3.2.3 Irrigation Water Availability

(1) Available Water for Irrigation

Actually released water from the Angat Reservoir for irrigation as well as for additional power generation, as previously referred to in 3.2.1, and intermediate runoff from the residual drainage area of the Angat River between the Ipo and Bustos Dam were put into the computation of water balance at the point of the Bustos Diversion Dam. As for the Maasim River, the generated runoff by the Tank Model was used as available water in the river.

The existing small scale irrigation systems which receive water by use of small pumping facilities for irrigation of 100 hectares from the Angat River between the Ip and Bustos Dams, and of 183 hectares from the Maasim River between the gaging station No.56 and Upper Maasim Dam were taken into consideration giving the first priority in utilizing the river water.

The maximum amount of the supplementary water supply from the Angat to the Maasim was, in the computation, limited to 1.5 cu.m/sec taking into account the available carrying capacity of the Lateral B of the Angat North Main Canal.

(2) Water Balance Study

Water balance study was made, inputting the irrigated area and the cropping pattern of presently adopted, on 10 daily basis for 11 years from 1972 up to 1982.

Figure A.3.2-3 illustrates the diagram prepared for present condition of water balance study.

According to the computed results, shortage of irrigation water supply occurred twice during the wet season in October 1977 and in September 1979. They are, however, minor in volume of shortage and counted within once in five years probability. On the other hand during the dry season, the area suffered from a shortage of irrigation water diversion as frequently as eight times in the recent 11 years.

It is also clear from the study that the water shortages at the Lower Bustus Dam are influenced to some extent by the available carrying capacity of the Lateral B through which irrigation water is supplied from the Angat River.

The study is summarized in Table A.3.2-15 to A.3.2-17 for shortages in dry season. Shortages computed at the Bustos Dam are also illustrated in Figure A.3.2-4.

Judging from the output of the study, as well as the inflow into the reservoir, storage capacity and demands reported by MWSS and NPC for water supply and power generation respectively, it could be expected that the presently irrigated area in the AMRIS would not meet lack of irrigation water supply even during a drought of once in five years frequency, if the operation rule curve of the Angat Reservoir is slightly modified just to meet the actual demand for irrigation.

Present irrigation networks are shown in Figures A.3.2-5 and A.3.2-6.

TABLE A.3.2-1 INFLOW INTO THE ANGAT RESERVOIR (DRAINAGE AREA - 568 km^2)

(Unit: MCM)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1972	222.66	67.38	78.62	58.71	64.12	84.72	959.98	474.70	279.67	167.17	286.07	249.68	2,993.48
1973	63.48	89.09	40.04	21.63	24.49	30.49	83.65	96.08	122.17	435.56	370.82	214.10	1,591.60
1974	54.24	86.08	72.48	13.03	70.56	135.85	112.82	639.16	81.13	276.26	639.95	506.75	2,668.31
1975	237.92	101.47	62.70	122.32	41.46	72.91	59.40	218.54	150.44	172.92	189.50	581.85	2,011.43
1976	155.30	65.84	62.59	29.92	618.18	269.79	249.51	156.82	263.84	161.96	242.68	212.57	2,489.00
1977	163.32	84.29	76.10	33.29	66.42	32.72	208.37	168.53	200.76	82.59	272.14	73.00	1,460.53
1978	54.60	10.74	22.49	15.91	39.42	66.97	78.92	297.96	373.33	672.07	250.87	244.59	2,127.87
1979	95.00	47.40	34.36	46.76	65.19	118.69	139.46	265.42	140.95	251.94	334.10	105.38	1,644.65
1980	77.30	42.50	126.89	38.39	48.94	132.41	323.69	90.26	217.05	363.45	424.79	143.95	2,029.62
1981	84.73	57.01	18.79	17.99	26.32	170.29	275.55	252.97	148.61	341.23	554.81	262.87	2,211.17
1982	84.01	59.63	43.94	47.74	41.91	50.11	316.34	296.63	188.12	111.59	238.79	156.71	1,635.52
Average	117.41	64.68	58.09	40.52	100.64	105.90	255.24	268.82	196.92	276.07	345.87	250.13	2,080.29

TABLE A.3.2-2 WATER RELEASE THROUGH MAIN POWER GENERATORS

(Unit: MCM)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Remarks
1972	308.33	169.14	204.73	228.50	212.40	93.08	154.75	320.15	332.76	255.22	202.47	177.83	2,659.36	
1973	88.19	89.18	149.52	97.52	165.75	121.64	129.64	58.28	61.08	138.09	119.90	182.62	1,401.41	
1974	121.84	136.77	104.26	73.27	58.91	125.84	92.09	97.91	209.47	26.45	272.27	338.53	1,707.61	
1975	209.08	152.11	153.45	189.73	137.97	148.18	108.86	88.82	186.42	92.43	112.75	118.36	1,698.16	
1976	101.85	124.38	147.14	157.89	166.65	305.21	314.56	340.30	205.66	159.24	188.15	226.63	2,437.66	
1977	205.54	228.52	31.17	2.77	1.88	24.32	66.54	94.07	52.32	41.71	45.13	63.96	857.93	
1978	79.32	80.84	63.39	32.99	39.82	89.57	81.02	88.02	111.15	228.97	290.67	122.89	1,308.65	
1979	106.47	146.35	163.07	42.34	49.14	156.25	156.26	178.38	83.02	149.63	89.78	72.48	1,393.17	
1980	86.53	102.07	97.17	115.49	52.34	172.16	201.79	110.60	93.20	203.50	233.47	141.41	1,609.73	
1981	94.09	111.52	87.94	69.13	31.23	97.35	176.35	174.20	186.92	177.82	206.93	213.21	1,627.14	
1982	86.51	120.31	143.10	160.33	39.96	166.69	30.06	122.82	142.99	98.89	143.11	110.07	1,635.38	
Average	135.25	132.84	122.27	106,36	86.91	136.43	137.45	152.14	151.36	147.45	173.15	160.73	1,666.93	

TABLE A.3.2-3 ACTUAL DISCHARGE FOR AUXILIARY POWER STATION AND MWSS FROM ANGAT RESERVOIR

(Unit: MCM)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Total of Spillage
1972	19.90	23.12	27.08	29.33	19.61	8.91	3.47	27.48	28.71	25.08	23.41	24.86	260.96	181.42
1973	33.71	31.40	35.84	35.01	33.26	28.62	23.62	16.99	15.95	8.46	17.40	26.43	306.69	-
1974	34.46	29.27	33.58	30.51	33.67	23.60	20.25	11.08	26.71	18.32	18.79	24.40	304.64	404.94
1975	29.53	30.58	34.37	34.13	35.79	33.20	32.63	27.22	24.18	23.57	29.30	24.67	359.17	-
1976	29.46	30.99	34.31	34.36	30.25	25.93	23.50	24.14	23.99	25.10	31.95	33.34	347.32	1.88
1977	34.65	31.42	34.07	33.74	34.84	33.00	27.35	19.36	8.81	27.49	25.79	31.82	342.34	-
1978	33.68	3.20	37.06	36.35	36.69	35.43	32.50	12.46	7.70	29.90	20.15	32.63	317.75	417.68
1979	33.49	32.42	36.01	35.49	34.99	26.88	19.54	9.45	17.14	18.77	30.01	33.01	327.20	8.43
1980	33.99	31.23	34.09	33.66	33.77	32.11	22.31	26.65	15.53	22.57	20.07	32.44	338.42	-
1981	33.70	31.60	36.01	37.64	41.15	23.65	9.84	6.83	19.56	26.56	28.06	46.53	341.13	104.11
1982	45.41	32.49	39.80	44.76	45.20	41.80	29.73	15.47	28.05	43.59	51.44	52.76	470.50	-
Average	32.91	27.97	34.75	35.00	34.47	28.47	22.25	17.92	19.67	24.49	26.94	32.99	337.83	101.68

TABLE A.3.2-4 GENERATED RUNOFF OF THE MAASIM RIVER
(AT GAGING STATION NO. 56, D.A = 150 km^2)

(Unit: MCM)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Remarks
1972	2.52	0.52	0.54	0.50	3.13	22.30	146.47	128.33	46.61	13.00	3.72	1.23	368.86	
1973	0.79	0.41	0.30	0.85	0.58	6.37	26.92	19.30	22.34	58.49	15.27	4.09	155.70	
1974	0.79	0.59	0.36	1.26	0.54	26.00	13.78	84.92	19.87	32.69	36.38	19.49	236.64	
1975	3.63	0.96	0.61	0.36	0.25	19.59	12.43	48.84	20.95	32.84	10.11	1.71	152.26	
1976	0.59	0.39	0.34	0.18	55.93	29.30	47.82	37.34	46.99	19.41	3.84	1.21	243.35	
1977	0.72	0.37	0.28	0.18	8.06	9.08	42.68	41.90	37.42	8.05	14.87	1.41	165.01	
1978	0.53	0.34	0.26	0.30	1.78	11.32	21.36	71.86	21.19	50.41	20.47	3.04	202.85	
1979	0.74	0.46	0.35	0.22	3.07	12.03	10.16	35.69	11.39	8.56	3.45	0.52	86.65	
1980	0.36	0.24	1.79	0.34	2.45	1.76	28.35	28.70	42.70	9.31	10.69	0.91	127.59	
1981	0.48	0.31	0.23	0.15	0.10	6.83	16.53	16.03	7.93	2.78	8.07	0.54	59.99	
1982	0.33	0.22	0.18	0.16	3.49	11.73	37.67	34.41	29.43	5.63	1.11	0.72	125.07	
Average	1.04	0.44	0.48	0.41	7.22	14.21	36.74	49.76	27.89	21.92	11.63	3.17	174.91	
"	(0.39)	(0.18)	(0.18)	(0.16)	(2.70)	(5.48)	(13.72)	(18.58)	(10.76)	(8.18)	(4.49)	(1.18)	(5.55)	(Unit: m^3/s)

TABLE A.3.2-5 ANNUAL OPERATION AND MAINTENANCE COST AND IRRIGATION SERVICE FEE COLLECTED IN EXPANSION AREA

Name of Farmers Association	Number of Farmers	Service Area	O & M Cost		Fee Collected
			Annum	Per hectare	
1. San Juan F.A. No. 1	50	80	₱ 35,000	438 P/ha	10 cav./ha
2. Laxamang PIS	7	10	5,000	500	6
3. Labo PIS	2	12	7,000	583	6
4. San Juan F.A. No. 2	50	70	30,000	429	12
5. San Nicolas F.A.	67	122	70,000	574	12
6. Clarin PIS	11	30	15,000	500	10
7. Sta. Monica F.I.A.	75	160	107,000	669	12
8. San Nicolas PIS No. 1	104	170	134,000	788	10
9. San Nicolas PIS No. 2	25	70	40,000	571	10
10. Sta. Cruz PIS	35	60	40,000	667	10
11. San Miguel PIS	50	135	100,000	740	9
12. Cansinala PIS	72	130	50,000	385	9
13. Escaler PIS	30	75	35,000	467	8
14. Tabuyoc PIS	74	130	63,000	485	7
15. Cabrena PIS	11	27	15,000	556	10
16. San Vicente PIS No. 1	20	50	32,000	640	10
17. San Vicente PIS No. 2	14	30	15,000	500	9
18. Cunanan PIS	3	12.5	10,000	800	9
19. Cruz PIS	5	18	15,000	833	9
20. Maglalang PIS	3	9	7,000	778	9
21. Capalanaan PIS	NA	90	130,000	1.444	10
22. Sapang Bayan PIS	NA	50	80,000	1.600	10
Average or Total		1,540.5		679	9.4

TABLE A.3.2-6 (1) STATEMENT OF PUMP IRRIGATION FACILITIES RELATED TO EXPANSION AREA

Name of Farmer Association	Number of Farmers	Service Area (ha)	Dimensions of Pumping Facilities					
			Dia of Pump (mm)	Total Lift Head (m)	Discharge m^3/Sec.	Output of Motor (HP)	Number of Unit	Date Install
1. San Juan Farmers Asso. 1	50	80	400	6.09	0.455	75	1	1960
2. Laxamang P.I.S.	7	10	200	7.60	0.152	15	1	1960
3. Labo Pump Irrigation System	2	12	150	7.60	0.114	15	1	1960
4. San Juan Farmers Asso. 2	50	70	400	6.09	0.455	100	1	1957
5. San Nicolas F.A. (San Luis)	67	122	500	6.09	0.682	150	1	1955
6. Clarin Pump Irrigation System	11	30	200	6.09	0.152	15	1	1965
7. Sta. Monica F.I.A.	75	160	400	7.60	0.455	75	1	1958
8. San Nicolas P.I.S. No. 1	104	170	250 500	5.00 5.00	0.303 0.682	50 60	1 1	1975
9. San Nicolas P.I.S. No. 2	25	70	250	6.09	0.303	60	1	1976
10. Sta. Cruz P.I.S.	35	60	400	5.00	0.455	70	1	1956
11. San Miguel P.I.S.	50	135	450	10.70	0.606	100	1	1974

TABLE A.3.2-6 (2) STATEMENT OF PUMP IRRIGATION FACILITIES RELATED TO EXPANSION AREA

2/2

Name of Farmer Association	Number of Farmers	Service Area (ha)	Dimensions of Pumping Facilities					
			Dia of Pump (mm)	Total Lift Head (m)	Discharge m^3/Sec.	Output of Motor (HP)	Number of Unit	Date Install
12. Cansinala P.I.S.	72	130	400	5.00	0.455	75	1	1954
13. Escaler P.I.S.	30	75	400	6.09	0.455	70	1	1960
14. Tabuyoc P.I.S.	74	130	450	10.36	0.530	110	1	1957
15. Cabrena P.I.S.	11	27	150	7.60	0.114	15	1	1958
16. San Vicente P.I.S. No. 1	20	50	200	6.09	0.152	20	1	1957
17. San Vicente P.I.S. No. 2	14	30	150	7.60	0.114	15	1	1957
18. Cunanan P.I.S.	3	12.5	150	7.60	0.114	15	1	1958
19. Cruz P.I.S.	5	18	200	6.09	0.152	20	1	1960
20. Maglalang P.I.S.	3	9	150	6.09	0.114	15	1	1960
21. Capalanaan P.I.S.	-	90	300	7.50	0.379	70	1	1961
22. Sapang Bayan P.I.S.	-	50	300	7.00	0.379	70	1	1960

TABLE A.3.2-7 MONTHLY MEAN DAILY PAN EVAPORATION AT ULINGAO

(Unit: mm/day)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1970	4.19	4.76	7.25	6.94	6.61	4.10	4.35	3.49	3.75	4.51	3.99	4.15	4.84
1971	4.39	4.88	6.17	7.88	5.18	4.78	5.15	5.43	4.63	3.94	3.65	3.86	5.00
1972	4.29	5.56	6.50	7.67	6.47	6.10	4.23	4.71	5.07	4.90	4.25	4.28	5.34
1973	4.38	5.30	7.01	9.16	7.46	6.67	5.58	4.72	5.01	5.22	4.39	3.61	5.71
1974	4.58	5.27	5.90	7.13	5.37	5.20	5.63	3.62	5.38	3.97	4.47	3.59	5.01
1975	3.81	5.33	4.98	3.96	4.58	3.19	4.00	4.12	5.02	5.59	4.67	3.38	4.39
1976	3.93	4.45	6.32	7.14	6.51	5.91	4.74	4.57	4.80	5.06	4.64	4.38	5.20
1977	4.93	4.38	5.68	6.60	5.86	5.81	4.42	5.42	5.03	5.21	4.46	4.12	5.16
1978	5.15	4.78	6.11	6.06	5.79	4.39	4.74	3.07	4.69	3.84	4.17	4.69	4.79
1979	5.14	5.29	5.68	5.33	4.43	3.70	5.22	4.35	5.22	5.72	5.94	5.59	5.13
Mean	4.48	5.00	6.16	6.79	5.83	4.99	4.81	4.35	4.86	4.80	4.46	4.17	5.06

TABLE A.3.2-8 PRESENT SERVICE AREA OF AMRIS

(Unit; hectare)

Name of Blocks	Wet Season		Dry Season		Service Area	Remarks
	Area	Cropping Pattern	Area	Cropping Pattern		
Upper Maasim	2,111	C	603	C	2,111	Type A,C; Non-Submerged Pattern
Lower Maasim	299	A	299	A	299	
			760	B	760	
Sub-Total	299		1,059		1,059	
North Main Canal of Angat	9,317	A	9,087	A	9,317	Type B; Submerged Pattern
			5,651	B	5,651	
Sub-Total	9,317		14,738		14,968	
South Main Canal of Angat	10,353	A	10,060	A	11,180	
			881	B	881	
Sub-Total	10,353		10,941		12,061	
Tibagan Pump I.S.	1,286	A	1,286	A	1,286	
Total	23,366		28,627		31,485	
(Type A;	21,255		20,732		22,082	
(" B;	0		7,292		7,292	
(" C;	2,111		603		2,111	

TABLE A.3.2-9 FIELD IRRIGATION REQUIREMENT (PRESENT, PATTERN-A, WET)

MONTH	JUN			JUL			AUG			SEP			OCT			NOV			DEC			
10 DAYS	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
CROPPING PATTERN				L.S.	L.P.					WR 133 NORMAL IRRIGATION						T.D.						L.S.; LAND SOAKING L.P.; LAND PREPARATION T.D.; TERMINAL DRAINAGE
1. ELEMENT																						
PERCENT OF GROWING SEASON		8	17	25	33	41	50	58	67	75	83	92	100									
CROP COEFFICIENT (Kc)	0.80	0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85									
		0.80	0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85								
			0.80	0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85							
				0.80	0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85						
					0.80	0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85					
						0.80	0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85				
							0.80	0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85			
Kc AVERAGE	0.80	0.80	0.81	0.84	0.88	0.92	0.95	1.00	1.06	1.11	1.12	1.09	1.06	1.05	1.01	0.97	0.90	0.85	0.85			
EVAPORATION (Ep,mm/day)		5.0			4.8			4.4			4.9			4.8			4.5			4.2		
EVAPOTRANSPIRATION (ET,mm/d)	4.0	4.0	4.1	4.0	4.2	4.4	4.2	4.4	4.7	5.4	5.5	5.3	5.1	5.0	4.8	4.4	4.1	3.8	3.6			
PERCOLATION (P,mm/day)		1.9			1.9			1.9			1.9			1.9			1.9			1.9		
Sn + S (mm)		14.5																				Sn; Soil Saturation Req.
0.8 x Ep + P (mm/day)		5.9			5.7			5.4			5.8			5.7			5.5			5.3		S; Standing Water
ET + P (mm/day)	5.9	5.9	6.0	5.9	6.1	6.3	6.1	6.3	6.6	7.3	7.4	7.2	7.0	6.9	6.7	6.3	6.0	5.7	5.5			
2. EQUATION																						
LAND SOAKING	1/7	1/7	1/7	1/7	1/7	1/7	1/7															
LAND PREPARATION		1/7	1/7	1/7	1/7	1/7	1/7	1/7														
NORMAL IRRIGATION			1/7	2/7	3/7	4/7	5/7	6/7	7/7	→	→	7/7	6/7	5/7	4/7	3/7	2/7	1/7				
3. WATER REQUIREMENT																						
LAND SOAKING (mm)	20.7	20.7	20.7	20.7	20.7	20.7	20.7															(Sn+S) x Equation
LAND PREPARATION (mm)		8.4	8.4	8.1	8.1	8.1	7.7	7.7														(0.8 x Ep + P) x 10 x Equation
NORMAL IRRIGATION (mm)			8.6	16.9	26.1	36.0	43.6	54.0	66.0	73.0	74.0	72.0	60.0	49.3	38.3	27.0	7.1	8.1				(ET + P) x 10 x Equation
10 days TOTAL (mm)	20.7	29.1	37.7	45.7	54.9	64.8	72.0	61.7	66.0	73.0	74.0	72.0	60.0	49.3	38.3	27.0	17.1	8.1				
MONTHLY TOTAL (mm)	87.5			165.4			199.7			219.0			147.6			52.2						
4. FLDP (mm)	35.7	71.4	82.8	94.2	105.6	117.0	128.4	104.1	80.0	80.0	80.0	80.0	68.4	57.0	45.6	34.2	22.8	11.4				FLDP; ALLOWABLE FLOODING DEPTH
WWL (mm)	2.9	5.8	8.7	11.6	14.5	17.4	20.0	20.0	20.0	20.0	20.0	20.0	17.4	14.5	11.6	8.7	5.8	2.9				WWL; STANDING WATER LEVEL (MIN)

TABLE A.3.2-10 FIELD IRRIGATION REQUIREMENT (PRESENT, PATTERN-A, DRY)

MONTH	OCT			NOV			DEC			JAN			FEB			MAR			APR			MAY			
10 DAYS	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
CROPPING PATTERN						L.S.	L.P.				NORMAL IRRIGATION		DR 133						T.D.						L.S. LAND SOAKING L.P. LAND PREPARATION T.D. TERMINAL DRAINAGE
1. ELEMENT																									
PERCENT OF GROWING SEASON				8	17	25	33	41	50	58	67	75	83	92	100										
CROP COEFFICIENT (Kc)				0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85										
					0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85									
						0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85								
							0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85							
								0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85						
									0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85					
Kc AVERAGE				0.80	0.82	0.85	0.90	0.94	0.97	1.04	1.10	1.14	1.14	1.09	1.05	1.01	0.97	0.90	0.85	0.85					
EVAPORATION (Ep, mm/d)					4.5			4.2			4.5			5.0			6.2			6.8					
EVAPOTRANSPIRATION (ET, mm/d)				3.6	3.7	3.8	3.8	3.9	4.1	4.7	5.0	5.1	5.7	5.5	5.3	6.3	6.0	5.6	5.8	5.8					
PERCOLATION (P, mm/day)					1.6			1.6			1.6			1.6			1.6			1.6					
Sn + S (mm)					116																				Sn; Soil Saturation Req.
0.8 x Ep + P (mm/day)					5.2			5.0			5.2			5.6			6.6			7.0					S; Standing Water
ET + P (mm/day)				5.2	5.3	5.4	5.4	5.5	5.7	6.3	6.6	6.7	7.3	7.1	6.9	7.9	7.6	7.2	7.4	7.4					
2. EQUATION																									
LAND SOAKING				1/6	1/6	1/6	1/6	1/6	1/6																
LAND PREPARATION					1/6	1/6	1/6	1/6	1/6	1/6															
NORMAL IRRIGATION						1/6	2/6	3/6	4/6	5/6	6/6				6/6	5/6	4/6	3/6	2/6	1/6					
3. WATER REQUIREMENT																									
LAND SOAKING (mm)				19.3	19.3	19.3	19.3	19.3	19.3																(Sn + S) x Equation
LAND PREPARATION (mm)					8.7	8.7	8.3	8.3	8.3	8.7															(0.8 x Ep + P) x 10 x Equation
NORMAL IRRIGATION (mm)						9.0	18.0	27.5	38.0	52.5	66.0	67.0	73.0	71.0	69.0	65.8	50.7	36.0	24.7	12.3					(ET + P) x 10 x Equation
10 days TOTAL (mm)				19.3	28.0	37.0	45.6	55.1	65.6	61.2	66.0	67.0	73.0	71.0	69.0	65.8	50.7	36.0	24.7	12.3					
MONTHLY TOTAL (mm)					84.3			166.3			194.2			213.0			152.5			37.0					
4. FLDP (mm)				41.7	83.4	96.7	110.0	123.3	136.6	108.2	80.0	80.0	80.0	80.0	80.0	66.5	53.2	39.9	26.6	13.3					FLDP; ALLOWABLE FLOODING DEPTH
WWL (mm)				3.3	6.6	9.9	13.2	16.5	20.0	20.0	20.0	20.0	20.0	20.0	20.0	16.5	13.2	9.9	6.6	3.3					WWL; STANDING WATER LEVEL (MIN.)

TABLE A.3.2-11 FIELD IRRIGATION REQUIREMENT (PRESENT, PATTERN-B, WET)

MONTH	MAR.			APR.			MAY			JUN.			JUL.			AUG.			SEP.			
10 DAYS	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
CROPPING PATTERN				L.S	L.P			NORMAL			WR 120 IRRIGATION				T.D							L.S; LAND SOAKING L.S; LAND PREPARATION T.D; TERMINAL DRAINAGE
1. ELEMENT																						
PERCENT OF GROWING SEASON		9	18	27	36	45	55	64	73	82	91	100										
CROP COEFFICIENT (Kc)		0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85	0.85										
			0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85	0.85									
				0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85	0.85								
					0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85	0.85							
						0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85	0.85						
							0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85	0.85					
Kc AVERAGE		0.80	0.82	0.85	0.90	0.94	0.99	1.06	1.11	1.12	1.09	1.05	1.01	0.97	0.90	0.85	0.85					
EVAPORATION (Ep, mm/day)		6.2			6.8			5.8			5.0			4.8			4.4					
EVAPOTRANSPIRATION (ET, mm/day)		5.0	5.1	5.8	6.1	6.4	5.7	6.1	6.4	5.6	5.5	5.3	4.6	4.7	4.3	3.7	3.7					
PERCOLATION (P, mm/day)		1.9			1.9			1.9			1.9			1.9			1.9					
Sn + S (mm)		145																				Sn; Soil Saturation Req.
0.8x Ep + P (mm/day)		6.9			7.3			6.5			5.9			5.7			5.4					S; Standing Water
ET + P (mm/day)		6.9	7.0	7.7	8.0	8.3	7.6	8.0	8.3	7.5	7.4	7.2	6.7	6.6	6.2	5.6	5.6					
2. EQUATION																						
LAND SOAKING		1/6	1/6	1/6	1/6	1/6	1/6															
LAND PREPARATION			1/6	1/6	1/6	1/6	1/6	1/6														
NORMAL IRRIGATION				1/6	2/6	3/6	4/6	5/6	6/6	←	→	6/6	5/6	4/6	3/6	2/6	1/6					
3. WATER REQUIREMENT																						
LAND SOAKING (mm)		24.2	24.2	24.2	24.2	24.2	24.2															(Sn + S) x Equation
LAND PREPARATION (mm)			11.5	12.2	12.2	12.2	10.8	10.8														(0.8 x Ep + P) x 10 x Equation
NORMAL IRRIGATION (mm)				12.8	26.7	41.5	50.7	66.7	83.0	75.0	74.0	72.0	55.8	44.0	31.0	18.7	9.3					(ET + P) x 10 x Equation
10 days TOTAL (mm)		24.2	35.7	49.2	63.1	77.9	85.7	77.5	83.0	75.0	74.0	72.0	55.8	44.0	31.0	18.7	9.3					
MONTHLY TOTAL (mm)		59.9			190.2			246.2			221.0			130.8			28.0					
4. FLDP (mm)		41.7	83.4	96.7	110.0	123.3	136.6	106.2	80.0	80.0	80.0	80.0	66.5	53.2	39.9	26.6	13.3		FLDP; ALLOWABLE FLOODING DEPTH			
WWL (mm)		3.3	6.6	9.9	13.2	16.5	20.0	20.0	20.0	20.0	20.0	20.0	16.5	13.2	9.9	6.6	3.3		WWL; STANDING WATER LEVEL (MIN)			

TABLE A.3.2-12 FIELD IRRIGATION REQUIREMENT (PRESENT, PATTERN-B, DRY)

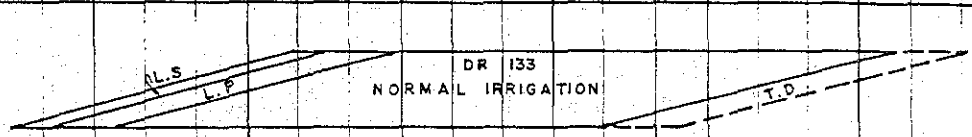
MONTH	OCT.			NOV.			DEC.			JAN.			FEB.			MAR.			APR.			
10 DAYS	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
CROPPING PATTERN																						L.S; LAND SOAKING L.P; LAND PREPARATION T.D; TERMINAL DRAINAGE
1. ELEMENT																						
PERCENT OF GROWING SEASON		8	17	25	33	41	50	58	67	75	83	92	100									
CROP COEFFICIENT (Kc)		0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85									
			0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85								
				0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85							
					0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85						
						0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85					
							0.80	0.83	0.93	1.04	1.12	1.12	1.20	1.21	1.15	1.01	0.85	0.85	0.85			
Kc AVERAGE		0.80	0.82	0.85	0.90	0.94	0.97	1.04	1.10	1.14	1.14	1.09	1.05	1.01	0.97	0.90	0.85	0.85	0.85			
EVAPORATION (Ep, mm/day)		4.8			4.5			4.2			4.5			5.0			6.2			6.8		
EVAPOTRANSPIRATION (ET, mm/day)		3.8	3.9	3.8	4.1	4.2	4.1	4.4	4.6	5.1	5.1	4.9	5.3	5.1	4.9	5.6	5.3	5.3	5.8			
PERCOLATION (P, mm/day)		1.6			1.6			1.6			1.6			1.6			1.6			1.6		
Sn + S (mm)		116																				Sn; Soil Saturation Req.
0.8x Ep + P (mm/day)		5.4			5.2			5.0			5.2			5.6			6.6			7.0		S; Standing Water
ET + P (mm/day)		5.4	5.5	5.4	5.7	5.8	5.7	6.0	6.2	6.7	6.7	6.5	6.9	6.7	6.5	7.2	6.9	6.9	7.4			
2. EQUATION																						
LAND SOAKING		1/7	1/7	1/7	1/7	1/7	1/7	1/7														
LAND PREPARATION			1/7	1/7	1/7	1/7	1/7	1/7	1/7													
NORMAL IRRIGATION				1/7	2/7	3/7	4/7	5/7	6/7	7/7			7/7	6/7	5/7	4/7	3/7	2/7	1/7			
3. WATER REQUIREMENT																						
LAND SOAKING (mm)		16.6	16.6	16.6	16.6	16.6	16.6	16.6														(Sn + S) x Equation
LAND PREPARATION (mm)			7.7	7.4	7.4	7.4	7.1	7.1	7.1													(0.8 x Ep + P) x 10 x Equation
NORMAL IRRIGATION (mm)				7.7	16.3	24.9	32.6	42.9	53.1	67.0	67.0	65.0	69.0	57.4	46.4	41.1	29.6	19.7	10.6			(ET + P) x 10 x Equation
10 days TOTAL (mm)		16.6	24.3	31.7	40.3	48.9	56.3	66.6	80.2	67.0	67.0	65.0	69.0	57.4	46.4	41.1	29.6	19.7	10.6			
MONTHLY TOTAL (mm)	40.9			120.9			183.1			199.0			172.8			90.4			10.6			
4. FLDP (mm)		35.7	71.4	82.8	94.2	105.6	117.0	128.4	104.1	80.0	80.0	80.0	80.0	68.4	57.0	45.6	34.2	22.8	11.4			FLDP; ALLOWABLE FLOODING DEPTH
WWL (mm)		2.9	5.8	8.7	11.6	14.5	17.4	20.0	20.0	20.0	20.0	20.0	20.0	17.4	14.5	11.6	8.7	5.8	2.9			WWL; STANDING WATER LEVEL (MIN)

TABLE A.3.2-13 FIELD IRRIGATION REQUIREMENT (PRESENT, PATTERN-C, WET)

MONTH	MAY			JUN			JUL			AUG.			SEP			OCT			
10 DAYS	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
CROPPING PATTERN				L.S.	L.P.			WR 120 NORMAL IRRIGATION						T.D.					L.S.; LAND SOAKING L.P.; LAND PREPARATION T.D.; TERMINAL DRAINAGE
1. ELEMENT																			
PERCENT OF GROWING SEASON			10	20	30	40	50	60	70	80	90	100							
CROP COEFFICIENT (Kc)			0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85							
				0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85						
					0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85					
						0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85				
							0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85			
Kc AVERAGE			0.80	0.82	0.85	0.90	0.94	1.02	1.10	1.14	1.14	1.08	1.06	1.00	0.93	0.85			
EVAPORATION (Ep, mm/day)		5.8			5.0			4.8			4.4			4.9			4.8		
EVAPOTRANSPIRATION (ET, mm/d)			4.6	4.1	4.3	4.5	4.5	4.9	5.3	5.0	5.0	4.8	5.2	4.9	4.6	4.1			
PERCOLATION (P, mm/day)		1.9			1.9			1.9			1.9			1.9			1.9		
Sn + S (mm)		145																	Sn; Soil Saturation Req.
0.8 x Ep + P (mm/day)		6.5			5.9			5.7			5.4			5.8			5.7		S; Standing Water
ET + P (mm/day)			6.5	6.0	6.2	6.4	6.4	6.8	7.2	6.9	6.9	6.7	7.1	6.8	6.5	6.0			
2. EQUATION																			
LAND SOAKING			1/5	1/5	1/5	1/5	1/5												
LAND PREPARATION				1/5	1/5	1/5	1/5	1/5											
NORMAL IRRIGATION					1/5	2/5	3/5	4/5	5/5	→	→	5/5	4/5	3/5	2/5	1/5			
3. WATER REQUIREMENT																			
LAND SOAKING (mm)			29.0	29.0	29.0	29.0	29.0												(Sn + S) x Equation
LAND PREPARATION (mm)				11.8	11.8	11.8	11.4	11.4											(0.8 x Ep + P) x 10 x Equation
NORMAL IRRIGATION (mm)					12.4	25.6	38.4	54.4	72.0	69.0	69.0	67.0	56.8	40.8	26.0	12.0			(ET + P) x 10 x Equation
10 days TOTAL (mm)			29.0	40.8	53.2	66.4	78.8	65.8	72.0	69.0	69.0	67.0	56.8	40.8	26.0	12.0			
MONTHLY TOTAL (mm)	29.0			160.4			216.6			205.0			123.6			12.0			
4. FLDP (mm)			50.0	100.0	116.0	132.0	148.0	114.0	80.0	80.0	80.0	80.0	64.0	48.0	32.0	16.0			FLDP; ALLOWABLE FLOODING DEPTH
WWL (mm)			4.0	8.0	12.0	16.0	20.0	20.0	20.0	20.0	20.0	20.0	16.0	12.0	8.0	4.0			WWL; STANDING WATER LEVEL (MIN)

TABLE A.3.2-14 FIELD IRRIGATION REQUIREMENT (PRESENT, PATTERN-C, DRY)

MONTH	SEP			OCT			NOV			DEC			JAN			FEB			MAR			
10 DAYS	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
CROPPING PATTERN				L.S. / L.P.						NORMAL IRRIGATION	WR 120					T.B.						L.S.; LAND SOAKING L.P.; LAND PREPARATION T.D.; TERMINAL DRAINAGE
1. ELEMENT																						
PERCENT OF GROWING SEASON				10	20	30	40	50	60	70	80	90	100									
CROP COEFFICIENT (Kc)				0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85									
					0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85								
						0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85							
							0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85						
								0.80	0.83	0.93	1.04	1.12	1.20	1.21	1.15	1.01	0.85					
Kc AVERAGE				0.80	0.82	0.85	0.90	0.94	1.02	1.10	1.14	1.14	1.08	1.06	1.00	0.93	0.85					
EVAPORATION (Ep, mm/day)					4.8			4.5			4.2			4.5			5.0					
EVAPOTRANSPIRATION (ET, mm/day)				3.8	3.9	4.1	4.1	4.2	4.6	4.6	4.8	4.8	4.9	4.8	4.5	4.7	4.3					
PERCOLATION (P, mm/day)					1.6			1.6			1.6			1.6			1.6					
Sn + S (mm)					116																	Sn; Soil Saturation Req.
0.8 x Ep + P (mm/day)					5.4			5.2			5.0			5.2			5.6					S; Standing Water
ET + P (mm/day)				5.4	5.5	5.7	5.7	5.8	6.2	6.2	6.4	6.4	6.5	6.4	6.1	6.3	5.9					
2. EQUATION																						
LAND SOAKING				1/5	1/5	1/5	1/5	1/5														
LAND PREPARATION					1/5	1/5	1/5	1/5	1/5													
NORMAL IRRIGATION						1/5	2/5	3/5	4/5	5/5			5/5	4/5	3/5	2/5	1/5					
3. WATER REQUIREMENT																						
LAND SOAKING (mm)				23.2	23.2	23.2	23.2	23.2														(Sn+S) x Equation
LAND PREPARATION (mm)					10.8	10.8	10.4	10.4	10.4													(0.8 x Ep+P) x 10 x Equation
NORMAL IRRIGATION (mm)						11.4	22.8	34.8	49.6	62.0	64.0	64.0	65.0	51.2	36.6	25.2	11.8					(ET+P) x 10 x Equation
10 days TOTAL (mm)				23.2	34.0	454	56.4	68.4	60.0	62.0	64.0	64.0	65.0	51.2	36.6	25.2	11.8					
MONTHLY TOTAL (mm)				102.6			184.8			190.0			152.8			37.0						
4. FLDP (mm)				50.0	100.0	116.0	132.0	148.0	114.0	80.0	90.0	80.0	80.0	64.0	48.0	32.0	16.0					FLDP; ALLOWABLE FLOODING DEPTH
WWL (mm)				4.0	8.0	12.0	16.0	20.0	20.0	20.0	20.0	20.0	20.0	16.0	12.0	8.0	4.0					WWL; STANDING WATER LEVEL

TABLE A.3.2-15 WATER SHORTAGE OF BUSTOS DAM AREA FOR DRY SEASON CROP

(Unit: MCM or %)

Year	Oct.		Nov.		Dec.		Jan.		Feb.		Mar.	
	Deficit	Ratio	Deficit	Ratio	Deficit	Ratio	Deficit	Ratio	Deficit	Ratio	Deficit	Ratio
1972	-	-	-	-	-	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	4.865	8	-	-	-	-
1974	-	-	-	-	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	2.727	9	-	-	-	-
1977	5.337	9	-	-	-	-	-	-	-	-	19.607	32
1978	-	-	-	-	-	-	9.075	10	19.615	20	2.937	11
1979	-	-	-	-	6.643	23	-	-	-	-	-	-
1980	-	-	-	-	-	-	7.198	23	4.102	6	4.135	15
1981	-	-	-	-	-	-	5.491	17	2.385	8	3.761	19
1982	-	-	-	-	-	-	6.647	21	3.024	9	-	-
Frequency		1		0		1		6		4		4

Note : Rate = $\frac{\text{Deficit volume}}{\text{Water requirement}} \times 100$

TABLE A.3.2-16 WATER SHORTAGE OF UPPER MAASIM DAM AREA FOR DRY SEASON CROP

(Unit: MCM or %)

Year	Oct.		Nov.		Dec.		Jan.		Feb.		Mar.	
	Deficit	Ratio	Deficit	Ratio	Deficit	Ratio	Deficit	Ratio	Deficit	Ratio	Deficit	Ratio
1972	–	–	–	–	1.092	60	0.105	20	0.187	100	–	–
1973	–	–	–	–	0.061	10	1.177	84	0.313	100	–	–
1974	–	–	–	–	–	–	1.476	92	0.295	100	–	–
1975	–	–	–	–	0.843	66	–	–	0.167	71	–	–
1976	–	–	–	–	0.971	75	1.562	99	0.319	100	–	–
1977	–	–	–	–	1.216	85	1.097	98	0.301	100	–	–
1978	–	–	–	–	0.022	3	1.629	100	0.319	100	–	–
1979	–	–	0.759	51	1.982	99	1.545	95	0.319	100	–	–
1980	–	–	–	–	1.793	84	1.629	100	0.319	100	–	–
1981	0.354	83	–	–	2.009	94	1.629	100	0.319	100	–	–
1982	–	–	0.943	74	1.511	86	1.629	100	0.319	100	–	–
Frequency		1		2		10		10		11		0

Note : $\text{Ratio} = \frac{\text{Deficit volume}}{\text{Water requirement}} \times 100$

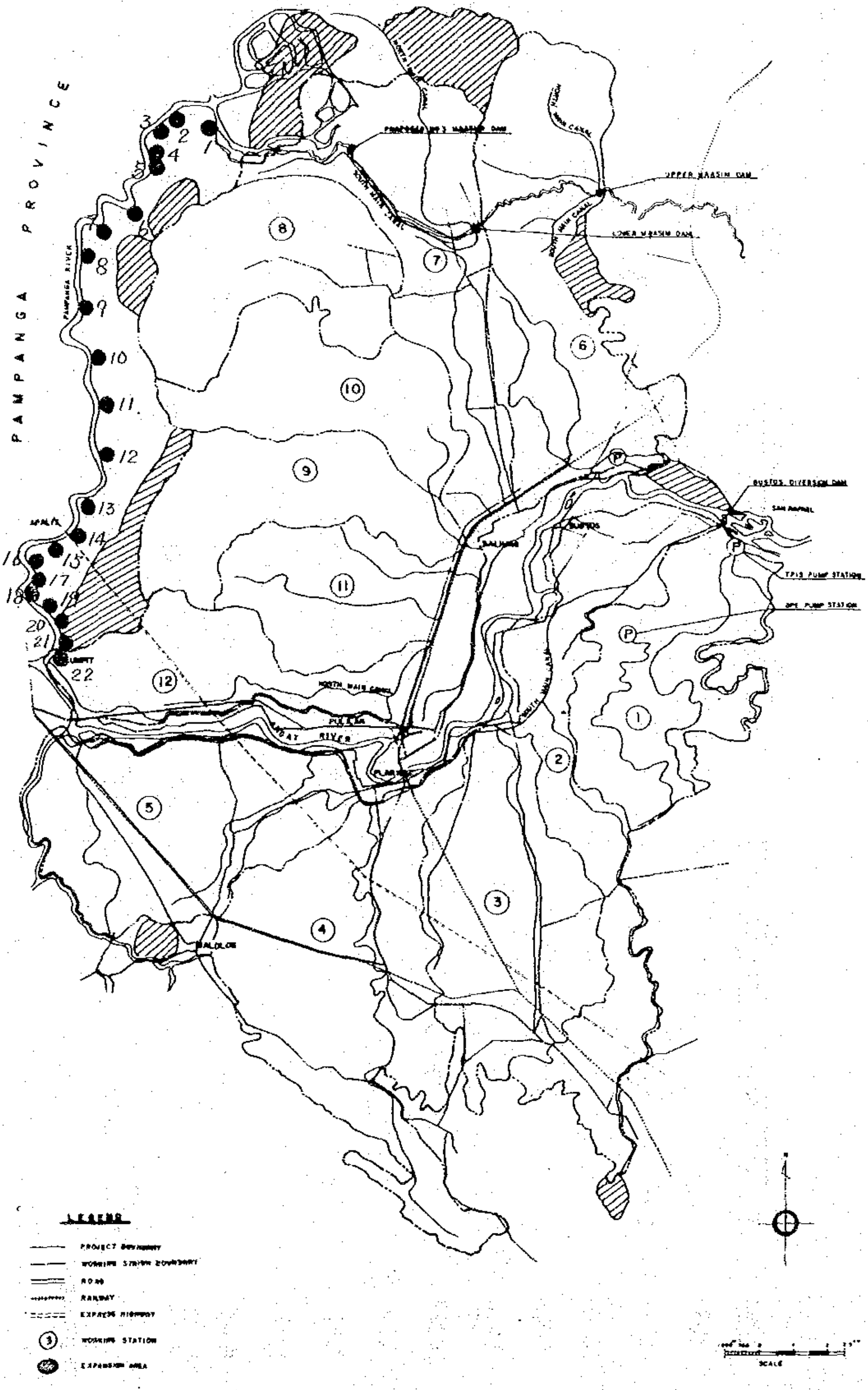
TABLE A.3.2-17 WATER SHORTAGE OF LOWER MAASIM DAM AREA FOR DRY SEASON GROUP

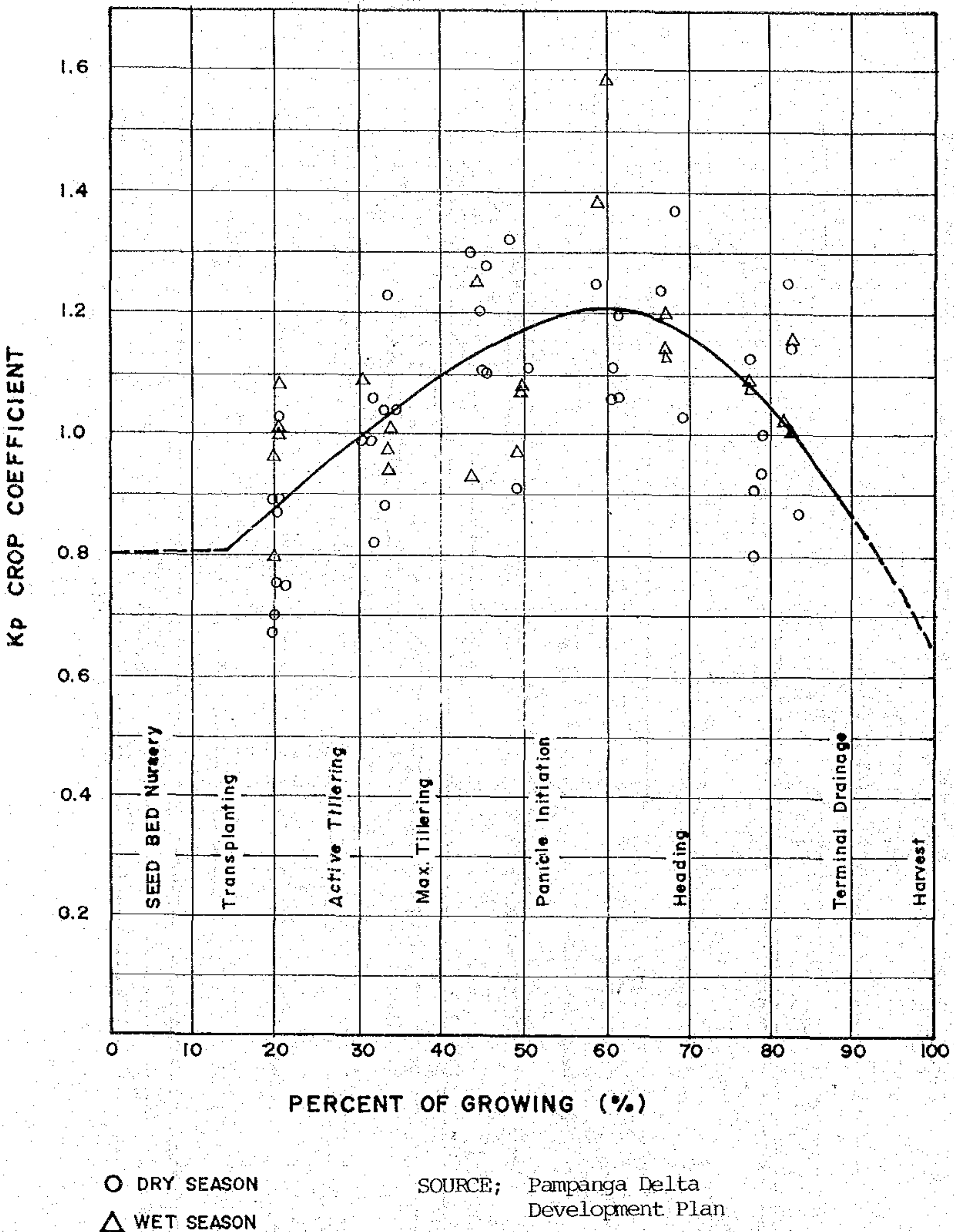
(Unit: MCM or %)

Year	Oct.		Nov.		Dec.		Jan.		Feb.		Mar.	
	Deficit	Ratio	Deficit	Ratio	Deficit	Ratio	Deficit	Ratio	Deficit	Ratio	Deficit	Ratio
1972	-	-	-	-	-	-	0.014	1	-	-	-	-
1973	-	-	-	-	-	-	2.572	100	0.491	36	-	-
1974	-	-	-	-	-	-	0.014	1	0.083	6	-	-
1975	-	-	-	-	-	-	-	-	0.083	6	-	-
1976	-	-	-	-	-	-	1.304	50	0.083	6	-	-
1977	-	-	-	-	-	-	-	-	0.083	6	1.947	100
1978	-	-	-	-	0.007	1	2.587	67	3.547	100	0.886	100
1979	-	-	-	-	1.303	100	0.014	1	0.083	6	-	-
1980	-	-	-	-	0.007	1	1.310	100	2.538	100	0.886	100
1981	-	-	-	-	0.007	1	1.310	100	1.081	46	0.643	100
1982	-	-	-	-	-	-	1.310	100	1.379	100	-	-
Frequency		0		0		4		9		10		4

Note : Ratio = $\frac{\text{Deficit volume}}{\text{Water requirement}} \times 100$

FIGURE A.3.2-1 LOCATION OF EXISTING PUMP

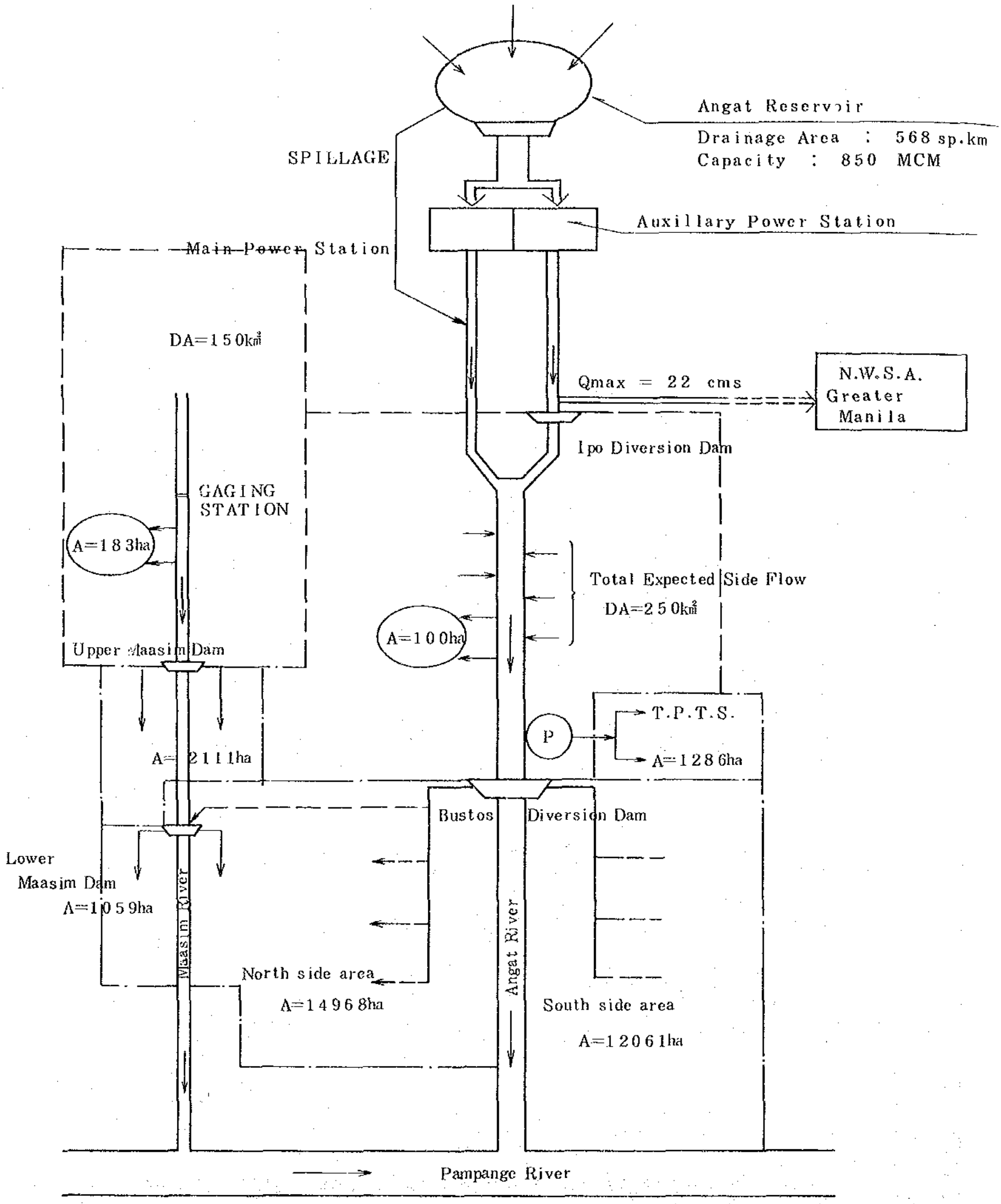


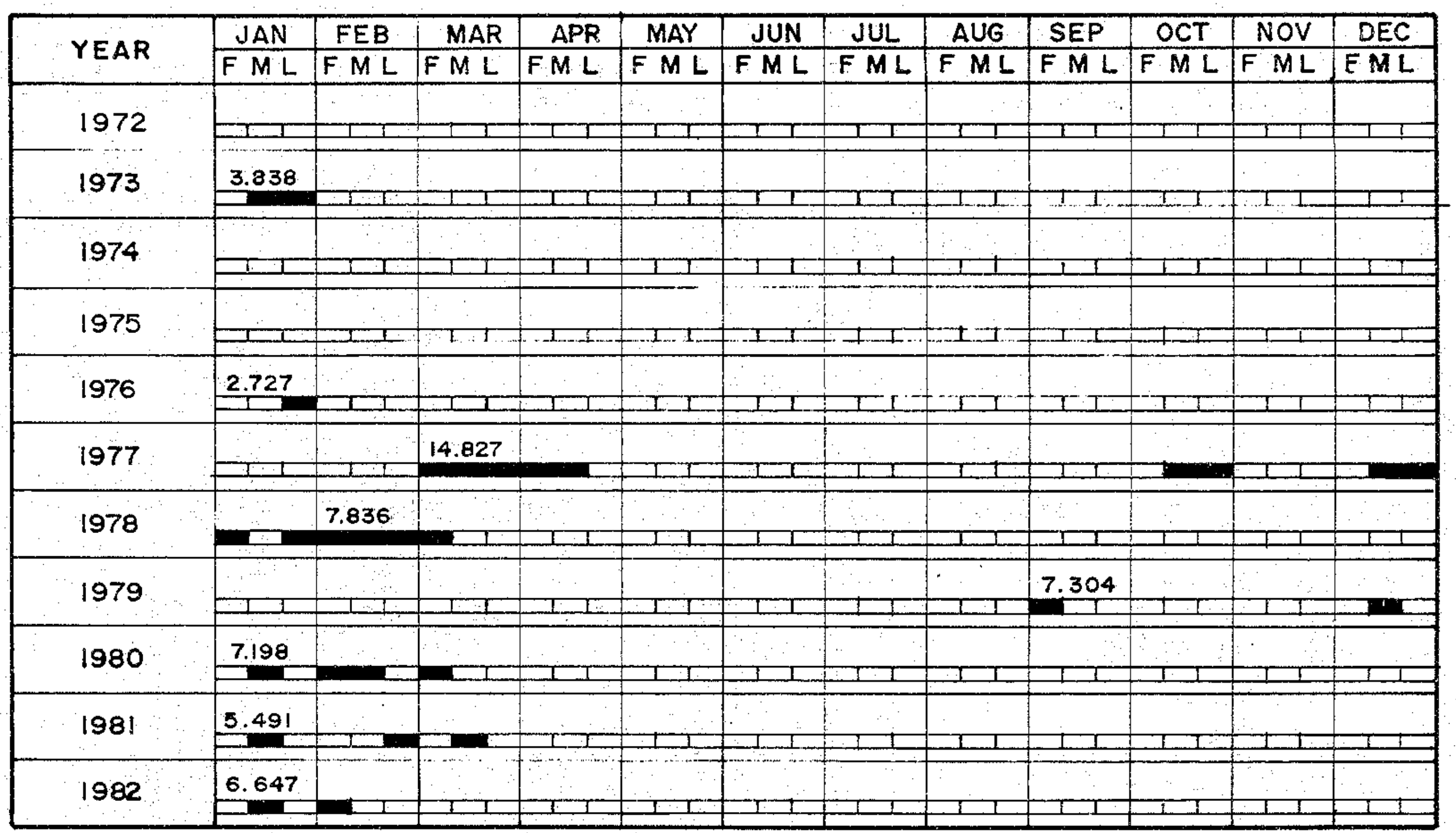


SOURCE; Pampanga Delta Development Plan

FIG. A.3.2-2 **SEASONAL VARIATION OF CROP COEFFICIENT OF PADDY**

FIGURE A.3.2-3 DIAGRAM FOR WATER BALANCE (PRESENT CONDITION)





REMARK: FIGURES SHOW THE MAXIMUM SHORTAGE IN MCM/10 DAYS.

FIGURE A.3.2-4 **SHORTAGE OF IRRIGATION WATER DIVERSION AT BUSTOS DAM**

'IGURE A.3.2-5 IRRIGATION NETWORK (PRESENT CONDITION,NORTH ZONE)

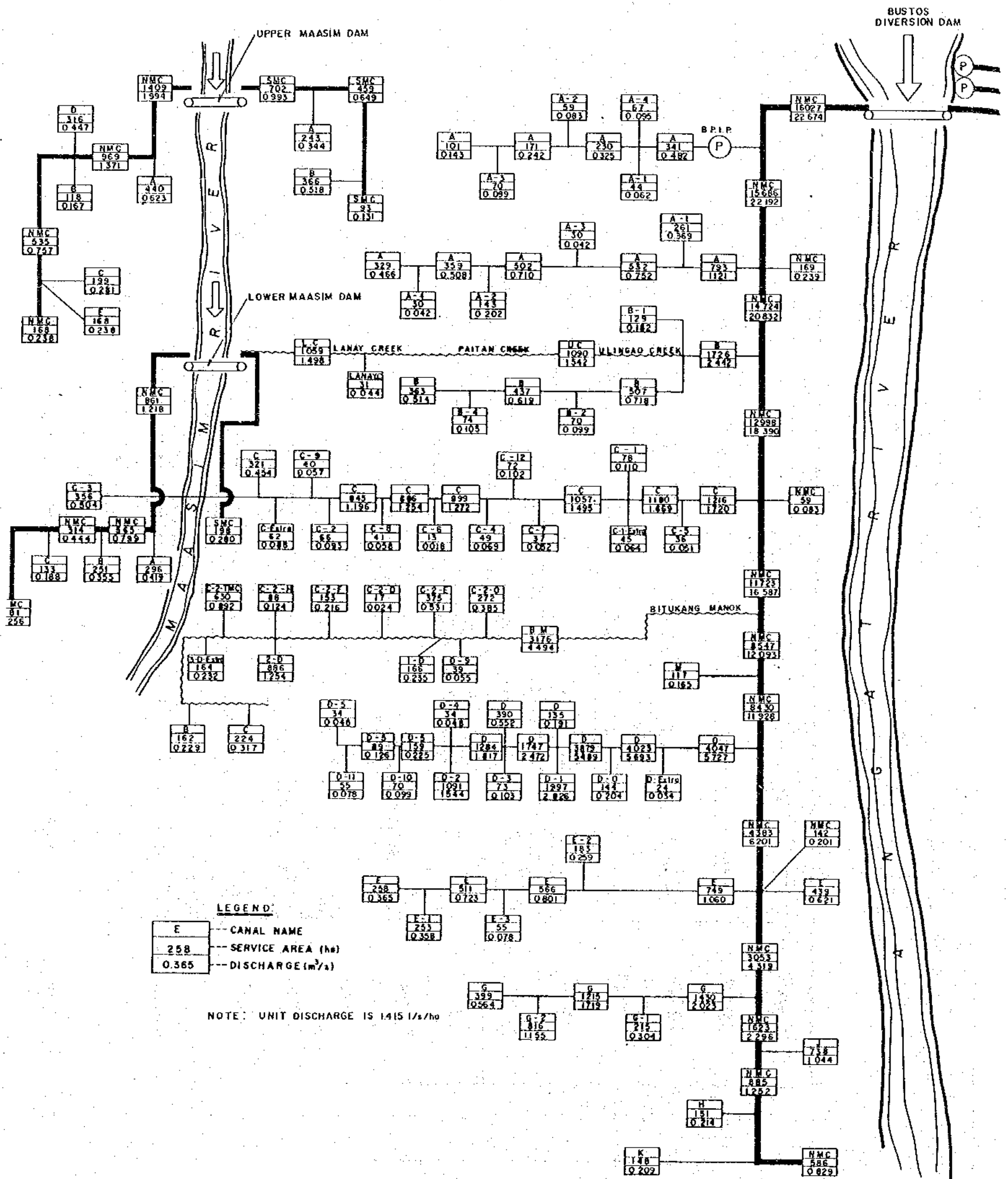
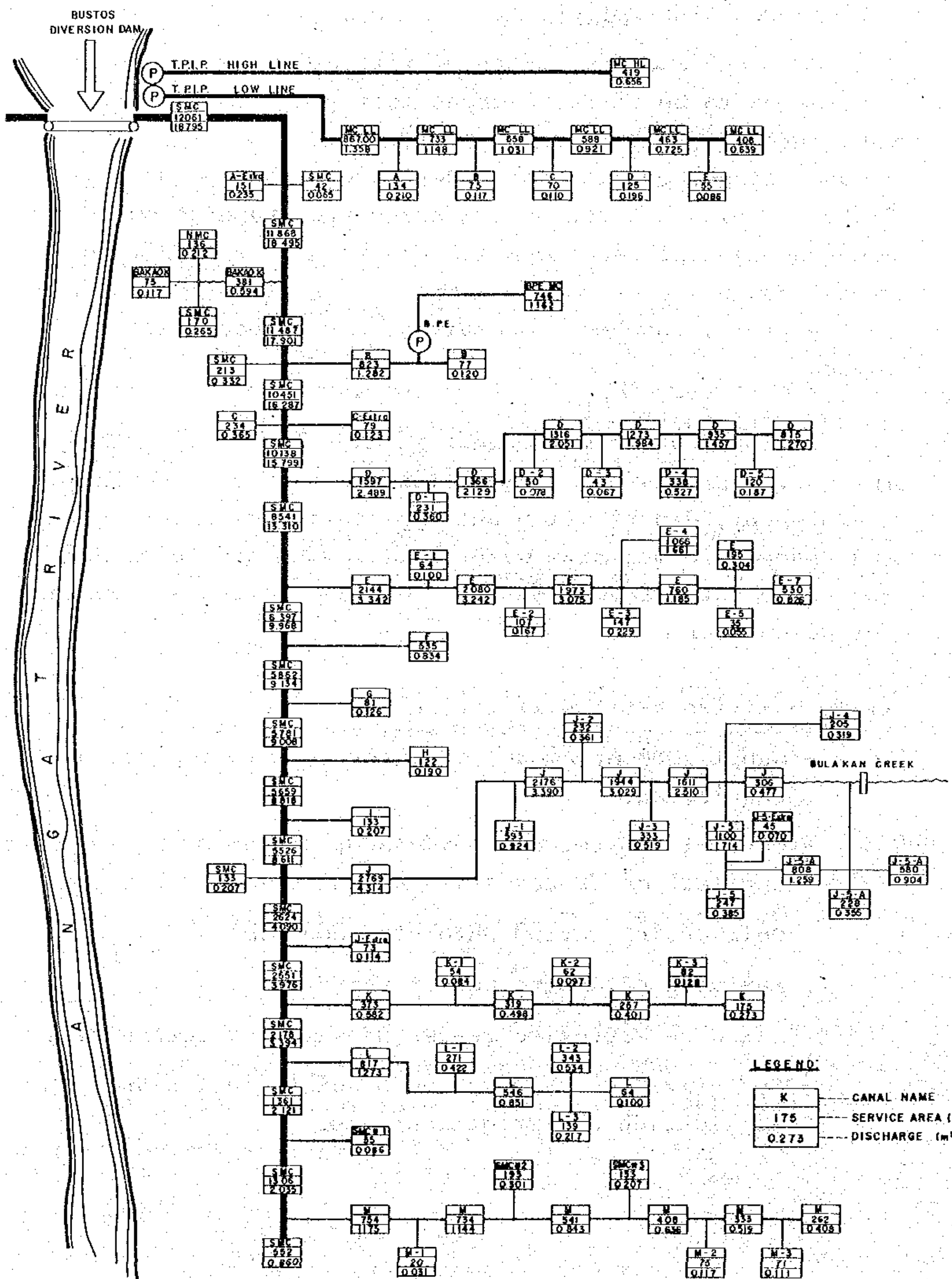


FIGURE A.3.2-6 IRRIGATION NETWORK (PRESENT CONDITION,SOUTH ZONE)



NOTE : UNIT DISCHARGES ARE GIVEN AS FOLLOWS

T.P.I.P : 1.565 l/s/ha

S.M.C : 1.558 l/s/ha

3.3 Irrigation Scheme

3.3.1 Upgrading Irrigation Efficiency and Water Management

(1) General Discription

Farm application losses of irrigation water are considered to be on-farm losses mostly due to farmer's managenal capacity as well as farm activity. Conveyance losses are, on the other hand, composed of physical factors, which are seepage, leakage and evaporation losses, and non-physical factors which are rather related to operational factors such as over-application of irrigation water in the field, unscheduled drainage and illegal diversion losses.

Improved water management is expected only by the integrated processes of diversion, conveyance, regulation, measurement, distribution and application of water in time and space. To maximize water utilization and to promote increased farm production, the following items are subject for discussion.

1) To Maximize Water Utilization

- Supply proper amount of water just to meet crop requirement
- Control and reduce conveyance, distribution and farm application losses
- Deliver irrigation water in good time
- Maximize effective use of rainfall
- Maximize effective re-use of water or return flow
- Systemize suitable scheme of distribution and application of irrigation water

2) To Promote Increased Farm Production

- Plan a proper land use scheme
- Improve farm management techniques
- Accelerate active participation of irrigator's associations

(2) Definition and Factors Affecting Diversion Water Requirement

1) Definition of Parameters of Irrigation Water Requirement

Irrigation diversion water requirement is the total amount of water diverted from a source for evapotranspiration, percolation losses in the soil, farm application losses, distribution and conveyance losses, minus effective rainfall in the field and the re-use of water.

a) Evapotranspiration is the amount of water transpired from plants and evaporated from soil and or water surface in the field.

b) Percolation is the amount of water unavoidably lost due to the downward movement of water through the soil to the water table.

c) Crop water requirement is the amount of water needed for optimum plant growth which is the sum of evapotranspiration (or consumptive use) and percolation.

d) Farm application losses are the amount of water lost in the farm and not further used for irrigation due to leakage through the paddy dikes, over application of water in the field, spillage and unscheduled drainage.

e) Conveyance losses are the amount of water lost and wasted in conveying water along main, lateral and sub-lateral canals due to seepage in the wetted surface of the canal and leakages through crab holes and control gates, and illegal diversions. This loss is limited to the main, lateral and sub-lateral canals only.

f) Distribution losses are the amount of water lost and wasted in distributing and conveying water along farmditches due to seepages and leakages.

g) Effective rainfall is the amount of rainfall which is considered usable for crop water requirements.

h) Re-use water or return flow are water coming from irrigated land to the drainage channels which can be re-used for irrigating other area.

2) Factors Affecting Parameter of Irrigation Water Requirement

a) Evapotranspiration: The factors of plant growth stage, temperature, sunlight, humidity, wind velocity, soil texture and water supply will affect the values of evapotranspiration.

b) Percolation: The factors of texture and structure in layers of soil profile, soil permeability, depth to impervious layer and depth to water table will govern percolation losses.

c) Effective rainfall: Intensity of rainfall, depth of submergence, size and maintenance condition of farm dikes and topography of land will influence maximizing effective rainfall. To maximize effective rainfall, the followings are to be considered.

- Improvement of farm dikes to increase pondage
- Adoption of irrigation suspension schedule
- Application of shallow depth of irrigation water
- Practice of intermittent application of irrigation water

3) Factors Affecting Farm Application, Conveyance and Distribution Losses

a) Texture of soil, depth of water table, permeability of soil, age of canal and compactness of canal embankment will affect seepage losses.

b) Maintenance condition of canals as well as gates and tightness of gates will influence leakage losses.

c) With cooperation of irrigators, illegal diversion of irrigation water will be avoided by adequate supervision and patrolling of the system.

d) With cooperation of irrigators, over-application of irrigation water will be avoided by adequate supervision of water distribution system.

e) In the same way as above, unscheduled drainage can also be avoided.

f) Appropriate maintenance of paddy levee will decrease leakage through it.

(3) Study of Integrated Irrigation Efficiency Observed in AMRIS Area

1) Basic Formula of Efficiency

The integrated irrigation efficiency can be expressed in division form as follows:

$$\frac{1}{fi} = \frac{1}{(1 - fa) \times (1 - fc) \times (1 - fd)}$$

Where,
fi: Integrated irrigation efficiency
fa: Ratio of farm application losses
fc: Ratio of canal conveyance losses
fd: Ratio of distribution losses

2) Analysis of Integrated Irrigation Efficiency

Lateral canals selected under the study are lateral D, E, F and G along the Angat South Main Canal and lateral A, B, C, D, E and G along the Angat North Main Canal respectively. The proportion of irrigated area to potential area covered by ten (10) selected canal routes are approximately 45 percent of wet season and 50 percent of dry season during the crop year of 1981 and 1982.

Results of the integrated irrigation efficiency are tabulated in Table A.3.3-1. The efficiencies are indicated by the ratio of crop water requirements to actual diverted discharges at the headgate of respective lateral canals taking actual cropping pattern, irrigated area, and effective rainfall into consideration.

The averaged efficiencies are about 57.3 percent in the dry season and 33.7 percent in the wet season. The efficiency in the wet season is fairly lower than that in the dry season. The major reason for this is that diverted water did not correspond to actual water requirement in the field, because effective rainfall was not fully considered in operating irrigation diversion.

3) Consideration of Canal Conveyance Losses

Conveyance losses of lateral and sub-lateral canals in the entire project area during both the wet and dry season were computed based on the observed rate of conveyance losses, irrigated area and canal length used for paddy plantation concerned. In the Project, canal conveyance losses are calculated by the following equation.

$$Qcl = Lc \times Wp \times Ccl$$

Where, Qcl: Discharge of canal conveyance losses in cubic meters per second

Lc: Canal length in meters

Wp: Wetted perimeter of the canal in meters

Ccl: Rate of canal conveyance losses by soil texture

As shown in Table A.3.3-2 and A.3.3-3, the ratios of averaged conveyance losses were obtained at 24.0 percent and 22.8 percent in the dry and wet season respectively.

4) Evaluation of Relationship between Integrated Irrigation Efficiency and Respective Factors Concerned

According to the NIA standard on Operation and Maintenance Plan for Irrigation System Management, in the absence of actual field data, farm application losses are assumed to be about 30 percent of the crop water requirement.

In this discussion, fi, fa and fc values are known in the previous evaluation and computation, so that the actual fd value can be developed by the following equation.

$$fd = 1 - \frac{fi}{(1 - fa)(1 - fc)}$$

Where, $fa = 1 - \frac{1}{1 + 0.30} \fallingdotseq 0.23$

Dry season:

$fi = 0.573$

$$fc = 1 - \frac{1}{1.00 + 0.24} \fallingdotseq 0.19$$

$$fd = 1 - \frac{0.573}{(1 - 0.23)(1 - 0.19)} \fallingdotseq 0.08$$

Wet season:

$fi = 0.337$

$$fc = 1 - \frac{1}{(1.00 + 0.23)} \fallingdotseq 0.19$$

$$fd = 1 - \frac{0.337}{(1 - 0.23)(1 - 0.19)} \fallingdotseq 0.46$$

As the result of evaluation, distribution efficiency in the wet season was shown to be quite low mainly due to a lack of consideration of effective rainfall and the undeveloped system of water management.

For the purpose of the effective utilization of limited water resources, the integrated irrigation efficiency should be increased in both technical and economical manners.

Upgrading farm application efficiency seems, however, to be difficult when the actual situation of on-farm development and farmers attitude are taken into consideration. To prevent leakage losses from the paddy field and to demolish illegal diversion and so forth, greater attention should be paid by the farmers concerned.

Although preventing conveyance losses in canals by means of concrete lining is considered to be rather difficult because of the availability of funds, it would be to some extent possible to improve conveyance efficiency by undertaking careful supervision and maintenance of canal systems.

The only way of upgrading integrated irrigation efficiency is to increase distribution and farm application efficiencies through provision of good water management, supported by the farmers' cooperation and improvement of water control as well as on-farm facilities.

The final goal of the integrated irrigation efficiency is expected to be about 60 percent with increasing distribution and farm application efficiencies of about 2 to 3 percent respectively.

3.3.2 Proposed Irrigation Schedule

(1) Proposed Cropping Schedule

For the parpose of upgrading irrigation efficiency and crop production, studies were made intensively on a systematic usage of the water resources, improved operation and maintenance of the irrigation facilities and the future trend of farm production as well as marketing, putting great emphases on the followings.

- Expansion of new irrigable areas as extensively as irrigation capacity makes it possible to support crop growth.

- Increase in cropping intensity both in wet and dry season crops through drainage improvement.

- Introduction of an upland crops diversification scheme to the well-drained areas.

The proposed average of the area for irrigation is 26,573 ha and 34,965 ha for wet and dry season respectively. In comparison with the present irrigated area, increase of 3,207 ha in wet season contains 380 ha of new expansion area (WS-Ex.1 & EX-2) and 2,827 ha of existing area which are not planted to rice at present because of bad drainage but which may be planted when the proposed cropping pattern D is applied.

As much as 6,338 ha of area is expected to be newly irrigated in the dry season, containing 3,480 ha of expansion area proposed as WS2-Ex, WS5-Ex, WS6-Ex.1 to Ex.3, WS7-Ex, WS8-Ex.1 to Ex.2 and WS9-Ex, and 1,508 ha of the existing area which is belonging to the Upper Maasim but is not irrigated due to the frequent lack of available runoff water in the Maasim River.

The future land use will be slightly changed compared to the present one provided there are adequate irrigation and drainage systems and proper water management for the existing area as well as the proposed expansion area. The proposed areas of land use in terms of land classification are summarized below.

Proposed Land Use (ha)

Land Classification	Present	Proposed	Difference
Paddy	33,886	34,965	1,079
Upland	630	630	0
Forest or Orchard	1,580	1,580	0
Waste Land/Swamp	3,710	2,470	(-) 1,240
Right of Way	2,164	2,325	161
Residence/Industrial	4,730	4,730	0
Total	46,700	46,700	0

Proposed irrigable area is only paddy of 34,965 ha in total and, accordingly, 3,480 ha of paddy is proposed to be expanded. In the future with project, cropping intensity in the present service area would increase by 9 and 16% in the wet and dry season respectively, or 9,240 ha of increased planted area would be expected including the expansion areas. Figure A.3.3-1 illustrates the location of such proposed expansion areas.

(2) Cropping Pattern

Five patterns of proposed cropping calendar were applied to the project, namely: proposed pattern A, B, C, D and E. Pattern formulation depends largely on the topographic features as well as soil characteristics of the land, which may affect irrigability, drainability and submergence during the wet season.

Each cropping calendar was formulated following the irrigation program and the water availability. In addition, a fallow season of about two months, from April to May, was needed for repair and maintenance of the canals and other irrigation facilities. The proposed cropping patterns in relation to topography, drainability and submergence condition are summarized in the following table.

Proposed Cropping Pattern by Topography, Drainability & Submergence

Submergence during wet season	Cropping pattern	Topography	Drainage
Non-submerged	A	Almost flat	Imperfectly drained
		Flat to slightly undullating	Moderately well to imperfectly drained
	B	Undullating to rolling	Moderately well drained
	C	Almost flat	Imperfectly drained
		Flat to slightly undullating	Well to moderately well drained
Submerged	D	Flat to slightly sloping, partly swampy	Imperfectly to poorly drained
	E	Flat to slightly depressed	Imperfectly to poorly drained

Pattern A - Double cropped for rice with late maturing varieties; the most major pattern covering almost two thirds of the total planted area; stable and higher yield.

Pattern B - Ditto, but with early maturing varieties; drought-suffered area due to the shortage in water supply; the dry season rice must be planted in October to advance harvest (October Rice).

Pattern C - Triple cropped, once with late maturing rice in wet season and twice with diversified upland crops in dry season.

Pattern D - Double cropped for rice with early maturing varieties; the wet season rice crop must be planted in March to finish harvest before July in order to avoid typhoon season; poorly drained area.

Pattern E - Single cropped for late maturing rice in dry season; common to submerged lands including expansion areas.

In connection with the proposed cropping pattern, the proposed land use and planting program in terms of planted area is presented in Table A.3.3-4.

3.3.3 Water Management Scheme

(1) Cases for Water Management Scheme

The proposed area for irrigation includes some local areas which could be served by using return flow. The proposed expansion area of 680 ha (WS7-Ex) served by the proposed Third Maasim Dam and the existing service area of 1,010 ha by the Angat North Main Canal fall into this category.

Two proposed alternatives were planned to be processed considering the characteristics of return flow area, as;

- Alternative Case-1

  In this case all proposed area is served mainly by the Angat water, supplementary by the Maasim water.

- Alternative Case-2

  1,690 hectares were subtracted from the proposed area of Case-1.

Accordingly the scheduled areas for irrigation with respect to the proposed cropping pattern are listed as below. Further details are also presented in Table A.3.3-5.

Proposed Irrigation Area by Cropping Pattern

Irrigation Block		Proposed Cropping Pattern (ha) A	B	C	D	E	Total
Upper Maasim	Wet		2,111				2,111
	Dry		2,111			900	3,011
Lower Maasim	Wet	299					299
	Dry	299				760	1,059
Third Maasim	Wet						-
						(-)	(-)
	Dry					680	680
Angat North	Wet	9,147		550	2,000		11,697
						(4,011)	(15,708)
	Dry	9,147		550	2,000	5,021	16,718
Anagt South	Wet	9,480		1,700			11,180
	Dry	9,480		1,700		1,031	12,211
T.P.I.S	Wet	1,286					1,286
	Dry	1,286					1,286
Total	Wet	20,212	2,111	2,250	2,000	-	26,573
						(6,702)	(33,275)
	Dry	20,212	2,111	2,250	2,000	8,392	34,965

Note : Parentheses indicate values for Case-2.

(2) Diversion Water Requirement

The only points which differ from the procedures employed in estimation of the present irrigation water requirement are 1) adoption of the upgraded integrated irrigation efficiency of 0.60, as previously discussed in 3.2.2, and 2) introduction of diversified upland crops as designated by the proposed cropping pattern C.

In the project, a total area of 2,250 ha is planted to diversified crops such as green corn, yellow corn, water melon and pole sitao. In estimating the consumptive use of such diversified crops, the feasibility report on the Improvement of 18 National Irrigation Systems, NIA, in which potential evapotranspiration of crops by the Modified Penman Method was calculated based on the climatorological condition observed in the Central Luzon, was referred to.

Field water requirement on a 10 day basis was estimated based on the proposed cropping schedule, percolation rate and water requirements for land soaking, as well as land preparation. Table A.3.3-6 to A. 3.3-18 present such procedures.

Regarding diversified upland crops, potential evapotranspiration values estimated by the Modified Penman Method were used in the study.

Potential Evapotranspiration (ETp) in mm/day

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.
ETp	3.15	4.14	4.83	5.25	4.93	4.64
Month	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
ETp	4.31	3.79	4.05	3.56	3.52	3.16

Crop coefficients (Kc) were obtained based on the procedures given in the technical paper No.24 "Crop Water Reguirement" published by FAO. Necessary data such as wind speed, relative humidity and so on from actual observations in the Luzon were used. As the reference crops, Sweet Corn, Green Corn, Melon and Green Bean were used instead of Green Corn, Yellow Corn, Water Melon and Pole Sitao, respectively. Correlation curves of Kc values with crop's growing stage so obtained are shown in Figure A.3.3-2.

to A.3.3-5. In addition, real ratios of plantation of Green Corn plus Water Melon and Yellow Corn plus Pole Sitao were assumed to be 70% and 30%, respectively.

Effective rainfall covers a considerable percentage of the farm irrigation requirement, and covered a wide range, as shown in Table A.3.3-19, from 10% to 43% of annual rainfall on the irrigated field in the wet season and from 5% to 14% in the dry season, depending on the growing stage of crops designated by each cropping pattern and seasonal fluctuation of rainfall.

For diversified upland crops, effective rainfall was assumed to be 70% of rainfall amount but not exceeding the Total Readily Available Moisture value (TRAM) of 40 mm. TRAM was estimated by the following equation.

$$TRAM = (Fc - Pwp) \times D \times 1/Cp \quad (mm)$$

Where, Fc : water holding capacity after 24 hours of soil saturation (%)

Pwp : depletion of moisture content for optimum growth (%)

D : effective soil layer (mm)

Cp : value of soil maisture extraction pattern of effective layer (%)

In the project area values of Fc and Pwp are assumed as 27% and 13% respectively for predominant soil texture of Clay Loam by NIA's standard criteria prepared for National Irrigation Project. Assuming Cp = 40% and D = 100 mm,

$$TRAM = (27 - 13) \times 100 \times 1/40 = 35 \div 40 \text{ mm}$$

Diversion water requirements were thus estimated for the proposed alternative cases, as summarized in Table A.3.3-20 to A. 3.3-26 for Case-1 and in Table A.3.3-27 to A.3.3-32 for Case-2.

Annual Diversion Water Requirement in MCM

Requirement	Maasim Upper	Maasim Lower	Maasim Third	Angat Main North	Angat Main South	Tibagan I.P.S	Total
Alternative Case-1							
Average	32.6	12.4	7.4	222.4	158.5	17.6	450.9
Maximum	42.4	14.4	8.4	262.3	194.0	21.5	543.0
Minimum	18.4	9.0	5.0	175.1	133.2	14.4	355.5
Alternative Case-2							
Average	32.6	12.4	-	211.4	158.5	17.6	432.5
Maximum	42.4	14.4	-	249.8	194.0	21.5	522.1
Minimum	18.4	9.0	-	167.6	133.2	14.4	343.0

(3) Water Resources Availability and Expansion Area Development

1) General

The detailed water balance study was conducted for the purpose of evaluation of water resources availability as well as of new expansion area development. Based on the proposed schedule of agriculture and irrigation, various operation rule curves of the Angat reservoir were inputted in the study in order to simulate the optimal solution of the reservoir operation which meets all demands of water required by MWSS for water supply to Metro Manila, NPC for power generation and NIA for irrigation, even during a critically droughty period.

The Angat Reservoir, which receives about 2,080 MCM or 66 cms of annual inflow, and releases 1,667 MCM or 53 cms of water for irrigation and hydraulic power generation, 338 MCM or 11 cms for water supply to Metro Manila and 102 MCM or 3 cms as spillage at present, is contributing to a great extent to the project as the major water source for irrigation.

In addition to the description on the present status of the Angat Reservoir operation previously discussed in 3.2.1, more detailed investigations were made on the hydrological and operational status of the reservoir in order to conduct the detailed water balance study which involved the reservoir operation.

The Angat Reservoir is operated under the specified operation rule curves by NPC. Concerning the administration of the reservoir, NWRC recommended the adoption of peculiar rule curves in 1979 and 1983. Such curves are presented in Table A.3.3-33.

As a result of reservoir operation, water surface elevations in the reservoir are reported by NPC as shown in Figure A.3.3-6 as well as in Table A.3.3-34.

Hydrological data, such as water releases through main and auxillary power generators and spillages, are also observed and recorded by NPC on a daily unit. Inflows into the reservoir are estimated based on these data as already compiled in Table A.3.2-1 to A.3.2-3 together with water release records. Actual achievement of production of power generation is also calculated by applying the correlation curve of available water head in the reservoir with potential power generation. Table A.3.3-35 presents the correlation curve and the actual production of power generation as reported by NPC is summarized in Table A.3.3-36.

Water surface elevation - surface area - capacity curve as prepared by NPC is shown in Figure A.3.3-7 as well as in Table A.3.3-37.

2) Other Water Demands

In addition to and prior to water supply for irrigation, the Angat Reservoir contributes to municipal and industrial water supply to Metro Manila by MWSS, and Hydroelectric power generation by NPC.

i. MWSS Water Supply Demand

Monthly variations in water supply demand were excerpted from the "MWSS Manila Water Supply Project Report" dated May 1976, in which seasonal demand variations for water supply are programmed.

Seasonal Demand Variations for Water Supply

Month	Water Supply Demand		
	% of Average (%)	Discharge (cu.m/sec)	Volume (MCM)
January	100	22.00	58.9
February	100	22.00	55.1
March	100	22.00	58.9
April	110	24.19	62.7
May	125	27.52	73.7
June	120	26.39	68.4
July	95	20.91	56.0
August	95	20.91	56.0
September	90	19.79	51.3
October	90	19.79	53.0
November	90	19.79	51.3
December	85	18.71	50.1
Total	-	-	695.4
Average	100	22.00	57.0

ii. NPC Requirement for Power Generation

There is no specified rule to measure water requirement for power generation. According to the actual achievement of production of generated power reported by NPC for the past five years, almost randum pattern of seasonal power generation, depending upon inflow, irrigation water demand and available water surface elevation was examined. The actual results of power generation were, however, carefully reviewed and placed in the water balance computation in order to supervise the computed results.

3) Available Water Resource for Irrigation

In order to involve the operation of the Angat Reservoir, a water balance study was based on the reservoir inflow. Stored water in the reservoir is released through main power generators for irrigation and power generation, and through auxillary power generators for water supply to Metro Manila.

Regarding the intermediate runoffs of the Angat River below the Ipo Dam but above the Bustos, they were estimated based on the inflow into the reservoir in proportion to areal ratio of drainage basin, reducted by the ratio of areal rainfall.

$$\text{Intermediate Runoff} = \text{Reservoir Inflow} \times C1 \times C2$$

$$\text{Where, } C1 = \frac{\text{Residual Drainage Area}}{\text{Reservoir Drainage Basin}} = \frac{250}{568}$$

$$C2 = \text{Ratio of Areal Rainfall between Basins} = 0.469$$

As for the Maasim River, Generated runoffs were directly inputted in the study.

4) Water Balance Study

Figure A.3.3-8 demonstrates the diagram developed for water balance study. An items involved in the model are briefly described in Table A.3.3-38. In the conception of the model, the followings are included.

- The inflows into the Angat Reservoir from the drainage basin of 568 sq.km are prepared based on the actual observation of hydrology by NPC.

- The reservoir has a capacity of 1,028 MCM at the full water stage of 217.0 m above mean sea level, of which 180 MCM below the elevation of 160.0 m are not usable.

- The water surface elevation of the reservoir is controlled by application of the operation rule curves, and the reservoir releases water to meet various demands requested by MWSS for water supply, by NIA for irrigation and by NPC for power generation.

- The operation rule of the Angat Reservoir was prooposed by two curves presenting the upper and lower limits of the water surface elevation by time.

- The water surface elevation in the Angat Reservoir is not allowed to fall below the lower rule curve at any given time.

- The water surface elevation in the reservoir is not allowed to rise, during the flood season from the beginning of July to the end of October, above the upper rule curve unless the water release provided to the main power generators exceeds the allowable carrying capacity of 168.8 cu.m/sec. (42.2 cu.m/sec x 4 units)

- Water release for MWSS water supply is made through the auxiliary power generators taking the first priority in utilizing the reservoir water, and is diverted at the Ipo Dam with an average discharge of 22 cu.m/sec.

- Water release for irrigation as well as for additional power generation is made through the main power generators as long as the water surface elevation is above the lower limit of rule curve. During critically dry periods when actual inflow is less than that expected in development of the rule curve, releases for irrigation, in addition to water supply requirement, can be allowed unless the resulting reservoir level will fall below the rule curve. Otherwise the required irrigation releases are cleared in the first place.

- Spillage is allowed only when the reservoir level exceeds the allowable maximum stage, resulted by a huge inflow greater than the allowable carrying capacity of the power generators plus the storage capacity allowance at the time.

- In addition to the releases through the main generators and spillage, intermediate runoff is available for irrigation.

- Upstream along the Angat River, the existing small irrigation systems of 100 hectares in total utilize river water.

- Of the sub-systems included in AMRIS, the Tibagan Pump Irrigation System diverts the river water just upstream from the Bustos Dam.

- Prior to irrigation water diversion at the Bustos Dam, some water releases, as listed below, are made for the purpose of salt water exclusion.

Required Release for Salt Water Exclusion

Period	Requirement
3rd decade of February	6.0 cu.m/sec x 48 hrs. = 1.0368 MCM
1st and 3rd decades of March	- do -
2nd decade of April	- do -

- Irrigation water is diverted from the river at the Bustos Diversion Dam and provided to the areas served by both the North and South Main Canals, and as the same time, to the area served by the Maasim River covering a considerable percent of demand needed.

- Along the Maasim River upstream from the Upper Maasim Dam, an irrigated area of 183 hectares receives river water prior to the AMRIS area.

- In utilizing the Maasim water, the Upper Maasim Dam has the first priority of irrigation water diversion while the Lower and Third Maasim Dams have the second and third priorities, respectively.

- In utilizing water supplemented from the Angat River, priorities were given in order of the Lower Maasim Dam, the Third and the Upper Maasim Dam.

- In addition, computation of possible production of power generation was included in the study by employing the NPC correlation curve of potential power generation against discharge given, with respect to water head available.

The studies were made paying great attention to the followings;

- 100 percent of MWSS requirement was considered with the first priority of utilizing water.
- NPC's actual achievements of production of power generation was fully considered in terms of both amount and seasonal pattern.
- Hydrological records on inflow into the reservoir as well as on the operated water stages in the reservoir by time were carefully reviewed and examined in order to ensure storage capacity required for flood control.

5) Evaluation of Water Balance Study

During the course of the study various modifications were made to the proposed rule curves until they verified the simulated results so that all kinds of water demand were satisfied. The proposed rule curves finally obtained are pictured in Figure A.3.3-9. As is seen in the said figure, the proposed lower curve almost follows the NWRC curve and the upper curve was derived from the NPC curve.

In application of the proposed rule curves, the following two cases of computations were further progressed.

Prototype (Case-A)	:	The upper and lower rule curves were applied throughout the season.
Alternative (case-B)	:	The lower rule curve was applied throughout a year, while the upper curve was allotted only during the flood season from the beginning of July to the end of October.

Together with NPC as well as NWRC rule curves shown in Table A.3.3-39, the proposed ones are presented in terms of reservoir surface elevations at the end of months. Every combination of the proposed irrigation areas (Case-1 and Case-2) and proposed application of rule curves (Case-A and Case-B) were analyzed as summarized in Table A.3.3-40 to A.3.3-43. For the selected cases of Case-1 plus Case-A and Case-1 plus Case-B, the simulated results of the reservoir in terms of surface water level are demonstrated in Figure A.3.3-10 and A.3.3-11.

The computed results of the study, under the proposed condition of the irrigation schedule accompanied with the proposed operation rule curves, indicate the followings as a summary obtained.

- No shortage of MWSS water supply during the whole period of 11 years was examined.

- Estimated possible production of power generation and its seasonal pattern was examined in close correlation with the actual generated result, as shown in Figure A.3.3-12 and A.3.3-13.

- With regard to irrigation, shortage of water occurred once during the most critical dry period in 1978. The total shortage of irrigation water was computed at 114 MCM for Alternative Case-1 and 100 MCM for Alternative Case-2. Furthermore from statistical evaluation, the year of 1978 was examined as the critically dry year of once in more than 10 years probability.

In reference to the computed results of water balance, annual summaries of water balance, shortage and estimated production of power generation are compiled in Table A.3.3-44 to A.3.3-47.

Consequently, according to the irrigation plan and schedule, irrigation network with project is proposed as shown in Figure A.3.3-14 and A.3.3-15.

3.3.4 Facility Improvement Plan and Design

(1) Diversion Dam

In order to cope with the problems investigated, rehabilitation of the Bustos, Upper and Lower Maasim Diversion Dams are required by the Project in addition to the construction of the proposed Third Maasim Dam.

1) Rehabilitation of Bustos Dam

- Replacement of automatic operation mechanism and opening indicators and its accessories for the six sector gates is required to make operation of the gates safe and easy.
- To prevent and decrease silt sedimentation in the gate chamber, rubber gate sealer replacement is also needed along with the repainting of the gate body. At the same time, sedimentation of soils in front of the dam should be excavated and removed to reduce siltation in the gate chambers.
- In addition to the above, sideslope protection of the river immediately downstream of the dam should also be sufficiently provided.

Outline of the dam gate automatic control system is briefly given as follows:

a) System Configuration

This system enables automatic control of the gate position of the Bustos dam, and is composed of the following devices or equipments

i) Gate Operation Console (Desk)
ii) Gate Automatic Control Panel
iii) Relay Equipment
iv) Control Center
v) Water Level Gauge
vi) Gate Opening Gauge
vii) Electrovalve for Gate Control

Gates operation control is to be made in the control house for each individual by two ways; remote manual control and automatic control by means of keeping upstream water level constant, which can be changed by manual switching on the operation desk. Control water level is assumed tentatively to be 17.55 m above MSL with upper and lower limits of 17.65 m and 17.45 m, respectively.

b) Control Method

As illustrated in the following figure, position control of each gate is made separately by the following system.

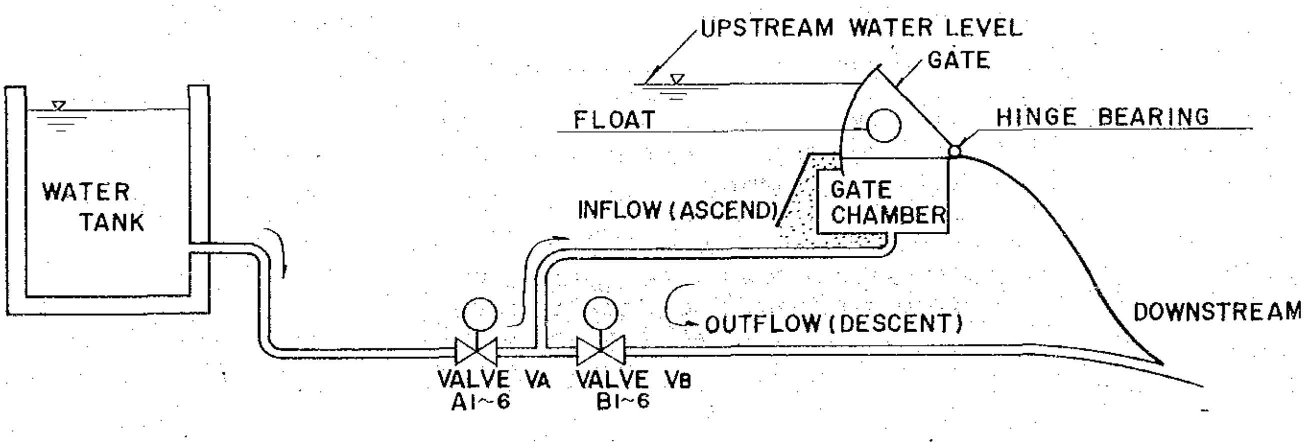
- Closing (ascend) poeration of gate

  By opening the valve VA, water stored in the tank flows into the gate chamber and the gate raises. By closing the valve VA, the gate comes to a standstill.

- Opening (descent) operation of gate

  By opening the valve VB, water in the gate chamber is drained out and the gate moves downward. By closing the valve VB, the gate comes to a standstill.

GATE CONTROL SYSTEM



c) Installation of Gate Position Gauge

To install gate position gauge, the following three methods are available.

i) To measure water pressure in the pipe linked to the gate chamber (0 - 0.5 kg/cm^2)

This method allows the construction to be done inside the control house and installation is expected to be easy. However indication error of the gauge would be considerable while water pressure fluctuation is remarkable especially during the opening or closing operation of the valve. Furthermore, leakage water from the gate chamber would influence the accuracy of measurement.

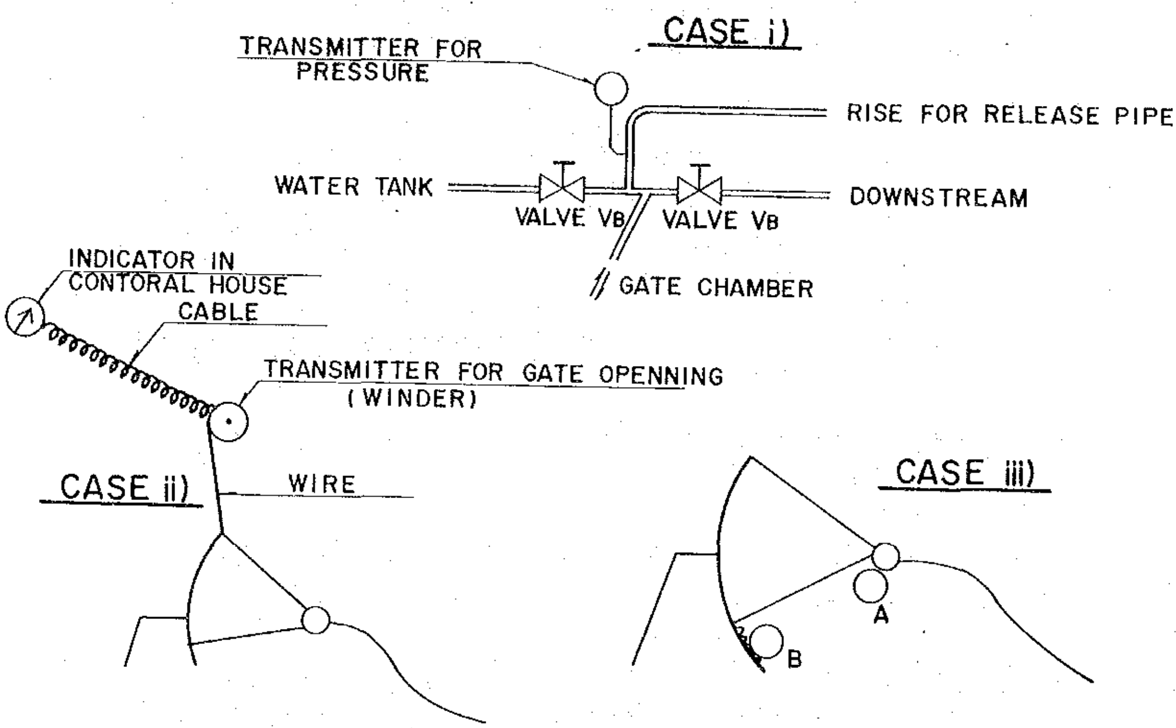
ii) To operate the gauge by wire connected to the top of the gate

Accurate measurement of gate position is expected by this method. However during flood, floating material such as a driftwood would influence the gauge indication, and cutting of wire would occasionally happen. The gauge should be supported in an adequately high position and protected against the probable peak water level and from floating materials.

iii) To gear the position gauge with the gate

At the point A or B, the gauge is geared with the gate. In this case, the gauge and cable are placed under water and, therefore, a waterproof type must be selected.

Although more detailed study is required to select the nost suitable case, case i) was adopted in the project as the most simple and easiest case for installation, considering the present status of the feasibility study.



2) Improvement of Upper Maasim Dam

Based on the findings obtained by the study, gate installation with concrete work related on both flood and scouring sluice way should be reconstructed together with intake work as well as upstream and downstream river protections, while existing bridges on the dam and downstream apron could be used with only minor rehabilitation works.

There are several alternative plans for the determination of gate type and gate span allocation from the technical and economical points of view. General comparison of the gate type is discussed in Table A.3.3-48 prepared for comparative study of the proposed Third Maasim Dam. Rubber type gates will be more advantageous than other gate types. Advantages and disadvantages of rubber type gate are described as below.

a) Advantage

- ° Gate span can be widened to 100 m or more
- ° No piers are necessary so that flood carrying capacity will be bigger than with pier gate types.
- ° Automatic self deflation function
- ° Structural safety against shifting sand and rolling rocks.
- ° Easiness of dam installation, at any angle of the river bank to river bed.
- ° Flexibility of construction in adjusting to changes in river bed terrain
- ° Good performance for water sealing

b) Disadvantage

- ° Difficulty of constant opening of dam
- ° Difficulty of keeping constant over flow depth of water.
- ° Limited experence in the Philippines except the Baka Dam

As concerns gate span allocation, river situation, gate lifting mechanism and safeness from flood were investigated in addition to the economic aspect. One of the advantages of a rubber type gate is that the gate span can be prolonged across the river. A single span gate is more economical than a gate of two or more spans and consequently a single span rubber type gate was selected.

In addition, a scouring sluiceway is needed to control river bed material, and the slide type gate was found to be most suitable since the required gate span is very short.

Existing bridge could be used with minor rehabilitation work such as concrete repair and handrail installation. Protection work of river downstream was proposed by means of constructing grouted boulder riprap. To cope with increased intake discharge, the intake facility is also in need of reconstruction.

3) Improvement of Lower Maasim Dam

Rehabilitation works needed for improvement of the Lower Maasim Dam are replacement of floodway gates as well as scouring sluiceway gates. For the same reasons as discussed previously, a rubber type gate and a slide type gate were chosen for floodway and scouring sluiceway, respectively. Intake facility, downstream apron and river protection can still be used without any rehabilitation work.

4) Proposed Third Maasim Dam

a) General

As water resources for the proposed irrigable area at the dam site, a certain amount of water is expected as return flow from the Maninging, Pakate and Victoria creeks which have about 50 sq.km of drainage area receiving excess water from the Lower Maasim Dam.

According to the information provided by the AMRIS office, the proposed area of 680 ha is being supplied with irrigation water from the temporary earth dam in the dry season. Furthermore, supplemental water from Bustos Dam could be confirmed sufficiently based on the results of a water balance study on the Angat Reservoir.

b) Layout

i) Study on Dam Location

Dam location would be recommended at approximately 200 m upstream from the existing temporary dam for several reasons as follows:

- To be near the service area.
- To be in the straight portion of river.
- To be downstream from the Victoria creek.
- To be outside the residential area for construction.
- Impossible to feed water to the existing Lateral A of the Lower Maasim, because of comparatively high water level in Lateral A.

ii) Regulating Intake Water Level (R.I.W.S.)

Regulating intake water level should be determined with respect to topographic elevation, depth of flooding water and various kinds of head looses expected.

R.I.W.S. = Paddy field elevation + depth of Water + diversion losses + friction loss of canal related structures

= 3.00 + 0.15 + 0.05 + 3,000/5,000 + 0.20

= 4.00 m

iii) Gate Type and Span Allocation

Table A.3.3-48 presents a comparative study on various types of gate. Accordingly, a rubber type gate of two spans was proposed.

iv) Hightening of the River Dike

As shown in Figure A.3.3-17, regulating intake water level of 4.0 meters above mean sea level is estimated slightly higher than the top of the existing river dike. The top elevation of the bank should be at least 2.0 meters higher than operating water level which is equivalent to the regulating intake water level. Furthermore the operating water level should be lower than or equal to the existing elevation of protected lowland.

(2) Irrigation Canal and Related Structures

1) Rehabilitation of Canal

Except for a negligible part of the irrigation canals, almost all canals in the area are earth-lined. In many sections of canals, siltation, erosion of side slope, weakening of berm and weeding were found. Rehabilitation is to be progressed on canals which are in a bad condition in terms of insufficient carrying capacity and water head.

a) Canals to be Rehabilitated

Field investigation was undertaken during the course of the survey based on the information and reports collected from working stations in the area. Consequently irrigation canals to be rehabilitated are listed as shown below.

List of canals to be rehabilitated

Class of Canal	Length in Need of Rehabilitation, Km				
	Desilting	Widening	Heightening	Others	Total
Main	3.0	2.3	5.9	-	11.2
Lat./Sub Lat.	68.5	12.8	68.5	0.2	149.9
Total	71.5	15.1	74.4	0.2	161.1
(%)	(45)	(9)	(46)	(0)	(100)

A Cross-sectional and longitudinal survey was conducted for the canals listed above for the purpose of hydraulic investigation as well as cost estimation for construction.

Regarding the required capacity of canal, cross-section is determined based on the design unit discharge for irrigations as discussed later in this paragraph in connection of the proposed irrigation network.

i) Desilting

Sediment siltation is reported at many portions of gently sloping of at the end of canal, causing a decrease in carrying capacity. Especially in the area inundated during the wet season, maintenance work on canal is conducted insufficiently once a year and many requests for rehabilitation are concentrated in this area.

ii) Heightening of embankment

Overtopping of water or short of freeboard was found in many sections of the canals. Major reasons are considered to be increase of required water head, decrease of carrying capacity and lowering of embankment due to erosion of side slope of canal.

2) Development of Canal System in Expansion Area

To feed irrigation water to the area newly expanded, the existing irrigation canals are to be extended or widened if necessary. The following presents such irrigation canals and their required capacities.

Existing Canal to be Extended or Widened

Expansion Area Name	Acreage (ha)	Canal	Required Capacity (cms)	Length (Km)
WS2-Ex	90	Lat.D, Angat S.M.C	2.118 - 0.113	None 1/
WS5-EX	60	Lat.M, -do-	1.021 - 0.075	-do-
WS6-Ex.1	150	Angat N.M.C	0.187	-do-
-Ex.2	230	Lat.A, Feeder to Maasim	0.286	-do-
-Ex.3	900	U.Maasim N.M.C	3.318 - 1.121	5.7
WS7-EX	680	Lat B, Angat N.M.C	2.997 - 0.847	None
WS8-Ex.1	178	Lat.B, Bitokan Manok	0.340 - 0.222	1.5
-Ex.2	416	Lat.C, -do-	0.797 - 0.518	3.0
WS9-Ex	466	Lat.D, D-1-A ex.2, N.M.C	5.617 - 0.580	16.5
WS12-EX	310	Lat.J, J-3-B, -do-	1.305 - 0.386	13.5
Total	3,480			30.2 2/

Notes: 1/ ..... "None" indicates canal capacity is adequate to carry additional discharge required in expansion area.

2/ ..... This figure is included in the length of canal for rehabilitation. For further details, Table 3.3-49 presents the existing and proposed hydraulic dimensions of such canals.

In total, above 57 km of new canals are estimated to be developed in the proposed expansion area. Design of these canals will be made paying careful attention to required water head in the area as well as on available water level in the existing canal extensions. Service roads should also be constructed along the newly developed canal, and in order to guarantee embankment materials side borrow pits should be selected along the canal.

In addition, the same is applicable for canals with a total length of 8 km which are newly constructed within the existing service area.

3) Proposed Canal Network

A proposed canal network which consists of the existing canal, newly extended in the existing area and developed in the proposed expansion area is visualized as previously referred to in Fig.A.3.3-14 and 3.3-15. In this connection, the unit discharge for design of canal was obtained from water balance computation as the value of weighted average of irrigated area multiplied by diversion water requirement by cropping pattern for the first 10 days of February, during which the value was estimated to be area maximum.

Unit Design Discharge for Irrigation

Area	Unit Discharge (l/sec/ha)
N.M.C of Angat, Maasim	1.245
S.M.C of Angat	1.255
T.P.I.P	1.408

4) Proposed Feeder Canal between Bustos and Maasim

a) Canal Location

Between the Bustos Diversion Dam and the Upper Maasim Dam, the canal alignment is proposed only on the line along the National Highway of Baliwag to San Ildefonso because of limited effective heads. This undulating section, elevated between 7 m and 20 m above mean sea level, would force the alignment to meandes. An alternative plan of short-cut from the B.P.I.P outlet of the North Main Canal up to Sampaloc would create the maximum cutting depth of 9.5 m, and is not recommendable. Accordingly, the alignment, in principle, follows the line of Lateral A and A-1, of the Angat North Main Canal.

Lateral A will be improved with widening, and the new canal is to be constructed along the Lateral A-1 shifting the location mountain side, because in the canal a higher water level is to be maintained in order to preserve energy of water.

Although the topography in this section is predominably complicated, the total length of canal could be reduced by means of short-cuts, when the cutting depth is expected to be not too high. On the portion where the canal crosses the Dagat Dagatan creek, construction of a flume type aqueduct is recommended. Figure A.3.3-16 shows the proposed canal alig alignment.

b) Longitudinal Profile

Water level in the canal at the beginning and the end ponts, length and longitudinal profile of the canal are roughly estimated as follows. Longitudinal profile is estimated very gentle.

i) Water level at the beginning of Lateral A
   = W.L 13.20 m
   Required head at the end of feeder canal
   = O.W.L at the Upper Maasim Dam = W.L 10.30 m
   Difference = Available water head = 2.90 m

ii) Total length L = 2.774 (Lat.A) + 21,600 (constructed)
   = 15,374 = 15,400 m

iii) Effective head of water He = 2.90 - 9 x 0.10*/
= 2.00 m

where, */ denotes siphon loss.

iv) Mean longitudinal slope I = He/L = 1/7,700

Accordingly the longitudinal slope of the canal is estimated at 1/7,000 for Lateral A and at 1/8,000 for the feeder canal newly constructed. Figure A.3.3-16 and 3.3-18 present such conditions of canal location and hydraulics.

As concerns the lining of the canal, concrete lining was adopted in view of the following.

- To minimize conveyance loss of water
- To minimize friction loss in the canal as well as various losses at the points of appurtenant structures
- To lighten operation and maintenance works

5) Appurtenant Structures

Appurtenant structures to be rehabilitated or constructed are as follows:

Appurtenant Structures for Rehabilitation or Construction

Structure	Existing Area Rehabilitation (pcs)	Existing Area Construction (pcs)	Proposed in Expasion Area (pcs)	Total (pcs)
Check Gate	46	6	5	57
Head Gate	35	8	13	56
Parshall Flume	55	3	9	67
Flume	6	6	10	22
Siphon	16	5	19	40
Drainage Culvert	-	2	7	9
Road X'ing	48	6	27	81
Thresher X'ing	-	2	2	4
Bridge	-	1	-	1
Weir	16	-	-	16
Spill way	2	-	-	2
End check	3	8	19	30
Staff Gauge	8	6	-	14
Intake Gate	-	-	1	1
Confluence	-	-	2	2
B.C. X'ing	-	-	3	3
Head Gate, only	56	-	-	56
Check Gate, only	57	-	-	57
Riprap	471	-	-	471
Measuring Gauge	2,047	-	-	2,047

During the course of field investigation, major problems in need of improvement are as follows:

a) Constant Control Gate

On both North and South main canal of the Angat area, constant control gates equipped by radial gates are installed to control intake discharge in the canal. Both gates are well functioning and the only object for rehabilitation is the eroded riprap located on the left bank downstream from the gate facility of the North main canal, Angat.

b) Wasteway of North Main Canal, Angat

Around station No.6 of the North main canal of the Angat, the wasteway is so situated that excess water is spilled when discharge in the canal exceeds the design capacity of 22 cu.m/sec. To cope with the increased discharge of 26 cu.m/sec in the Angat North Main Canal, it was decided to highten the sill elevation of the wasteway. However the existing structure is considered to be too old and deteriorated for improvement works. Accordingly the gate is to be reconstructed with a roller type gate, 4.50 m x 5.00 m in dimension, equipped with engine drive.

c) Check Gate

Since check of water level is practised by stop logs installed along with thresher crossing, handling performances in response to changes in discharge are not expected to be good. Inconstantly controlled water level makes it difficult to keep uniform intake discharge at a head gate. It is, therefore, necessary to replace stop logs by steel gates gradually from the major check gate structures which need improvement or rehabilitation.

d) Head Gate

In consideration of operation and management, a gate of under flow type is recommended. Operation is based on the required discharge as any time by adjusting the gate opening with respect to the diverted discharge measured at the parshall flume. The gate opening is maintained without calibration as long as the required discharge is fixed, and therefore the gate should be equipped with a lock mechanism.

e) Parshall Flume

To measure discharge in a canal, a parshall flume is located in combination with a head gate. Although a proper water head is required in order to expect perfect function of a parshall flume, some are not functioning under hydraulically submerged condition due to lack of water head. In addition, many staff gauges are missing or indistinct.

For such badly maintained and defficient structures, appropriate countermeasures are to be elaborated to cope with hydraulic situation. Major constraints found in the field are as follows:

- Unfit dimension of structure
  Dimension of structure are to be designed so as to measure 30% to 120% of design discharge.
- Unsuitable sill height
  Sill height is to be determined strictly considering hydraulic condition both upstream and down stream in the canal.
- Inadequate water head in the upstream
- Dammed up downstream water level

As concerns staff gauges, fast painted and rust preventive material should be used. The use of recently developed durable materials such as enameled ironware or acrylic resin is recommended.

(3) On-farm Facilities

Improvement and upgrading of on-farm facilities are to be carried out in expectation of better performance of irrigation water distribution and management. On-farm facility consists of farm ditches, farm drains, turnout structures with regulating and measuring devices and others.

On-Farm Facilities of Various Stage

Stage	Farm Ditch M.F.D	S.F.D	Total	Farm Drain
	(m/ha)	(m/ha)	(m/ha)	(m/ha)
Existing	17	26	43	13
Proposed 1/	20(3) 3/	40(14)	60(17)	16(3)
NIA Standard 2/	20	50	70	16

Remarks: 1/ Proposed by on-going feasibility study for new expansion area

2/ Recommended by NIA in design criteria for farm level facilities

3/ Proposed for improvement in the existing area

Regarding farm ditches and drains, the poor condition of the existing facilities must be increased in the entire project area including the new expansion area to, at least, the minimum standard density level in order to expect efficient water management and distribution. Location of the facility is to be checked based on accurate topographic information, and some will be relocated.

Improvement and construction of turnouts include rehabilitation of gate systems and elimination of unnecessary facilities. Rehabilitation of gate system includes the renewal of gate and measuring devices. Some existing turnouts, which are located along and receiving water directly from the main canal, should be rearranged and relocated for the purpose of easier operation and management of irrigation water.

Regarding structure, two types of turnout namely, single gated with measuring device and double gated of constant head orifice, are recommended. Required number of turnout facilities to be reconstructed or equipped with gates in the existing service area are shown as follows:

Rehabilitation of Turnout Facilities in Existing Area

Required	Double Gated (pcs)	Single Gated (pcs)	No Gated (pcs)
Reconstruction 1/	171	41	36
Gate Only 2/	117	49	37
New Construction	18	-	-
Total	306	90	73

Notes: 1/··· Reconstruction of facility includes gate installation

2/··· Gate facility to be replaced or installed

In addition, new construction of turnouts required in the expansion area is as follows:

Construction of Turnout Facilities in Expansion Area

	Required No. of Turnout (pcs)
Double Gated	140
Single Gated	47
Total	187