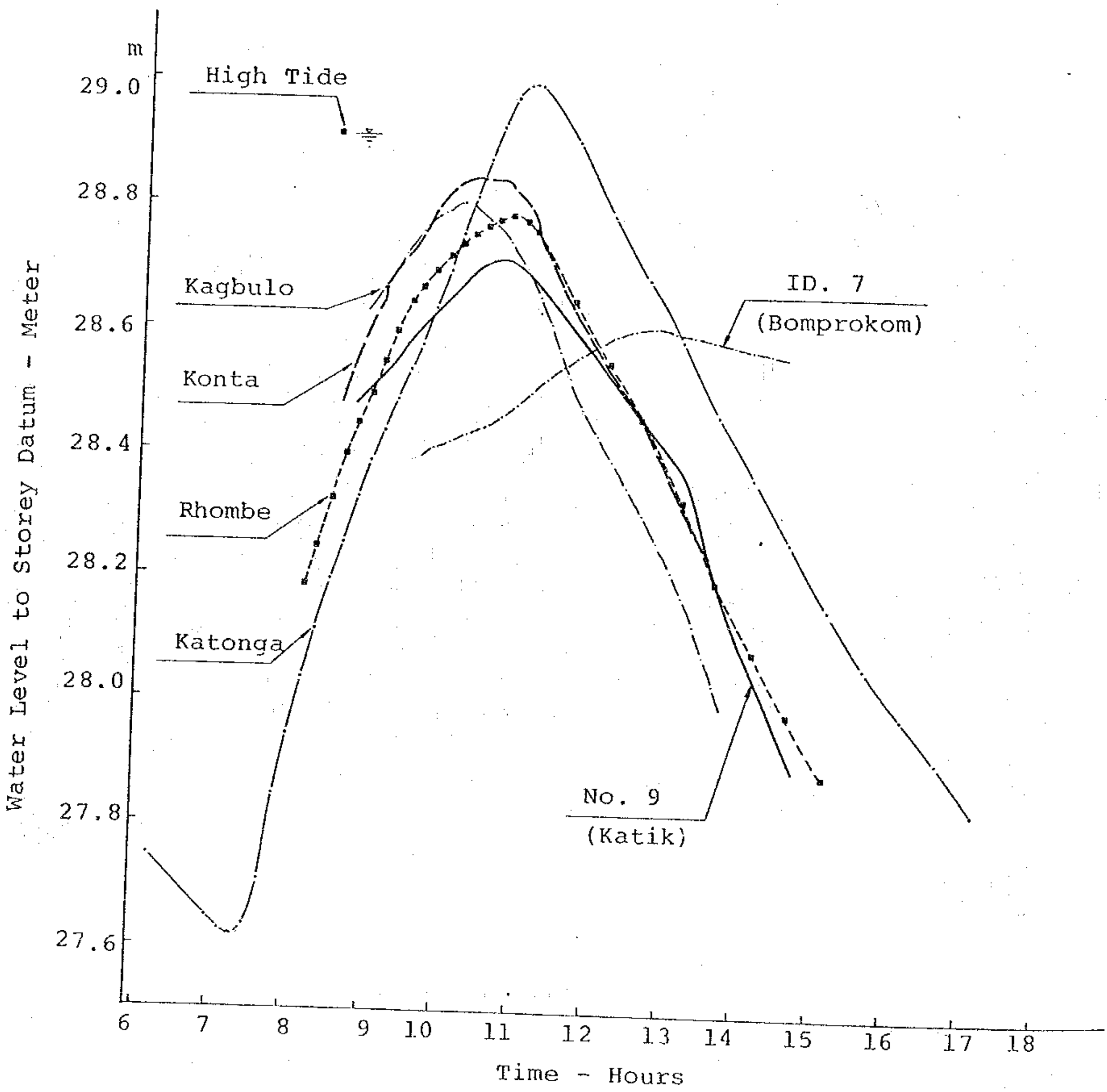


Fig. 4-2-9 DAILY WATER LEVEL VARIATIONS 2-12-1982

(FULL MOON SPRING TIDE)



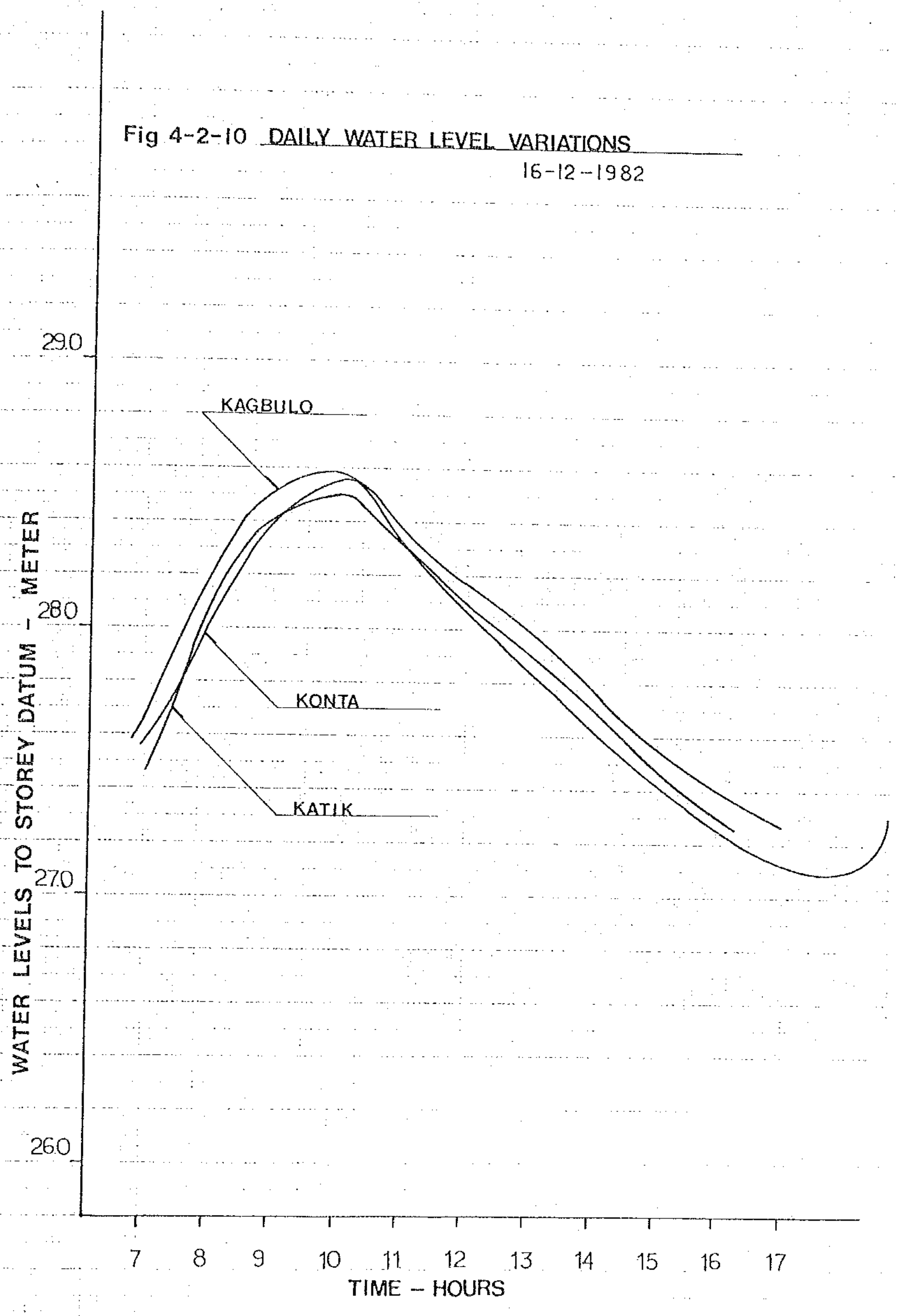


Fig 4-2-10 DAILY WATER LEVEL VARIATIONS
16-12-1982
KAGBULO
KONTA
KATIK
29.0
28.0
27.0
26.0
WATER LEVELS TO STOREY DATUM - METER
7
8
9
10
11
12
13
14
15
16
17
TIME - HOURS

Fig 4-2-11 DAILY WATER LEVEL VARIATIONS 31 DEC. 1982

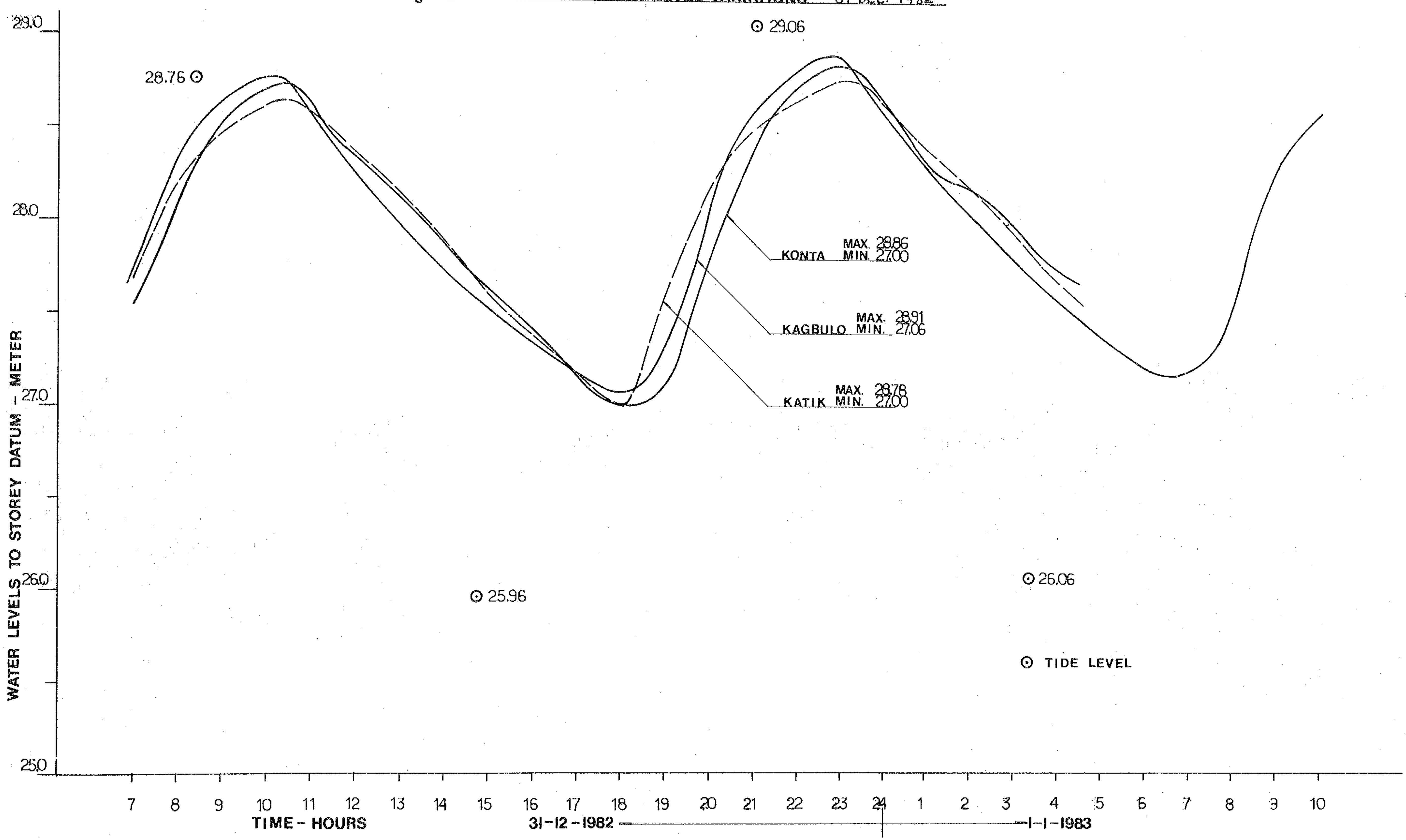


Fig 4-2-12 DAILY WATER LEVEL VARIATIONS AT KONTA 7-1-1983

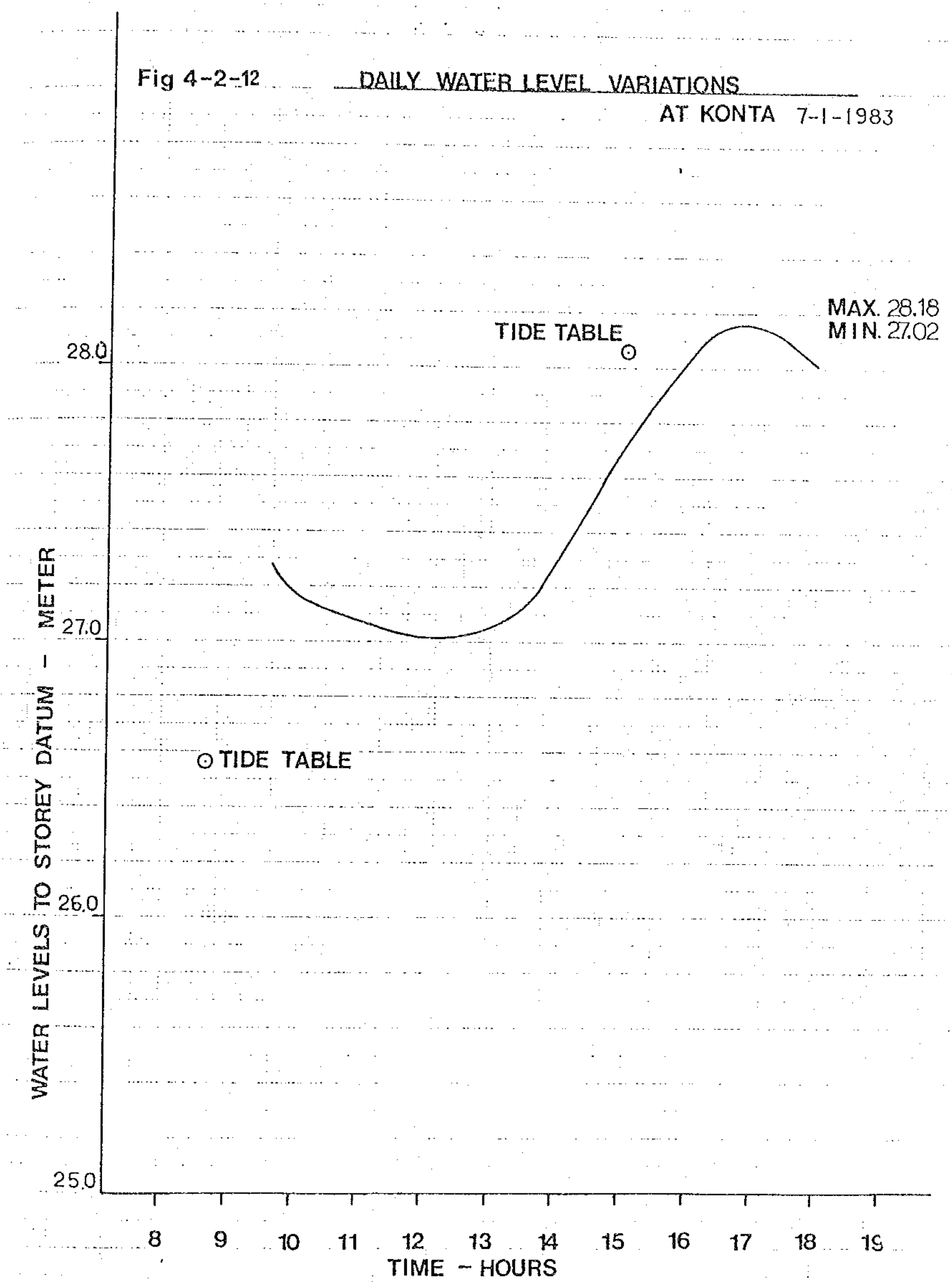


Fig 4-2-13 DAILY WATER LEVEL VARIATION

18-1-1983

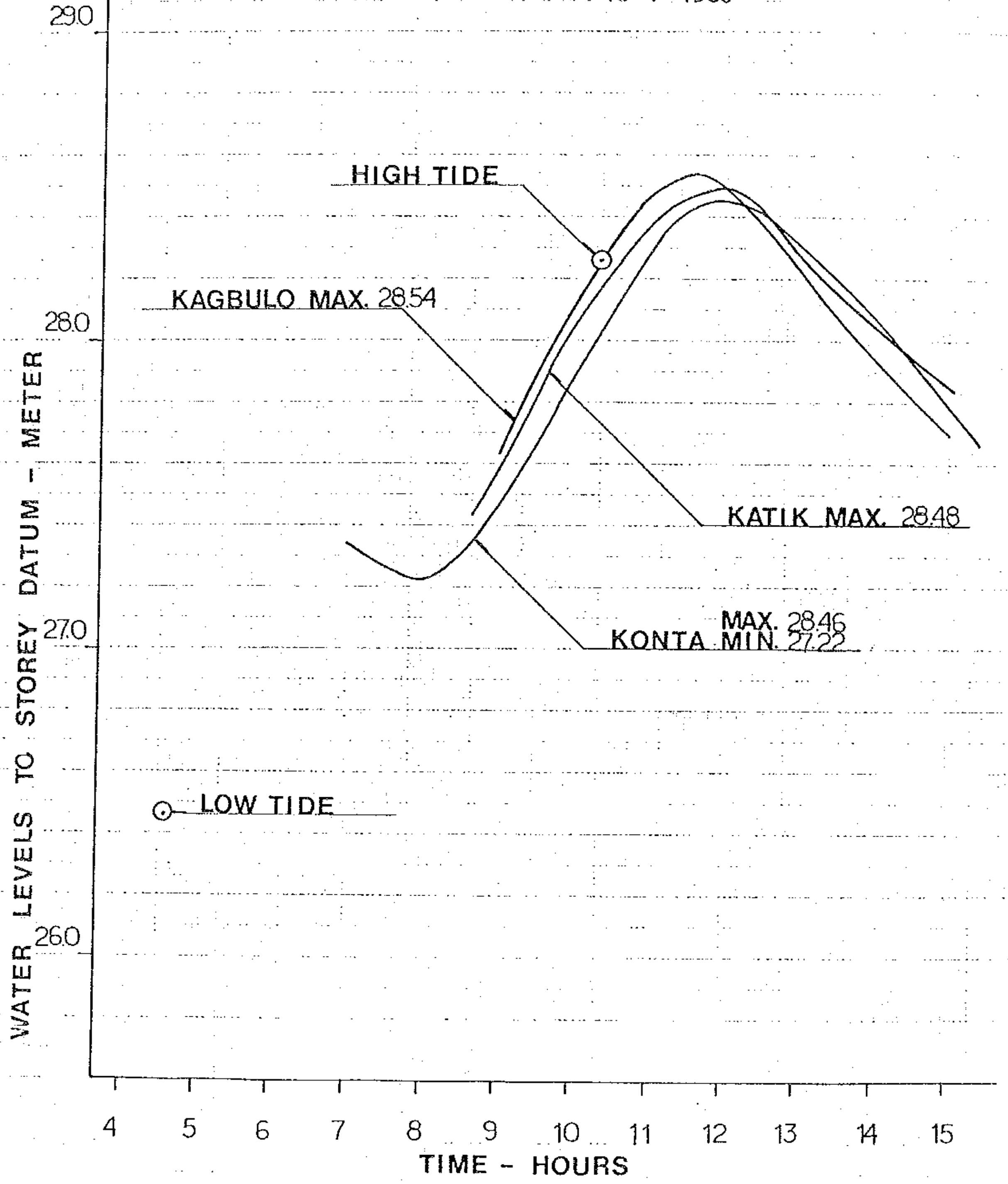


Fig 4-2-14 DAILY WATER LEVEL VARIATIONS

21-1-1983

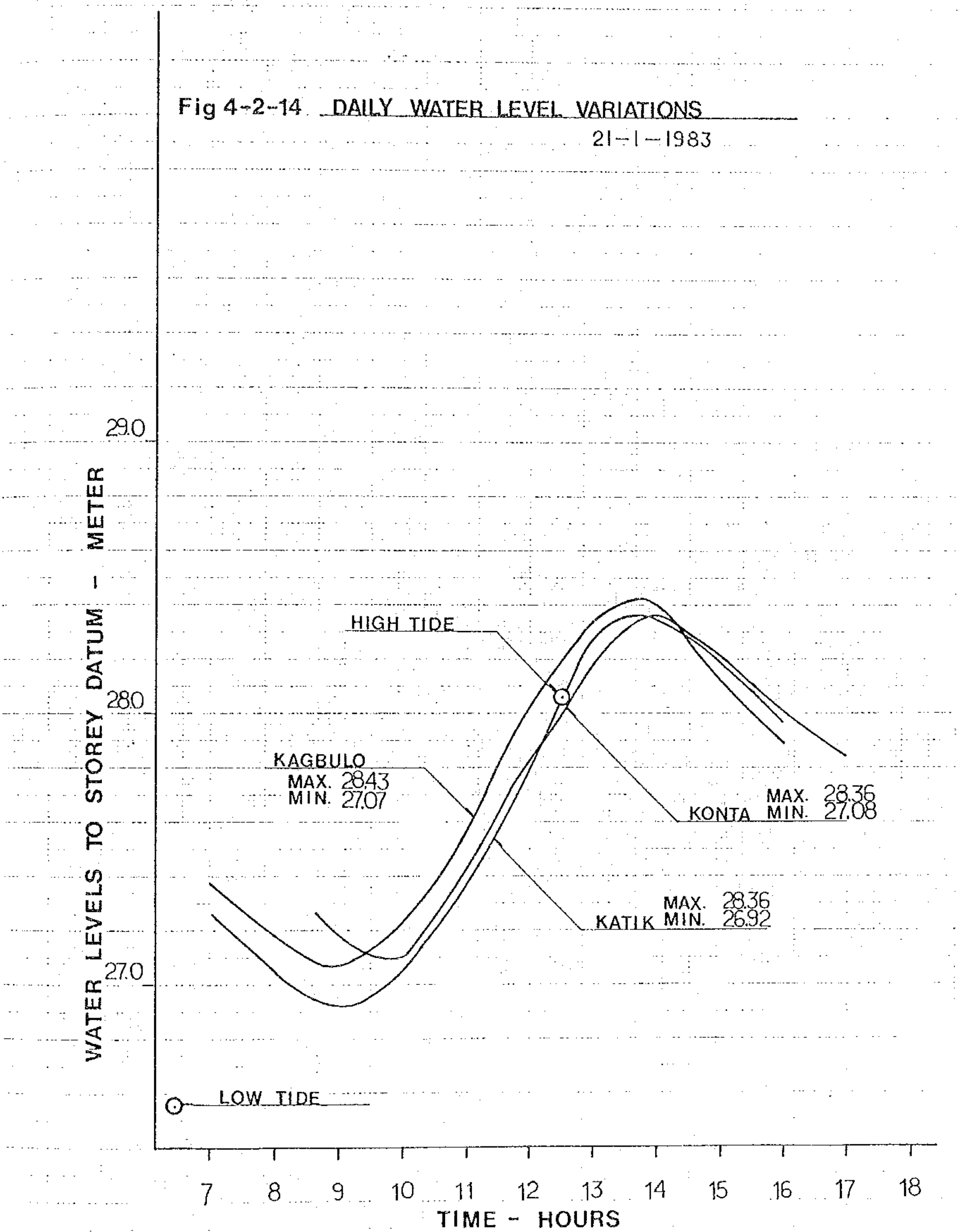


Fig. 4-2-14 Daily Water Level Variations on 21 Jan. 1983 at Kagbulo, Katik and Konta

During the wet season, the reasons why the required amount of water for crops will be supplied almost entirely by rainfall are given in Sub section of 9-1-1. Although irrigation in the dry season will depend on pumping, as much water as possible should be taken in naturally at high tide by using Miter gates to be installed for each polder.

(1) Lowest water level in dry season at Rhombe

The lowest intake water level at Rhombe during irrigation periods in the dry season can be estimated using Table 4-2-5. Estimations have been made by using the records of water level at Konta and Kikam to obtain the following results:

Unit: m

	Jan.	Feb.	Dec.
1960	-	-	-
1961	27.14	27.15	27.26
1962	27.30	27.39	27.26
1963	-	-	-

Calculation: 2/5 of the difference between the values of water level observed at Konta and at Kikam is added to the value of water level of Konta.

The lowest intake water level is 27.14 m in January 1961.

It has been observed in recent investigations that this lowest water level occured irrespective of the tidal difference in the tidal records (See Fig. 4-2-11 to Fig. 4-2-14). It follows that even if the low tide level fluctuates between 0.2m to 0.8m according to tide table, the water level at Konta maintains its constant value of about 27.0m (Storey datum).

The reason for this constant level for low flows can only be a matter of speculation, but as far as possible an attempt has been made to understand this. Most of the flow in the river from mid-November until the end of May, usually comes from groundwater storage, recharging water to the river. Inspection of monthly rainfall records for Kabala, Makeni and Rokupr shows that the effective rainfall on the catchment will seldom be above zero for these months and therefore surface runoff is unlikely. Low flows in the river will therefore depend on the volume of groundwater in storage. With such heavy rainfall on the catchment in the wet season it is unlikely that the maximum volume of water in groundwater storage will vary considerably from year to year, but rather that the groundwater will be topped up to a maximum level and surface water runoff will show greatest variation. Each year, when rainfall falls off, the groundwater reservoir will be at the same level and the low flows in the river will therefore depend on the length of time since ground water has started to contribute to the flow and the effective rainfall during that period. But at these low flow stages, the differences from year to year will be too small to be noticeable.

It can be concluded from the above that there is not a clear correlation between the precipitation in the upper reaches of the river and the lowest water level recorded. The estimation of the lowest water level cannot be gauged precisely, due to the lack of information available, but taking into consideration the findings of survey by interview it can be assumed that the design water level should be 27.14 m.

(2) Lowest high tide level in dry season at Rhombe

According to the report by MRT, the highest water level recorded at Kikam is as follows.

	Jan.	Feb.	Dec.
1960	-	-	28.35
1961	28.22	28.20	28.47
1962	28.32	28.38	28.22
1963	-	28.32	-

by Storey Datum

The above values agreed approximately with the values of the highest water level at Konta in Table 4-2-5, so the values of the highest water level at Rhombe, which is located mid-way between Kikam and Konta, can be estimated by interpolation.

However, a recent observation on the 7th of January 1983 indicated that the highest water level at Konta reached only 28.18 m (See Fig. 4-2-12).

It should be concluded that the lowest water level at high tide to be used for the determination of the intake water level during a dry season at Rhombe is set to 28.18 m allowing for a margin of safety.

(3) Highest annual water level at Kagbulo

It is difficult to assess the return period of flooding in this reach as it is dependent on tidal level, river flow and the river hydrograph for the flood peak. For example, in 1962, the peak flow was 2,434 m^3/S which has a return period of 1 in 6 years according to MRT. But it occurred at the time of neap tides and therefore flood levels were low. Maximum flooding occurred during the spring tides when the flow had fallen to 1,981 m^3/S. If it is assumed that a peak flow lasts for 6 days then the chance of the peak occurring during the high spring tides, which last for about 7 days each lunar month, is about 1 in 3.6.

A peak flow of 1,981 m^3/S has a return period of 1 in 1.3 years and so the flooding observed in 1962 is likely to occur approximately every 4.7 years.

As shown in Table 4-2-5 the highest water level of 1962 occurred in August with a height of 29.35 m.

Taking into consideration the result of the interview with the local people and our observations, 29.40 m (Storey datum) is a reasonable highest water level for design.

(4) Highest annual water level at Konta

Likewise, the highest water level of 1962 at Konta is 29.57 m.

Although a value as high as 29.75 m was recorded in September 1961, this value has been negated judging from other observations, since the difference between the level at Konta and at Kagbulo was 0.49 m which is unusual. We can suppose a water level height of 29.60 m will occur approximately once every five years.

(5) Determination of bund height

As previously shown in (3) and (4), the estimated values of the annual highest water level at Kagbulo and at Konta are 29.40 m and 26.60 m respectively. These values indicate about a 1/5 probability of a flooding water level occuring.

The design bund height has been determined taking into consideration reasonable free board as follows:

	1/5 Probability flooding water level	Bund Height	Freeboard
Kagbulo	29.40 m	30.5 m	1.10 m
Konta	29.60 m	30.7 m	1.10 m

It can be said, judging from the survey by interview on the past highest flooding water level that the above values of the bund height have never been exceeded within the past 50 years.

4-2-4 Discharge of the Little Scarcies

(1) Probability of annual rainfall

The measurement of the discharge in the Little Scarcies, which was made by MRT, is the only information available and is shown in Table 4-2-6. Data on the water level of the Little Scarcies which were taken between 1960 and 1963 is shown in Table 4-2-5.

The probabilities of the annual precipitation at Kabala, Makeni and Rokupr, which are located in the upper catchment area of the Little Scarcies,

Table 4-2-6 VARIATION IN THE FLOW OF THE LITTLE SCARCIES DURING 1971

(Based on stage measurements at Robat and stage discharge relationships developed)

Date	Stage to datum (mm)	Corr. stage (-0.21)	Flow m³/sec	Date	Stage of datum (mm)	Corr. stage (-0.21)	Flow m³/sec
1971				4 Sept	5.30	5.09	1231.1
15 Feb	1.07	0.86	22.1	4 Sept	5.30	5.09	1231.1
25	0.94	0.73	15.6	11	5.88	5.67	1584.8
				16	6.19	5.98	1584.8
6 Mar	0.91	0.70	15.6	18	5.91	5.70	1599.0
26	0.69	0.48	5.9	25	5.58	5.37	1386.7
				29	5.49	5.28	1358.4
7 April	0.67	0.46	5.7				
14	0.84	0.63	10.8	2 Oct	5.24	5.03	1188.6
21	0.82	0.61	10.5	9	5.24	5.03	1188.6
25	0.84	0.63	11.0	12	4.97	4.76	905.6
29	0.87	0.66	12.2	16	5.18	4.97	1160.3
				23	4.94	4.73	1047.1
5 May	1.16	0.95	32.5	29	4.36	4.15	764.1
13	1.03	0.82	20.4				
19	0.91	0.70	13.9	6 Nov	3.54	3.33	467.0
				10	3.38	3.17	438.7
5 June	1.16	0.95	27.7	13	3.35	3.14	424.5
9	1.22	1.01	34.0	19	3.08	2.87	331.1
12	1.01	0.80	18.7	27	3.29		396.2
20	1.07	0.86	22.1				
				11 Dec	2.59	2.38	220.7
1 July	2.77	2.56	277.3	18	2.80	2.59	266.0
5	3.08	2,87	325.5	21	2.19	1.98	147.2
10	2.98	2.76	311.3				
14	3.72	3.51	534.9	1972			
15	3.66	3.45	523.6	8 Jan	2.01	1.80	118.9
17	3.54	3.33	478.3	15	1.86	1.65	96.2
24	3.84	3.63	283.0	22	1.74	1.53	82.1
27	4.11	3.90	665.1	29	1.65	1.44	70.8
28	4.18	3.97	693.4				
29	4.42	4.21	806.6	5 Feb	1.55	1.34	59.4
				12	1.40	1.19	45.3
7 Aug	4.33	4.12	764.1				
12	5.15	4.94	1231.1				
13	5.30	5.09	1231.1				
14	5.76	5.55	1471.6				
21	5.88	5.67	1584.8				
23	5.82	5.61	1726.3				
28	5.82	5.61	1556.5				

are given by using a standard probability paper as shown in Fig. 4-2-15 to Fig. 4-2-17.

The probabilities of the annual rainfall stated above can be summarized as shown in Table 4-2-7 ~ 10.

(2) Probability of discharge

The measurement of the discharge in the Little Scarcies is not currently being undertaken, so no data are available to estimate the flood discharge and the drought discharge. For this reason, these are to be estimated referring to the analysis adopted by MRT.

The probability of flood discharge and low flow are shown in Table 4-2-11 and Table 4-2-12 respectively.

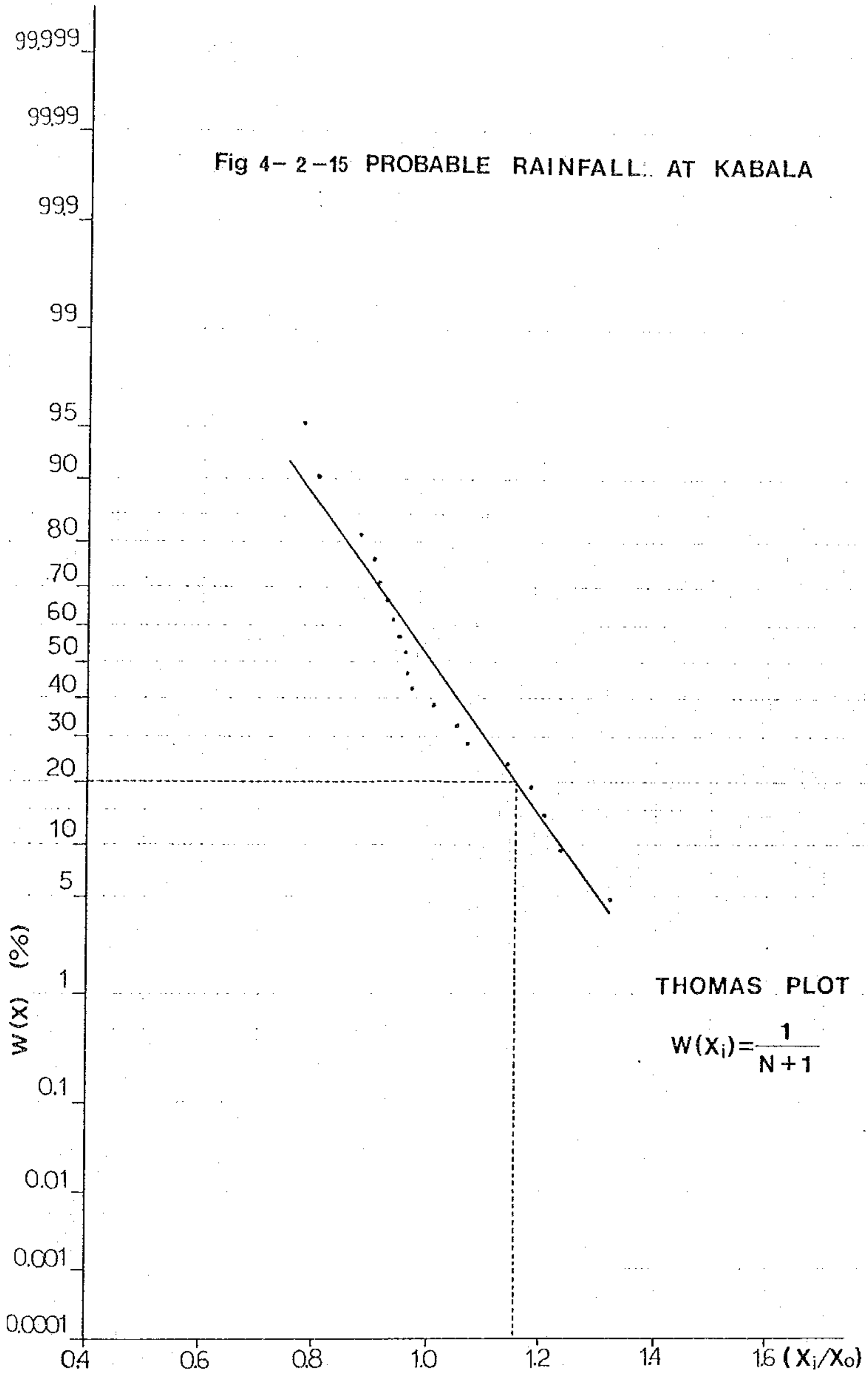


Fig 4-2-15 PROBABLE RAINFALL AT KABALA
99.999
99.99
99.9
99
95
90
80
70
60
50
40
30
20
10
5
1
0.1
0.01
0.001
0.0001
W(X) (%)
THOMAS PLOT
W(Xi)=1/N+1
0.4
0.6
0.8
1.0
1.2
1.4
1.6 (Xi/Xo)

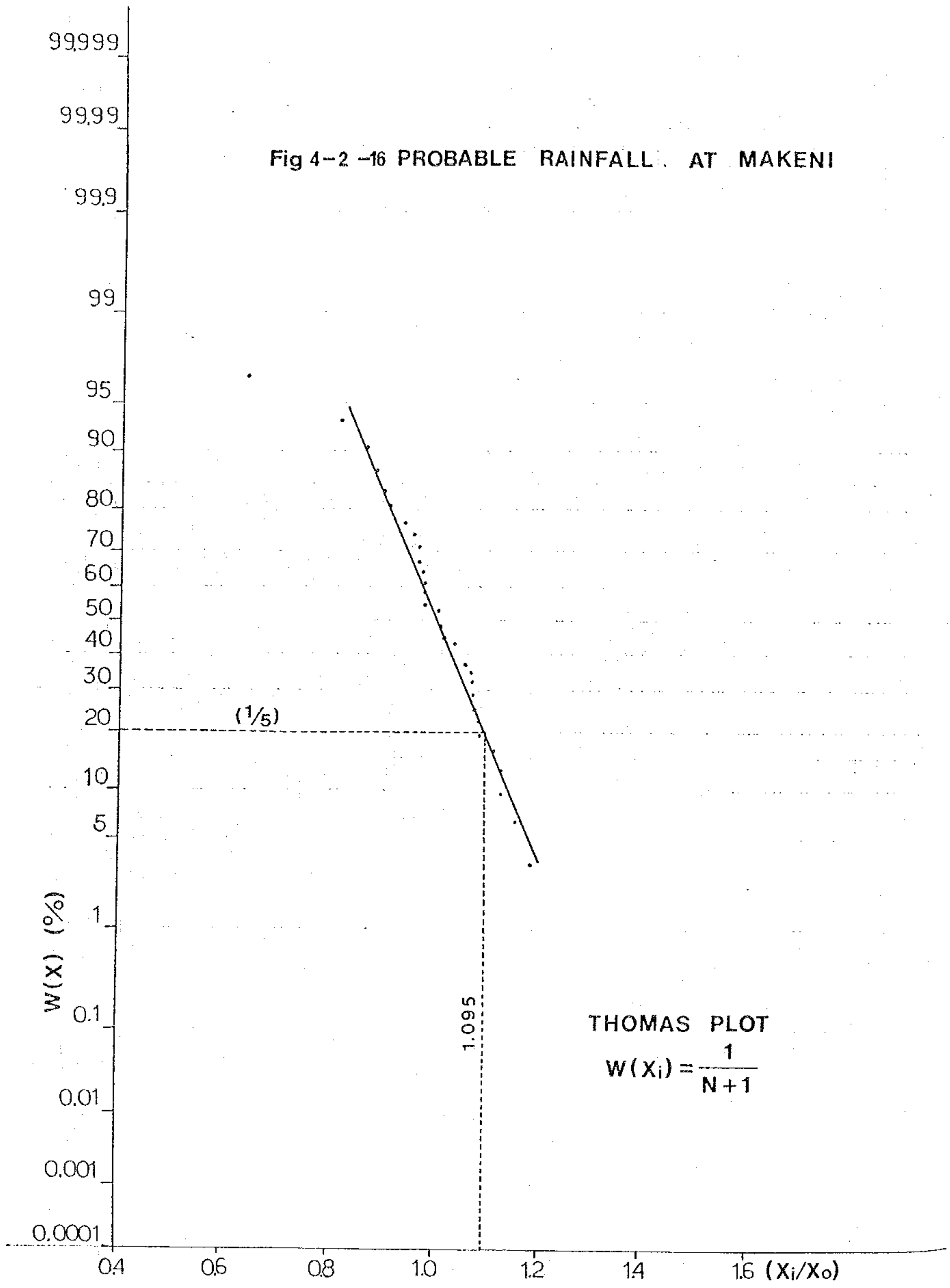


Fig 4-2 -16 PROBABLE RAINFALL AT MAKENI
99.999
99.99
99.9
99
95
90
80
70
60
50
40
30
20
10
5
1
0.1
0.01
0.001
0.0001
W(X) (%)
(1/5)
1.095
THOMAS PLOT
W(Xi) = 1/(N+1)
0.4
0.6
0.8
1.0
1.2
1.4
1.6 (Xi/Xo)

Fig. 4-2-17 PROBABLE RAINFALL AT ROKUPR

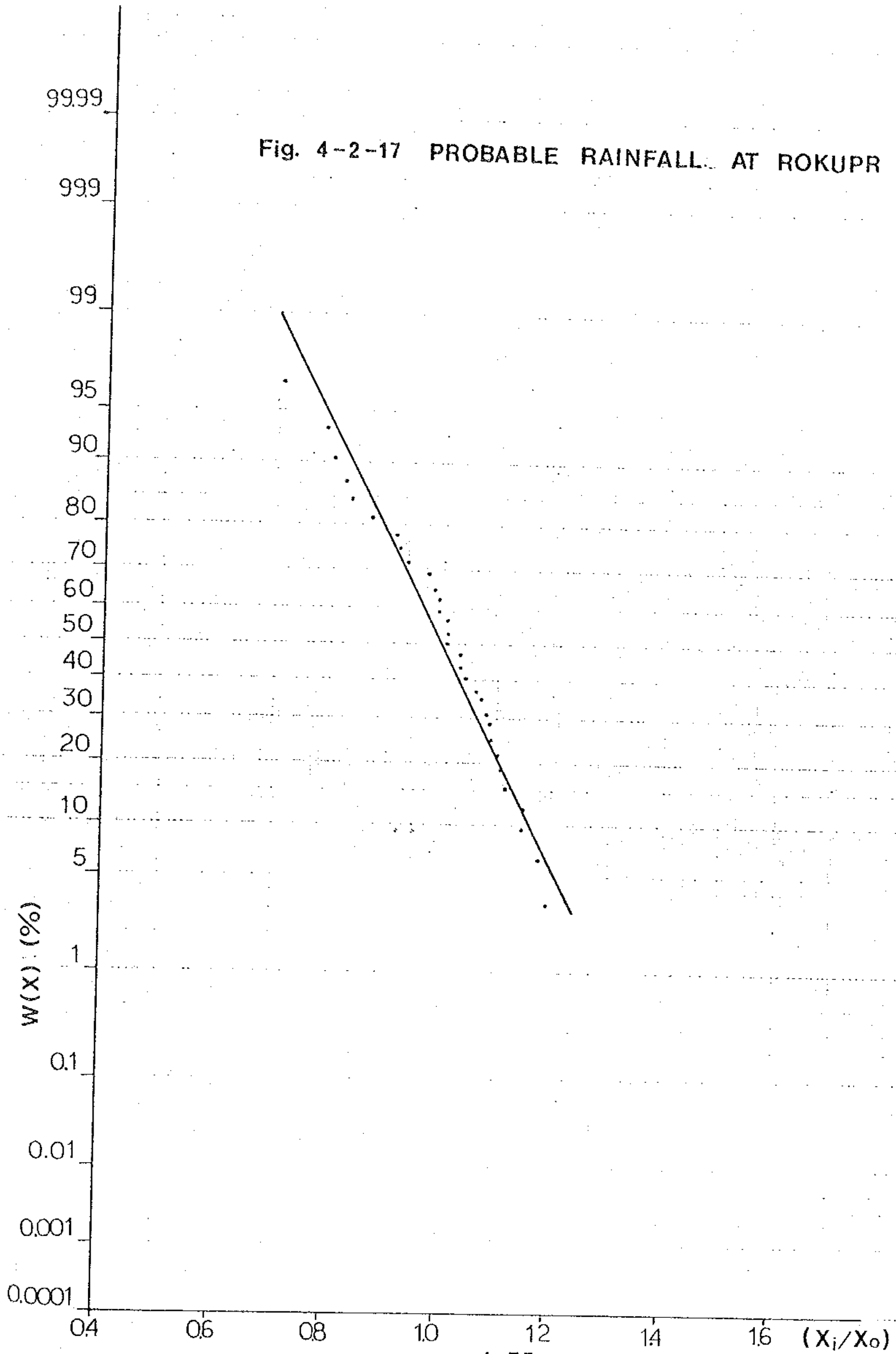


Table 4-2-7 PROBABLE ANNUAL RAINFALL

Year	Kabala		Makeni		Rokupr	
	Rainfall mm	Return Period	Rainfall mm	Return Period	Rainfall mm	Return Period
1959	1,991	1/1.5	3,424	1/6.1	3,174	1/3.2
1960	2,305	1/2.9	3,000	1/1.6	2,952	1/1.9
1961	2,038	1/1.6	2,659	1/1.1	3,075	1/2.5
1962	2,611	1/7.1	3,555	1/11.4	3,301	1/5
1963	2,089	1/1.8	2,940	1/1.5	3,014	1/2.2
1971	-		3,320	1/3.8	-	
1982	-		-	3,200	3,200	1/3.6

Table 4-2-8 CALCULATION OF PROBABLE RAINFALL AT KABALA

ORDER	YEAR	RAIN FALL Xi mm	$\frac{Xi}{Xo}$	PLOTTING POSITION % $W(x) = \frac{i}{n+1}$
1	1968	2,846	1.318	4.8
2	1958	2,675	1.238	9.5
3	1962	2,611	1.209	14.3
4	1969	2,569	1.189	19.0
5	1966	2,462	1.140	23.8
6	1960	2,305	1.067	28.6
7	1981	2,267	1.050	33.3
8	1957	2,183	1.011	38.1
9	1963	2,089	0.967	42.9
10	1967	2,073	0.960	47.6
11	1976	2,065	0.956	52.4
12	1961	2,038	0.944	57.1
13	1978	2,020	0.935	61.9
14	1956	2,002	0.927	66.7
15	1959	1,991	0.922	71.4
16	1979	1,946	0.901	76.2
17	1980	1,889	0.875	81.0
18	1964	1,756	0.813	85.7
19	1965	1,733	0.802	90.5
20	1977	1,678	0.777	95.2
TOTAL		43,198		
1/n		2,159.9		

Annual rainfall is regarded as normal distribution, the probability of rainfall/in 5 years is 2,495 mm.
(Refer to Fig. 4-2-12)

Table 4-2-9 CALCULATION OF PROBABLE RAINFALL AT MAKENI

Order	Year	Rainfall Xi mm	$\frac{Xi}{Xo}$	Plotting Position % $W(x) = \frac{i}{n+1}$
1	1981	3,645	1.182	3.2
2	1962	3,555	1.153	6.5
3	1952	3,473	1.126	9.7
4	1953	3,473	1.126	12.9
5	1959	3,424	1.110	16.1
6	1954	3,336	1.082	19.4
7	1945	3,333	1.081	22.6
8	1971	3,320	1.076	25.8
9	1969	3,302	1.071	29.0
10	1955	3,299	1.070	32.3
11	1964	3,296	1.069	35.5
12	1980	3,250	1.054	38.7
13	1951	3,194	1.036	41.9
14	1970	3,128	1.014	45.2
15	1979	3,115	1.010	48.4
16	1957	3,098	1.004	51.6
17	1966	3,019	0.979	54.8
18	1965	3,013	0.977	58.1
19	1946	3,008	0.975	61.3
20	1960	3,000	0.973	64.5
21	1974	2,989	0.969	67.7
22	1958	2,983	0.967	71.0
23	1963	2,940	0.953	74.2
24	1973	2,896	0.939	77.4
25	1977	2,801	0.908	80.6
26	1956	2,766	0.897	83.9
27	1949	2,735	0.887	87.1
28	1961	2,659	0.862	90.3
29	1950	2,516	0.816	93.5
30	1978	1,968	0.638	96.8
Total		92,534		
$Xo = \frac{1}{n}$		3,084.5		

The probability of rainfall 1 in 5 years is 3,378 mm (Refer to Fig. 4-2-13).

Table 4-2-10 CALCULATION OF PROBABLE RAINFALL AT ROKUPR

Order	Year	Rainfall Xi mm	$\frac{Xi}{Xo}$	Plotting Position % $W(x) = \frac{i}{n+1}$
1	1964	3,562	1.193	3.1
2	1969	3,526	1.181	6.3
3	1970	3,439	1.152	9.4
4	1954	3,432	1.149	12.5
5	1978	3,322	1.113	15.6
6	1962	3,301	1.106	18.8
7	1955	3,293	1.103	21.9
8	1952	3,249	1.088	25.0
9	1951	3,240	1.085	28.1
10	1977	3,225	1.080	31.3
11	1982	3,200	1.072	34.4
12	1959	3,174	1.063	37.5
13	1958	3,115	1.043	40.6
14	1966	3,082	1.032	43.8
15	1961	3,075	1.030	46.9
16	1963	3,014	1.009	50.0
17	1980	3,011	1.008	53.1
18	1965	2,992	1.002	56.3
19	1967	2,960	0.991	59.4
20	1960	2,952	0.989	62.5
21	1981	2,919	0.978	65.6
22	1974	2,904	0.973	68.8
23	1953	2,776	0.930	71.9
24	1968	2,735	0.916	75.0
25	1976	2,720	0.911	78.1
26	1975	2,579	0.864	81.3
27	1979	2,473	0.828	84.4
28	1956	2,445	0.819	87.5
29	1972	2,394	0.802	90.6
30	1957	2,347	0.786	93.8
31	1973	2,103	0.704	96.9
Total		92,559		
$Xo = \frac{1}{n}$		2.985.8		

The probability of annual rainfall 1 in 5 years in 3,299 mm.
(Refer to Fig. 4-2-14)

Table 4-2-11 ESTIMATED RETURN PERIOD FOR FLOOD PEAKS

Return period (years)	Year of occurrence	Estimated flood peak m^3/s	Return period (years)	Year of occurrence	Estimated flood peak m^3/s
39	1964	2,603	1.95	1934	
19	1969		1.85	1965	
13	1945		1.77	1941	
9.8	1967	2,490	1.69	1939	
7.8	1946		1.62	1959	
6.5	1970	1,924	1.56	1944	
5.6	1968		1.50	1971	1,783
4.9	1966		1.44	1958	
4.3	1954		1.39	1960	1,811
3.9	1962	2,433	1.34	1963	1,953
3.5	1961	2,264	1.30	1956	
3.2	1953		1.26	1949	
3.0	1938		1.22	1942	
2.78	1952		1.18	1950	
2.60	1948		1.15	1943	
2.44	1951		1.11	1937	
2.30	1955		1.08	1936	
2.16	1957	2,179	1,05	1935	
2.05	1947		1.03	1940	

Note:

Years giving maximum monthly rainfall on the Little Scarcies catchment area ranked in descending order. Peak flows are given for the years where these values could be estimated.

Table 4-2-12 ESTIMATED FLOWS FOR LOW FLOW MONTHS 1941 TO 1972

	Estimated flows (m^3/s)				
Year	Dec.	Jan.	Feb.	Mar.	Apr.
*1971/72	240	102	51		
*1970/71	102	49	24	11	9
1969/70	113	45	21	13	10
1968/69	150	48	23	19	12
1967/68	91	37	20	10	8
1966/67	164	51	24	12	8
1965/66	91	37	20	11	8
1964/65	283	93	34	15	10
1963/64	85	34	19	11	7
1962/63	93	48	24	12	8
1961/62	91	37	20	10	10
1960/61	105	40	20	11	9
1959/60	91	37	20	11	8
1958/59	283	105	34	20	11
1957/58	96	45	22	13	12
1956/57	340	68	28	13	10
1955/56	170	51	24	13	12
1954/55	119	42	22	13	14
1953/54	122	45	23	13	14
1952/53	102	40	21	11	9
1951/52	113	42	28	14	9
1950/51	93	68	28	16	10
1949/50	130	45	22	12	9
1948/49	93	37	21	15	12
1947/48	74	34	20	10	8
1946/47	255	59	27	14	9
1945/46	153	48	25	13	9
1944/45	113	42	22	11	9
1943/44	283	59	28	15	11
1942/43	425	79	31	15	15
1941/42	91	45	23	13	9

* Values for 1970-72 are observed values.

4-2-5 Water levels at Makemba North Swamp

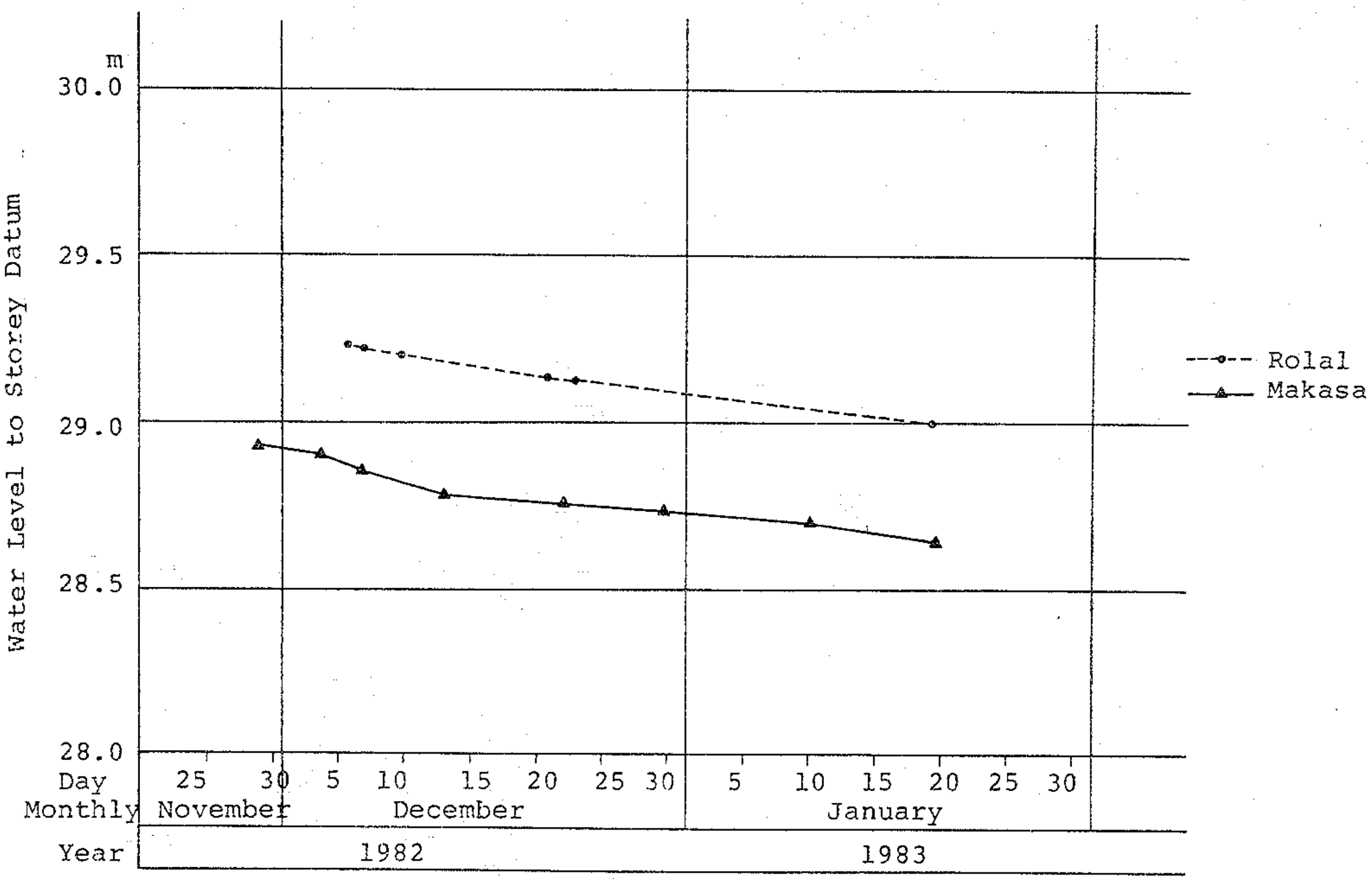
The water level at Rolal and Makasa has been observed by setting a staff at each place (See Fig. 4-2-18).

The ground elevation at Rolal is 28.90 m (Storey datum). The ground elevation at Makasa is 28.52 m (Storey datum).

As shown in the graph, the water dropped to ground level on the 20th of January 1983. There are higher points in the region than the ground elevations stated above; therefore at that time dry ground could be seen at many places around the region.

It has been concluded from this that it is impossible to obtain water from this swamp after mid-January, unless the water of the swamp is contained by bunds to be installed around the swamp.

Fig. 4-2-18 FLUCTUATION OF SWAMP WATER LEVEL



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5-1 Method of Water Quality Investigation

The Little Scarcies river and swamps are important sources of water supply for irrigation in this agricultural development scheme. Several water quality investigations for these resources were carried out. Points of these investigations are shown in Fig. 3-3-1 and 3-4-1.

Items of the investigation were water temperature, pH and electrical conductivity.

Water samples were taken at a depth of 1 m below surface by a bailer-type water samples to avoid suspended solids.

Measurement instruments employed were as follows:

Water temperature	:	A mercurial thermometer and a portable pH meter YEW PH51
pH	:	Portable pH meter YEW PH51
Electrical Conductivity	:	Portable EC meter KURITA TS-4

5-2 The Little Scarcies River

The Little Scarcies is a tidal river which is affected by tidal change and is penetrated by sea water. In order to gauge the influence of the sea water intrusion, a series of ten water samples was taken and measured along the reach of the Little Scarcies, from the mouth of Gbenti Creek upstream to Retung, at high tide. Furthermore, another series of water samples at water-level gauging stations was taken to clearly define the daily change in the salinity correspondent to water level fluctuation.

5-2-1 Water temperature and pH

Water temperature in the Little Scarcies ranged from 26.9°C to 27.8°C in the wet season and varied from 29.2°C to 29.5°C in the dry season.

Values of pH ranged from 7.3 to 7.6 in the wet season and varied from 7.0 to 7.7 in the dry season. The pH indicated a weak alkaline content in both seasons.

5-2-2 Electrical conductivity

(1) Salinity in relation to the river water level fluctuation

The locations of four gauging stations, where a continuous measurement of the water level fluctuation was carried out, are shown in Fig. 3-3-1. The measurement was carried out at a full moon spring high tide. The results are shown in Fig. 5-2-1 to 5-2-3. The high tide level at Freetown was 3.1 m on the 2nd Dec., 3.0 m on the 30th Dec., and 3.3 m on the 31st Dec. in 1982.

As shown in Fig. 5-2-1 to 5-2-3, electrical conductivity increased with a raising of the water level and the peak of electrical conductivity was noted to practically coincide with the time when the water level reached the maximum. After that, both the water level and the electrical

Fig. 5-2-1 FLUCTUATION OF ELECTRICAL CONDUCTIVITY WITH TIDAL CHANGE

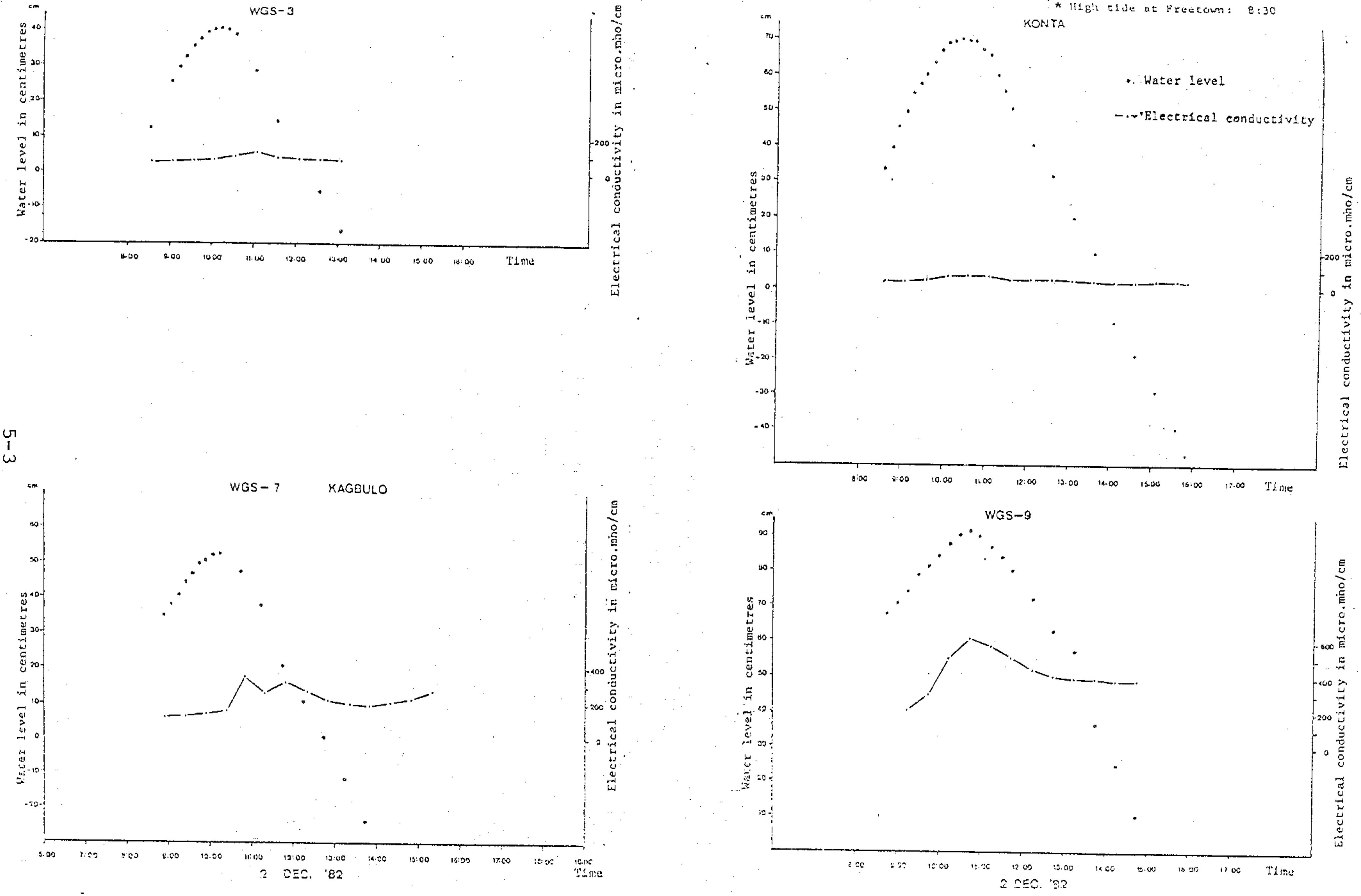


Fig. 5-2-2 FLUCTUATION OF ELECTRICAL CONDUCTIVITY WITH TIDAL CHANGE

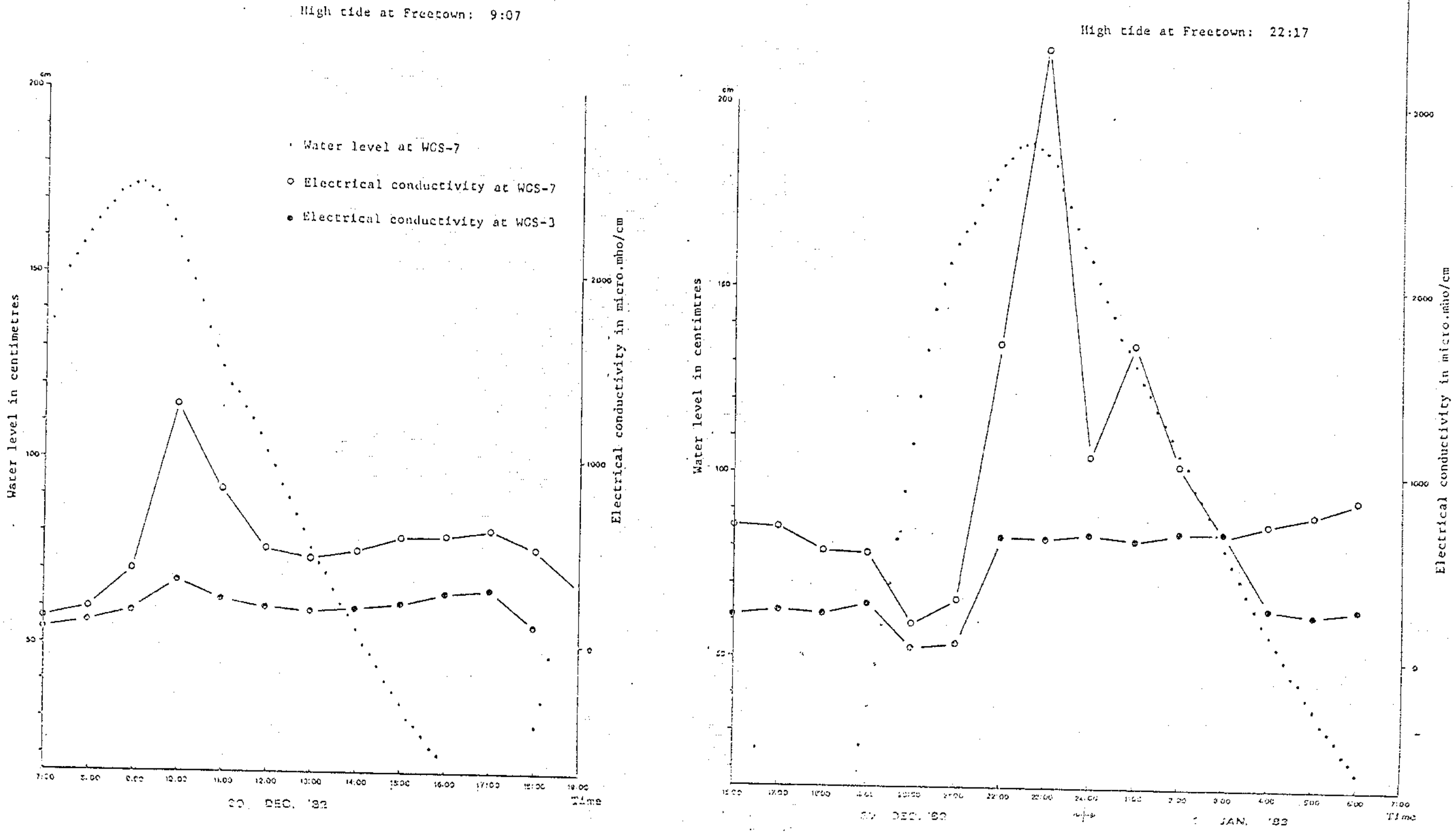
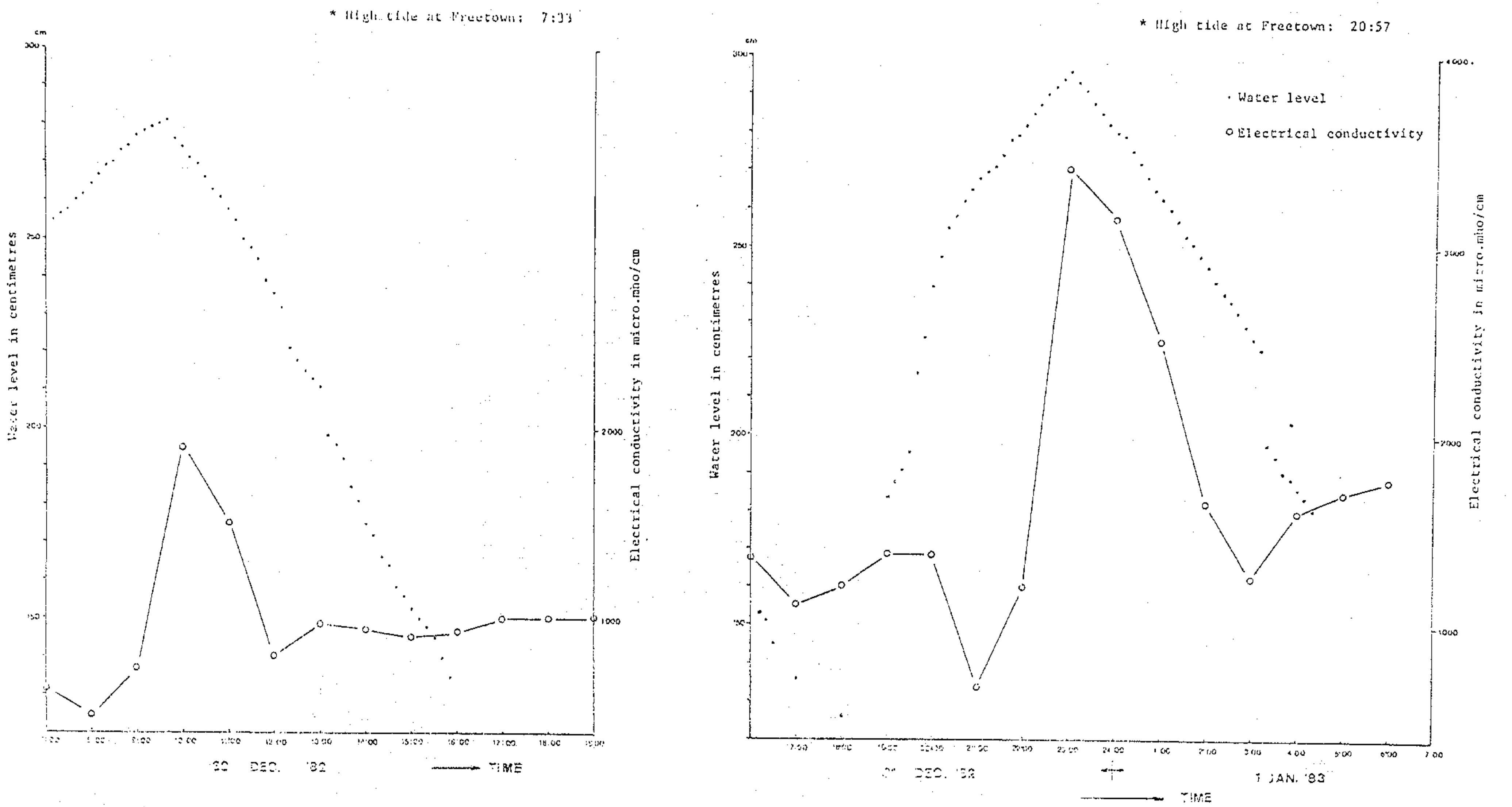


Fig. 5-2-3 FLUCTUATION OF ELECTRICAL CONDUCTIVITY WITH TIDAL CHANGE AT WGS-9



conductivity decreased but the electrical conductivity showed a tendency to increase again.

A difference in high tide level at Freetown affected both the water level and the electrical conductivity, i.e., while the maximum of electrical conductivity was 1,900 µS/cm on the 30th Dec., the maximum on the 31st Dec. was 3,400 µS/cm. A high concentration of electrical conductivity, at the time of the present survey, was limited to 1 to 2 hours before and after the peak of the river water level.

(2) Salinity along the river

A measurement of electrical conductivity along the river was carried out six times for this study. The results are shown in Table 5-2-1.

Furthermore, water samples were taken and measured at varying depths at each point. As a result, it was found that a difference of water quality at varying depths was negligible (Table 5-2-2). It was also found that the type of sea water intrusion was a strong mixed type.

The Fig. 5-2-4 was drawn from Table 5-2-1, and indicates that as the dry weather progressed, it had an influence on the intrusion of sea water into the river. In the wet season, however, it has been concluded that the sea water intrusion did not occur within the project area, because, there was hardly any difference in electrical conductivity between the mouth of Gbenti Creek and Retung.

But, in the dry season which starts in November every year, an influence of the sea water intrusion appeared in the electrical conductivity.

Table. 5-2-1 WATER QUALITY ALONG THE LETTLE SCARCIES OF HIGH TIDE

Unit: micro.mho/cm

No. / Location / Date	1 Gbenti mouth	2 TAS BM-I	3 Kagbulo	4 WGS-3	5 Konta	6 Kikam	7 Katoma	8 Katonga	9 Sirian	10 Retung	Time & Level of H-L Tide at Freetown
9 Sep. 1982	12:30 23.0	12:10 22.0	11:50 19.7	11:25 19.0	11:10 18.0	10:50 17.0	10:30 17.5	10:15 18.0	9:50 18.0	9:30 20.0	H.T. 11:25 - 2.7m 5:25 - 0.7m L.T. 17:53 0.7m
20 Nov. 1982	10:45 220.0	11:10 85.0	11:30 50.0	12:05 35.0	12:25 28.0	13:00 23.0	13:50 22.0	14:10 22.0	14:37 22.0	15:05 22.0	H.T. 10:17 2.5 22:44 2.6 L.T. 4:38 0.8 16:35 0.8
1 Dec. 1982	9:15 3,700	9:24 1,250	9:40 160.0	9:55 80.0	10:15 38.0	10:35 26.0	10:55 24.0	11:05 24.0	11:33 24.0	11:47 24.0	H.T. 7:44 3.1 20:18 3.2 L.T. 1:49 0.4 14:09 0.2
10 Dec. 1982	10:30 2,050	10:39 280.0	10:56 150.0	11:08 46.0	11:22 33.0	12:06 28.0	12:33 26.0	12:55 28.0	13:10 25.0	13:22 28.0	H.T. 9:29 2.6 21:53 2.8 L.T. 3:49 0.7 15:46 0.6
30 Dec. 1982	8:36 9,700	8:51 6,200	9:03 1,300	9:22 200	9:35 72.0	9:50 37.0	10:05 31.0	10:13 31.0	10:28 30.0	10:40 35.0	H.T. 7:33 3.0
30 Dec. 1982	15:48 400	16:01 105	16:17 57.0	16:27 34.0	16:43 34.0	17:01 30.5	17:20 30.5	17:33 30.0	17:47 30.0	18:01 28.0	L.T. 13:55 0.2
18 Jan. 1983	11:30 15,700	11:49 6,500	12:02 1,160	12:10 463	12:20 148	12:38 49.0	12:56 30.6	13:03 30.1	13:15 30.1	13:27 30.6	H.T. 10:21 2.5 22:37 2.8 L.T. 4:35 0.7 16:34 0.6

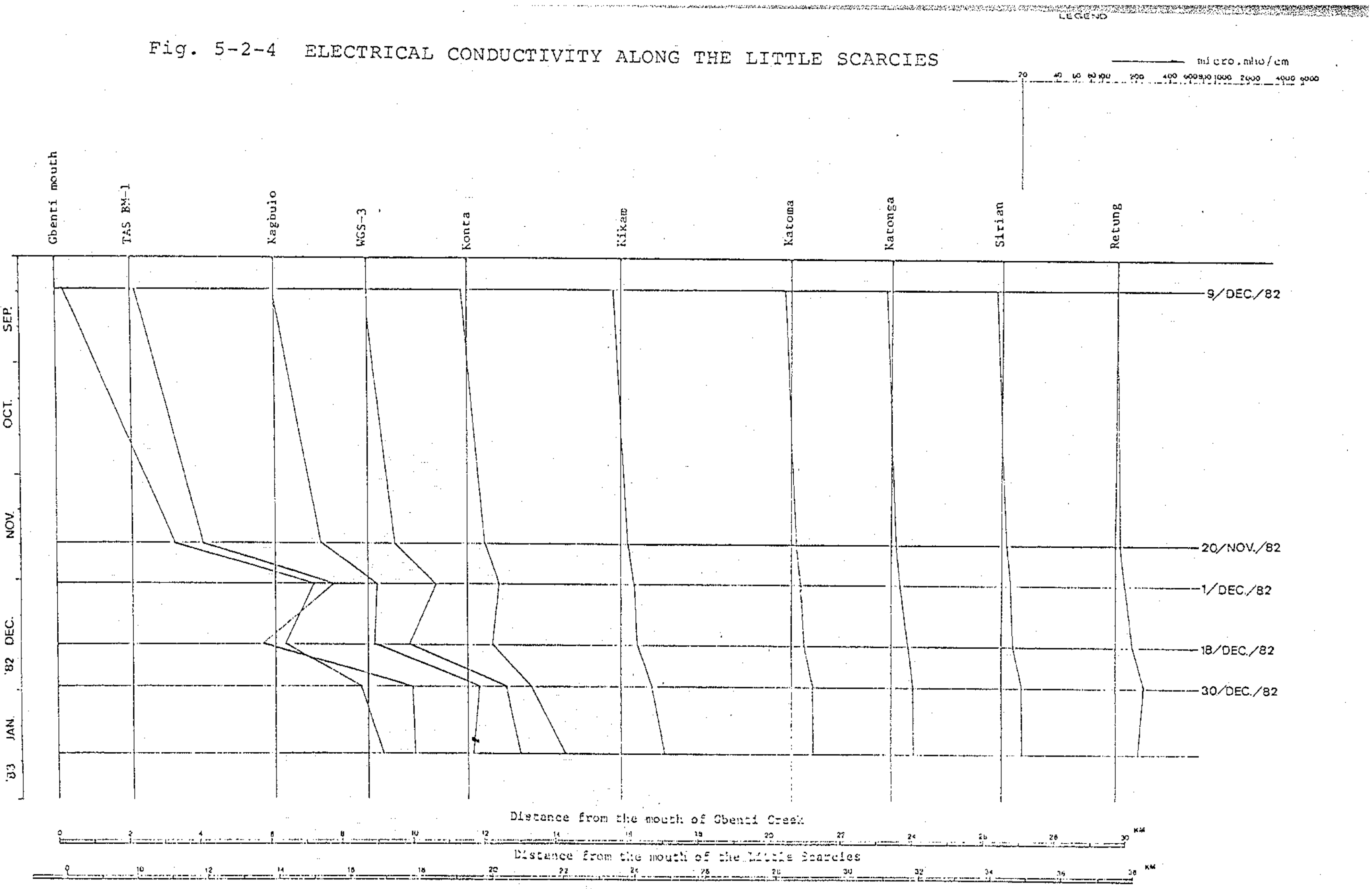
upper: Sampling time
lower: Electrical conductivity

Table 5-2-2 WATER QUALITY ALONG THE LITTLE SCARCIES

Depth	Sampling point / Time / Item	No.1 Gbenti m.	No.2 TAS BM-1	No.3 Kagbulo	No.4 WGS-3	No.5 Konta	No.6 Kikam	No.7 Katoma	No.8 Kotonga	No.9 Sirian	No.10 Retung	Tide Level at Freetown
		9 Sep.'82 12:30	12:10	11:50	11:25	11:10	10:50	10:30	10:15	9:50	9:30	
upper layer	Temp(°c)	27.8	27.8	27.4	27.6	27.5	27.3	27.4	27.2	27.2	26.9	
	pH	7.4	7.3	7.3	7.3	7.3	7.4	7.5	7.4	7.6	7.6	9th Sep.'82
	NaCl(ppm	10.6	10.3	9.3	9.2	8.8	8.3	8.5	8.8	8.8	9.5	
middle layer	Temp(°c)	27.7	27.8	27.4		27.4			27.1	27.1	27.1	High Tide
	pH	7.4	7.4	7.4	---	7.3	---	---	7.4	7.5	7.5	11:25 (2.7m)
	NaCl(ppm	10.3	10.3	9.2		8.6			8.4	8.3	8.7	
lower layer	Temp(°c)	27.7	27.8	27.3	27.6	27.4	27.3	27.3	27.1	27.1	27.1	Low Tide
	pH	7.5	7.5	7.5		7.4	7.5	7.5	7.5	7.4	7.4	5:25, 17:53
	NaCl(ppm	10.3	10.3	9.2	9.0	8.6	8.3	8.2	8.4	8.3	8.7	(0.7m)
Water depth (m)		4.0	3.8	4.0	2.1	5.0	3.0	2.7	5.0	5.6	4.7	

Depth	Sampling point / Time / Item	No.1 Gbenti m.	No.2 TAS BM-1	No.3 Kagbulo	No.4 WGS-3	No.5 Konta	No.6 Kikam	No.7 Katoma	No.8 Katonga	No.9 Sirian	No.10 Retung	Tide Level at Freetown
		20 Nov.'82 10:45	11:10	11:30	12:05	12:25	13:00	13:50	14:10	14:37	15:05	
upper layer	Temp(°c)	29.5	29.2	29.2	29.4	29.3	29.3	29.3	29.2	29.4	29.3	
	pH	7.0	7.3	7.3	7.7	7.5	7.4	7.5	7.5	7.4	7.5	20th Nov.'82
	NaCl(ppm	110.0	42.0	25.0	17.0	14.0	11.0	10.0	11.0	10.0	10.0	
middle layer	Temp(°c)			29.2		29.3			29.2			High Tide
	pH			7.3		7.4			7.4			10:17 (2.5m)
	NaCl(ppm			24.0		14.0			10.0			22:44 (2.6m)
lower layer	Temp(°c)	29.5	29.2	29.2	29.4	29.2	29.2		29.2	29.4		Low Tide
	pH	7.1	7.3	7.3	7.6	7.3	7.3		7.4	7.4		4:38 (0.8m)
	NaCl(ppm	100.0	40.0	24.0	16.0	14.5	11.0		10.0	10.0		16:35 (0.8m)
Water depth (m)		2.65	1.10	3.85	2.20	4.10	2.60	1.25	3.50	2.90	1.75	

Fig. 5-2-4 ELECTRICAL CONDUCTIVITY ALONG THE LITTLE SCARCIES



The electrical conductivity of the river mouth of Gbenti Creek was 220 µS/cm on the 20th Nov. then, it rose to 9,700 µS/cm on the 30th Dec. in 1982 (the full moon spring high tide) and it reached 15,700 µS/cm, which was the highest concentration during this study, on the 18th Jan. in 1983. An increase in the electrical conductivity was observed at the other points as the dry season progressed. This influence of the sea water intrusion was strongest near the river mouth and diminished as the distance from the river mouth increased. From these observations it was found that the limit of sea water intrusion was reached between Kikama and Katoma during this study. The limit of high concentration above 2,000 µS/m which had a negative effect on crops was between TAS BM 1 and Kabgulo and had not affected the project area at that time. However, it is estimated that the limit of high concentration in the river will move still further upstream as the dry season progresses through to May every year (Fig. 5-2-5). Based on Table 5-2-1, a salinity variation in the future at WGS-3 and Konta was estimated as shown in Fig. 5-2-6.

The formulas of both points are respectively as follows:

WGS-3: $Y = 17.97 \ e^{0.0412 \ t}$ (r = 0.99)

Konta: $Y = 16.37 \ e^{0.0270 \ t}$ (r = 0.99)

where, Y: electrical conductivity µS/cm

t: days

r: a coefficient of correlation

From these formulas, the electrical conductivity of WGS-3 will exceed 2,000 µS/cm at the end of February. On the other hand, the electrical

Fig. 5-2-5 WATER LEVEL FLUCTUATION AT BANTRO

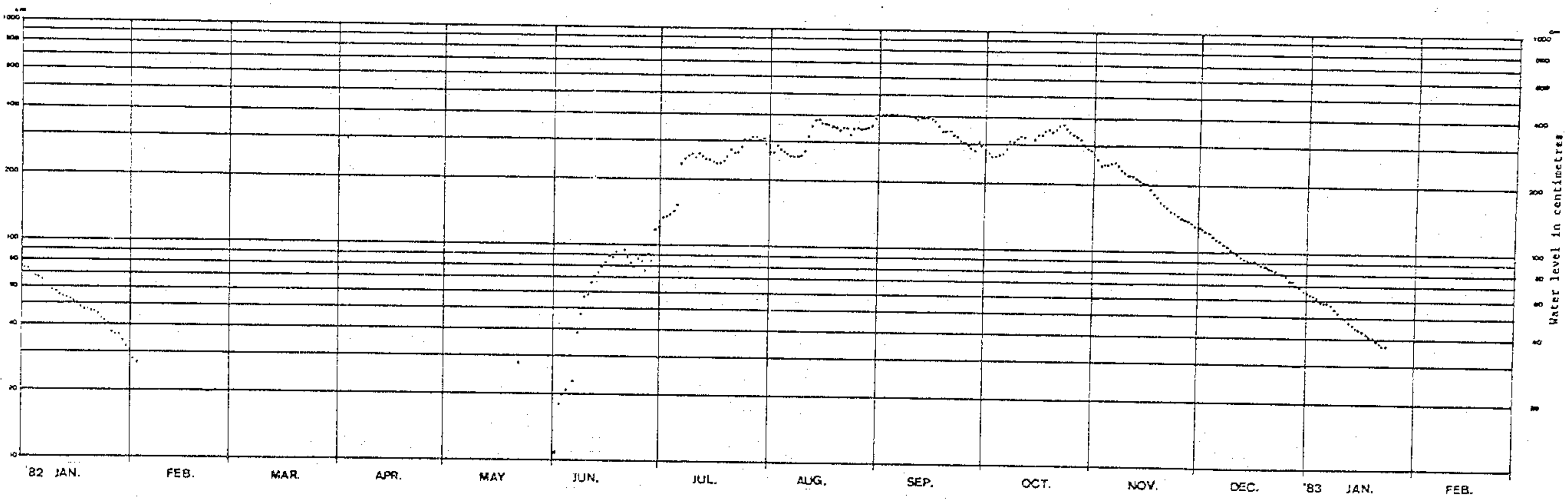
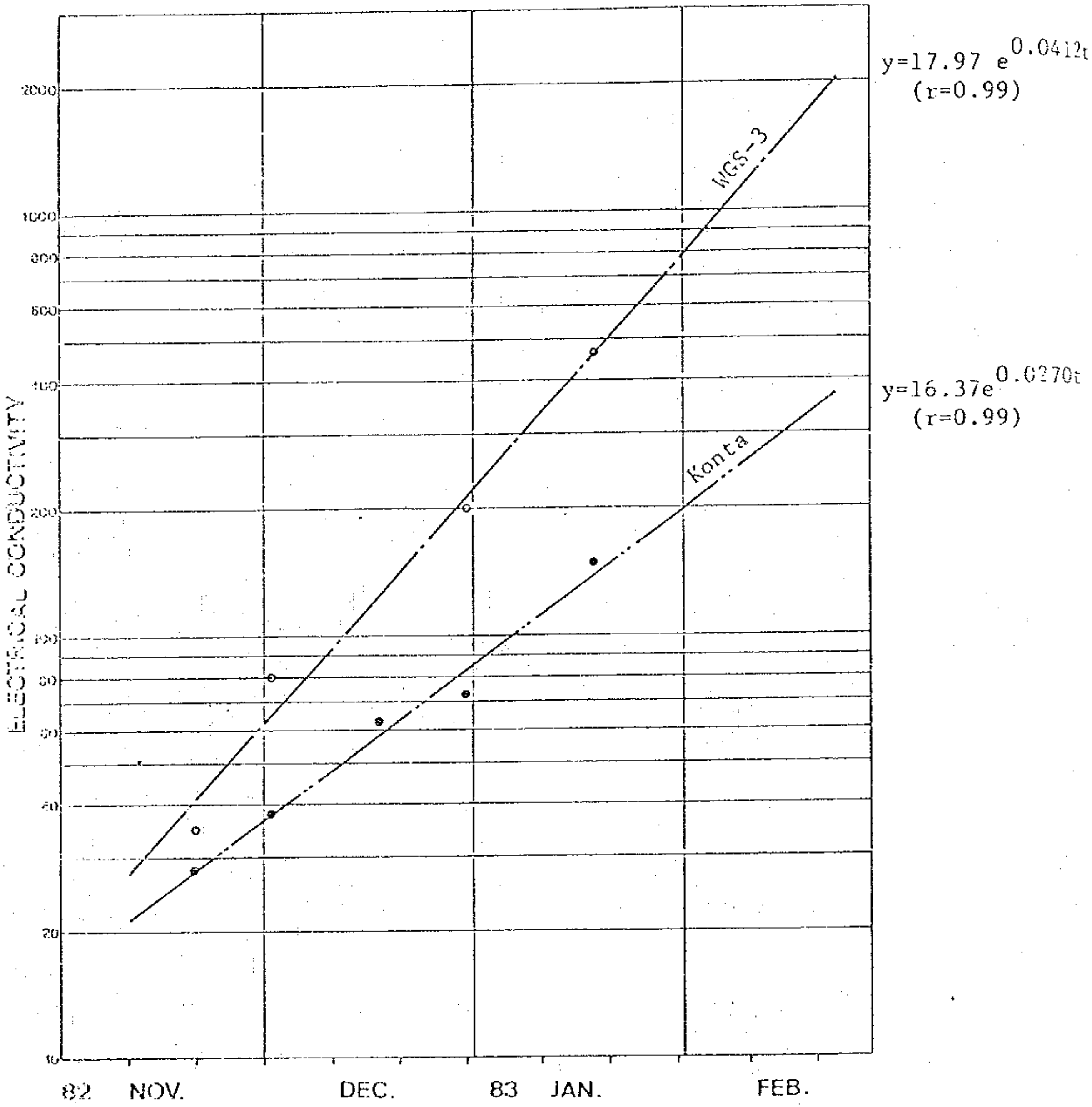


Fig. 5-2-6 ELECTRICAL CONDUCTIVITY AT SPRING HIGH TIDE



conductivity of Konta will still be below 1,000 μS/cm at the end of February. It is therefore estimated that the limit of high concentration which has a negative effect on crops will be between WGS-3 and Konta at the end of February.

5-3 Swamp

Water quality observation for swamp water was carried out at both Gbenti and Makemba swamp. Observation points are shown in Fig. 3-3-1.

5-3-1 Gbenti swamp

The results of the measurement are shown in Table 5-3-1.

There were slight differences in water temperature and pH between the wet season and the dry season.

EC values in the dry season were higher than in the wet season and varied from 190 μS/cm to 1,350 μS/cm. It is assumed that the water quality of Gbenti swamp was also affected when the Little Scarcies was influenced by sea water intrusion (through the Creeks).

5-3-2 Makemba swamp

Makemba swamp is situated east of the project area and is a possible water reservoir for the project area.

Water quality was measured at seven points along the reach from Rhombe Village to Makemba Village. Sampling points and the results are shown in Fig. 3-3-1 and Table 5-3-2 respectively.

Water temperature ranged from 25.2°C to 29.8°C.

Table 5-3-1 WATER QUALITY IN THE GBENTI SWAMP

Location	Item	10/Sept/82		26/Nov/82		31/Dec/82	
GS-1	W. Temp (°c)	27.8	11:19	26.8	9:20	28.5	12:58
	pH	6.7		6.8		6.7	
	EC (S/cm)	28.0		240.0		175	
	Salinity (ppm)	12.0		120.0			
GS-2	W. Temp (°c)	29.3	11:51	27.3	9:42	28.4	12:45
	pH	6.2		6.8		6.8	
	EC (S/cm)	52.0		190.0		200	
	Salinity (ppm)	26.0		90.0			
GS-3	W. Temp (°c)	30.3	12:29	27.6	10:35	27.7	12:16
	pH	6.3		6.7		6.8	
	EC (S/cm)	34.0		580.0		380	
	Salinity (ppm)	170		290.0			
GS-4	W. Temp (°c)	28.4	13:36	27.9	11:15	27.7	11:50
	pH	6.5		6.3		6.9	
	EC (S/cm)	35.0		750.0		1,350	
	Salinity (ppm)	17.0		380.0			
GS-5	W. Temp (°c)	30.9	14:36			26.5	9:56
	pH	6.5				6.7	
	EC (S/cm)	41.0				420	
	Salinity (ppm)	20.0					
High Tide		0:03	2.6m	3:43	2.5m	8:23	3.0m
		12:25	2.6m	16:30	2.5m	20:57	3.3m
Low Tide		6:19	0.9m	10:14	0.9m	2:30	0.3m
		18:52	0.9m	22:26	1.0m	14:44	0.2m

Table 5-3-2 WATER QUALITY IN THE MAKEMBA SWAMP

Location	Item	19/Sept/82		25/Nov/82		17/Dec/82	
MS-1	W. Temp (°c)			27.2	8:45	26.1	10:15
	pH			5.6			
	EC (S/cm)			17.0		31.0	
MS-2	W. Temp (°c)	29.1	12:15	27.4	9:00	25.8	10:24
	pH	5.5		5.5			
	EC (S/cm)	13.5		16.5		28.0	
MS-3	W. Temp (°c)	29.5	12:05	27.7	9:28	25.4	10:37
	pH	5.8		5.7			
	EC (S/cm)	10.0		14.0		15.0	
MS-4	W. Temp (°c)			27.8	9:43	25.3	10:47
	pH			5.6			
	EC (S/cm)			11.0		14.0	
MS-5	W. Temp (°c)			28.3	10:20	25.2	11:17
	pH			5.5			
	EC (S/cm)			8.5		9.2	
MS-6	W. Temp (°c)			28.5	10:48	27.5	11:37
	pH			5.5			
	EC (S/cm)			8.8		7.8	
MS-7	W. Temp (°c)			29.8	11:35	27.2	12:00
	pH			5.7			
	EC (S/cm)			7.0		7.8	
High Tide		9:05	3.2m	2:40	2.4m	8:56	2.6m
		21:27	3.1m	15:29	2.3	21:22	2.8
Low Tide		3:03	0.3	9:17	1.1	3:15	0.7
		15:25	0.3	21:27	1.2	15:14	0.5

Values of pH varied from 5.5 to 5.8 and were largely different from those recorded for Gbenti Swamp and the Little Scarcies. It is assumed that this high acidity is due to humic acid or soil characteristics.

EC values ranged from 7.0 μS/cm to 31 μS/cm and the water is almost pure.

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CHAPTER 6 SOIL

6-1 The Method of Survey

We carried out the soil survey by observing the soil profile, deciding the soil type at each point and then classified the project area by grouping similar soil types.

The important factors of observation are as follows:

i) Thickness of layer

ii) Texture

iii) Colour

iv) Glie layer

v) Hummus, peat, muck content

vi) Oxidized sediments

vii) Compactness

The total number of surveyed points in the project area was 52. Several additional points outside the project area were also surveyed.

We categorized the soil in the area into 3 groups based on the above mentioned factors.

6-2 Results of Survey

6-2-1 Thionic fluvisol (Ft)

The factors that effect soil formation or soil type most are weather, rocks, plant cover, ground water and human beings.

Generally speaking, the soil of this project is influenced by the ground water and plant cover, as the name of mangrove swamp soil suggests.

In the paddy fields near Kagburo creek, Mango creek and Panpa creek in the west part of the Project area, an accumulation of a most productive and suitable mud for paddy fields is found.

We named this group of soil Thionic Fluvisols (Ft).

In general, the west part of the Project area is very fertile. Rice yield is very good without fertilizer application.

The natural fertility of the muds is quite high for the relatively high levels of bases due to the flooding twice a day of brackish water and the Little Scarcies river water.

As sulfide and chloride from the seawater in the soil is washed away by the heavy discharge of fresh run-off river water which is rich is based, the pH of the soil in the area remains neutral.

When drained, in the dry season, the sulfides are oxidized to sulfates giving a drop in the pH of 2 to 3 units. During the wet season, the pH returns to neutral. So after the completion of polders, as long as the irrigation water supply is sufficient, we presume the soil will remain neutral.

6-2-2 Plinthic Gleysols (Gp)

Plinthic Gleysols (Gp) is the soil group covering the second largest area of this project. The soil is found far from the Little Scarcies and Tidal effect is indirect, so the supply of mud from the river is less compared to areas where Thionic Fluvisol soils are found, though there are high tides twice a day during the wet season.

The soil is a bog soil containing muck or peat and mostly comes from the nearby Gbenti swamp and the Tertiary hill.

6-2-3 Gleyic Cambisols (Gg)

The third group of soil in the project area, Gleyic Cambisols (Gg), occupies a very small area. It is a brown soil type resembling the upland soil.

Gg is found in the areas which are only flooded in the wet season.

6-2-4 Profile Description

Representative soil profile descriptions of the above mentioned soil groups are presented in the next section.

(1) Profile description No. 31

Date of survey	:	1st December 1982
Location	:	Masama
Slope	:	Nearly level
Farmer's Name	:	Yanken
Land use	:	Paddy field
Geology	:	Bullom series
Soil group	:	Thionic Fluvisols (Ft)

Profile description

0 - 10 cm	:	10 YR 2/1 Silt loam, humus content
10 - 40 cm	:	10 YR 3/3 Silt loam
40 - 100 cm	:	10 YR 5/4 Clay Fe_2O_3 mottled.

Remarks: Rice yield is good.

(2) Profile description No. 38

Date of survey	:	3rd December 1982
Location	:	Near Yale bana
Slope	:	Nearly level
Farmer's name	:	Unknown
Land use	:	Paddy field
Geology	:	Bullom series
Soil group	:	Thionic Fluvisols (Ft)

Profile description

0 - 15 cm	:	10 YR 3/1 Clay loam to clay wet
15 - 60 cm	:	7.5 YR 6/7 Clay Fe_2O_3 yellowish mottled wet
60 - 100 cm	:	10 YR 4/2 peaty clay, peat mottled wet

Remarks: Water table is 40 cm. Rice yield is very good. Also easy to penetrate.

(3) Profile description No. 37

Date of survey	:	3rd December 1982
Location	:	Rogbaneh area
Slope	:	Level
Farmer's name	:	Unknown
Land use	:	Grass cover
Geology	:	Bullom series
Soil group	:	Thionic Fluvisol (Ft)

Profile description

0 - 25 cm	:	10 YR 2/2 Fine sandy clay, hard test meter 15 - 16.5 mm
25 - 60 cm	:	10 YR 7/2 Clay sand, Fe_2O_3 yellowish mottled, hard test meter 15 - 18.0 mm
60 - 100 cm	:	Same as 25 - 60

Remarks: The deeper you go the coarser the sand,
Slightly hard to penetrate from 25 cm downwards
Water table at 60 cm
After 100 cm you have fine sandy clay.

(4) Profile Description No. 41

Date of survey	:	6th December, 1982
Location	:	Bomprokon
Slope	:	Less than 1%
Farmer's name	:	Unknown
Land use	:	Natural vegetation - water grass
Geology	:	Bullom series
Soil group	:	Plinthic Gleysols (Gp)

Profile description

0 - 15 cm	:	10 YR 1.7/1 Humus rich content, peaty loam - moist hard test meter 12 - 13 mm
15 - 30 cm	:	10 YR 7/1 fine sandy clay, Fe_2O_3 mottled - very moist hard test meter 21 - 22.5 mm
30 - 100 cm	:	10 YR 7/1 Clay sand Fe_2O_3 mottled, moist hard test meter 20.5 mm

Remarks: Water table at 45 cm
mottling reducing with depth
sand - medium sand

(5) Profile description No. 42

Date of survey	:	6th December, 1982
Location	:	Massama
Slope	:	Less than 1%
Farmer's name	:	Unknown

Land use : Grass (dense mat)

Geology : Bullom series

Soil group : Plinthic Gleysols (Gp)

Profile description

0 - 20 cm : 10YR 4/1 Humus - very rich peaty loam - moist
hard test meter 8.5 - 9.0 mm

20 - 25 cm : 10 YR 2/1 Humus - very rich clay loam - moist
hard test meter 11.0 - 14.5 mm

25 - 100 cm : 10 YR 7/1 Clay
Fe_2O_3 yellowish red
hard nodules i.e. plinthite
hard test meter 16 - 17.5 mm

Remarks: 5 cm layer of accumulation of organic matter and iron. Thick surface of organic matter-accumulation from decomposing plants.

(6) Profile description

Date of survey : 29th November, 1982

Location : Konta - Magben

Slope : Nearly level

Farmer's name : Foday B. Bangura

Land use : Grass
Rice nursery near the river bank

Geology : Bullom series

Soil group : Gleyic Cambisols (Gg)

Profile description

0 - 15 cm : 10 YR 4/3 Humus content, silty loam
hard test meter 21 - 22 mm

15 - 45 cm : 10 YR 5/2 Silty clay loam, Fe_2O_3 mottled,
hard test meter 23.5 - 25.0 mm
slightly sticky

45 - 70 cm	:	10 YR 5/1 fine sandy clay loam or fine sandy clay hard test meter 17.5 - 20.5 mm Fe_2O_3mottled, moist
70 - 100 cm	:	10 YR 6/1 fine sandy clay, slightly greyed Fe_2O_3mottled hard test meter 17.5 - 18.5 mm

Remarks: Wet season from January through March
flood about 30 cm deep
Rice nursery near the river bank
Farmers uprooting for transplanting

6-2-5 Soil Conductivity

According to the standard method of soil conductivity determination, 100 cc of water is added to a soil sample 20 g. But we add 150 cc of water to 50 g of soil samples instead.

In the Gp soil group, the conductivity of the soil from the surface to 100 cm beneath, was very uniform, ranging around 1,000 µmho. The Gg soil group had very low conductivity (See Table 6-2-1).

We took soil samples from the Ft and Gg soil areas a second time and measured the soil conductivity by the same method again (See Table 6-2-2).

6-2-6 Chemical Analysis

There is no great difference in pH (H_2O) for each group, but exchangeable bases are higher in Ft and Gg than Gp (See Table 6-2-3).

Table 6-2-1 SOIL CONDUCTIVITY AT 25°C

Group	Sample	Layer (cm)	µmho/cm
Ft	No. 15	0 - 15	768.0
		15 - 30	2,103.0
		30 - 100	908.0
	No. 37	0 - 25	40.0
		25 - 60	3,346.0
Gp	No. 42	0 - 20	1,002.0
		20 - 25	1,049.0
		25 - 100	1,049.0
	No. 41	0 - 15	996.0
		15 - 30	1,057.0
		30 - 100	1,033.0
Gg	No. 23	0 - 15	31.5
		15 - 45	25.1
		45 - 70	27.4
		70 - 100	21.6

Table 6-2-2 SOIL CONDUCTIVITY AT 25°C

Group	Sample	Layer (cm)	µmho/cm
Ft	No. 1	0 - 30	2,376.0
		30 - 60	1,728.0
	No. 2	0 - 30	3,456.0
		30 - 60	1,188.0
Gg	No. 7	0 - 30	45.3
		30 - 60	30.0

Table 6-2-3 CHEMICAL ANALYSIS

Group	Sample No.	Layer (cm)	pH (H_2O)	Exchangeable bases (Milli equivalent (meq) per 100 g of air dried soil)						P_2O_5(%)
				Ca++	Mg++	K+	Na+	C.E.C.	Available	Total
Ft	37	0 - 25	4.8	0.58	0.63	0.04	0.05	10.7	0.02	0.12
		25 - 60	4.7	0.13	0.32	0.02	0.07	3.5	0.04	0.12
	15	0 - 15	4.4	2.61	7.70	0.73	0.50	25.5	0.02	0.23
		15 - 30	3.9	4.52	8.10	0.50	1.75	28.4	0.32	0.59
		30 - 100	5.6	2.77	7.65	0.75	2.25	15.4	0.04	0.07
Gp	41	0 - 15	4.0	-	0.18	0.04	0.11	2.3	0.02	0.02
		15 - 30	3.8	0.04	4.10	0.02	0.03	7.2	0.02	0.04
		30 - 100	4.0	-	0.66	0.10	0.23	25.6	0.03	0.18
	42	0 - 20	4.4	0.18	1.06	0.17	0.29	26.7	0.03	0.04
		20 - 25	4.0	0.23	0.14	0.10	0.20	20.1	0.02	0.23
		25 - 100	3.7	0.43	0.19	0.40	0.03	11.4	0.02	0.06
Gg	23	0 - 15	5.3	4.26	2.88	0.21	0.09	15.7	0.02	0.28
		15 - 45	4.5	2.02	1.90	0.06	0.09	13.4	0.02	0.18
		45 - 70	4.4	1.77	1.63	0.06	0.05	11.2	0.03	0.22
		0 - 100	4.5	0.91	0.95	0.07	0.03	6.1	0.05	0.06

6-2-7 Conclusion

The percentage of the 3 soil groups only in paddy fields are as follows:

Project area	1,208 ha	100%
Thionic Fluvisols	824 ha	68.2
Plinthic Gleysols	347	28.7
Gleyic Gambisols	37	3.1

6-3 Reference

The data for salinity and pH of soils collected along the Great Scarcies is shown in Table 6-3-1.

The data shows that the greater the distance from the sea, the less the salt content of the soil. Salt levels found in February would probably not have affected matured rice plants, except possibly at Balansera, but there might have been an adverse effect on crops in their early phase as far as 17 miles inland from the sea.

Table 6-3-1 SALT AND PH ALONG THE RIVER

Conductivity and pH values of soils from twelve sites spread along twenty miles of swamps along the Great Scarcies.

Miles from the sea		Conductivity mmho		pH	
		February 4th	March 4th	February 4th	March 4th
22	- Rokon	0.45	0.59	6.0	5.1
19	- Rombomboli	1.17	1.80	6.4	5.5
17	- Rosoria	2.86	4.93	6.5	6.5
15	- Rika	1.82	5.26	5.3	6.6
12.5	- Mahai	1.93	7.17	5.7	5.1
10	- Kamom	3.03	6.62	5.7	5.4
8.5	- Kararo	4.55	9.55	5.5	5.8
6.5	- Royel Walah	4.82	11.15	5.6	5.4
5	- Majorboh	4.07	11.95	5.5	5.1
3	- Kychom	7.94	14.35	5.9	5.5
3	- Gbantuk	6.85	10.8	6.0	5.9
1	- Balansera	31.8	30.2	5.3	5.0

Source: WARDA research report

CHAPTER 7 SUBSURFACE SURVEY

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CHAPTER 7 SUBSURFACE SURVEY

7-1 Boring

7-1-1 General

The subsurface investigation of the project area consisted of bore-hole drilling including standard penetration test (SPT), and samples of the substrata were obtained using the split-spoon sampler. The main objective of this investigation was to provide information about the present subterranean conditions existing in the area for the designing of the structures for the Rhombe Swamp Agricultural Development Project.

7-1-2 Location

The area under investigation is located within the Bullom Group and it consists of a sedimentary sequence of clays, sand and gravel with laterite and lignite of probably Eocene age.

The boreholes are sited in the following villages:

BH 1 - Sirian
BH 2 - Rhombe
BH 3 - Mapekr
BH 4 - Gbenti

7-1-3 Field work

A total of four (4) boreholes were drilled (see Fig. 7-1-1) and standard penetration tests were carried out at depth intervals of two (2) metres.

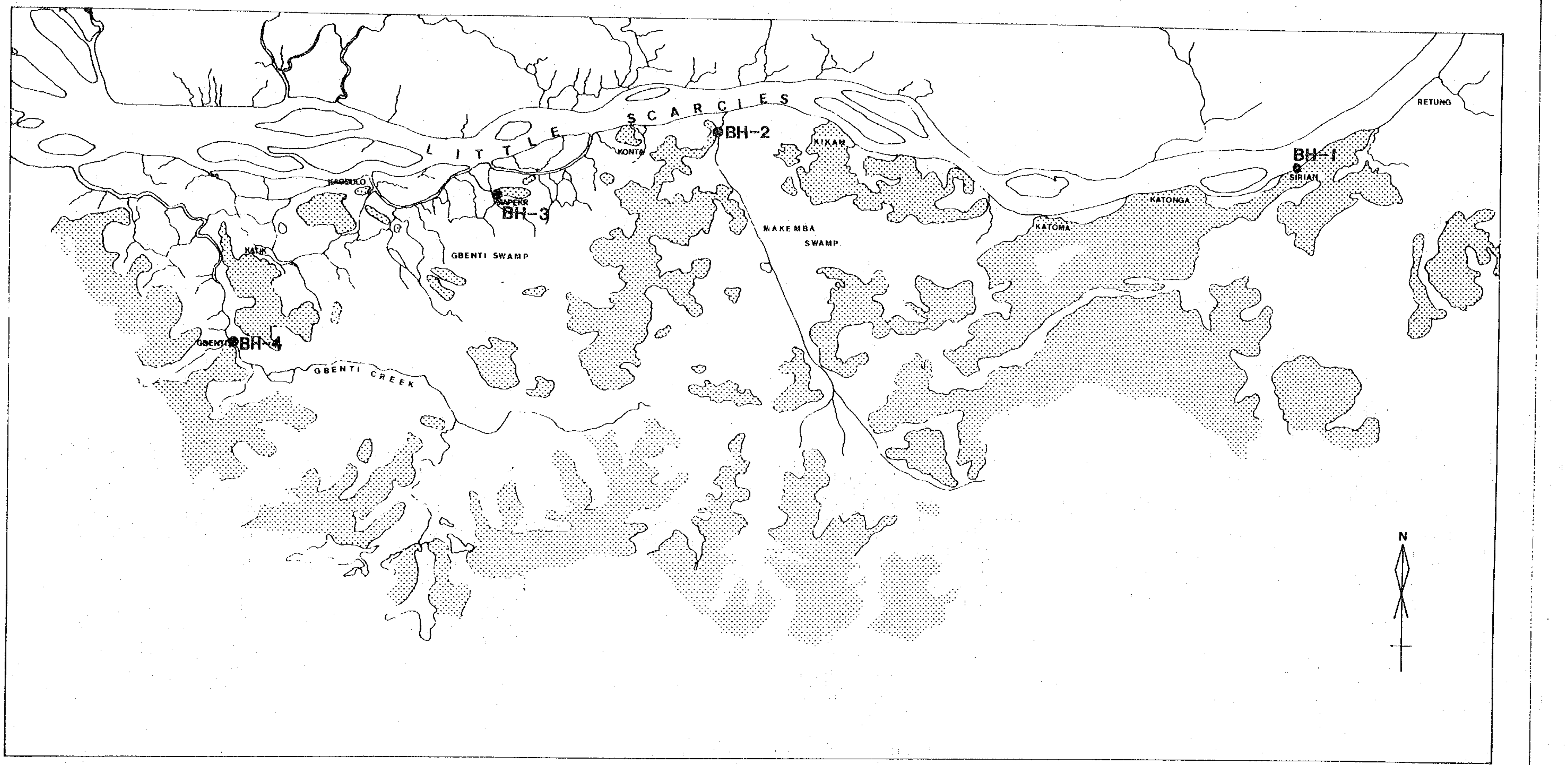


Fig. 7-I-I LOCATION MAP OF BORING

0 1 2 3 4 5KM

Fig 7－1－2 (1) BORING LOG

BORING NO. : BH－1
GROUND ELEVATION : 31.7

DEPTH	ELEVATION	GRAPHIC SYMBOL	CLASS BY FIELD IDENT	"N" Value	STANDARD PENETRATION TEST (0 10 20 30 40 50)	REMARKS
	30.7		top soil			
	29.7		coarse sand	4		
5	25.7		sandy clay	11		
				13		
10	21.7		coarse sand			
15						
20						
25						
30						
35						
40						

Fig 7-1-2(2) BORING LOG

BORING NO. : BH-2
GROUND ELEVATION : 30.3

DEPTH	ELEVATION	GRAPHIC SYMBOL	CLASS BY FIELD IDENT	"N" Value	STANDARD PENETRATION TEST (0, 10, 20, 30, 40, 50)	REMARKS
	28.3		clay loan	9		
5	24.3		heavy clay	33		
	22.3		alternative of sand&clay	8		
10				9		
				18		
	16.3		clay	37		
15	14.3		fine sand	50/22		
	12.3		sandy clay	33		
20	8.3		weathered schist rock	50/12		
				50/7		
				50/2		
25						
30						
35						
40						

Fig 7-1-2(3) BORING LOG

BORING NO. : BH-3
GROUND ELEVATION : 29.1

DEPTH	ELEVATION	CLASS BY FIELD IDENT	"N" Value
	27.1	clay loan	3
5			4
			6
			6
10	19.1	sandy clay	12
			14
15	15.1	clay	11
	13.1	medium sand	11
			3
20	9.1	fine sand	11
	7.1	silt	18
25			24
			50/12
	1.1	wheathered shist rock	50/6
30			
35			
40			

STANDARD PENETRATION TEST (0, 10, 20, 30, 40, 50)

REMARKS

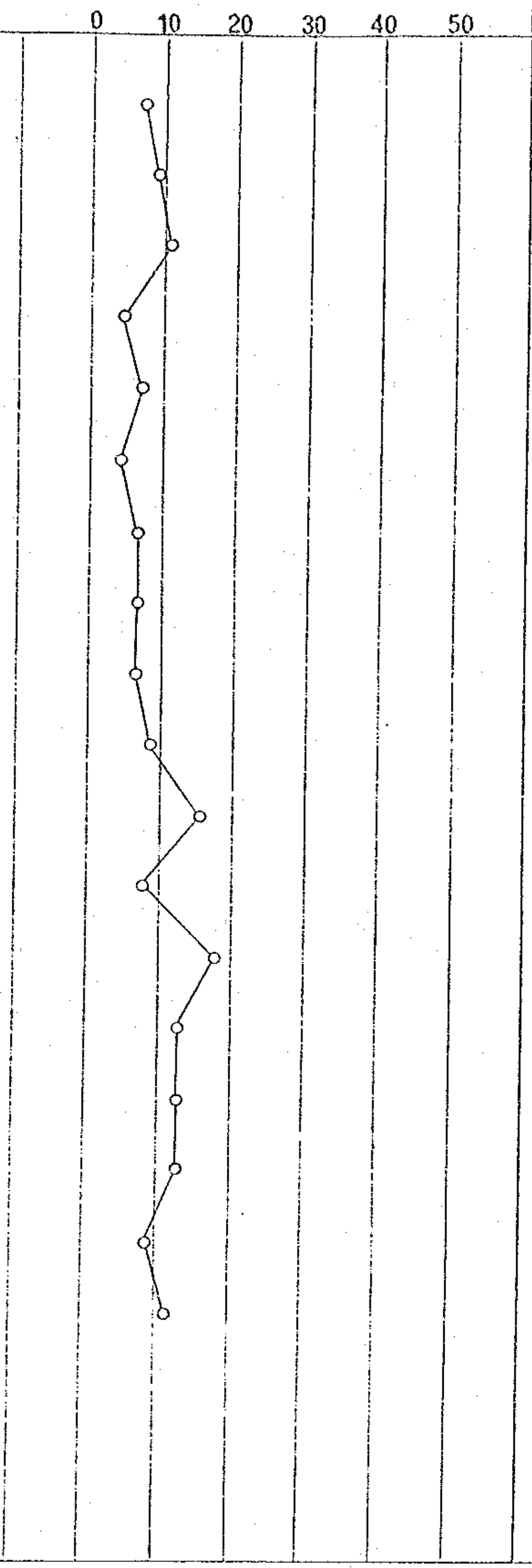
Fig 7－1－2(4) BORING LOG

BORING NO. : BH－4
GROUND ELEVATION : 31.7

DEPTH	ELEVATION	CLASS BY FIELD IDENT
	29.7	clay loam
5	25.7	lateritic clay
	23.7	Clay
10	19.7	sandy clay
	17.7	coarse sand
15	15.7	fine sand
20	11.7	clay
	7.7	coarse sand
25	5.7	clay
30	1.7	lignite
35	-4.3	alternation of fine sand & clay
40		

"N" Value: 7, 9, 11, 4, 7, 4, 7, 7, 7, 9, 16, 8, 18, 13, 13, 13, 9, 12

STANDARD PENETRATION TEST



REMARKS

The standard Koken SD-3A (Rotary Hand Feed Type) drilling machine was used during the operation. The drilling fluid used was Bentonite.

The results of the borings are shown in Fig. 7-1-2 and Table 7-1-1. Atention must be drawn to Borehole No. 1 at Sirian. A depth of only 10 m was attained as a result of the fact that too much water was entering the hole and the wall kept on collapsing. The total length drilled in the four (4) boreholes was 96 metres. The depth of drilling for each borehole was determined by the site engineer. Vertical holes were drilled conforming to the ASTM standard designation D2113.

Table 7-1-1 COMPLETED BORING WORKS

Boring No.	Boring Length (M)	SPT (PCS)	Sampling (PCS)
BH - 1	10	3	4
BH - 2	22	11	12
BH - 3	28	14	14
BH - 4	36	18	19
Total	96	46	49

7-1-4 Standard Penetration Tests

Standard Penetration Tests conforming to the ASTM Standard Designation D.1586 were carried out during the drilling at two (2) metre depth intervals.

The split-spoon sampler is first driven through 15 cm as a seating drive and then driven a further 30 cm. The penetration resistance, N, is the number of blows required to drive the sampler the further 30 cm after the seating drive.

There were 46 standard penetration tests carried out and 49 samples taken.

7-2 Cone penetration test

Cone penetration test was made at 15 points as shown in Fig. 7-2-1 and Fig. 7-2-2.

Shape of cone is as follows:

Tip angle	30°
Bottom area	6.45cm^2

Fig. 7-2-1 LOCATION OF CONE PENETRATION TEST

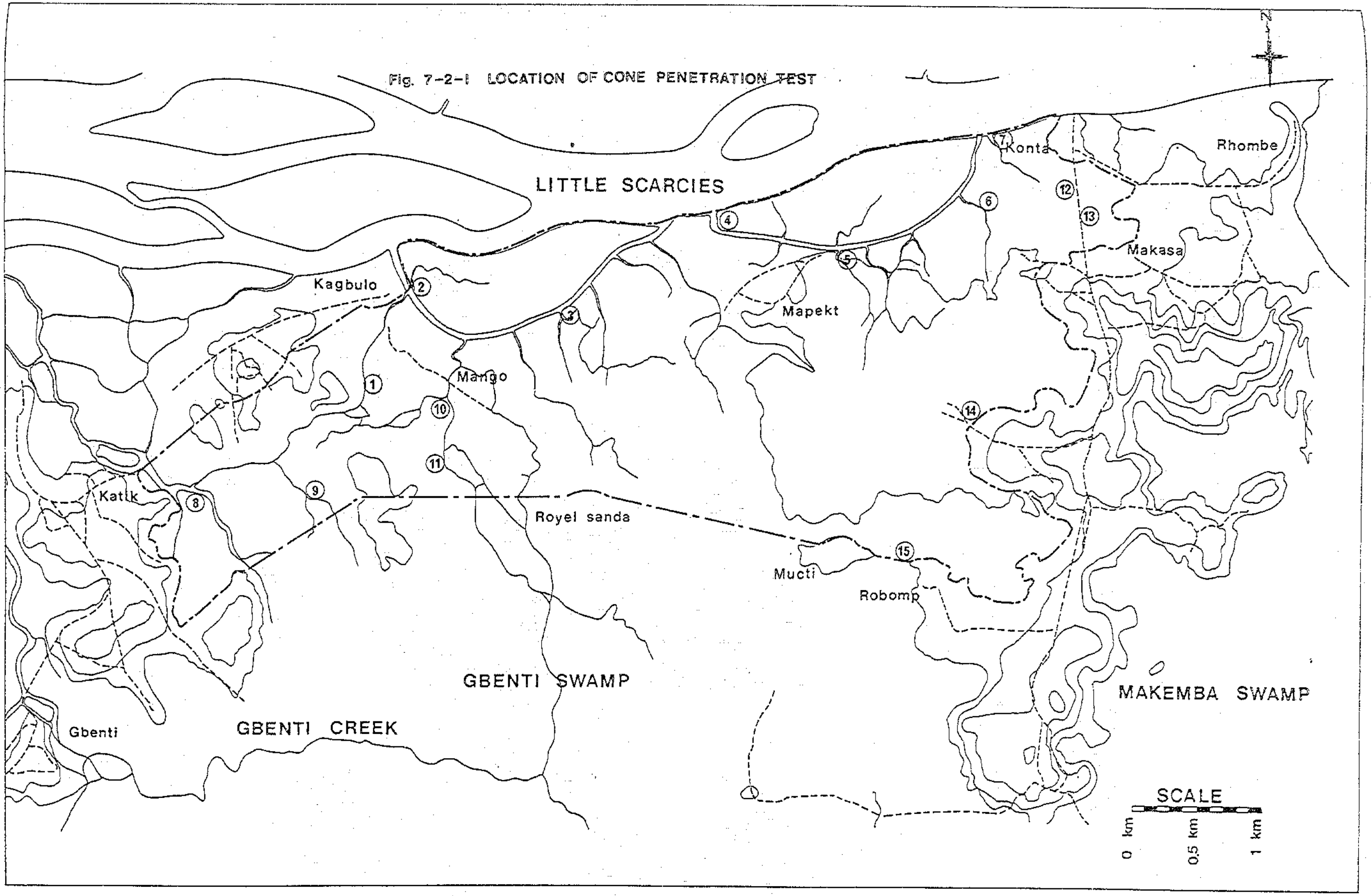


Fig. 7-2-2 (1) CONE PENETRATION TEST

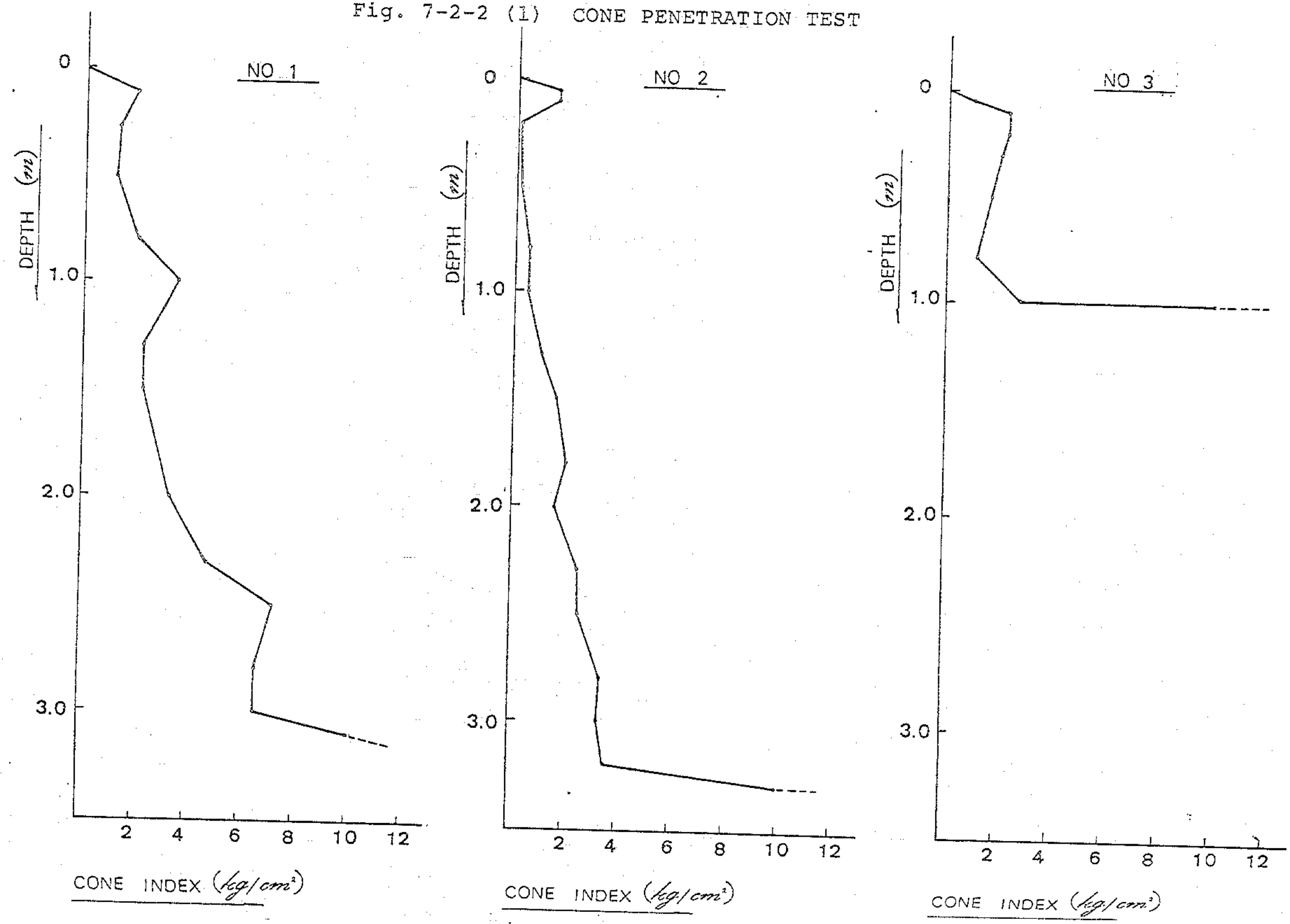
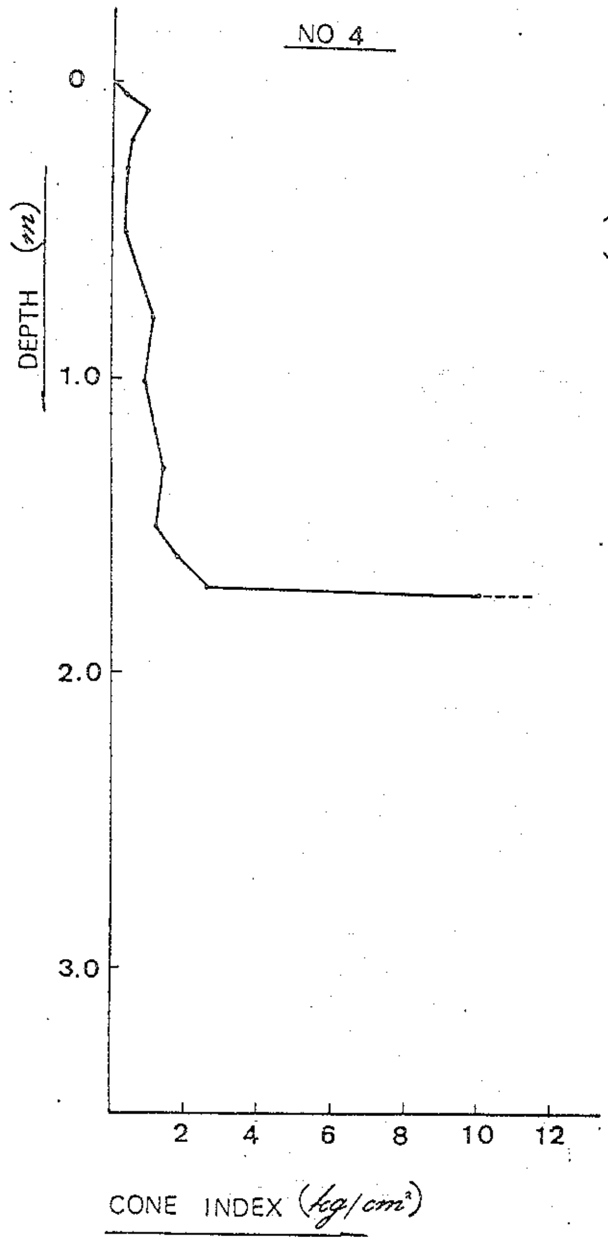
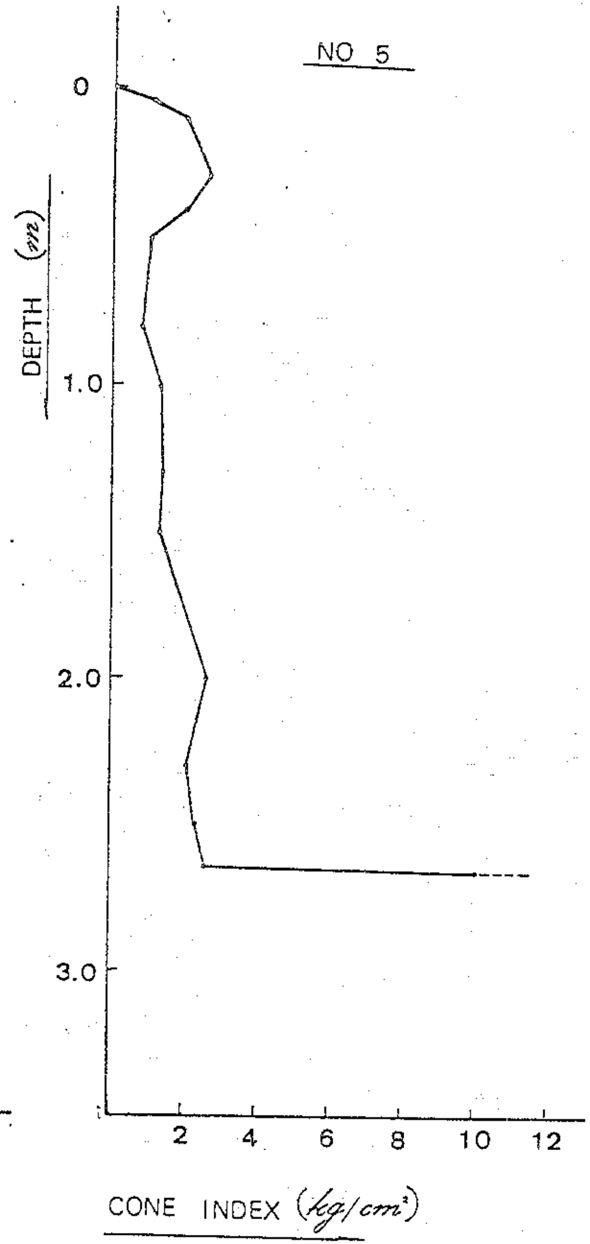


Fig. 7-2-2 (2) CONE PENETRATION TEST





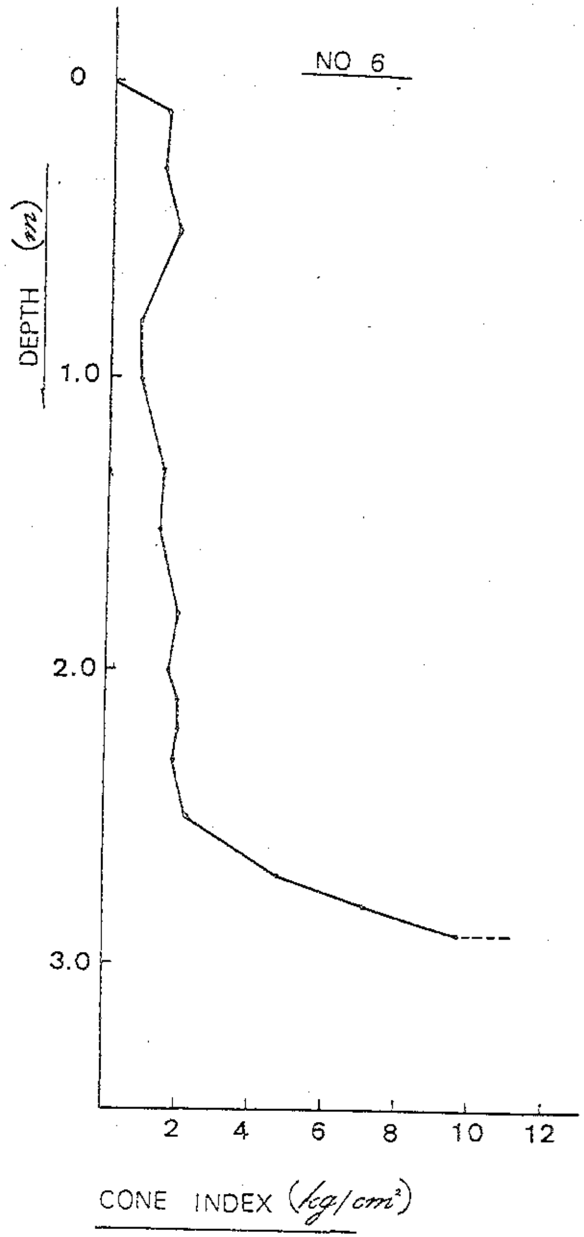


Fig. 7-2-2 (3) CONE PENETRATION TEST

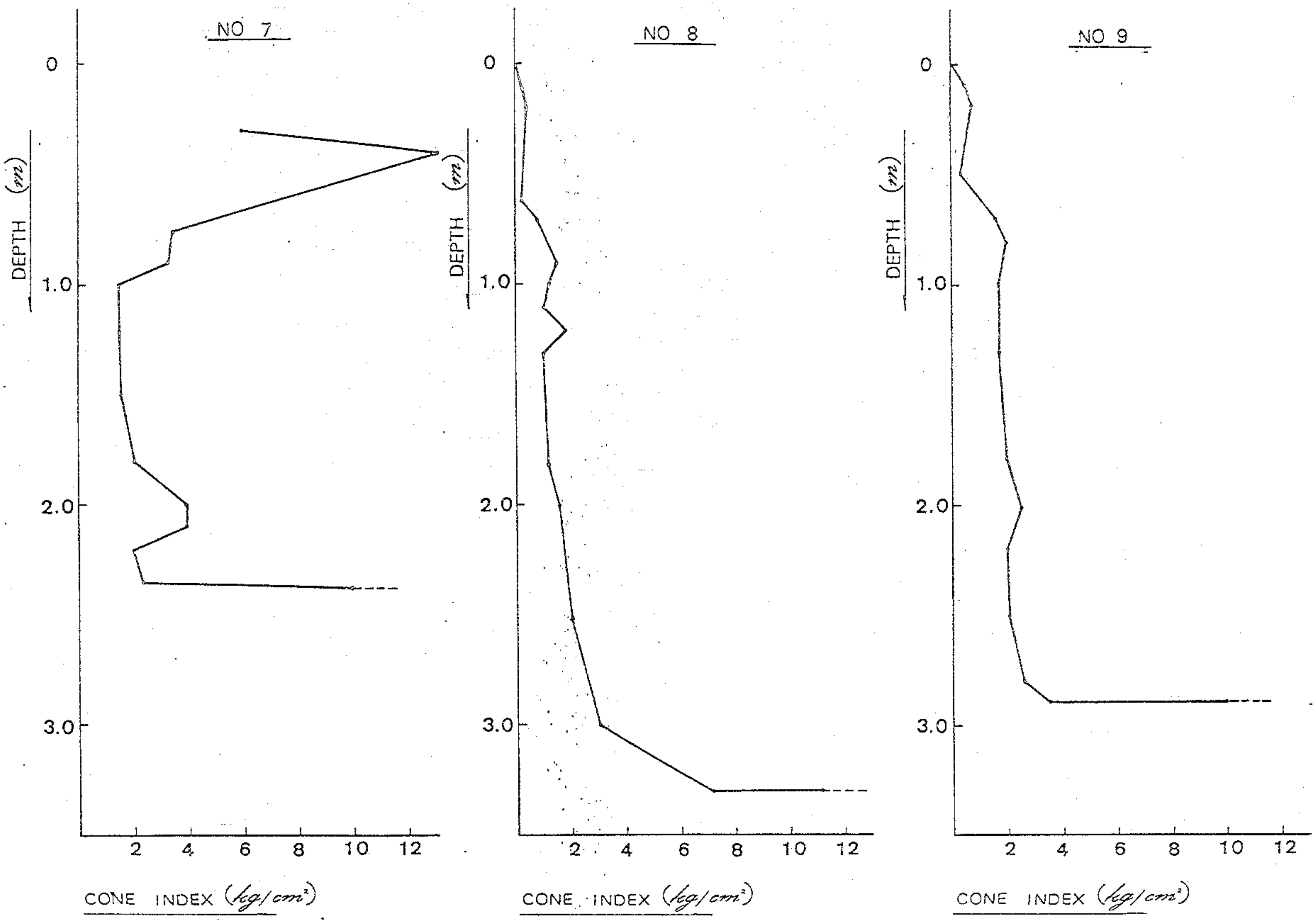
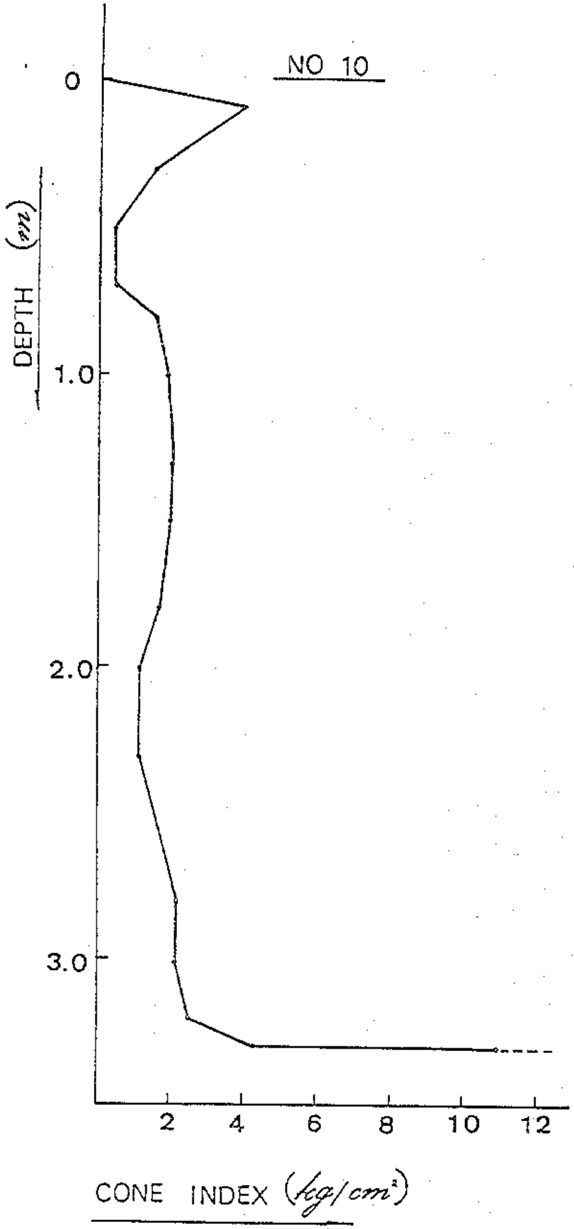
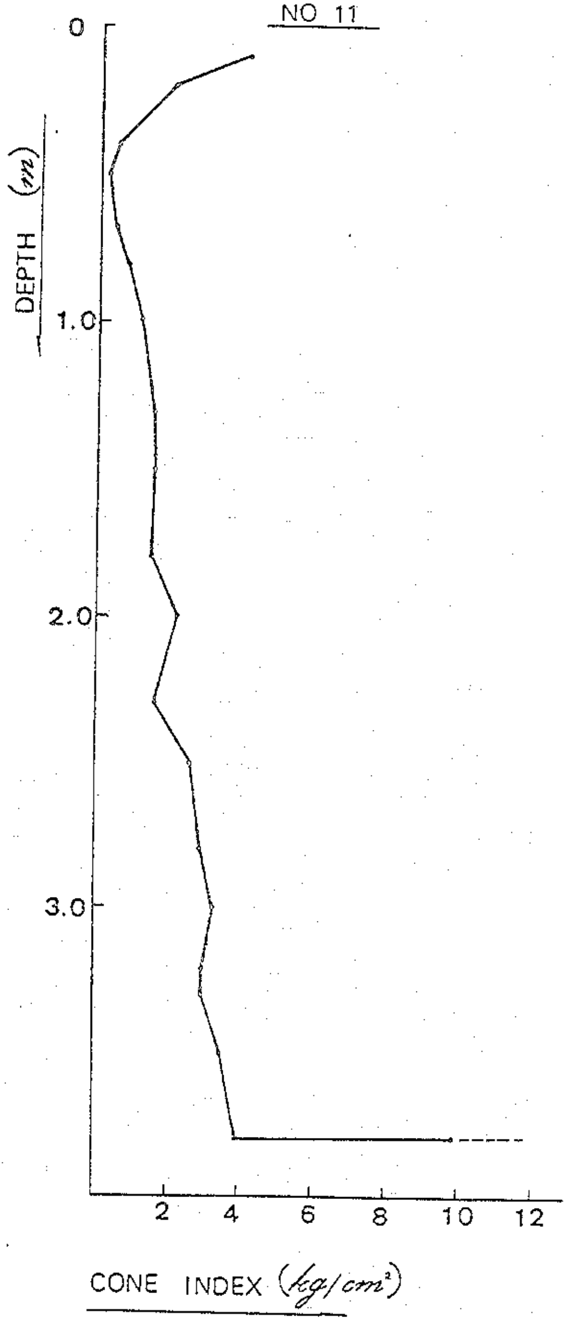


Fig. 7-2-2 (4) CONE PENETRATION TEST





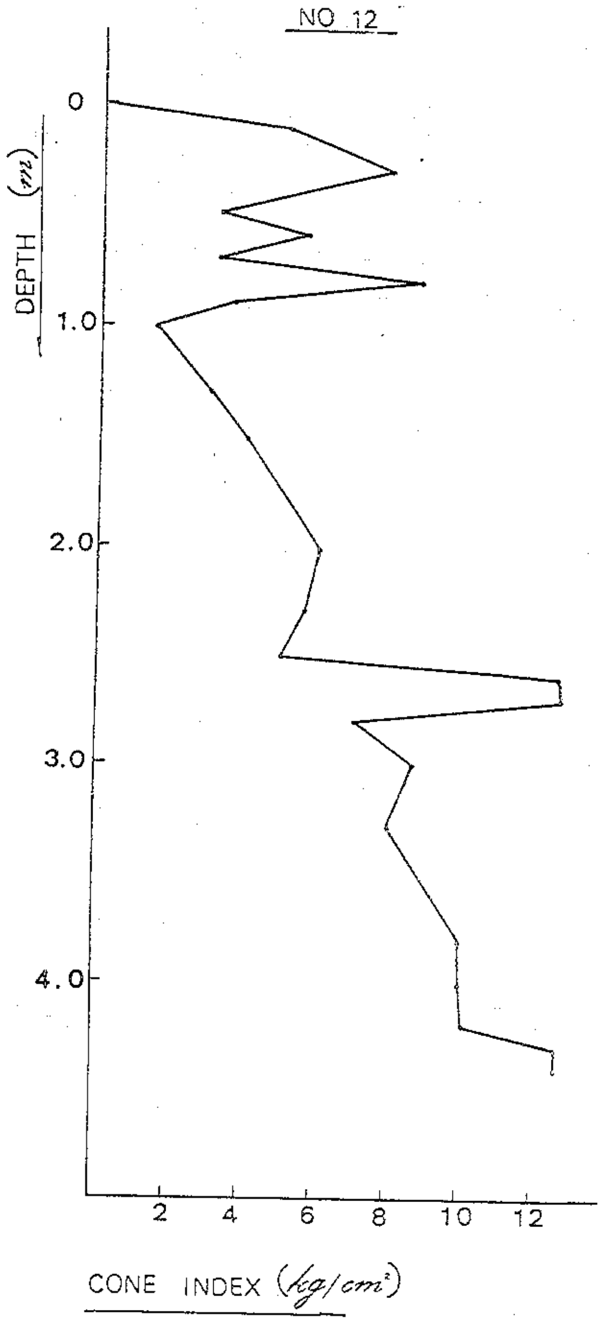
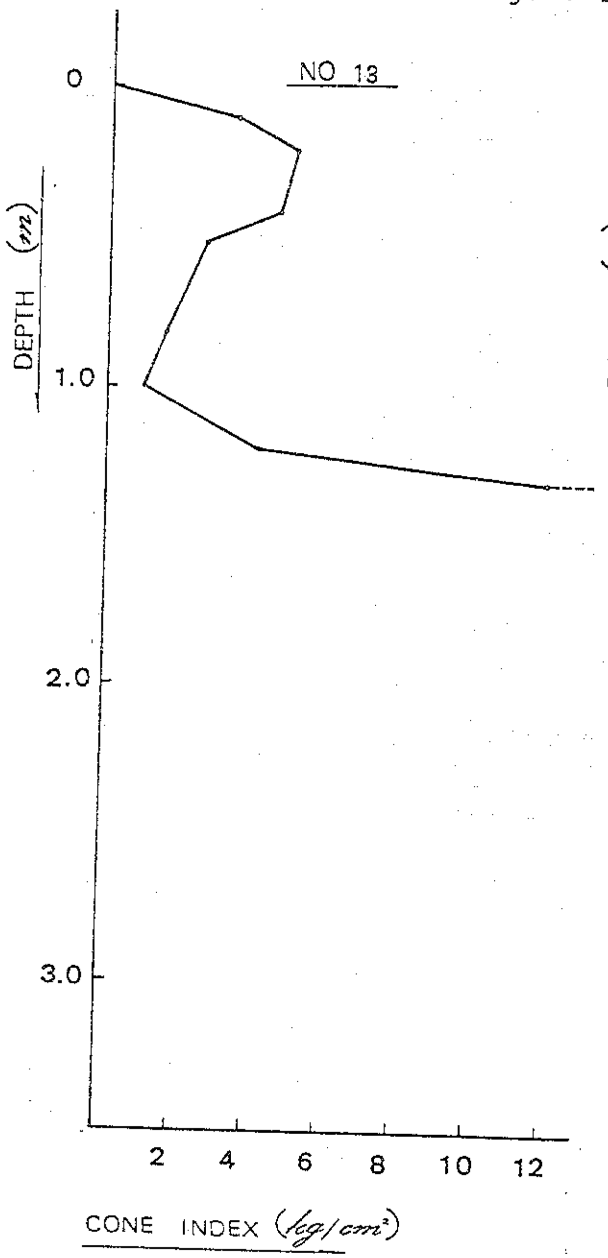
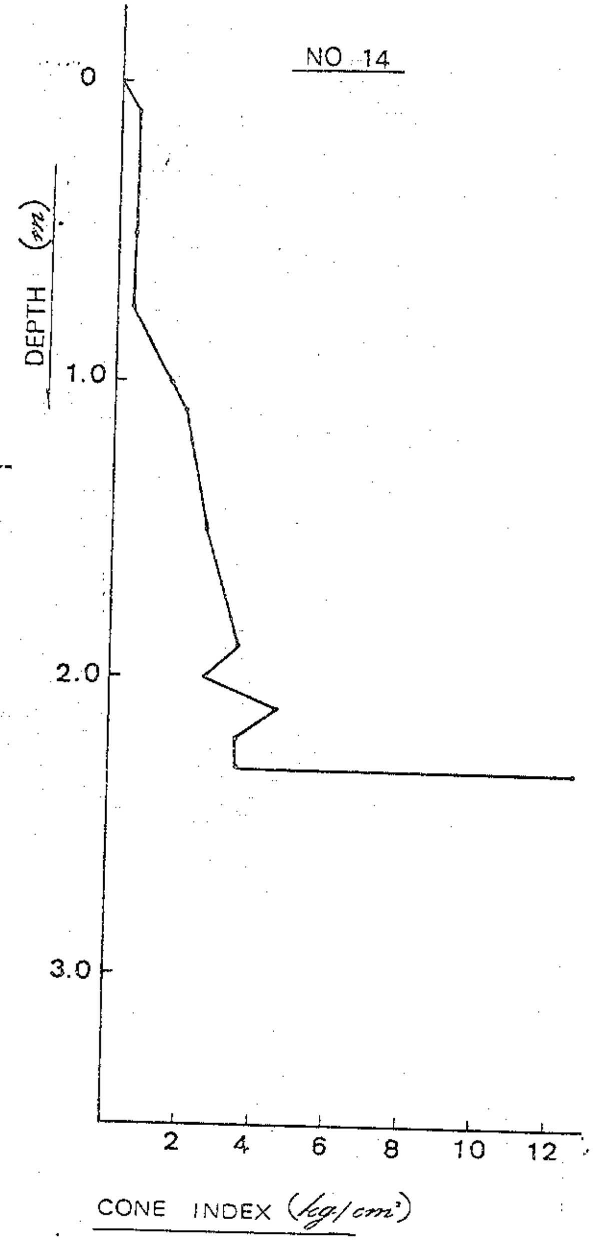
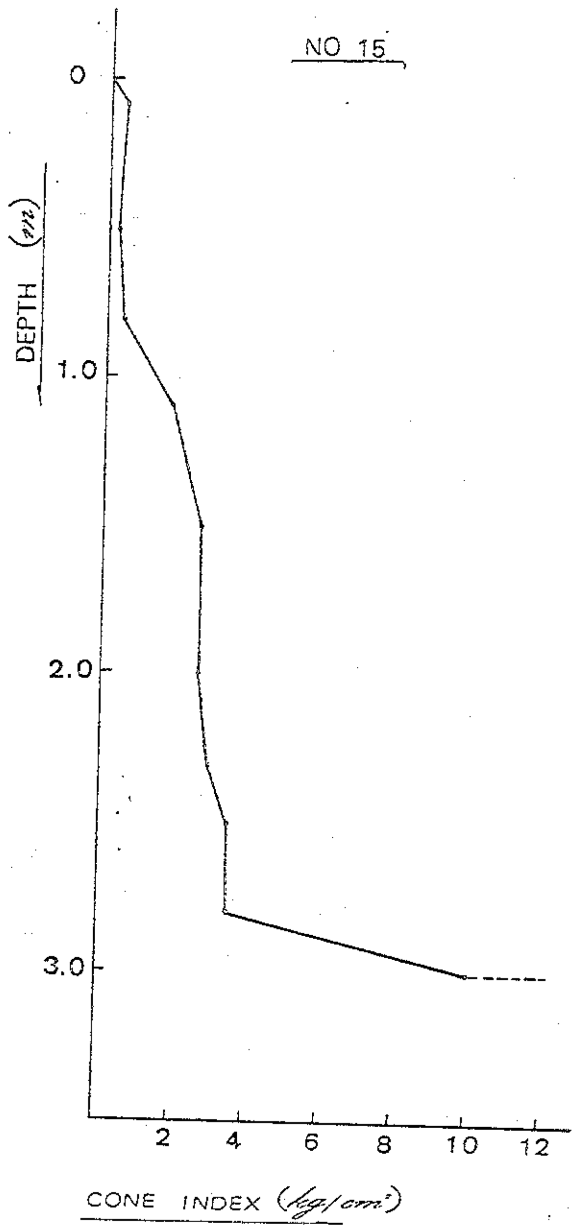


Fig. 7-2-2 (5) CONE PENETRATION TEST







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CHAPTER 8 DEVELOPMENT ALTERNATIVES CONSIDERED

The development area of the project is very flat and the elevation is approximately between 28.0m and 30.0m (Storey datum). In the present situation, flooding in the wet season and intrusion of salty water in the dry season are significant features of this area.

Utilizing tide movement, irrigation and drainage are carried out twice a day, and rice is cultivated only in the wet season. There is absolutely no place where double rice cropping is employed in this area.

The objective of improvement of this area is to make possible double rice cropping each year. Therefore, correct irrigation and drainage is necessary throughout the year.

Fundamentals of the development plan from the engineering point of view are as follows:

(1) Flood protection
(2) Drainage of excess rainfall
(3) Prevention of salt-water intrusion during dry season
(4) Security of steady water resources

Two crops of rice can be raised in the area when these conditions are fulfilled.

Several development alternatives were considered for the above mentioned purposes. They can be classified into how and where to get water, how to distribute it and how to consolidate this site. They are listed in Table 8-1-1.

The evaluation and comparison of minor structures will be made at the time of detailed design.

Table 8-1-1 LIST OF ALTERNATIVES

	Big Scale Polder Plan	Small Scale Polder Plan
Site Development Plan	Poor drainage in adjacent swamp area, as the bund will effectively isolate the project area. Necessity of installing a large scale drain pump and gate. Impossibility of transportation by boat at present. It is necessary to construct farm roads within the polder. This plan is not recommended.	Creeks will serve as drain channels and transportation by boat can continue uninterrupted. Bunds for polder can be used as farm roads. This plan is recommended.

Development plan	Small Scale Polder Plan							
Water resources	The Little Scarcies						Makemba Swamp	Groundwater
Method of intake	No Pumping I			Pumping II	Pumping III	No pumping IV	No pumping V	Pumping VI
Method of supply	No pumping			No pumping	No pumping	Pumping	Pumping	No pumping
Place of Intake	Sirian	Mange	Makane	Sirian	Rhombe	Rhombe	Makasa	Project area
Features	Necessary water level at this point is EL.35.24m to storey datum, whereas the mean low tide level in February is in fact EL.27.3m to story datum. This plan is impossible.	The necessary water level at Mange is El.36.7m, whereas the low water level is in fact EL.29.5m. Therefore this plan is impossible to intake water without pumping.	Construction of tunnel (L = 2.8km, ϕ2,500) and 23.9km long convey channel are necessary. Construction cost is estimated about Le. 30 million. This plan is not recommended.	Water quality is good for rice throughout the year. Construction cost is higher than Rhombe intake plan.	Operation of pumping is over by the middle of February. Water quality of this period is good for rice. Pump station for drainage is necessary at each polder. Necessary facilities: Irrigation pump station, Q = 1.2 m3/s x 3 H = 5.6m — 1 Drainage pump station, Q = 7 m3/min. x 2 H = 3.5m — 16 Convey channel (banking) — 8,200 m Convey channel (cut) — 2,000 m Siphon Dimension 2m x 1.5m — 4 Siphon Dimension ϕ800 — 4 Bund W = 3.0m — 38.9 km Land consolidation — 1,300 ha	Supply of irrigation water is pumped up by the small pump made at each polder. Drainage is performed by the same pump. Water control is performed by miter gates. Necessary facilities: Miter gate (Rhombe, Makasa) — 2 Pump station for irrigation and drainage 16 each 7 m3/min. x 2 H=3.5m — 16 Water supply channel (cut) — 13,250 m Siphon Dimension 2m x 1.5m — 4 Siphon Dimension ϕ800 — 4 Bund W=3.0m — 38.9 km Land consolidation — 1,300 ha	Little water in the dry season. When this swamp is used as a new reservoir, existing cultivating land, about 240 ha, will not be available. The Construction of dikes will be necessary to store water. Therefore this method is not so good as the direct intake at Rhombe on The Little Scarcies because of the high construction cost for reservoir.	A groundwater development is not recommended because a major part of the project area consists of impermeable layer such as swamp deposits and weathered basement with lack of sandy layers.

8-1 Site Development Plan

8-1-1 Large Scale Polder Plan

For the large scale polder plan, the total area is surrounded by a bund, and one large scale polder is constructed in the site.

This plan has the following features:

(1) Mango Creek, Katik Creek and Kagbulo Creek have a role as drainage channels of Gbenti Swamp. Under this plan these three creeks will be cut off, worsening the drainage in the total swamp area. As a result, the land presently under cultivation, which lies on the outskirts of the swamp area, will be greatly decreased, due to the inevitable rise in water level that will take place.

To clarify the full extent of the effect on the outlying area, a long term investigation will have to be undertaken.

(2) A large scale pump station for drainage and a gate should be constructed.

(3) Transportation by boat is very important for local people at present.

This manner of transportation will be rendered impossible under this plan. It is proposed that the traditional way of transportation should be retained, in the interest of the people.

(4) A farm road network will have to be arranged in the polder. This road network has almost the same role as that of the bund in the small polder plan. This means there is no big difference in the banking earth volume between the large and small scale plans.

8-1-2 Small Scale Polder Plan

The smale scale polder plan involves retaining the existing large creeks exactly as they are and dividing the site into 16 small scale polders.

Drainage will be conducted through miter gates constructed at each polder during the time of low tide and flooding water will be prevented from entering by the same gates.

Excessive rainfall will be drained by drain pumps during the time of external high water level.

The following features can be observed.

(1) As the existing large creeks are retained, no negative effect is created in the adjacent swamp area. Transportation by boat can continue uninterrupted, as it remains unaffected.

(2) Drainage of the site can be made into the existing creeks utilizing the movement of tide level.

(3) The bund made for each polder can double as a farm road.

In conclusion, this small scale polder plan is highly recommended for this site, because this scheme can easily be expanded to adjacent swamps.

8-2 Water Resources and Method of Intake and Supply

8-2-1 Intake and Supply without Pumping

The idea of this plan is to take water from the Little Scarcies, conveying this water to the site by gravity. As no pump is required, there are no operating problems, so this seems well suited to the prevailing conditions of the site.

(1) Intake at Sirian

Necessary elevation of the convey channel at the western end of the site is 31.5m (Storey datum). The gradient of the channel is assumed to be 1/5000, therefore the necessary elevation at Sirian should be as follows:

31.5 m + 12,500 m x 1/5000 = 34.0 m

The average low tide level at Sirian in February is observed to be 27.3 m. Therefore, intake at Sirian by this method is impossible.

(2) Intake at Mange

Distance between the Site and Mange is 26 km. The necessary elevation at Mange is as follows:

31.5 m + 26,000 x 1/5000 = 36.7 m

But, low water level at Mange bridge is estimated at 29.5 m, therefore intake at this point is also impossible (See Fig. 8-2-1).

(3) Intake at Makane, which is about 8 km upstream of Mange, appears possible. In this case, tunnel construction is necessary. The construction cost of this scheme can be calculated as follows:

1) Tunnel construction

Diameter of tunnel is assumed 2,500 mm.
Tunnel excavation cost is assumed Le. 300/m3
Length of tunnel 2.8 km

Construction cost

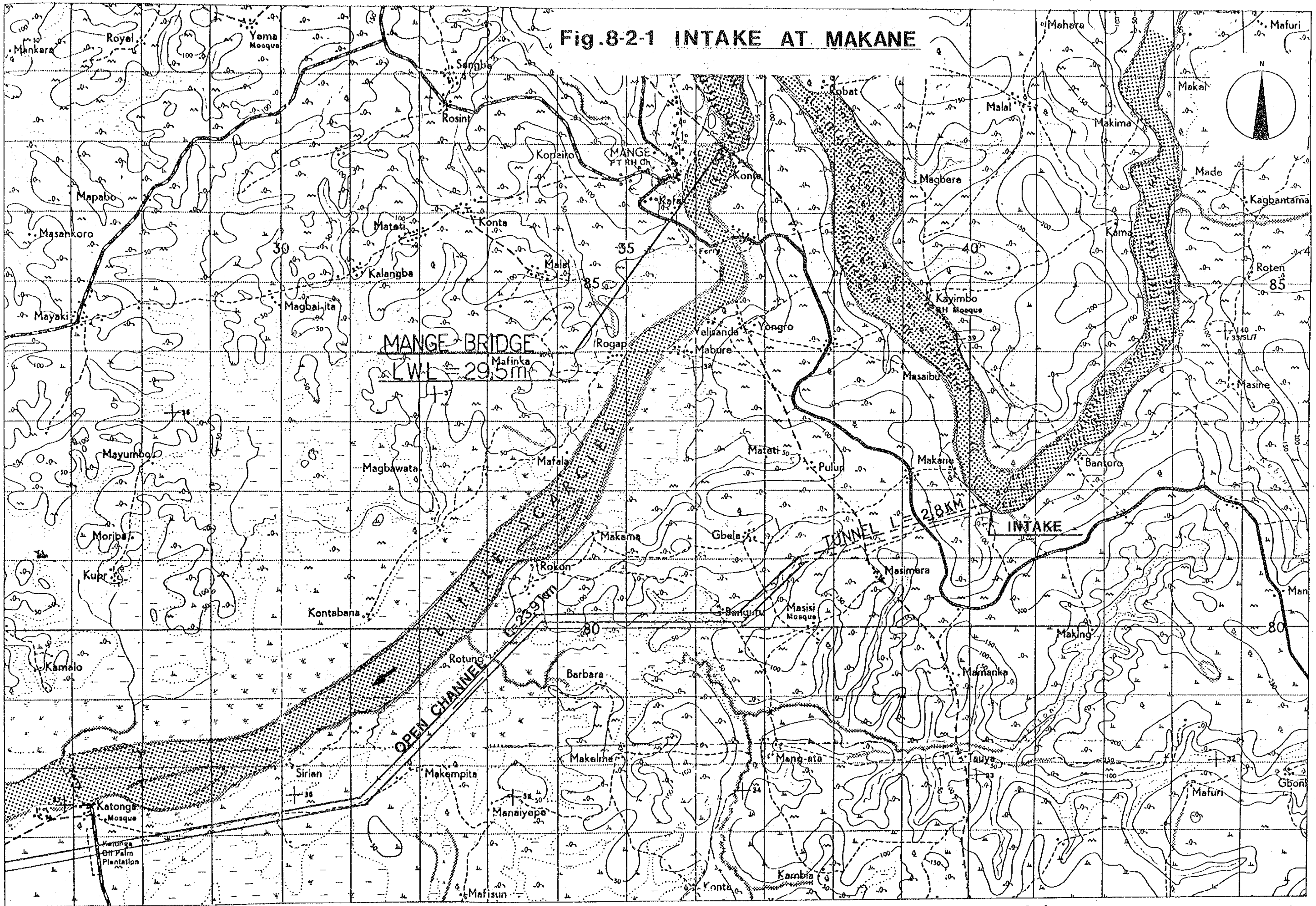
$$\frac{\pi \times 2.5^2}{4} \times 2.8 \text{ km} = 13,744 \text{ m}^3$$

$13,744 \text{ m}^3 \times$ Le. 300 = Le. 4,123,200

2) Convey channel

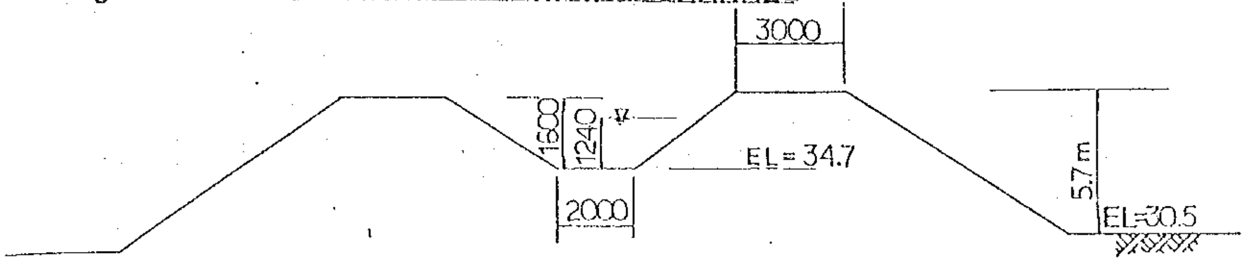
Elevation adjacent to Sirian is assumed at 30.5 m. A section of the channel is illustrated in Fig. 8-2-2.

Fig.8-2-1 INTAKE AT MAKANE



Scale = 1:10,000

Fig. 8-2-2 SECTION OF DRIVING CHANNEL



Banking volume V

= (1+1.5x1.6+3+5.7x1.5+3+1.5x1.6+1)x2x1/2x5.7

- (2+1.5x1.6)x1.6 = 121.7-7.0 = 114.7 m^2

114.7 x^2 x 23.9 km = 2,741,000 m^3

2,741,000 m^3 x Le. 8/m^3 = Le. 21,928,000

3) Total cost

Convey channel + Tunnel

= Le. 4,123,200 + Le. 21,928,000

= Le. 26,051,200

Including other supplementary structures, the total estimated cost will be Le. 30 million. This cost is extremely high, therefore, this plan is not recommended.

8-2-2 Intake or Supply by Pumping

(1) Pumping at Sirian

According to MRT report, even at the time of spring tide (3.3 m to tide table) on March 27, 1971, electrical conductivity at Sirian was 400 μs/cm, therefore intake of good quality water is possible all the year round at Sirian.

But following our investigation it is recommended that water be taken at Rhombe.

The reasons are related to the shorter cropping period and the operation of miter gates. (Refer to Chapter 2 and 9-1-3 water supply channel).

Therefore, the idea of an intake at Sirian is automatically ruled out.

(2) Pumping at Rhombe and Supply by Gravity

A pumping station should be adjacent to Makasa due to the suitability of the foundation and topography.

1) Capacity of pump

Irrigation requirement per 100 ha is calculated at about 10,000 m^3 per day.

The total area of paddy field is assumed to be about 1,300 ha. The operation hours of the pump are assumed to be 16 hours a day. Capacity of pump is:

10,000 m^3/100 ha x 1,300 ha ÷ (16 hours x 60 x 60) = 2.26 m^3/sec.

Allowing for an emergency situation, this capacity should be divided into two units, with the addition of one spare pump. Therefore 3 units of 1.13 m^3/sec pumps are proposed.

2) Pump head

Pump head will be determined by water depth of the channel. The proposed channel is illustrated in Fig. 8-2-3.

The calculation is made using Manning's formula.

$$Q = A.V.$$

$$V = \frac{1}{n}.R^{2/3}.I^{1/2}$$

where, Q : diacharge

A : area of cross-section of waterway

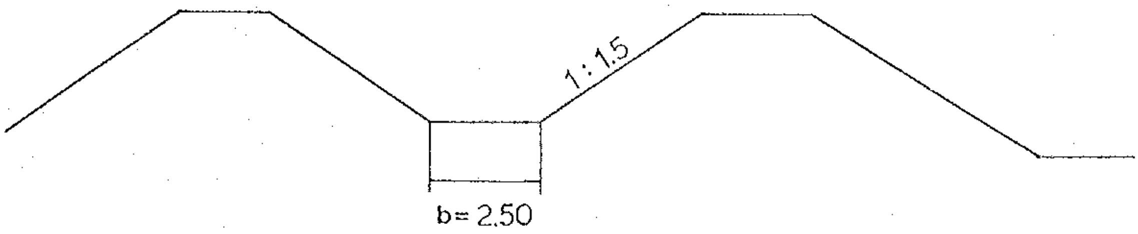
V : velocity

N : Manning's coefficient of rugosity

R : hydraulic mean radius

I : slope of water surface

Fig. 8-2-3 SECTION OF DRIVING CHANNEL



Elevation of channel end point 29.30 m

Assume beginning point elevation 31.50 m

$$I = \frac{31.50 - 29.80}{8,200} = 0.000207$$

Water depth:

$$K_1 = \frac{Q.n}{I^{1/2} \times b^{8/3}} = \frac{2.26 \times 0.027}{0.0144 \times 11.513} = 0.368$$

Refer to water depth calculation chart,

$$\frac{H}{b} = 0.48$$

$$H = 1.20 \text{ m}$$

$$V = \frac{1}{n} R^{2/3} I^{1/2} = 0.443 \text{ m/sec.}$$

Discharge elevation of pump is

31.5 m + 1.2 m = 32.7 m

Lowest suction elevation is 27.14 m

(Refer to 4-2-3)

Total net pump head is

32.7 m - 27.14 m = 5.56 m ≒ 5.6 m

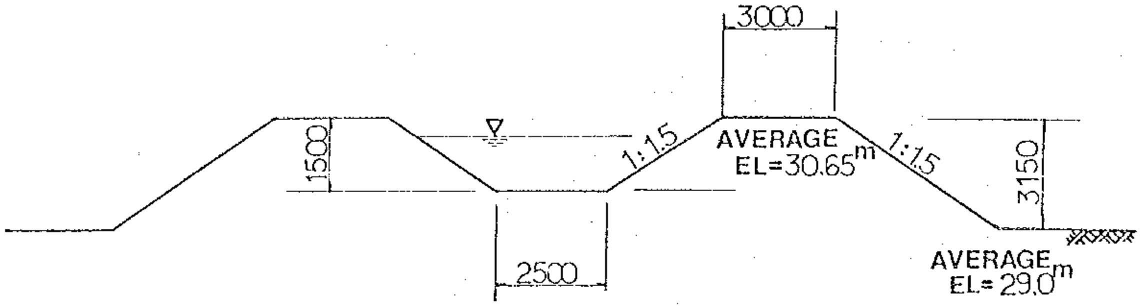
3) Necessary facilities

a. Pump station

$Q = 1.13 \text{ m}^3/\text{sec}$, H = 5.6 m x 3 each

b. Banking convey channel

Fig 8-2-4 SECTION OF DRIVING CHANNEL



Banking volume

$$V = (1.25+1.5\times1.5+3.0+1.5\times3.15+3.0+1.5\times1.5+1.25) \times 3.15$$
$$- (2.5+1.5\times1.5) \times 1.5$$
$$= 55.83 - 7.13 = 48.7\ m^3/m$$

Total length L = 8,200 m

c. Pump station for drainage

As mentioned in chapter 9, the necessary drainage capacity is 0.24 m^3/sec per 100 hectares. This volume is divided into two units, so that each pump station has two units (Q = 0.12 m^3/sec x 2 each, H = 3.5 m) of pumps.
16 pump stations are to be constructed in the total area.

d. Siphon crossing creek, irrigation and drainage of small channel, bund construction, land consolidation and others.

The construction cost of the above is almost equal to the cost of the alternative IV (Refer to Table 8-1-1).

(3) Intake at Rhombe without pumping and supply, by small pump at each polder.

Necessary water is taken through a miter gate constructed at Rhombe. When the river water level rises, water enters the water supply channel. But as the level in the channel rises and the river water level decreases, the miter gate closes and water is stored in the channel.

1) Necessary facilities

a.	Miter gate at Rhombe	1 unit
b.	Miter gate at Makasa	1 unit
c.	Water supply channel	13,250 m
d.	Pump station for irrigation and drainage	16 stations

(4) Water of Makemba Swamp

In the dry season, the surface of this swamp dries up.
To make this swamp a reservoir, existing cultivating land which lies on the outskirts of the swamp will be damaged, and also long distance bund construction is necessary for the retention of water.

Therefore this water resource is not better than the direct intake from the Little Scarcies because of the high cost of reservoir construction.

(5) Groundwater

A sand layer and a sand layer with a thin clay layer are hydrogeologically considered to be objects of a groundwater exploitation in and around the project area. Ground water of these layers has already been extracted by a deep well around the Rungi Airport and has also been utilized by some shallow wells in the project area.

The water quality of the groundwater was relatively stable, remaining unaffected by sea water intrusion, although there was a high level of acidity. Consequently if these sandy layers are distributed widely and thickly enough under the project area, it will be possible to extract groundwater to cover irrigation requirements.

In order to explore the potential of the above mentioned possibility some electrical soundings were conducted in and around the project area. As a result, it was found that a major part of the project area consisted of clayey sediments which were swamp deposits and clayey layers of Bullom series and a weathered basement with lack of sandy layers.

Taking the above hydrogeological findings into consideration it is concluded that a groundwater development is not appropriate in the project area.

8-3 Comparison of Construction Cost

As a result of investigation, the small scale polder plan is recommended as the most appropriate one for the site development. With regard to water resources, the final competitive alternatives proved to be III and IV. Therefore the construction and operation cost of each plan was compared, as listed in Table 8-3-1.

Table 8-3-1 COMPARISON OF INVESTMENT COST AND M/O COST

(Unit: Le. 1,000)

Item	Plan III	Plan IV
1. Pump Station	3,257	1,659
2. Water Supply Channel	5,982	1,849
3. Road and Bridges	4,386	4,386
4. Bund and Land Consolidation	7,092	7,029
5. Miter Gate	-	62
6. Others	13,171	13,171
Total	33,888	28,156
M/O Cost for Project Life	1,957	1,789

8-4 Recommended Plan

As a result of investigation, the small scale polder plan is recommended as the most appropriate for the site development, with regard to water resources and supply, the plan IV is recommended finally. (Refer to Table 8-1-1).

Summary of the recommended plan

a.	Method of development	:	Small scale polder plan
b.	Water resources	:	The Little Scarcies at Rhombe
c.	Method of Intake and supply water	:	Intake without pumping and supply by small pump
d.	Method of control of water	:	Miter gates are proposed

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CHAPTER 9 IRRIGATION AND DRAINAGE

9-1 Irrigation

9-1-1 Irrigation water requirement

(1) General

The water requirement for rice irrigation is estimated on the basis of the proposed cropping pattern programed in Chapter 2.

The following procedures were adopted:

- Estimation of crop evapotranspiration
- Estimation of effective rainfall
- Estimation of net irrigation water requirement
- Estimation of gross irrigation water requirement

It is noted that the estimate is made on the basis of a ten-day interval.

(2) Crop evapotranspiration

Crop evapotranspiration (ET crop) is estimated on the basis of reference crop evapotranspiration (ETo) and crop coefficient (Kc).

a) Reference crop evapotranspiration (ETo)

In estimating reference crop evapotranspiration (ETo) climatic data such as temperature, humidity, wind speed and sunshine hours obtained at the Lungi meteorological station have been referred to. Among the various methods for estimating reference crop evapotranspiration, the modified Penman method is applied in this case considering the level of accuracy of the results obtained from this method. The calculation is made on a monthly basis for a period of 21 years from 1960 to 1980, as shown in Table 9-1-1 (Sample) and Table 9-1-2 (Summary).

b) Crop coefficient (Kc)

Crop coefficient (Kc) changes by crops, time of planting or sowing, stage of crop growth and climatic conditions. The coefficient of rice in this study is determined in accordance with the FAO guideline. No difference is assumed in Kc values between broadcast and transplanted rice, since the coverage rate during first month after transplantation is little different from that of broadcast rice. The averaged Kc is estimated on a 10-day basis, as presented in Table 9-1-3.

c) Crop evapotranspiration (ETcrop)

Crop evapotranspiration is calculated by the following formula:

$$ETcrop = Kc \times ETc$$

(3) Percolation

In the wet season, the groundwater table is very close to the ground surface, and the rate of vertical percolation is assumed to be negligible. In the dry season, the groundwater table falls to a depth within one metre below the ground surface.

Generally, paddy is planted in the field of clayey soils. Judging from the results of field investigations and the MRT study, the percolation rate in the clayey soils will not exceed 1.0 millimetres per day. In view of this, percolation in the paddy field is assumed to be

Table 9-1-1 CALCULATION OF REFERENCE CROP EVAPOTRANSPIRATION

Year: 1974

Altitude: 0.5 - 4 m   Latitude: 8°50'N

	Data (Monthly Mean)		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Setp.	Oct.	Nov.	Dec.
i.	Air Temperature, T mean	°C	26.0	27.7	27.2	27.1	27.2	26.6	25.6	25.2	25.5	27.0	26.8	27.2
ii.	Relative Humidity, RH mean	%	73	77	72	70	74	83	88	89	86	82	77	80
iii.	Actual Sunshine Hours, n	hr/day	7.8	7.3	6.7	6.5	8.3	5.7	3.2	2.3	4.0	6.4	8.3	6.9
iv.	Wind Speed, U	km/day	247	293	336	323	336	273	270	283	236	253	253	253
CALCULATION														
1.	Saturation Vapour Pressure, ea	mbar	33.6	37.2	36.1	35.9	36.1	34.9	32.8	32.1	32.7	35.7	35.3	36.1
2.	Actual Vapour Pressure, ed	mbar	24.5	28.6	26.0	25.1	26.7	29.0	28.9	28.6	28.1	29.3	27.2	28.9
3.	ea - ed	mbar	9.1	8.6	10.1	10.8	99.4	5.9	3.9	3.5	4.6	6.4	8.1	7.2
4.	Wind Fucntion, $f(u)=0.27(1+\frac{U}{100})$		0.9	1.1	1.2	1.1	1.2	1.0	1.0	1.0	0.9	1.0	1.0	1.0
5.	Weighting Factor, 1 - W		0.25	0.23	0.24	0.24	0.24	0.24	0.25	0.26	0.26	0.24	0.24	0.24
6.	Aerodynamic Term, (1-W)f(u)(ea-ed)	mm/day	2.0	2.2	2.9	2.9	2.7	1.4	1.0	0.9	1.1	1.5	1.9	1.7
7.	Extra-Terrestrial RAdiation, Ra	mm/day	13.4	14.4	15.3	15.6	15.4	15.1	15.2	15.4	15.3	14.8	13.8	13.1
8.	Maximum Possible Sunshine Hours, N	hr/day	11.6	11.8	12.0	12.3	12.5	12.6	12.5	12.4	12.1	11.8	11.7	11.6
9.	Ratio n/N		0.67	0.62	0.56	0.53	0.66	0.45	0.26	0.19	0.33	0.54	0.71	0.59
10.	(0.19 + 0.60 n/N) : for West Africa		0.59	0.56	0.53	0.51	0.59	0.46	0.35	0.30	0.39	0.51	0.62	0.54
11.	Solar Radiation, Rs=(0.19+0.60 n/N)Ra	mm/day	7.9	8.0	8.1	8.0	9.1	6.9	5.3	4.6	6.0	7.5	8.6	7.1
12.	Net Shortwave Radiation, Rns=(1-α*)Rs	mm/day	5.9	6.0	6.1	6.0	6.8	5.2	4.0	3.5	4.5	5.6	6.5	5.3
13.	Effect on Long Wave Radiation													
	a. f(T)		15.9	16.2	16.1	16.1	16.1	16.0	15.8	15.8	15.8	16.1	16.1	16.1
	b. f(ed)		0.12	0.10	0.12	0.12	0.11	0.10	0.10	0.10	0.11	0.10	0.11	0.10
	c. f(n/N)		0.70	0.66	0.60	0.58	0.69	0.51	0.33	0.27	0.40	0.59	0.74	0.63
14.	Net Longwave Radiation, Rnl=axbxc	mm/day	1.3	1.1	1.2	1.1	1.2	0.8	0.5	0.4	0.7	0.9	1.3	1.0
15.	Net Radiation, Rn = Rns - Rnl	mm/day	4.6	4.9	4.9	4.9	5.6	4.4	3.5	3.1	3.8	4.7	5.2	4.3
16.	Weighting Factor, W		0.75	0.77	0.76	0.76	0.76	0.76	0.75	0.74	0.74	0.76	0.76	0.76
17.	Energy Term, W.Rn	mm/day	3.5	3.8	3.7	3.7	4.3	3.3	2.6	2.3	2.8	3.6	4.0	3.3
18.	Adjustment Factor, C		1.00	0.98	0.97	0.98	1.02	0.94	0.95	0.88	0.93	1.00	1.04	0.98
19.	Reference Crop Evapotranspiration, ETo**	mm/day	5.5	5.9	6.4	6.5	7.1	4.4	3.4	2.8	3.6	5.1	6.1	4.9

* α = 0.25

** Penman reference crop   ETo = c[W.Rn + (1 - W)f(u)(ea-ed)]

Table 9-1-2 MONTHLY REFERENCE CROP EVAPOTRANSPIRATION

Station: Lungi

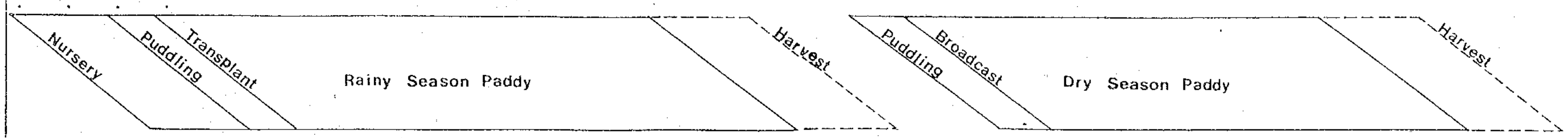
(mm/day)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1960	4.7	5.4	5.6	5.6	5.0	3.2	3.4	2.5	2.6	5.4	3.8	4.5	4.3
1961	4.1	4.5	6.3	5.9	5.4	2.9	2.1	3.4	2.0	4.2	3.8	4.0	4.1
1962	5.0	5.2	5.9	5.5	5.3	3.6	3.1	2.3	3.3	4.4	4.1	5.0	4.4
1963	4.4	4.9	6.5	6.2	5.1	4.3	3.1	2.9	3.6	4.4	5.1	4.4	4.6
1964	4.9	5.5	6.5	5.8	4.7	4.1	3.1	2.2	3.3	3.8	3.4	5.0	4.4
1965	5.1	6.2	6.6	5.8	4.6	3.4	3.3	3.1	3.1	4.3	4.3	4.3	4.5
1966	4.4	5.3	6.3	5.9	5.0	3.6	3.4	2.8	2.8	4.1	4.0	4.7	4.1
1967	5.2	5.9	6.3	6.5	5.2	3.7	2.8	2.5	3.1	4.7	4.0	4.5	4.5
1968	5.1	5.7	6.1	7.3	4.3	3.5	3.2	3.2	3.5	4.6	3.8	3.8	4.5
1969	4.6	5.6	6.2	5.7	4.7	3.8	2.6	2.8	3.0	3.8	4.2	4.7	4.3
1970	5.0	6.1	7.2	6.4	6.3	4.9	3.1	2.9	4.1	4.7	4.3	4.9	5.0
1971	5.1	5.9	6.9	6.4	5.7	4.5	3.6	2.9	3.7	5.1	3.8	4.0	4.8
1972	4.8	6.3	6.4	6.4	4.8	4.1	3.9	3.3	4.2	4.7	3.7	4.1	4.7
1973	5.3	6.1	6.7	6.5	6.7	4.0	4.0	3.8	4.1	4.7	5.7	5.1	5.2
1974	5.5	5.9	6.4	6.5	7.1	4.4	3.4	2.8	3.6	5.1	6.1	4.9	5.1
1975	6.0	6.2	7.4	6.1	6.2	4.7	3.5	2.9	3.2	4.7	5.0	4.4	5.0
1976	5.6	6.3	6.0	6.9	4.8	4.3	3.4	3.2	3.9	3.5	4.5	5.3	4.8
1977	5.1	5.0	5.9	6.5	5.2	3.8	3.0	2.9	3.6	4.2	5.1	4.7	4.6
1978	5.3	6.1	6.6	6.2	4.6	3.8	3.2	3.0	3.6	4.3	4.4	4.5	4.6
1979	5.2	5.9	6.1	5.9	5.6	4.3	3.1	3.0	4.1	4.4	4.2	4.2	4.5
1980	5.0	5.6	6.5	6.7	4.8	4.2	2.9	2.8	4.2	4.9	4.3	4.4	4.7
1981	5.0	5.4	5.5	5.6	4.2	3.9	2.6	2.8	3.8	4.6	4.5	3.9	4.1
Average	5.0	5.7	6.4	6.2	5.2	4.0	3.2	2.9	3.5	4.5	4.4	4.5	4.6

Table 9-1-3 CALCULATION OF NET IRRIGATION REQUIREMENT

Year: 1973 - 1974

(1) Cropping Pattern



	1973 May			Jun.			Jul.			Aug.			Sept.			Oct.			Nov.			Dec.			1974 Jan.			Feb.			Mar.		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
(2) Cropping Intensity — Nursery (A=50ha) i	1/6	1/2	2/3	1/2	1/6																												
PUddling ii			1/6	1/3	1/3	1/6												1/6	1/3	1/3	1/6												
General Growth iii				1/6	1/2	5/6	1	1	1	1	1	1	1	5/6	1/2	1/6			1/6	1/2	5/6	1	1	1	1	1	11/12	2/3	1/3	1/12			
ii + iii			1/6	1/2	5/6	1	1	1	1	1	1	1	1	5/6	1/2	1/6		1/6	1/2	5/6	1	1	1	1	1	1	11/12	2/3	1/3	1/12			
(3) Crop Coefficient (KC) a.	1.10	1.10	1.10	1.10	1.10	1.10	1.09	1.08	1.07	1.06	1.04	1.02	1.00	0.98					1.10	1.10	1.15	1.20	1.25	1.25	1.25	1.20	1.15	1.05					
b.		1.10	1.10	1.10	1.10	1.10	1.10	1.09	1.08	1.07	1.06	1.04	1.02	1.00	0.98					1.10	1.10	1.15	1.20	1.25	1.25	1.25	1.20	1.15	1.05				
c.			1.10	1.10	1.10	1.10	1.10	1.10	1.09	1.08	1.07	1.06	1.04	1.02	1.00	0.98					1.10	1.10	1.15	1.20	1.25	1.25	1.25	1.20	1.15	1.05			
d. Weighted Average	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.09	1.08	1.07	1.06	1.04	1.02	1.00	0.99	0.98			1.10	1.10	1.12	1.15	1.20	1.23	1.25	1.23	1.20	1.16	1.13	1.05			
(4) Ref. Crop Evapt. (ETo) mm	67	67	74	40	40	40	40	40	44	38	38	42	41	41	41	47	47	52	57	57	57	51	51	56	55	55	61	59	59	47			
(5) Crop Evapot. (ETrice)=(3 d)x(4) mm	74	74	81	44	44	44	44	44	48	41	40	44	42	41	41	46		57	63	63	64	59	61	69	69	68	73	68	67	49			
(6) Percoloation Loss mm	(10)	(10)	(11)	10	10	10	10	10	10	10	10	11	10	10	10	10	10)	11	10	10	10	10	10	11	10	10	11	10	10	8			
(7) Water Requirement (W.R.) = (5) + (6) mm	84	84	92	54	54	54	54	54	59	51	50	55	52	51	51	56		64	73	73	74	69	71	79	79	78	84	78	77	57			
(8) W.R. for Puddling mm			180	180	180	180												150	150	150	150												
(9) W.R. for Nursery mm	115	115	115	115	115																												
(10) Effective Rainfall (Pe) mm	47	32	49	100	41	82	54	54	59	51	50	55	52	51	51	56		49	82	0	0	0	0	0	0	0	0	0	0	0			
(11) Net Irrigation Requirement (N.I.R.) (7)-(10) mm	37	52	43	0	13	0	0	0	0	0	0	0	0	0	0	0		15	0	73	74	69	71	79	79	78	84	78	77	57			
(12) N.I.R. for Puddling (8)-(10) mm			131	80	139	98												101	68	77	76												
(13) N.I.R. for Nusery (9)-(10) mm	68	83	66	15	74																												
(14) (2iii) x (11) mm				0	7	0	0	0	0	0	0	0	0	0	0	0			0	0	0	69	71	79	79	78	77	52	26	5			
(15) (2ii) x (12) mm			22	27	46	16												17	23	26	13												
(16) (2i) x (14)/Groundwater (A = 50h) mm	11	42	44	8	12																												
(17) Net Irrigation Requirement/ Surface Water (14) + (15) mm			22	27	53	16	0	0	0	0	0	0	0	0	0	0		17	23	26	13	69	71	79	79	78	77	52	26	5			

1.0 millimetres per day throughout the year in estimating the irrigation water requirement for paddy.

(4) Nursery water requirement

The nursery water requirement is estimated for the amount of water necessary for preparation of the nursery bed, evapotranspiration from the nursery fields and percolation loss. Water resources for the nursery fields is in principle groundwater, as the river water is still saline and the required quantity of water is small.

The nursery water requirement is estimated considering the following conditions.

- Area required for nursery bed : 1/25 of main field
- Nursery period : 20 days
- Water required for 20 days :

	Wet season paddy
Preparation by nursery bed	100 mm
Evapotranspiration	104 mm (5.2 mm x 20 days)
Percolation (2mm/dayx20days)	20 mm
Total	230 mm

(5) Puddling water requirement

The puddling water requirement is estimated for the amount of (i) water needed for saturation of soil profile, (ii) loss of water occuring during water supply consisting of percolation and evapotranspiration losses and (iii) standing water after transplanting.

The puddling water is estimated as follows:

(i) Water needed for saturation of soil profile

75 mm (wet season)
45 mm (dry season)

(a) Depth of soil and porosity

Surface soil: 20 cm, 50%
Sub-soil : 10 cm, 50%

(b) Vapour phase in soil after paddling : 5%

(c) Soil moisture before water supply

Wet season : 20%
Dry season : 30%

(ii) Water losses occuring during water supply

(a) Percolation loss (1 mm/day x 10 day)

10 mm

(b) Evaporation loss, assuming the same as evapotranspiration under the initial paddy field condition.

Wet season (4.2 mm/day x 10 days)
42 mm

Dry season (4.4 mm/day x 10 days)
44 mm

(iii) Average standing water depth after transplanting: 50 mm

Total	Wet season	180 mm
	Dry season	150 mm

(6) Effective rainfall

By applying daily rainfall records at Rokupr, the effective rainfall for rice has been estimated by means of the daily water balance method under the following conditions:

For paddy field:

1) Rainfall of less than 5 mm/day is considered as ineffective.

2) Effective rainfall ranges from 5 mm/day up to the extent that the water depth in the field reaches 100 mm, because the excess rainfall will be drained and thus be ineffective.

3) Water consumption by paddy rice plus percolation occurs daily.

4) Irrigation water is applied up to 100 mm in depth.

On the basis of the daily water balance calculations, the effective rainfall has been estimated on a 10-day basis for the proposed cropping pattern, as indicated in Table 9-1-3.

Table 9-1-4 NET IRRIGATION WATER REQUIREMENT

(mm)

Year	May			Jun			Jul			Aug			Sept			Oct			Nov			Dec			Jan			Feb		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1960-61			18	40	45	21	0	0	0	0	0	0	0	0	0	0		6	38	53	69	62	64	73	61	60	60	41	20	4
61-62			16	41	46	23	0	0	0	0	0	0	0	0	0	0		13	25	51	69	56	58	55	73	72	70	47	23	4
62-63			27	31	37	19	0	0	0	0	0	0	0	0	0	0		10	31	37	14	68	70	79	65	64	49	45	22	4
63-64			18	53	33	20	0	0	0	0	0	0	0	0	0	0		7	45	28	13	61	63	70	71	70	63	49	24	5
64-65			10	42	42	21	0	0	0	0	0	0	0	0	0	0		9	37	56	65	68	66	79	74	73	72	41	27	7
65-66			19	37	51	20	0	0	0	0	0	0	0	0	0	0		8	52	74	73	59	62	69	65	64	63	47	23	4
66-67			18	43	43	20	0	0	0	0	0	0	0	0	0	0		9	35	35	23	64	36	75	75	74	72	52	26	5
67-68			23	32	42	41	0	0	0	0	0	0	0	0	0	0		8	36	65	71	62	64	73	74	73	72	46	25	5
68-69			16	46	39	22	0	0	0	0	0	0	0	0	0	0		14	28	32	69	30	23	71	50	67	66	50	24	5
69-70			-	7	43	0	0	0	0	0	0	0	0	0	0	0		9	37	78	54	64	66	75	73	72	71	61	30	6
70-71			24	37	41	19	0	0	0	0	0	0	0	0	0	0		18	52	39	39	66	69	77	73	72	71	54	26	5
71-72			20	35	47	20	0	0	0	0	0	0	0	0	0	0		-	-	-	-	56	58	65	70	69	50	55	27	6
72-73			23	27	42	21	0	0	0	0	0	0	0	0	0	0		13	56	67	25	57	59	66	76	75	74	54	26	5
73-74			22	27	53	16	0	0	0	0	0	0	0	0	0	0		17	23	26	13	69	71	79	79	78	77	52	26	5
74-75			22	53	32	19	0	0	0	0	0	0	0	0	0	0		23	43	89	90	66	69	77	85	84	83	55	27	5
75-76			10	42	38	18	0	0	0	0	0	0	0	0	0	0		7	52	83	80	42	63	70	80	79	78	55	27	5
76-77			9	46	29	30	0	0	0	0	0	0	0	0	0	0		11	33	68	75	71	74	82	74	73	72	45	22	4
77-78			16	45	34	22	0	0	0	0	0	0	0	0	0	0		14	61	54	81	64	33	75	76	75	65	53	26	5
78-79			21	35	40	26	0	0	0	0	0	0	0	0	0	0		7	30	70	74	52	47	73	75	74	72	52	26	5
79-80			14	45	38	23	0	0	0	0	0	0	0	0	0	0		11	31	65	73	58	60	52	73	72	71	30	24	5
80-81			21	40	38	33	0	0	0	0	0	0	0	0	0	0		7	28	61	15	61	33	70	73	72	71	49	24	4
Average			18	38	41	22	0	0	0	0	0	0	0	0	0	0		11	39	57	54	60	58	72	72	72	68	49	25	5

Note: Presented Irrigation Requirement is for Surface Water, not including that for groundwater.

(7) Irrigation water requirement

Net irrigation water requirement has been calculated by deducting effective rainfall from the crop water requirement. The results are shown on Table 9-1-4 and Fig. 9-1-1.

Peak water requirements are shown in Table 9-1-5, and the probable peak net irrigation requirement is estimated at 8.0 mm/day for the return period of 5 years as shown in Table 9-1-6 and Fig. 9-1-2.

Gross water requirement is estimated by dividing the net irrigation water requirement by overall irrigation efficiency, which is estimated considering the FAO guideline.

As the bottom of the water supply channel is low enough to receive groundwater supply and also drain water from the paddy field, drainage re-use should be considered. If the Conveyance losses are offset by the re-use, conveyance efficiency is determined to be 100%. Considering that it is possible to intake creek water directly from the mitre gates in case of higher water level, farm efficiency combining field canal and application efficiency is assumed to be 80%. Consequently a project efficiency of 80% is used in this study.

Gross water requirement in depth on 10-day basis is calculated for the proposed cropping pattern, as summarized on Fig. 9-1-1. The probable gross irrigation requirement is estimated at 10 mm/day or 1.15 l/sec/ha for the return period of 5 years.

Further, diversion water requirement is calculated by the following formula.

Fig 9-1-1 10DAYS IRRIGATION WATER REQUIREMENT

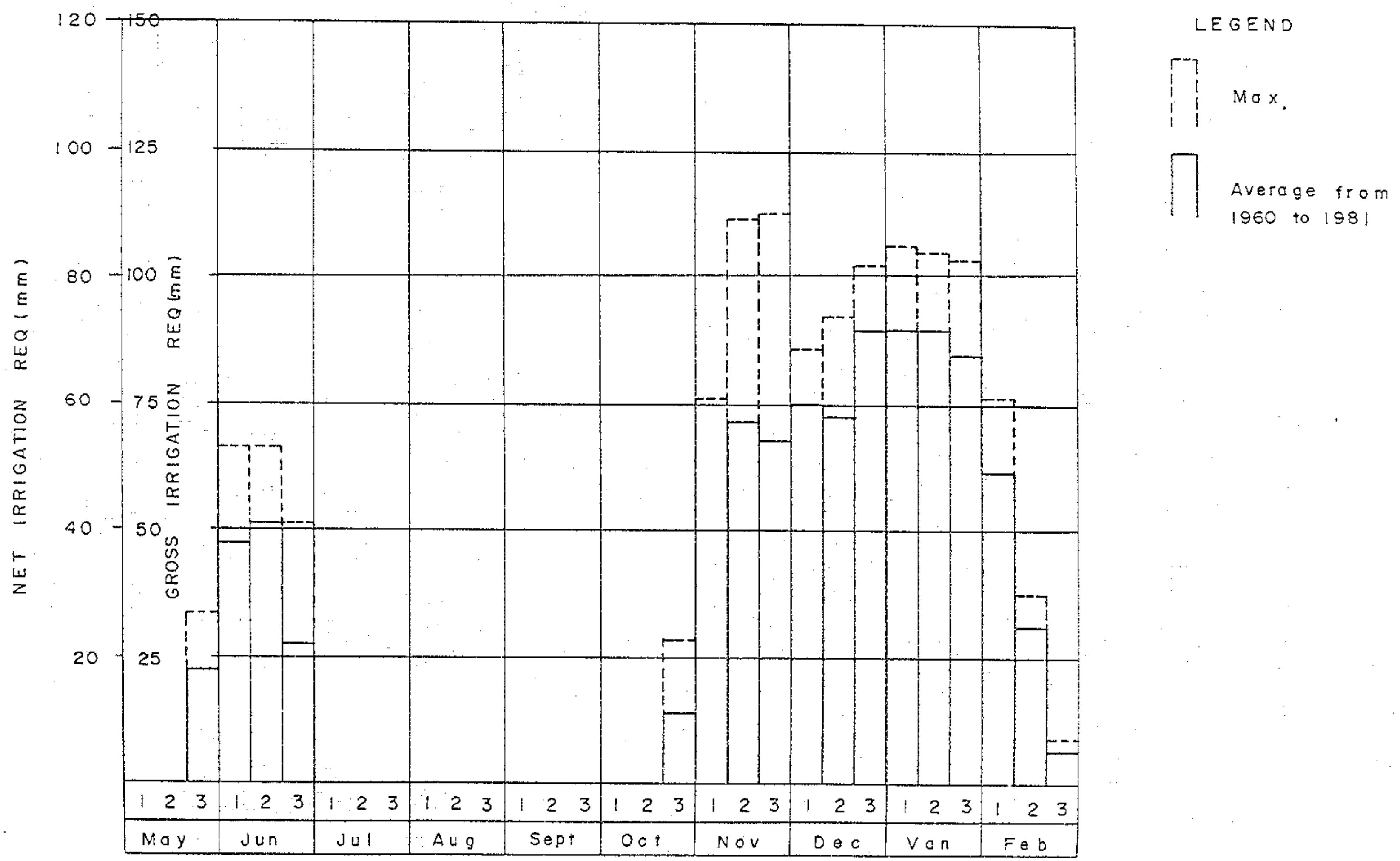


Table 9-1-5 PEAK WATER REQUIREMENT

Year	(1) Max. Net Irrigation Requirement	(2) = (1)/0.8 Gross Irrigation Requirement		(4)** Diversion Water Requirement	Period		Order
	mm/day	(2) mm/day	(3)* l/s/ha	m^3/S	Month	Decade	
1960-61	6.9	8.6	1.00	2.60	Nov.	3	20
61-62	7.3	9.1	1.05	2.73	Jan.	1	13
62-63	7.2	9.0	1.04	2.70	Dec.	3	17
63-64	7.1	8.9	1.03	2.68	Jan.	1	10
64-65	7.4	9.3	1.08	2.81	Jan.	1	10
65-66	7.4	9.3	1.08	2.81	Nov.	2	11
66-67	7.5	9.4	1.09	2.80	Jan.	1	7
67-68	7.4	9.3	1.08	2.81	Jan.	1	12
68-69	6.9	8.6	1.00	2.60	Nov.	3	21
69-70	7.8	9.8	1.13	2.94	Nov.	2	5
70-71	7.3	9.1	1.05	2.70	Jan.	1	14
71-72	7.0	8.8	1.02	2.70	Jan.	1	19
72-73	7.6	9.5	1.10	2.86	Jan.	1	6
73-74	7.9	9.9	1.15	2.99	Jan.	1	4
74-75	9.0	11.3	1.31	3.41	Nov.	3	1
75-76	8.3	10.4	1.20	3.12	Nov.	2	2
76-77	7.5	9.4	1.09	2.83	Dec.	3	8
77-78	8.1	10.1	1.17	3.04	Nov.	3	3
78-79	7.5	9.4	1.09	2.83	Jan.	1	9
79-80	7.3	9.1	1.05	2.73	Nov. Jan.	3 1	15
80-81	7.3	9.1	1.05	2.73	Jan.	1	16
Average	7.5	9.4	1.09	2.83	Jan.	1	-

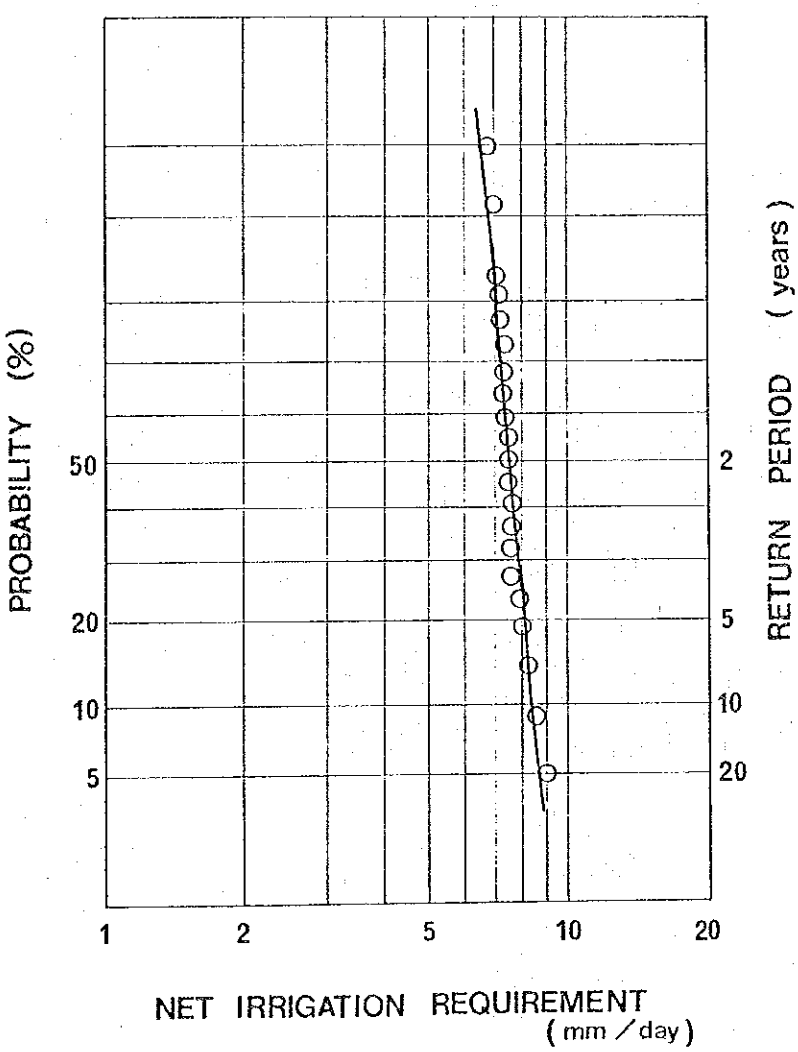
Note: * (3) = (2)/8.64
** (4) = (3) x 1,300 x 24/12/1000

Table 9-1-6 PROBABILITY OF PEAK WATER REQUIREMENT

Order (n)	Peak Water Requirement (mm/day)	Probability* $\frac{n}{N+1} \times 100$ (%)	Year of Occurance
1	9.0	5	1974 - 75
2	8.3	9	1975 - 76
3	8.1	14	1977 - 78
4	7.9	18	1973 - 74
5	7.8	23	1969 - 70
6	7.6	27	1972 - 73
7	7.5	32	1966 - 67
8	7.5	36	1976 - 77
9	7.5	41	1978 - 79
10	7.4	45	1964 - 65
11	7.4	50	1965 - 66
12	7.4	55	1967 - 68
13	7.3	59	1961 - 62
14	7.3	64	1970 - 71
15	7.3	68	1979 - 80
16	7.3	73	1980 - 81
17	7.2	77	1962 - 63
18	7.1	82	1963 - 64
19	7.0	86	1971 - 72
20	6.9	91	1960 - 61
21	6.9	95	1968 - 69

Note: Weibull (Thomas) plot method

Fig 9-1-2 PROBABLE NET IRRIGATION REQUIREMENT



$$Q = \frac{10\ Ig.A}{86,400} \cdot \frac{24}{A}$$

where,

- Q: Diversion water requirement in m^3/s
- Ig: Gross irrigation water requirement in mm/day
- A: Net irrigation area in Ha.
- 86,400: Seconds in one day
- T: Daily irrigation hours (12 hours)

The peak diversion water requirement is estimated as summarized on Table 9-1-5. The design discharge of 2.3 l/s/ha (or 3.0 m^3/sec for the whole project area of about 1,300 ha) is obtained for the 5 years recurrence.

In the paddy field, it is important and necessary to execute land levelling and to set up field levels in order to effectively store and utilize rainfall. After seeding, water is stored in the field at about 100 millimetres in depth as explained in the subsequent section on drainage. It is therefore recommended that the flood irrigation method be adopted for the paddy fields.

For irrigation in the paddy fields, water should be applied when water depth in the paddy field is less than 50 millimetres in the dry season.

During the wet season, practically no irrigation will be necessary after transplanting. On the contrary, when heavy rainfall occurs, depth of 200 millimetres of rainfall should be retained in the field and the excess rainfall drained.

9-1-2 Pumping station

Design pump discharge is 2.3 l/sec/ha, as calculated through the estimate of irrigation water requirement as noted in the foregoing Section 9-1-1. The design intake water level is decided at EL.26.3 metres.

With respect to the driving method, motor drive method and diesel engine drive method are conceivable, each having the requisite characteristics. In view of the poor hydroelectric energy available around the project area, and the economical, technical and environmental conditions, diesel engine driven method is recommended for the proposed pumping station installed on each polder's bund.

As mentioned above, the design intake water level is EL. 26.3 metres and the design outlet level is around 29.8 metres. In view of the suction head of about 3.5 m, the volute type pumps are adopted for the pumping station.

On the basis of economical and technical comparison, as well as from the viewpoint of operation and maintenance, 2 sets of pumps with 250 millimetre pump bore are recommended for the pumping stations which command a paddy field of approximately 100 hectares.

The pump house is designed to be a concrete block structure. Judging from the space required for installation of pumps and for operation and maintenance, the space of the pump house is estimated at 24 square metres (4 m x 6 m). The intake level is designed at EL. 26.3 metres with 1.2 metre of water depth at the intake. The suction box is designed to be 3.0 metres in width.

Fluctuation of water discharge to be pumped up in the dry season is relatively small, as noted in the foregoing section. Extremely severe discharge control is not recommended from the viewpoint of operation and maintenance. Taking the above into consideration, it is suggested that valve control be adopted, which is economical in installation and simple in operation. Valve control is most commonly used for smaller range of discharge control of pumps which are relatively small in size. The pump discharge may be decreased by valve control to the level of 60 - 70% of the design discharge. In case of operation in small discharge, it is proposed to carry out water control by limiting the operation hours of the pumps.

9-1-3 Water supply channel

Irrigation water is diverted at Rhombe and conveyed to the site through the channel made near Makasa (Refer to DWG. 1), a section and outline is shown in Fig. 9-1-3.

As this channel is also used as a drain for the site, the bottom elevation should be lower than the lowest part of the site. Elevation from 26.25 m to 25.25 m are proposed. Drain from the polder will be made during the time of the creek's lower water level. The system of the drain is explained in subsection 4-5-1-(4) and Fig. 4-5-6 of main report.

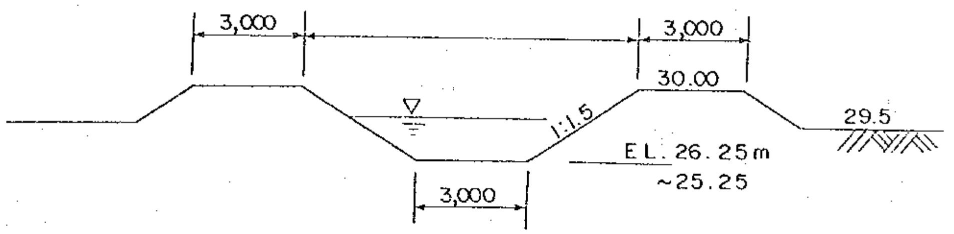
The maximum amount of irrigation water is to be pumped up from this channel. The capacity of the pump is determined by the irrigation requirements (See sub-section 9-1-2). That is 0.23 m^3/s per 100 ha.

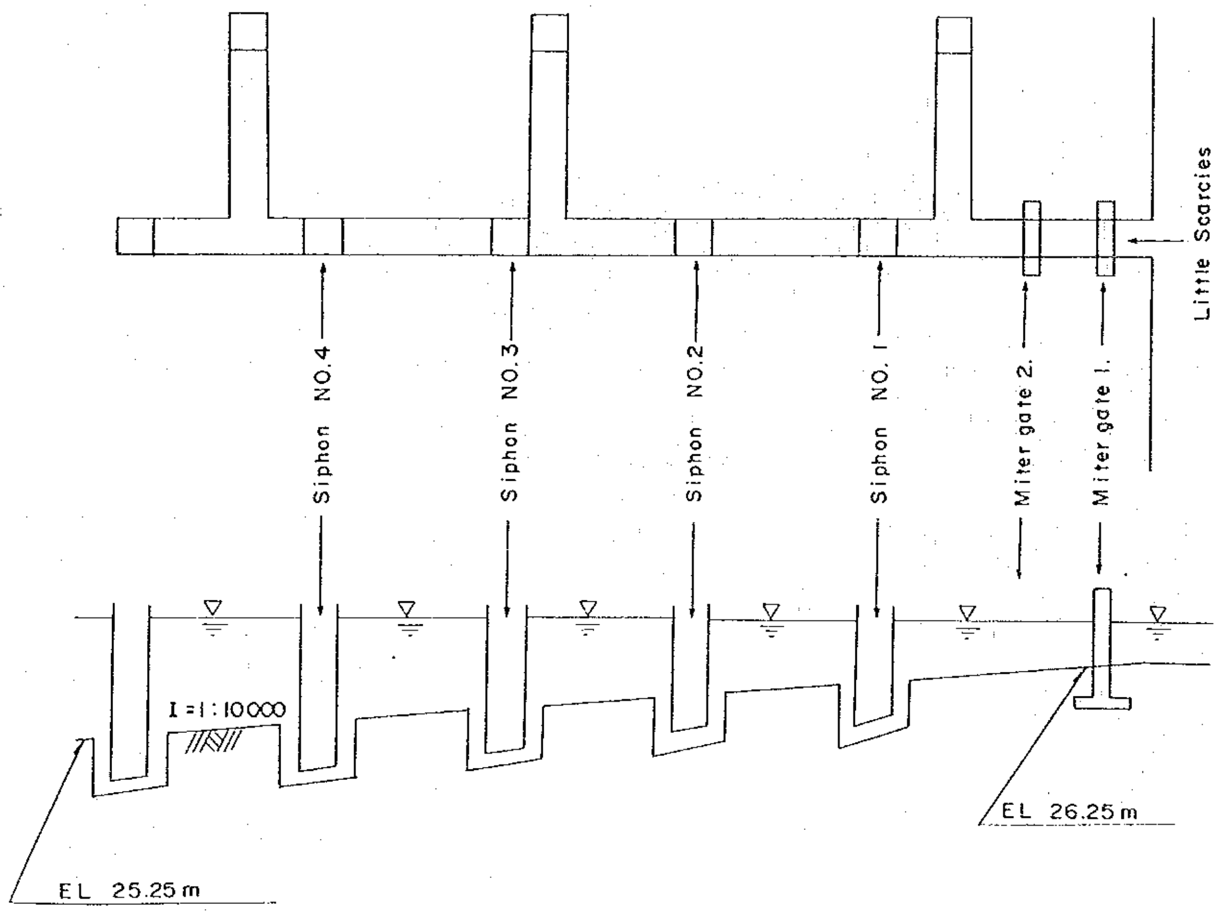
The total area of the paddy fields is about 1,300 ha. Therefore, the pumps' total capacity for irrigation is as follows:

$$1,300 \text{ ha} \div 100 \text{ ha} \times 0.23 \text{ m}^3/\text{s} = 2.99 \text{ m}^3/\text{s} \doteqdot 3.0 \text{ m}^3/\text{s}$$

This quantity of water is pumped up during the time of irrigation.

Fig 9-1-3 SECTION AND OUTLINE OF WATER SUPPLY CHANNEL

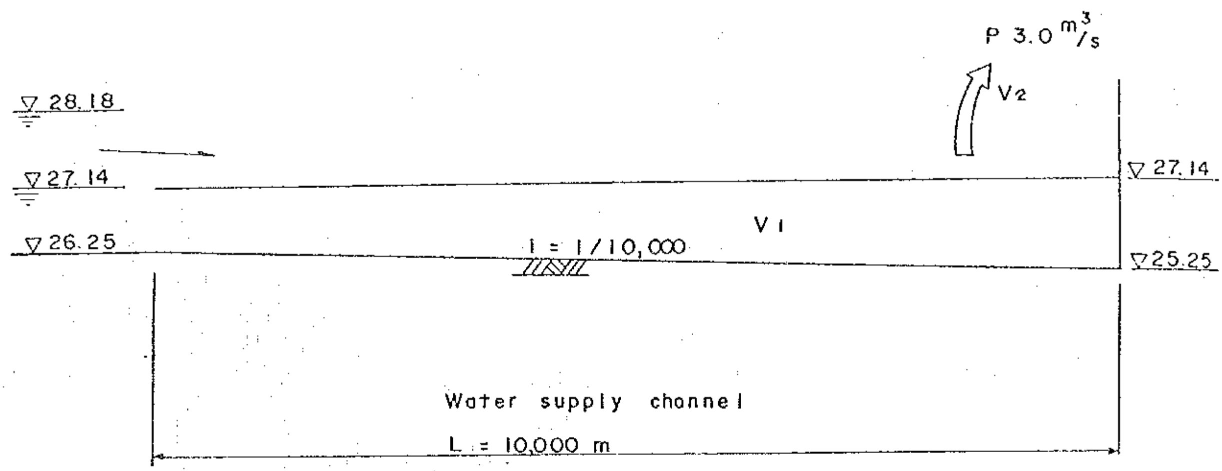




(1) Calculation of inflow

The minimum water level of the river is 27.14 m (See Subsection 4-2-3). In this case, assuming the above mentioned volume of water is pumped up, inflow to the channel is calculated as follows: (Refer to Fig. 9-1-4)

Fig. 9-1-4 ILLUSTRATING THE FLOW OF WATER



When pumping commences, the inside water level is at least 27.14 m. The volume of stored water V1 is calculated below.

$$V1 = (3.0 + 7.17) \times 1.39 \times \frac{1}{2} \times 10,000 \text{ m}$$

$$= 70,682 \text{ m}^3$$

(Calculated from using average section of the channel)

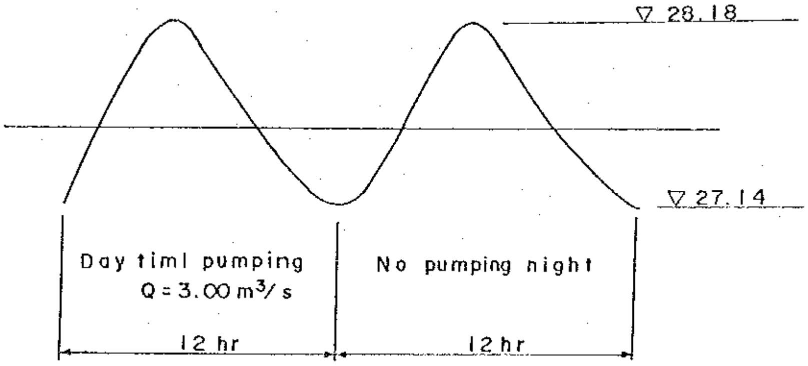
To make the calculation simple, pumping hours in the day time are assumed to be 12 hours, so the pumping volume V2 is;

$$V2 = 3.00 \text{ m}^3/\text{s} \times 12 \text{ hr} \times 3,600 \text{ s/hr}$$

$$= 129,600 \text{ m}^3$$

There are two cycles of water level in one day, varying between 27.14 m and 28.18 m by the assumed model. This is illustrated in Fig. 9-1-5.

FIG 9-1-5 ILLUSTRATING THE TIDE MOVEMENT



Method of Calculation:

a) Day time

River water level begins to increase, rising from 27.14 m when pumping for irrigation starts.

As water in the channel is being pumped, river water can enter into the channel to the extent of 3.00 m^3/s. This inflow can be considered a uniform flow and Manning's formula can be applied.

This cumulative inflow is calculated in Table 9-1-7.

b) Night

Inflow is calculated by applying Manning's formula also. But as the inside water is not being pumped up, the gradient of running water should be considered (Refer to Fig. 9-1-6).

$$I = \frac{\text{Inflow Level} - 27.14 \text{ m}}{10{,}000 \text{ m}}$$

FIG 9-1-6 ILLUSTRATING WATER SURFACE GRADIENT

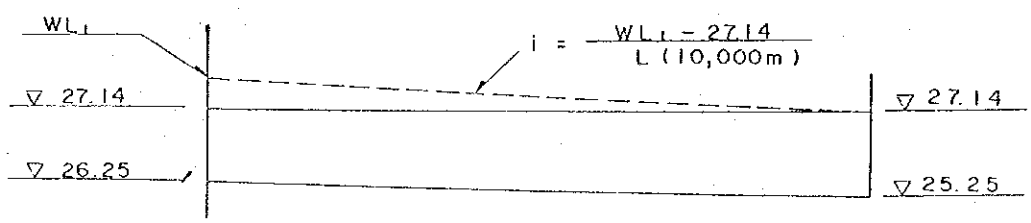


Table 9-1-7 INFLOW CALCULATION

Daytime

Time Minutes	Water Level m	Depth m	Inflow m^3/S	Inflow $m^3/10min.$	Cumulative Inflow m^3	Note
0	27.14	0.89	1.06	636	636	
10	27.14	0.89	1.06	636	1,272	
20	27.16	0.91	1.11	666	1,938	
30	27.18	0.93	1.18	708	2,646	
40	27.20	0.95	1.20	720	3,366	
50	27.23	0.98	1.25	750	4,116	
1 hr	27.27	1.02	1.34	804	4,920	
10	27.33	1.08	1.50	900	5,820	
20	27.39	1.14	1.64	984	6,804	
30	27.47	1.22	1.92	1,152	7,956	
40	27.55	1.30	2.16	1,296	9,252	
50	27.61	1.36	2.34	1,404	10,656	
2 hr	27.68	1.43	2.55	1,530	12,186	
10	27.75	1.50	2.80	1,680	13,866	
20	27.80	1.55	2.95	1,770	15,636	
30	27.87	1.62	3.0	1,800		Inflow by Q-H curve is more than 3.0 m^3/S during this part of time.
40	27.92	1.67	3.0	1,800		
50	27.96	1.71	3.0	1,800		
3 hr	28.00	1.75	3.0	1,800		
10	28.03	1.78	3.0	1,800		
20	28.06	1.81	3.0	1,800		
30	28.08	1.83	3.0	1,800		
40	28.10	1.85	3.0	1,800		
50	28.12	1.87	3.0	1,800		
4 hr	28.13	1.88	3.0	1,800		
10	28.15	1.90	3.0	1,800		
20	28.16	1.91	3.0	1,800		
30	28.17	1.92	3.0	1,800		
40	28.18	1.93	3.0	1,800		
50	28.18	1.93	3.0	1,800	42.636	

Table 9-1-7 INFLOW CALCULATION

Daytime

Time Minutes	Water Level m	Depth m	Inflow m^3/S	Inflow $m^3/10min.$	Cumulative Inflow m^3	Note
5 hr	28.17	1.92	3.0	1,800	44,436	Inflow by Q-H curve is more than 3.0 m^3/S during this part of time.
10	28.17	1.92	3.0	1,800		
20	28.16	1.91	3.0	1,800		
30	28.15	1.90	3.0	1,800		
40	28.14	1.89	3.0	1,800		
50	28.13	1.88	3.0	1,800		
6 hr	28.12	1.87	3.0	1,800		
10	28.10	1.85	3.0	1,800		
20	28.08	1.83	3.0	1,800		
30	28.06	1.81	3.0	1,800		
40	28.04	1.79	3.0	1,800		
50	28.02	1.77	3.0	1,800		
7 hr	27.98	1.73	3.0	1.800		
10	27.96	1.71	3.0	1,800		
20	27.94	1.69	3.0	1,800		
30	27.91	1.66	3.0	1,800		
40	27.88	1.63	3.0	1,800		
50	27.85	1.60	3.0	1,800	75,036	
8 hr	27.83	1.58	2.99	1,794		
10	27.80	1.55	2.95	1,770		
20	27.78	1.53	2.88	1,728		
30	27.75	1.50	2.80	1,680		
40	27.73	1.48	2.72	1,632		
50	27.71	1.46	2.68	1,608		
9 hr	27.68	1.43	2.55	1,530		
10	27.66	1.41	2.47	1,482		
20	27.63	1.38	2.40	1,440		
30	27.61	1.36	2.34	1,404		
40	27.58	1.33	2.30	1,380		
50	27.56	1.31	2.18	1,308		
10 hr	27.53	1.28	2.10	1,260	95,052	

Table 9-1-7 INFLOW CALCULATION

Daytime

Time Minutes	Water Level m	Depth m	Inflow m^3/S	Inflow $m^3/10min.$	Cumulative Inflow m^3	Note
10	27.51	1.26	2.04	1,224	96,276	
20	27.49	1.24	1.98	1,188		
30	27.46	1.21	1.89	1,134		
40	27.44	1.19	1.80	1,080		
50	27.41	1.16	1.72	1,032		
11 hr	27.39	1.14	1.64	984		
10	27.36	1.11	1.57	942		
20	27.34	1.09	1.60	960		
30	27.32	1.07	1.45	870		
40	27.31	1.06	1.40	840		
50	27.29	1.04	1.39	834		
12 hr	27.28	1.03	1.36	816	106,956	

Namely, the water level at the end point of channel is always lower than 27.14 m.

If this level exceeds 27.14 m, this means that the water stored is enough to start pumping again. This inflow is calculated in Table 9-1-8 (Refer to Fig. 9-1-7 and Fig. 9-1-8).

(2) Result of calculation

Water stored in the channel	:	V1 = 70,682 m^3
Pumping volume in the day time	:	V2 = 129,600 m^3
Inflow during day time	:	V3 = 106,956 m^3
Inflow during night for three hours and thirty minutes	:	V4 = 29,095 m^3

$V2 < V3 + V4$

This means, water stored in the channel never decreases. There is always enough water stored for irrigation.

(3) Siphon

This channel will cross several creeks. The elevation of the channel is from 26.25 m to 25.25 m, whereas that of the creeks is from 27.0 m to 26.5 m. So, siphons are proposed to cross the creeks. The discharge passing through the siphon varies from about 0.5 m^3/s during pumping time, to 1 - 3 m^3/s during intake. But the capacity of siphon need not meet the maximum discharge, because the channel has enough allowance in volume to store water, so that running water can be retained in the channel.

Table 9-1-8 INFLOW CALCULATION

Night

Time Min.	Water Level m	Depth m	Gradient of Water Surface I	$I^{1/2}$	A m^3	Wetted Perimeter P	Hydraulic Radius $R^{2/3}$	Inflow m^3/S	Inflow $m^3/10min.$	Cumulative Inflow m^3	Note
0	27.14	0.89	0								
10	27.14	0.89	0								
20	27.16	0.91	0.000002	0.00141	3,849	6,285	0.721	0.145	87	87	
30	27.18	0.93	0.000004	0.00200	3,990	6,357	0.733	0.217	130	217	
40	27.20	0.95	0.000006	0.00245	4,133	6,430	0.745	0.279	168	385	
50	27.23	0.98	0.000009	0.00300	4,351	6,538	0.762	0.368	221	606	
1 hr	27.27	1.02	0.000013	0.00361	4,651	6,682	0.785	0.488	293	899	
10	27.33	1.08	0.000019	0.00436	5,119	6,899	0.820	0.678	407	1,306	
20	27.39	1.14	0.000025	0.00500	5,609	7,115	0.853	0.886	532	1,838	
30	27.47	1.22	0.000033	0.00574	6,295	7,404	0.897	1.200	720	2,558	
40	27.55	1.30	0.000041	0.00640	7,020	7,693	0.941	1.566	939	3,497	
50	27.61	1.36	0.000047	0.00686	7,589	7,910	0.973	1.876	1,126	4,623	
2 hr	27.68	1.43	0.000054	0.00735	8,280	8,162	1.010	2.277	1,366	5,989	
10	27.75	1.50	0.000061	0.00781	9,000	8,415	1.046	2.723	1,634	7,623	
20	27.80	1.55	0.000066	0.00812	9,533	8,596	1.071	3.071	1,842	9,465	
30	27.87	1.62	0.000073	0.00854	10.303	8,848	1,107	3,607	2,164	11,629	
40	27.92	1.67	0.000078	0.00883	10.872	9,029	1,132	4,025	2,415	14,044	
50	27.96	1.71	0,000082	0.00906	11,337	9,173	1,152	4,382	2,629	16,673	
3 hr	28.00	1.75	0.000086	0.00927	11,813	9,318	1,171	4,749	2,850	19,523	
10	28.03	1.78	0.000089	0.00943	12,175	9,426	1,186	5,043	3,026	22,549	
20	28.06	1.81	0.000092	0.00959	12,543	9,534	1,201	5,351	3,210	25,759	
30	28.08	1.83	0.000094	0.00970	12,792	9,606	1,210	5,561	3,336	29,095	Fill up a deficiency of day time
40	28.10	1.85	0.000096	0.00980	13,043	9,679	1,220	5,776	3,465	32,560	
50	28.12	1.87	0.000098	0.00990	13,296	9,751	1,230	5,996	3,598	36,158	
4 hr	28.13	1.88	0.000099	0.00995	13,423	9,787	1,234	6,104	3,662	39,820	
10	28.15	1.90	0.000101	0.01005	13,680	9,859	1,244	6,334	3,801	43,621	
20	28.16	1.91	0.000102	0.01010	13,809	9,895	1,249	6,452	3,871	47,492	
30	28.17	1.92	0.000103	0.01015	13,939	9,931	1,254	6,571	3,943	51,435	
40	28.18	1.93	0.000104	0.01020	14,070	9,967	1,258	6,687	4,012	55,447	
50	28.18	1.93	0.000104	0.01020	14,070	9,967	1,258	6,687	4,012	55,449	

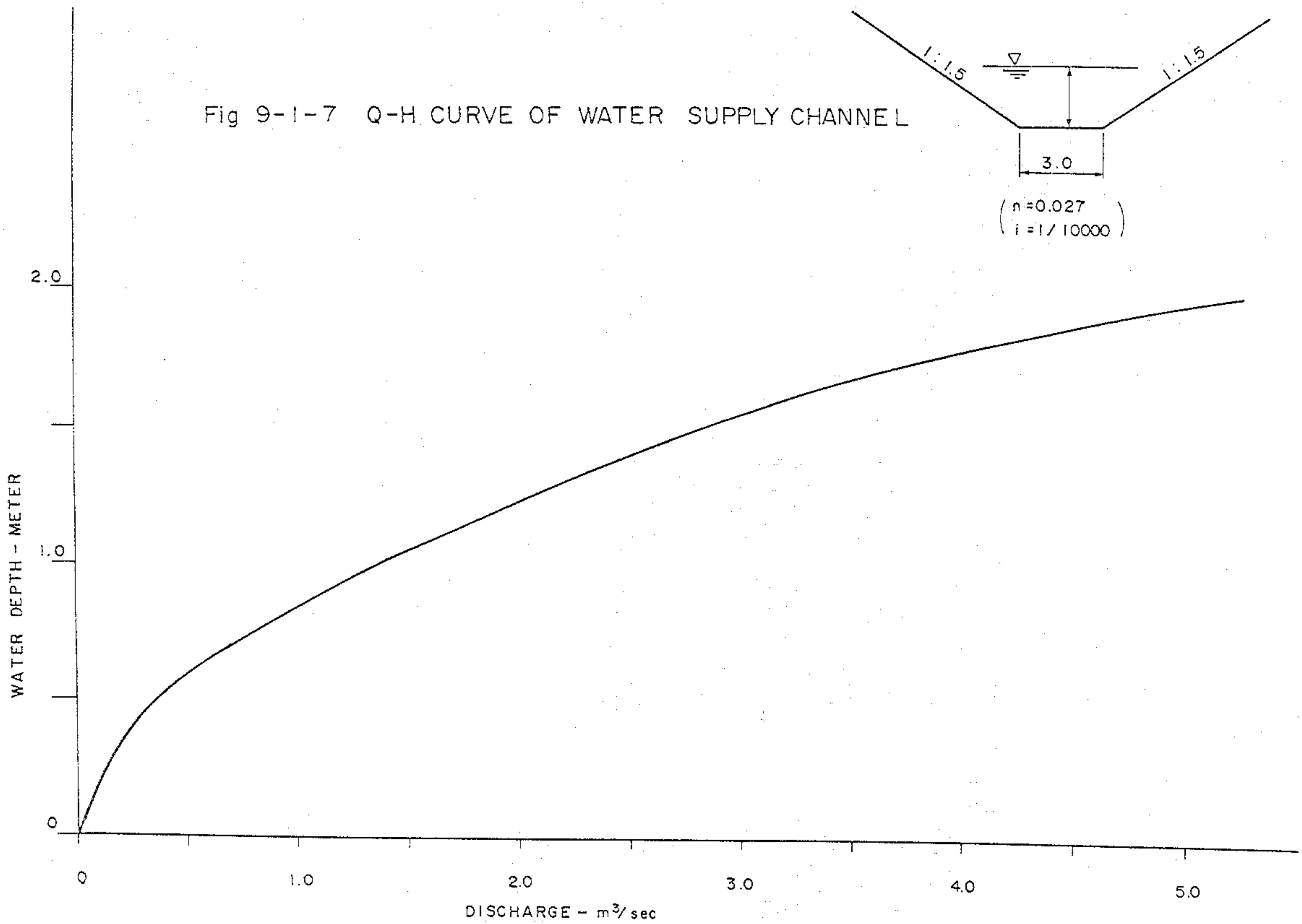
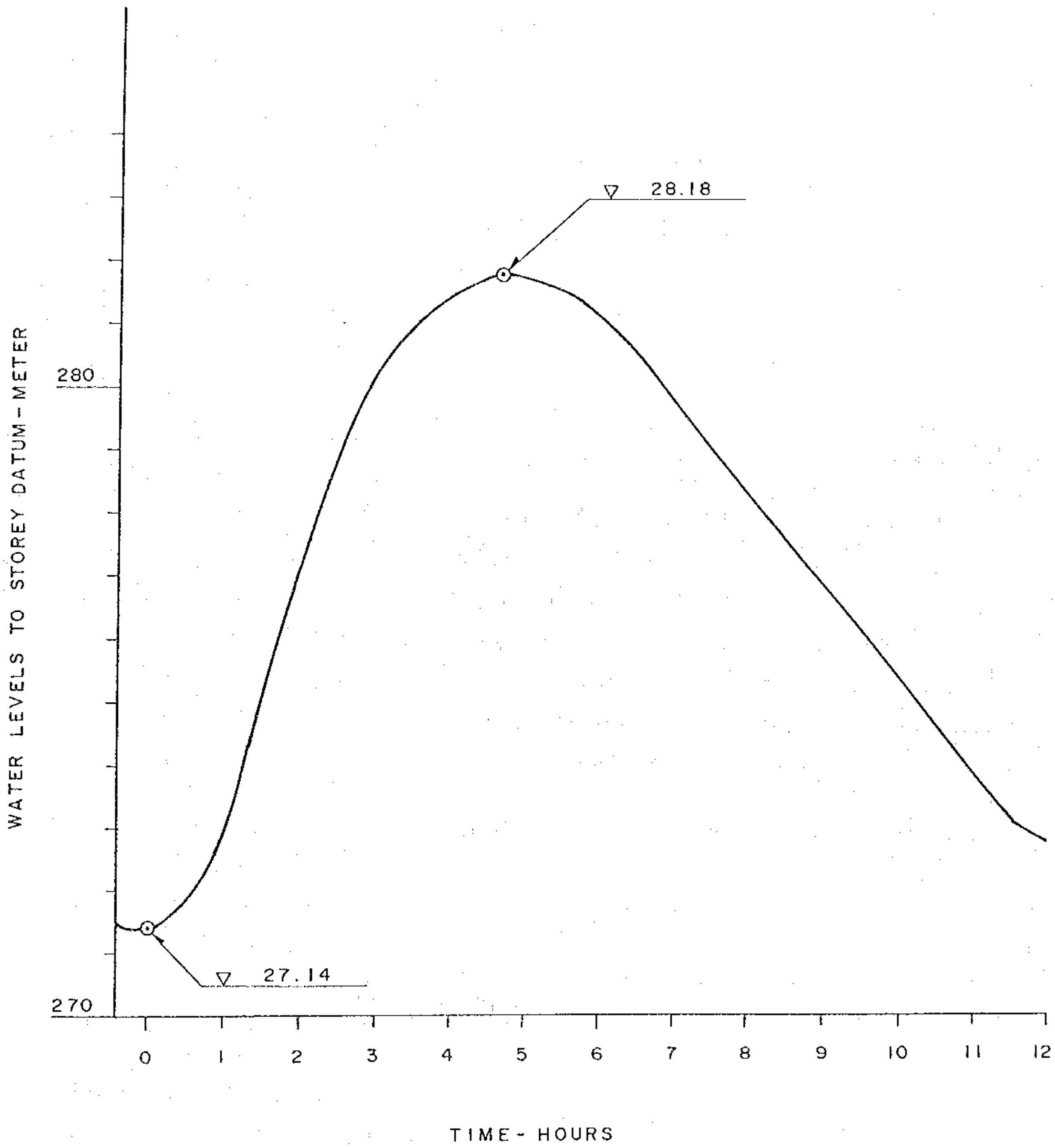
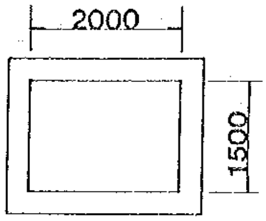


Fig 9-1-7 Q-H CURVE OF WATER SUPPLY CHANNEL

Fig 9-1-8 ASSUMED TIDAL MOVEMENT



Taking into consideration that sedimentation of sand must be allowed for, the following section is proposed.



2.0 m x 1.5 m concrete box culvert

The section of siphons fitted in branch channels is proposed to be ø800 concrete pipe.

(4) In this plan, water supply is not required after the end of Februrary, due to the cropping pattern. At the middle of February, half of all the rice fields in the area are already drained, so the amount of water required for irrigation, compared with the amount of water required to supply all the rice fields, can be cut by half. However, it can be envisaged that, depending on the circumstances, rice of a kind which needs a relatively long term to crop would be used for a dry season crop, so in such a case, sufficient water is needed even in the middle of February.

The quality of water in the Little Scarcies deteriorates towards the end of the dry season. It follows that highly concentrated salty water may intrude into the swamp in the middle of February at high tide. This has been proven to be true by the investigations conducted by MRT.

The phenomenon stated above may be anticipated by using a tide table of water level. In such a case, water should be taken in before high tide, and the miter gate to be installed at Makasa should be closed to prevent the intrusion of sea water.

It is gathered that the required amount of water for irrigation for the whole area during a period from the middle to the end of February, should be less than half the amount of water used to supply all the rice fields in the area. Since the water level of the water supply channel cannot be lower than the lowest water level at low tide at Rhombe, E.L. 27.14 m, as determined previously, at least 70,682 m^3 of water for irrigation will be reserved.

It is known by observations that the high flows of seawater last for a few hours. This fact is referred to in Chapter 7.

It has been concluded that water which is good for rice (the electric conductivity being 2,000 μs/cm or less) can be secured even at the end of February by using a miter gate to be installed.

9-2 Drainage

The unit drainage requirement is calculated based on the provable rainfall. Drain period is assumed in accordance with the allowable flooding depth and time.

The flooding water will not intrude into the polder because of bunds and miter gates to be constructed at each polder.

Referring to Table 4-2-5 (Appendix), water level at Konta for minimum low tide and maximum low tide for the month of September (1960 to 1962) are 28.41 m and 29.5 m with respect to the Storey datum.

Therefore, drainage by gravity through miter gates cannot be expected during this period at certain places which make up about 13% of the total project area. To resolve this limited problem, irrigation pumps could possibly serve as drainage aids.

The unit drainage requirement in the paddy fields is calculated in accordance with the following formula.

$$F = \frac{I - D}{T}$$

where, R: unit drainage requirement (mm/day)

I: design rainfall (mm)

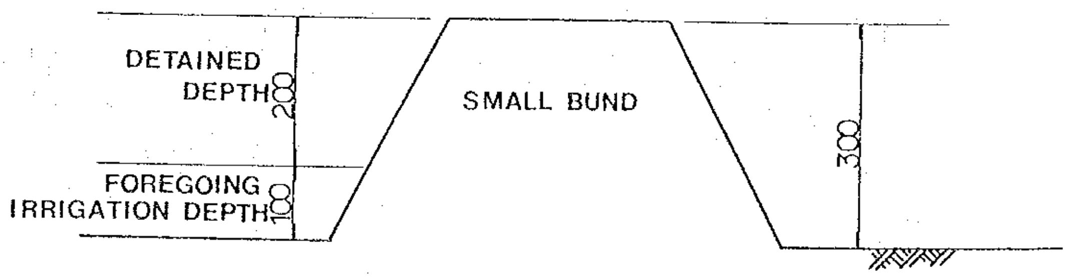
T: drainage period (day)

D: detained depth (mm)

Design rainfall (I) is defined as a maximum of 3 days' consecutive rainfall for the return period of 5 years. According to the MRT report (page I.32), it is estimated to be 252 millimetres from the 36 years' rainfall data at Rokupr, by applying the Weibull formula.

Drainage period (T) is assumed to be three days, and the detained depth (D) of 200 millimetres is proposed (Refer to Fig. 9-2-1). Accordingly, the unit drainage requirement in the paddy field is estimated at 17.3 millimetres per day, or 2 liters per second per hectare.

Fig 9-2-1 ILLUSTLATING DETAINED WATER IN ONE PLOT



CHAPTER 10 COST ESTIMATION

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