2-3-4. Design water requirements

Net water requirements for the on-farm level together with those for the quaternary and tertiary canals are based on peak daily consumptive use, while net water requirements for secondary and main canals are based on peak 10-day and 40-day average consumptive use, respectively.

Considering the estimated irrigation efficiencies for each irrigation canal, the design unit water requirements were decided, and the results are as shown below.

Canal	Unit Design Water Requirement
Main	1.04 ℓ/sec/ha
Secondary	1.23 ℓ/sec/ha
Tertiary & FD	1.55 ℓ/sec/ha

2-4. Proposed Irrigation System

2-4-1. Intake Pattern

On the basis of the two patterns of unit water requirements, net irrigable area and cropping calendar, 10-day average intake discharge has been estimated for 10 day basis for Barind area and Flood Plain area is illustrated in FIGURE VII-2-3.

The irrigation water intake at Barind area and Flood Plain area for design year (1980, 1982) are shown in FIGURE VII-2-4 VII-2-5, VII-2-6 and VII-2-7.

2-4-2. Estimated Sedimentation Volume

The quantity of Sedimentation in weight in the intake water has been estimated from the suspended discharge at Hardinge Bridge (TABLE VII-2-9).

The sediment volume of design year (1980,1982) for Barind area and Flood Plain area are shown in TABLE VII-2-3, VII-2-4 VII-2-5 and TABLE VII-2-6.

TABLE VII-2-3

PROJECT NAME : NORTH RAJSHAHI IRRIGATION PROJECT (SEDIMENT VOLUME) BARIND AREA

YEAR -- 1980

DISCHARGE : HARDINGE BRIDGE
1ST CROP :(PAT.1) JAN. -- MAY
--DO-- :(PAT.2) APR. -- JULY

NET AREA(HA) *	1ST CROP	2ND CROP
PATTERN 1 :	25320.	33760.
PATTERN 2 :	12660.	8440.

	WATER DISCHARGE Q*1000 M**3/S	PPM	PATTERN 1 UNIT W.R L/S/HA	PATTERN 1 DIVERSION W.R M**3/S	PATTERN 2 UNIT W.R L/S/HA	PATTERN 2 DIVERSION W.R M**3/S	TOTAL DIVERSION W.R M**3/S	SEDIMENT VOLUME TON
JAN. 1	1.519	3.124	0.343	8.685	0.000	0.000	8.685	23.438
JAN. 2	1.347	2.577	0.687	17.395	0.000	0.000	17.395	38.732
JAN. 3	1.158	2.024	0.678	17.167	0.000	0.000	17.167	33.021
FEB. 1	1.100	1.864	0.840	21.269	0.000	0.000	21.269	34.248
FEB. 2	1.015	1.639	0.840	21.269	0.000	0.000	21.269	30.118
FEB. 3	0.859	1.254	0.840	21.269	0.000	0.000	21.269	20.738
MAR. 1	0.942	1.454	1.166	29.523	0.000	0.000	29.523	37.082
MAR. 2	0.910	1.375	1.166	29.523	0.000	0.000	29.523	35.074
MAR. 3	0.883	1.312	1.126	28.510	0.696	5.874	34.385	42.872
APR. 1	0.939	1.447	1.202	30.409	0.962	12.179	42.588	53.224
APR. 2	0.940	1.450	0.793	20.079	1.288	16.306	36.385	45.576
APR. 3	0.950	1.474	0.386	9.774	1.387	17.559	27.333	34.810
MAY 1	1.156	2.018	0.000	0.000	0.183	2.317	2.317	4.039
MAY 2	1.195	2.128	0.000	0.000	0.356	4.507	4.507	8.286
MAY 3	1.290	2.405	0.000	0.000	0.204	2.583	2.583	5.903
JUNE 1	1.473	2.974	0.000	0.000	0.051	0.646	0.646	1.659
JUNE 2	3.319	10.908	0.065	2.194	0.000	0.000	2.194	20.682
JUNE 3	5.089	21.615	0.476	16.070	0.000	0.000	16.070	300.113
JULY 1	8.209	46.453	0.384	12.964	0.253	3.203	16.167	648.863
JULY 2	25.290	281.105	0.101	3.410	0.000	0.000	3.410	828.144
JULY 3	40.773	603.591	0.000	0.000	0.190	2.405	2.405	1379.862
AUG. 1	40.500	597.144	0.000	0.000	0.184	1.553	1.553	801.221
AUG. 2	51.750	883.909	0.000	0.000	0.379	3.199	3.199	2442.881
AUG. 3	51.445	875.601	0.000	0.000	0.112	0.945	0.945	786.634
SEP. 1	54.490	959.970	0.000	0.000	0.061	0.515	0.515	427.015
SEP. 2	47.150	761.591	0.000	0.000	0.001	0.008	0.008	5.554
SEP. 3	31.910	407.787	0.000	0.000	0.090	0.760	0.760	267.628
OCT. 1	22.000	224.920	0.715	24.138	0.979	8.263	32.401	6296.527
OCT. 2	12.910	95.859	0.680	22.957	0.863	7.284	30.240	2504.582
OCT. 3	9.091	54.692	0.000	0.000	0.000	0.000	0.000	0.000
NOV. 1	6.336	30.694	0.073	2.464	0.813	6.862	9.326	247.328
NOV. 2	4.927	20.525	0.024	0.810	0.899	7.588	8.398	148.923
NOV. 3	4.055	15.029	0.000	0.000	0.676	5.705	5.705	74.086
DEC. 1	3.276	10.683	0.000	0.000	0.301	2.540	2.540	23.449
DEC. 2	2.736	8.008	0.263	8.879	0.138	1.165	10.044	69.493
DEC. 3	2.221	5.736	0.511	17.251	0.000	0.000	17.251	94.043
TOTAL	4557529.00	5946.32	135.04	3701.49	111.86	1151.46	4852.94	17815.82

TOTAL D.W.R (DRY)JAN.--JUNE == 3383.67
--DO-- (WET)JULY--DEC. == 1469.28

TABLE VII-2-4

PROJECT NAME :   NORTH RAJSHAHI IRRIGATION PROJECT (SEDIMENT VOLUME)   BARIND AREA

YEAR -- 1982

DISCHARGE : HARDINGE BRIDGE
1ST CROP :(PAT.1) JAN. -- MAY
--DO-- :(PAT.2) APR. -- JULY

NET AREA(HA) *	1ST CROP	2ND CROP
PATTERN 1 :	25320.	33760.
PATTERN 2 :	12660.	8440.

	WATER DISCHARGE Q*1000 M**3/S	PPM	PATTERN 1 UNIT W.R L/S/HA	PATTERN 1 DIVERSION W.R M**3/S	PATTERN 2 UNIT W.R L/S/HA	PATTERN 2 DIVERSION W.R M**3/S	TOTAL DIVERSION W.R M**3/S	SEDIMENT VOLUME TON
JAN. 1	1.615	3.445	0.622	15.749	0.000	0.000	15.749	46.881
JAN. 2	1.424	2.817	0.687	17.395	0.000	0.000	17.395	42.335
JAN. 3	1.299	2.432	0.678	17.167	0.000	0.000	17.167	39.680
FEB. 1	1.294	2.417	0.502	12.711	0.000	0.000	12.711	26.542
FEB. 2	1.467	2.954	0.813	20.585	0.000	0.000	20.585	52.542
FEB. 3	1.387	2.702	0.813	20.585	0.000	0.000	20.585	38.449
MAR. 1	1.310	2.465	0.375	9.495	0.000	0.000	9.495	20.221
MAR. 2	1.286	2.393	1.003	25.396	0.000	0.000	25.396	52.507
MAR. 3	1.250	2.287	0.980	24.814	0.303	2.557	27.371	59.484
APR. 1	1.322	2.501	0.992	25.117	0.836	10.584	35.701	77.147
APR. 2	1.603	3.404	0.667	16.888	1.097	13.888	30.776	90.526
APR. 3	1.805	4.116	0.269	6.811	0.814	10.305	17.116	60.875
MAY 1	1.897	4.457	0.000	0.000	1.331	16.850	16.850	64.891
MAY 2	1.781	4.029	0.000	0.000	1.144	14.483	14.483	50.418
MAY 3	1.842	4.252	0.000	0.000	1.165	14.749	14.749	59.595
JUNE 1	2.037	4.995	0.000	0.000	0.139	1.760	1.760	7.594
JUNE 2	3.957	14.452	0.049	1.654	0.000	0.000	1.654	20.656
JUNE 3	7.584	40.925	0.015	0.506	0.000	0.000	0.506	17.906
JULY 1	6.836	34.660	0.801	27.042	0.415	5.254	32.296	967.144
JULY 2	9.945	63.142	1.002	33.827	0.425	5.380	39.208	2138.978
JULY 3	13.364	101.305	0.100	3.376	0.025	0.316	3.693	355.514
AUG. 1	25.420	283.421	0.000	0.000	0.085	0.717	0.717	175.673
AUG. 2	32.710	424.267	0.000	0.000	0.456	3.849	3.849	1410.783
AUG. 3	41.055	610.280	0.000	0.000	0.283	2.389	2.389	1385.364
SEP. 1	56.510	1017.540	0.000	0.000	0.374	3.157	3.157	2775.103
SEP. 2	51.900	888.012	0.525	17.724	0.619	5.224	22.948	17606.910
SEP. 3	34.840	469.327	1.079	36.427	0.926	7.815	44.242	17940.254
OCT. 1	15.760	131.899	0.995	33.591	1.021	8.617	42.208	4810.090
OCT. 2	8.148	45.902	0.778	26.265	1.021	8.617	34.883	1383.418
OCT. 3	5.830	26.867	0.322	10.871	0.691	5.832	16.703	426.495
NOV. 1	4.945	20.645	0.165	5.570	0.659	5.562	11.132	198.571
NOV. 2	4.431	17.320	0.000	0.000	0.065	0.549	0.549	8.210
NOV. 3	4.070	15.118	0.000	0.000	0.511	4.313	4.313	56.335
DEC. 1	3.661	12.762	0.000	0.000	0.313	2.642	2.642	29.128
DEC. 2	2.716	7.915	0.266	8.980	0.144	1.215	10.196	69.720
DEC. 3	2.035	4.989	0.522	17.623	0.000	0.000	17.623	83.558
TOTAL	3667257.00	4282.40	151.18	4394.38	151.09	1592.09	5986.45	52649.47

TOTAL D.W.R (DRY)JAN.--JUNE == 3018.62
--DO-- (WET)JULY--DEC. == 2967.86

TABLE VII-2-5

PROJECT NAME : NORTH RAJSHAHI IRRIGATION PROJECT (SEDIMENT VOLUME) FLOOD PLAIN AREA

YEAR -- 1980

DISCHARGE : HARDINGE BRIDGE
1ST CROP :(PAT.1) JAN. -- MAY
--DO-- :(PAT.2) APR. -- JULY

NET AREA(HA) *	1ST CROP	2ND CROP
PATTERN 1 :	5040.	7200.
PATTERN 2 :	2160.	1800.

	WATER DISCHARGE Q*1000 M**3/S	PPM	PATTERN 1 UNIT W.R L/S/HA	PATTERN 1 DIVERSION W.R M**3/S	PATTERN 2 UNIT W.R L/S/HA	PATTERN 2 DIVERSION W.R M**3/S	TOTAL DIVERSION W.R M**3/S	SEDIMENT VOLUME TON
JAN. 1	1.519	3.124	0.343	1.729	0.000	0.000	1.729	4.665
JAN. 2	1.347	2.577	0.687	3.462	0.000	0.000	3.462	7.710
JAN. 3	1.158	2.024	0.678	3.417	0.000	0.000	3.417	6.573
FEB. 1	1.100	1.864	0.840	4.234	0.000	0.000	4.234	6.817
FEB. 2	1.015	1.639	0.840	4.234	0.000	0.000	4.234	5.995
FEB. 3	0.859	1.254	0.840	4.234	0.000	0.000	4.234	4.128
MAR. 1	0.942	1.454	1.166	5.877	0.000	0.000	5.877	7.381
MAR. 2	0.910	1.375	1.166	5.877	0.000	0.000	5.877	6.982
MAR. 3	0.883	1.312	1.126	5.675	0.696	1.253	6.928	8.638
APR. 1	0.939	1.447	1.202	6.169	0.962	2.078	8.247	10.161
APR. 2	0.940	1.450	0.793	3.997	1.288	2.782	6.779	8.491
APR. 3	0.950	1.474	0.386	1.945	1.387	2.996	4.941	6.293
MAY 1	1.156	2.018	0.000	0.000	0.183	0.395	0.395	0.689
MAY 2	1.195	2.128	0.000	0.000	0.356	0.769	0.769	1.414
MAY 3	1.290	2.405	0.000	0.000	0.204	0.441	0.441	1.007
JUNE 1	1.473	2.974	0.000	0.000	0.051	0.110	0.110	0.283
JUNE 2	3.319	10.908	0.065	0.468	0.000	0.000	0.468	4.411
JUNE 3	5.089	21.615	0.476	3.427	0.000	0.000	3.427	64.005
JULY 1	8.209	46.453	0.384	2.765	0.253	0.546	3.311	132.900
JULY 2	25.290	281.105	0.101	0.727	0.000	0.000	0.727	176.618
JULY 3	40.773	603.591	0.000	0.000	0.190	0.410	0.410	235.427
AUG. 1	40.500	597.144	0.000	0.000	0.184	0.331	0.331	170.877
AUG. 2	51.750	883.909	0.000	0.000	0.379	0.682	0.682	520.994
AUG. 3	51.445	875.601	0.000	0.000	0.112	0.202	0.202	167.765
SEP. 1	54.490	959.970	0.000	0.000	0.061	0.110	0.110	91.070
SEP. 2	47.150	761.591	0.000	0.000	0.001	0.002	0.002	1.184
SEP. 3	31.910	407.787	0.000	0.000	0.090	0.162	0.162	57.077
OCT. 1	22.000	224.920	0.715	5.148	0.979	1.762	6.910	1342.860
OCT. 2	12.910	95.859	0.680	4.896	0.863	1.553	6.449	534.153
OCT. 3	9.091	54.692	0.000	0.000	0.000	0.000	0.000	0.000
NOV. 1	6.336	30.694	0.073	0.526	0.813	1.463	1.989	52.748
NOV. 2	4.927	20.525	0.024	0.173	0.899	1.618	1.791	31.761
NOV. 3	4.055	15.029	0.000	0.000	0.676	1.217	1.217	15.800
DEC. 1	3.276	10.683	0.000	0.000	0.301	0.542	0.542	5.001
DEC. 2	2.736	8.008	0.263	1.894	0.138	0.248	2.142	14.821
DEC. 3	2.221	5.736	0.511	3.679	0.000	0.000	3.679	20.057
TOTAL	4557529.00	5946.32	135.04	752.84	111.86	219.04	971.87	3726.75

TOTAL D.W.R (DRY)JAN.--JUNE == 661.02
--DO-- (WET)JULY--DEC. == 310.86

TABLE VII-2-6

PROJECT NAME : NORTH RAJSHAHI IRRIGATION PROJECT (SEDIMENT VOLUME) FLOOD PLAIN AREA

YEAR -- 1982

DISCHARGE : HARDINGE BRIDGE
1ST CROP :(PAT.1) JAN. -- MAY
--DO-- :(PAT.2) APR. -- JULY

NET AREA(HA) *	1ST CROP	2ND CROP
PATTERN 1 :	5040.	7200.
PATTERN 2 :	2160.	1800.

	WATER DISCHARGE Q*1000 M**3/S	PPM	PATTERN 1 UNIT W.R L/S/HA	PATTERN 1 DIVERSION W.R M**3/S	PATTERN 2 UNIT W.R L/S/HA	PATTERN 2 DIVERSION W.R M**3/S	TOTAL DIVERSION W.R M**3/S	SEDIMENT VOLUME TON
JAN. 1	1.615	3.445	0.622	3.135	0.000	0.000	3.135	9.332
JAN. 2	1.424	2.817	0.687	3.462	0.000	0.000	3.462	8.427
JAN. 3	1.299	2.432	0.678	3.417	0.000	0.000	3.417	7.898
FEB. 1	1.294	2.417	0.502	2.530	0.000	0.000	2.530	5.283
FEB. 2	1.467	2.954	0.813	4.098	0.000	0.000	4.098	10.459
FEB. 3	1.387	2.702	0.813	4.098	0.000	0.000	4.098	7.653
MAR. 1	1.310	2.465	0.375	1.890	0.000	0.000	1.890	4.025
MAR. 2	1.286	2.393	1.003	5.055	0.000	0.000	5.055	10.452
MAR. 3	1.250	2.287	0.980	4.939	0.303	0.345	5.485	11.919
APR. 1	1.322	2.501	0.992	5.000	0.836	1.806	6.805	14.706
APR. 2	1.603	3.404	0.667	3.362	1.097	2.370	5.731	16.858
APR. 3	1.805	4.116	0.269	1.356	0.814	1.758	3.114	11.075
MAY 1	1.897	4.457	0.000	0.000	1.331	2.875	2.875	11.071
MAY 2	1.781	4.029	0.000	0.000	1.144	2.471	2.471	8.602
MAY 3	1.842	4.252	0.000	0.000	1.165	2.516	2.516	10.168
JUNE 1	2.037	4.995	0.000	0.000	0.139	0.300	0.300	1.296
JUNE 2	3.957	14.452	0.049	0.353	0.000	0.000	0.353	4.405
JUNE 3	7.584	40.925	0.015	0.108	0.000	0.000	0.108	3.819
JULY 1	6.836	34.660	0.801	5.767	0.415	0.896	6.664	199.552
JULY 2	9.945	63.142	1.002	7.214	0.425	0.918	8.132	443.660
JULY 3	13.364	101.305	0.100	0.720	0.025	0.054	0.774	74.521
AUG. 1	25.420	283.421	0.000	0.000	0.085	0.153	0.153	37.466
AUG. 2	32.710	424.267	0.000	0.000	0.456	0.821	0.821	300.878
AUG. 3	41.055	610.280	0.000	0.000	0.283	0.509	0.509	295.457
SEP. 1	56.510	1017.540	0.000	0.000	0.374	0.673	0.673	591.846
SEP. 2	51.900	888.012	0.525	3.780	0.619	1.114	4.894	3755.034
SEP. 3	34.840	469.327	1.079	7.769	0.926	1.667	9.436	3826.124
OCT. 1	15.760	131.899	0.995	7.164	1.021	1.838	9.002	1025.849
OCT. 2	8.148	45.902	0.778	5.602	1.021	1.838	7.439	295.042
OCT. 3	5.830	26.867	0.322	2.318	0.691	1.244	3.562	90.959
NOV. 1	4.945	20.645	0.165	1.188	0.659	1.186	2.374	42.349
NOV. 2	4.431	17.320	0.000	0.000	0.065	0.117	0.117	1.751
NOV. 3	4.070	15.118	0.000	0.000	0.511	0.920	0.920	12.015
DEC. 1	3.661	12.762	0.000	0.000	0.313	0.563	0.563	6.212
DEC. 2	2.716	7.915	0.266	1.915	0.144	0.259	2.174	14.869
DEC. 3	2.035	4.989	0.522	3.758	0.000	0.000	3.758	17.820
TOTAL	3667257.00	4282.40	151.18	906.93	151.09	298.99	1205.93	11188.83

TOTAL D.W.R (DRY)JAN.--JUNE == 577.66
--DO-- (WET)JULY--DEC. == 628.27

TABLE Ⅶ-2-7 Annual Maximum Unit Water Requirement and Diversion Water Requirement (Barind Area)

Year		PATTERN 1			PATTERN 2			Total	
		Month	Unit W.R.	Diversion	Month	Unit W.R.	Diversion	Month	Diversion
		10-day period	l/s/ha	m^3/sec	10-day period	l/s/ha	m^3/sec	10-day period	m3/sec
1977	Dry	12.3	0.436	14.719	4.3	0.965	12.217	7.1	10.027
	Wet	9.3	0.743	25.084	11.1	0.751	6.338	9.3	28.915
1978	Dry	3.1	1.247	31.574	4.1	0.888	11.247	4.1	39.145
	Wet	8.3	1.038	35.043	8.3	1.076	9.081	8.3	44.124
1979	Dry	3.1	1.355	34.309	4.3	1.221	15.458	4.1	42.272
	Wet	9.3	0.422	14.247	10.3	1.021	8.617	10.3	19.792
1980	Dry	4.1	1.202	30.409	4.3	1.202	30.409	4.1	42.588
	Wet	10.1	0.715	24.138	10.1	0.979	8.263	10.1	32.401
1981	Dry	4.1	1.003	25.396	4.1	0.953	12.065	4.1	30.852
	Wet	10.2	0.823	27.784	10.2	1.079	9.107	10.2	36.891
1982	Dry	3.2	1.003	25.396	5.3	1.165	14.749	4.1	35.701
	Wet	9.3	1.079	36.427	10.1	1.021	8.617	9.3	44.242*
1983	Dry	1.2	0.687	17.395	4.3	1.189	15.053	4.1	38.208
	Wet	9.1	0.130	4.389	9.1	0.867	7.317	6.3	17.496
1984	Dry	3.3	1.257	31.827	4.3	1.146	14.508	4.3	37.550
	Wet	7.1	0.441	14.888	8.2	0.394	3.325	7.1	14.888
1985	Dry	3.1	1.355	34.309	5.2	0.806	10.204	4.1	38.208
	Wet	7.2	0.310	10.466	11.1	0.816	6.887	7.2	10.466
1986	Dry	3.1	1.214	30.738	4.3	1.132	14.331	3.3	35.549
	Wet	8.3	0.711	24.003	8.3	0.823	6.946	8.3	30.949

Note : — Maximum during Dry Season
— Maximum during Wet Season
* Maximum of annual maximum

TABLE VII-2-8 Annual Maximum Unit Water Requirement and Diversion Water Requirement (Paba Flood Plain Area)

Year		PATTERN 1			PATTERN 2			Total	
		Month	Unit W.R.	Diversion	Month	Unit W.R.	Diversion	Month	Diversion
		10-day period	1/s/ha	m3/sec	10-day period	1/s/ha	m3/sec	10-day period	m3/sec
1977	Dry	12.3	0.436	3.139	4.3	0.965	2.084	7.1	2.138
	Wet	9.1	0.481	3.463	8.3	0.506	0.911	9.3	6.167
1978	Dry	4.1	1.702	5.554	5.1	0.879	1.899	4.1	7.472
	Wet	8.3	1.038	7.474	8.3	1.076	1.937	8.3	9.410
1979	Dry	3.1	1.355	6.829	5.3	1.798	3.884	4.1	8.076
	Wet	9.3	0.422	3.038	10.3	1.021	1.838	10.3	4.221
1980	Dry	4.1	1.202	6.169	4.3	1.387	2.996	4.1	8.247
	Wet	10.1	0.715	5.148	10.1	0.979	1.7662	10.1	6.910
1981	Dry	3.1	1.003	5.055	5.1	0.687	1.484	4.1	5.798
	Wet	10.2	0.823	5.926	10.2	1.079	1.942	10.2	7.868
1982	Dry	3.2	1.003	5.055	5.1	1.331	2.875	7.2	8.132
	Wet	9.3	1.079	7.769	10.1	1.021	1.838	9.3	9.436*
1983	Dry	1.2	0.687	3.462	45.2	1.189	2.562	7.2	1.879
	Wet	7.2	0.261	1.879	11.1	0.867	1.561	6.3	3.439
1984	Dry	3.1	1.301	6.557	4.3	1.146	2.475	3.3	7.556
	Wet	7.1	0.441	3.175	11.1	0.732	1.319	7.1	3.175
1985	Dry	12.3	1.524	3.773	5.2	0.806	1.741	4.1	7.290
	Wet	7.2	0.310	2.232	11.1	0.816	1.460	10.3	3.101
1986	Dry	3.3	1.187	5.982	4.3	1.132	2.445	3.3	7.154
	Wet	8.3	0.711	5.119	8.3	0.823	1.481	8.3	6.601

Note : — Maximum during Dry Season
— Maximum during Wet Season
* Maximum of annual maximum

FIGURE VII-2-5 WATER INTAKE PATTERN IN FLOOD PLAIN AREA
" " BARIND AREA

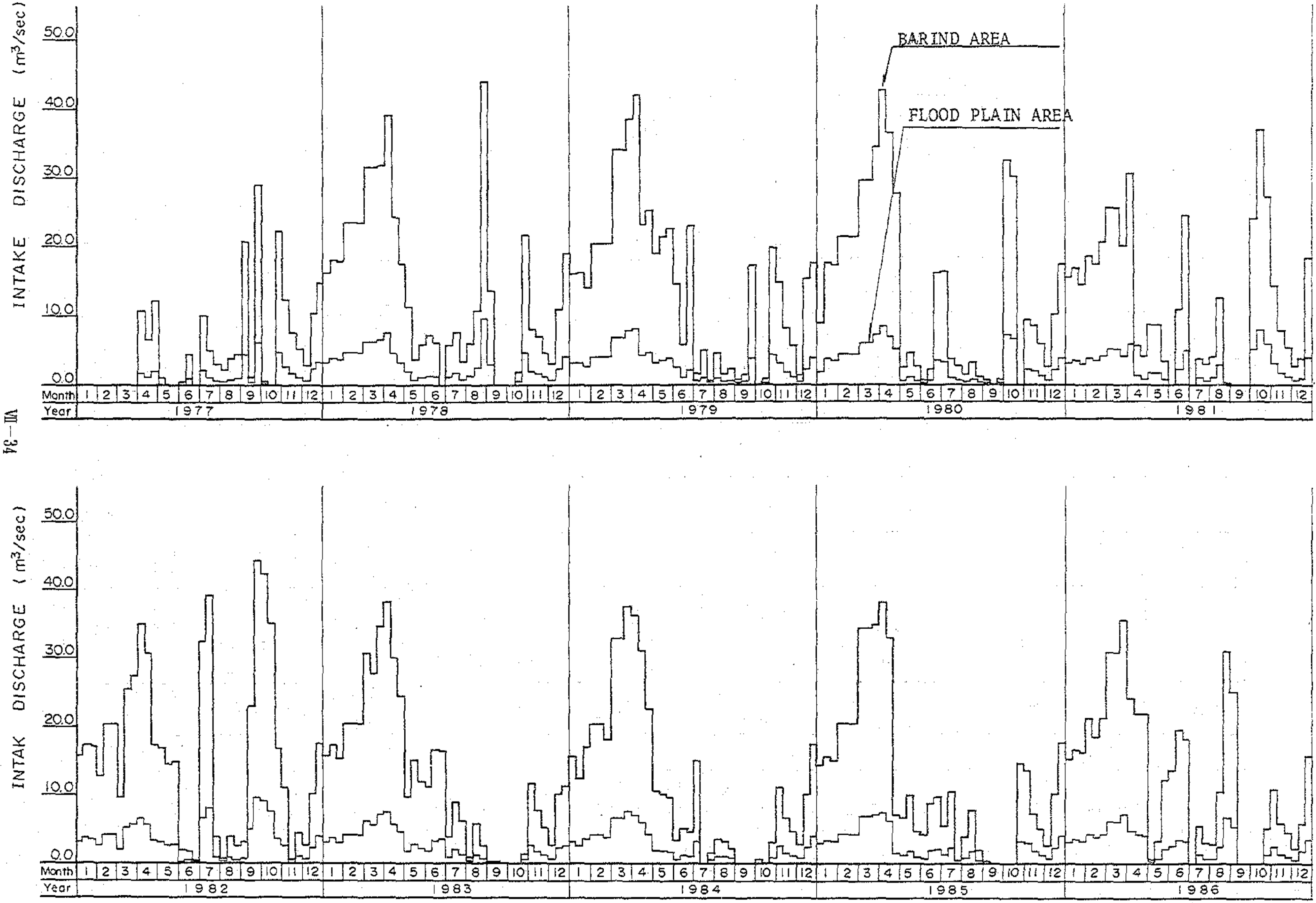


FIGURE VII-2-6

IRRIGATION WATER INTAKE AT BARIND AREA FOR DESIGN YEAR (1980)

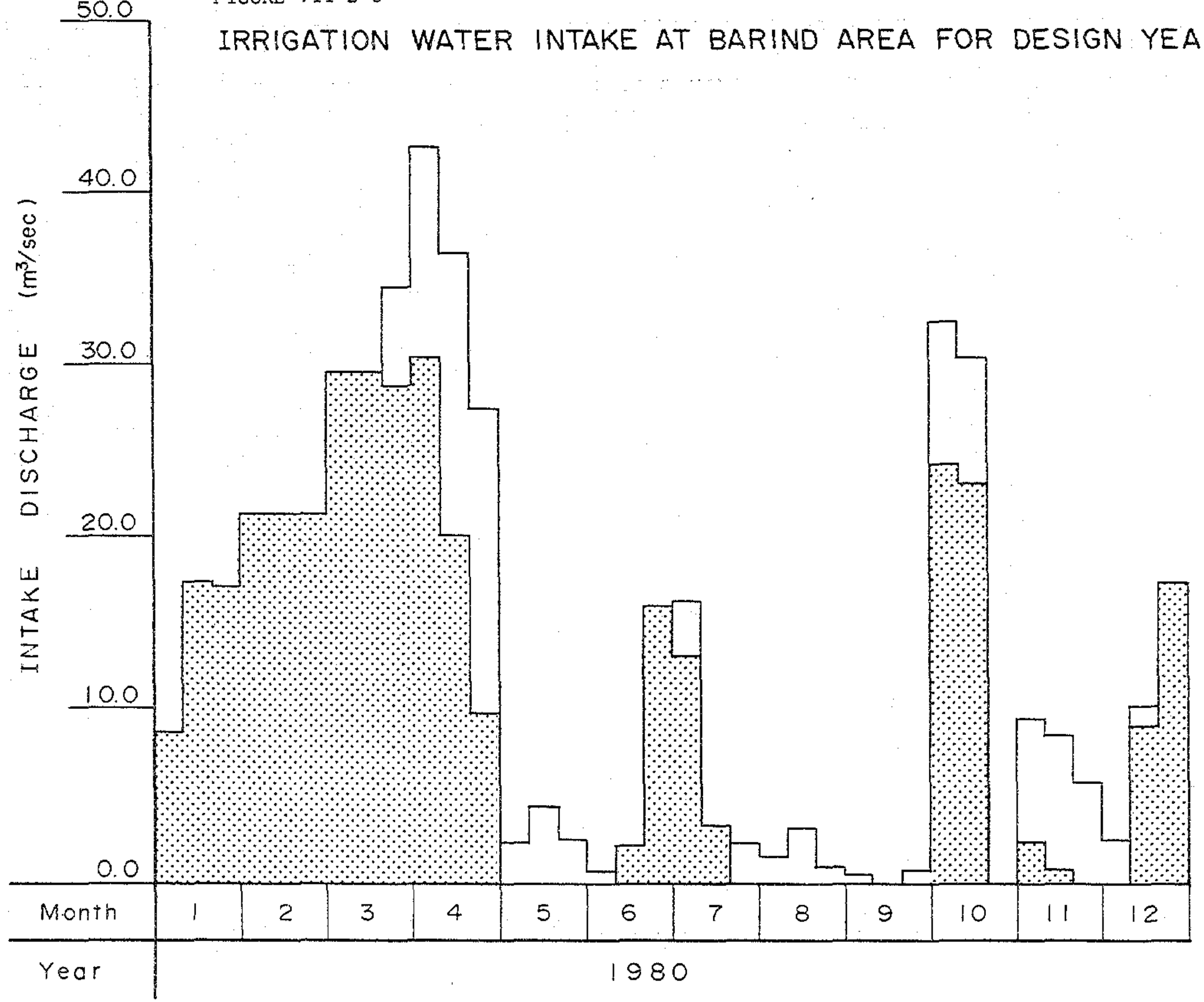


FIGURE VII-2-7

IRRIGATION WATER INTAKE AT BARIND AREA FOR DESIGN YEAR (1982)

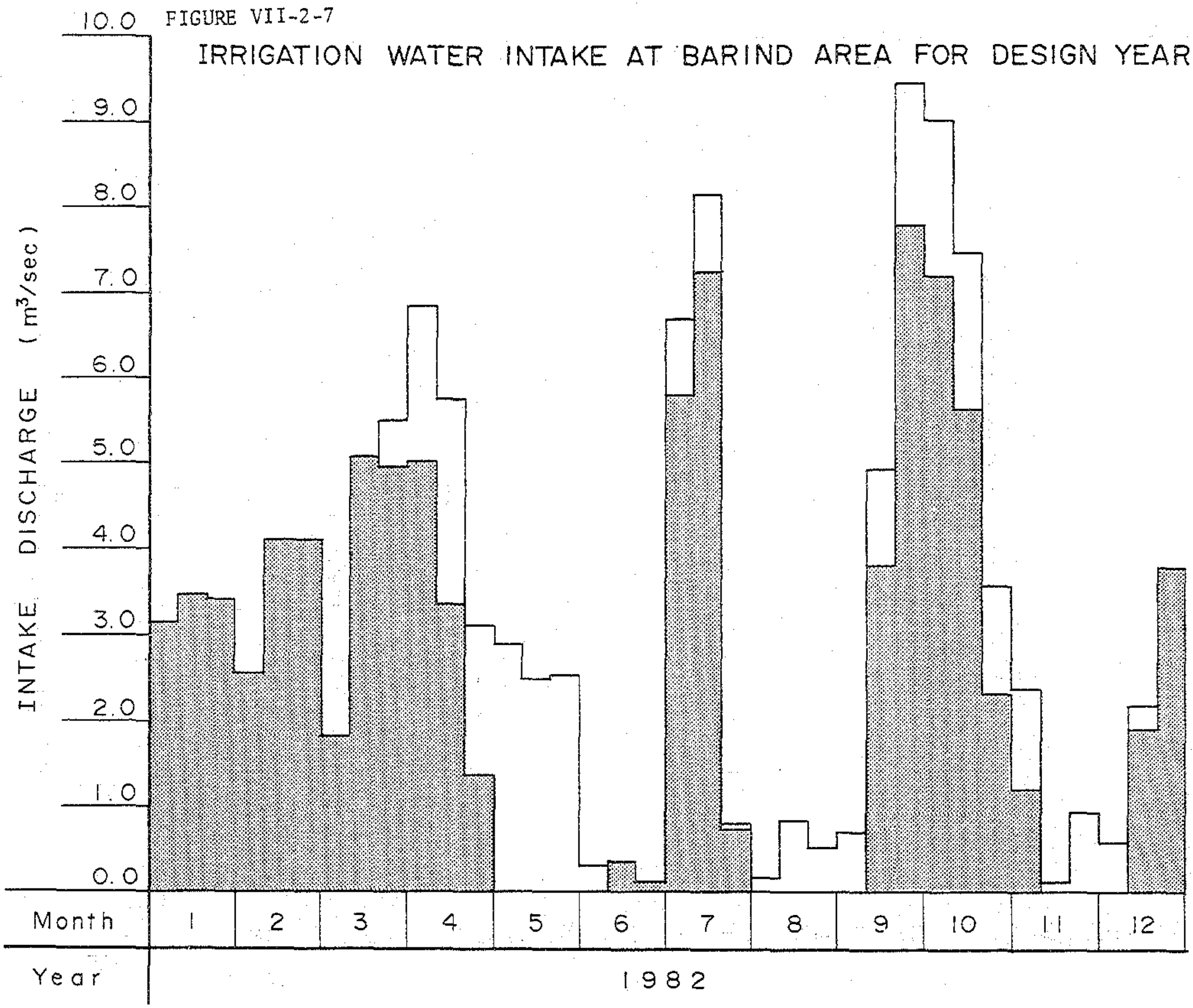


FIGURE VII-2-8

IRRIGATION WATER INTAKE AT FLOOD PLAIN AREA FOR DESIGN YEAR (1980)

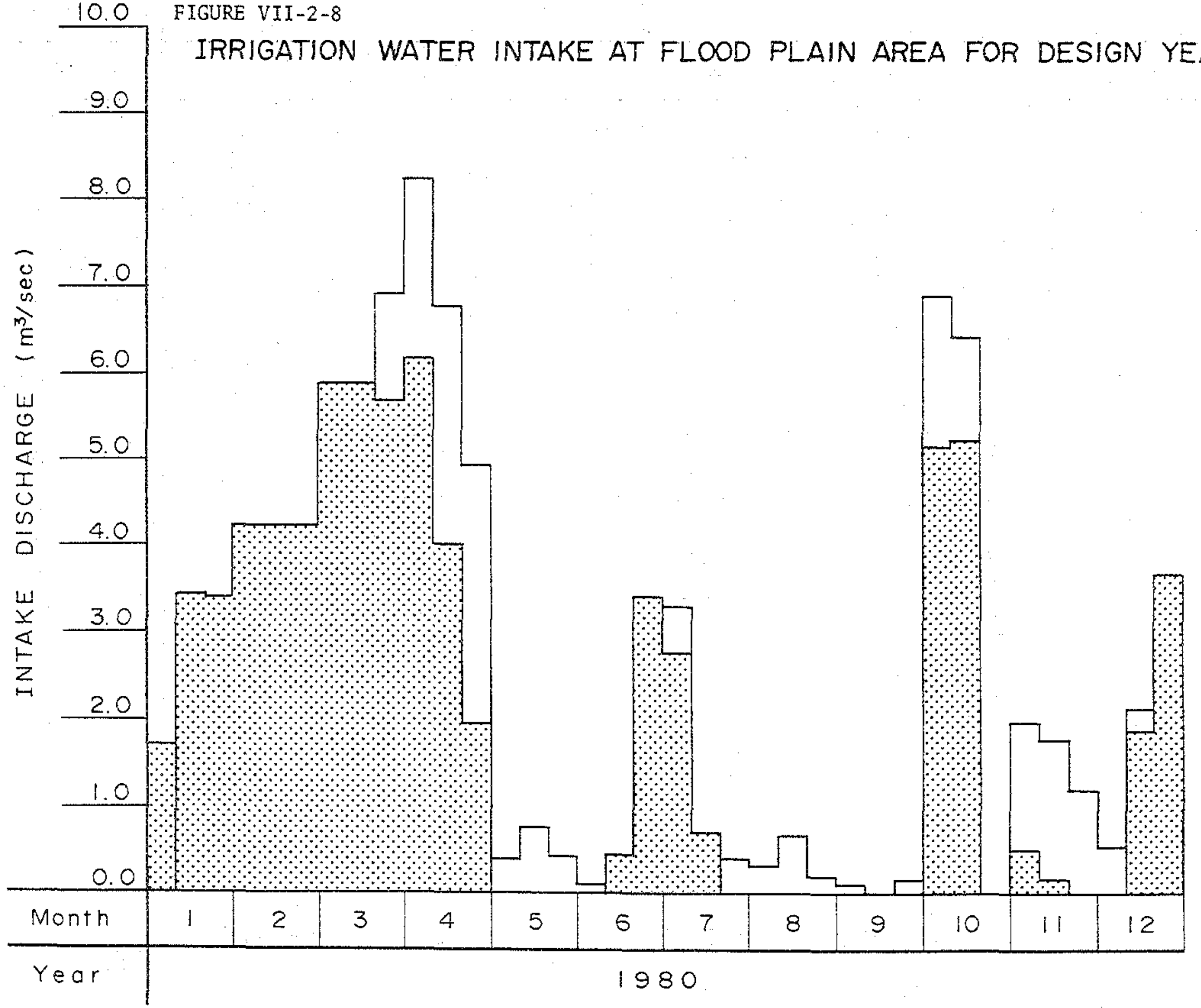


FIGURE VII-2-9

IRRIGATION WATER INTAKE AT FLOOD PLAIN AREA FOR DESIGN YEAR (1982)

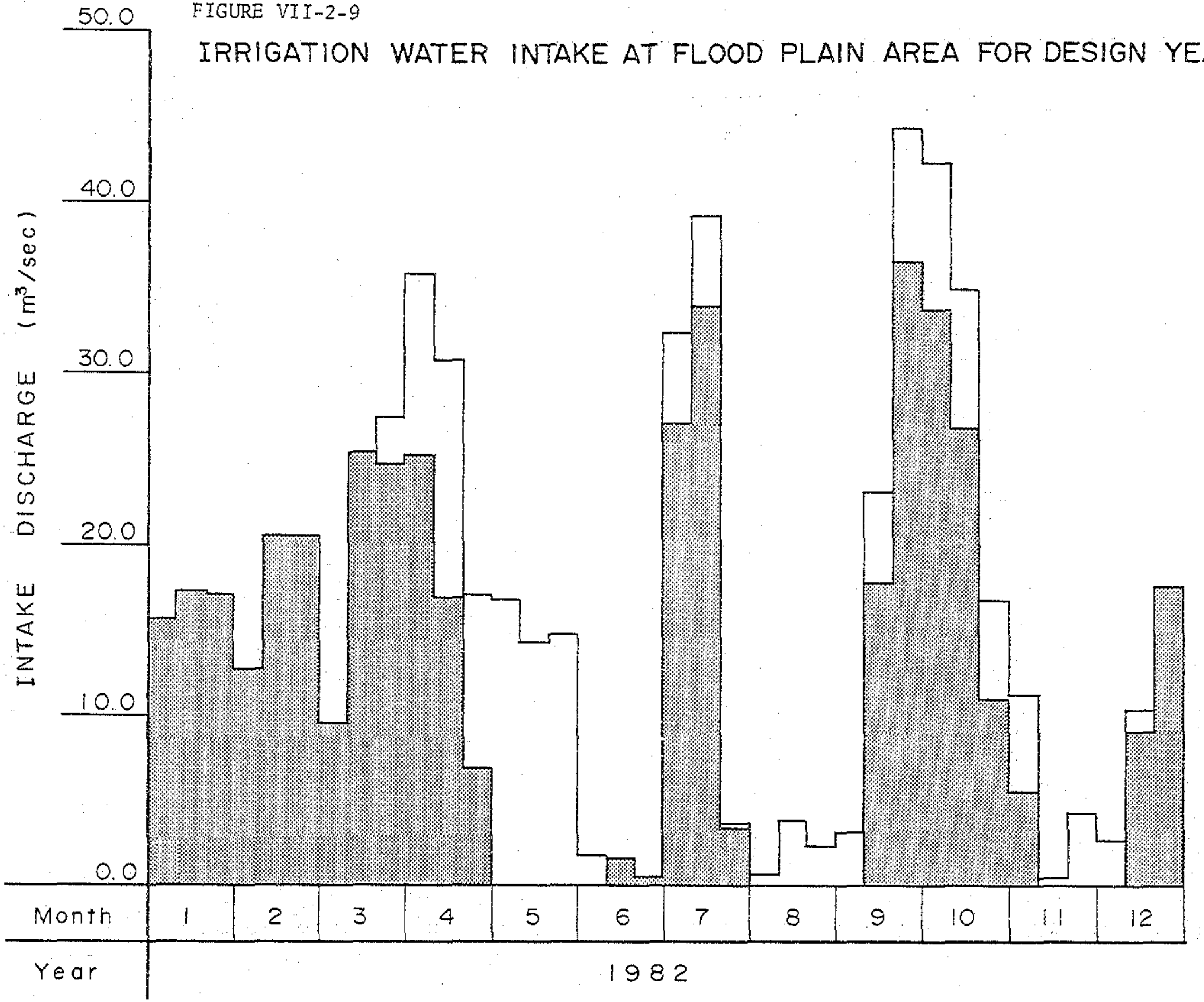


TABLE VII-2-9 Estimated Sedimentation in the Irrigation Water of the Project Area

	Sediment Volume (ton)		
Year	Barind Area	Paba Flood Plain Area	Total
1977	31,181	6,594	37,775
1978	72,976	15,476	88,452
1979	6,311	3,727	10,038
1980	17,816	1,315	19,131
1981	20,538	4,310	24,848
1982	52,649	11,188	63,837
1983	6,170	1,282	7,452
1984	7,576	1,583	9,159
1985	18,946	4,031	22,977
1986	876	175	1,051
Total (ton)	235,039	49,681	284,720
Average (ton)	23,504	4,968	28,472
Average (m^3)	14,245	3,011	17,256

Note : Relative density of sediment is 1.65 ton/m^3 based on the report Volume II, Feasibility Study of Ganges Kobadak Rehabilitation and Improvement Project, 1983

2-4-3. Irrigation Networks

Irrigation systems have been provided for the Flood Plain area (Paba) and Barind area separately.

In the Barind area, the irrigation area is a slope area and mainly paddy field.

The pumping station for Barind area can be proposed at Baraipara according to the River Shifting Records analysis (see VOLUME II).

In the Flood plain area (Paba), the pumping station can be proposed at Kasba.

Each Irrigation Networks are shown in FIG. VII-2-3, FIG. VII-2-4.

After thorough investigation of the topographical condition in the project area, layout of the canal network was plotted on a 1:7,920 (Eight Inch to One mile) topographical map, taking into account of following principles.

i) Irrigation systems are provided for the Flood Plain area (Paba) and Barind area separately.

ii) In the Barind Area, the irrigable area is characterized by uneven and undulating topographic features with high ridges and moderately leveled low area in between the ridges.

iii) In the Flood Plain Area, this area is characterize by more or less a plain land and is situated at much lower elevation than Barind area.

Canal Alignment

Irrigation canal routes have been selected by paying attention to the following points;

- to locate the canal route along the highest possible altitude, keeping enough head for water distribution to the secondary irrigation canals;
- to avoid canal alignment through village settlements as far as possible; and
- to avoid the proposed canal bed to be made up embankment as far as possible.

Barind main canal system belonging to Baraipara Pumping Station;

Flood Plain area (Paba) main irrigation canal system belonging to Kasba Pumping Station.

Barind irrigation main canal route has a total length of 48.8 km. Its starts, from Baraipara Pumping Station, running the highest area of Barind tract and crossing the Abdulpur-Amnura branch railway and it reaches Hakimpur.

Barind area is undulating and very irregular at places.

High ridges and arroyos (Khals) run across the area.

Therefore, the canal length density is higher than ordinary canal alignments (See TABLE VII-2-10).

Flood Plain main canal system is belonging to Kasba pumping station.

The main canal route has a total length of 13.9 km.

It starts from Kasba Pumping station running the center of this area, crossing Abdulpur, Amnura branch railway and it reaches Silimpur (See TABLE Ⅶ-2-11).

Secondary canal

Secondary and Sub-secondary canal have been so aligned as to make the entire area irrigable, by taking into consideration the topographical features of the project area.

	Length (km)	
	Secondary	Sub-secondary
Barind Area	157.7	285.5
Flood Plain Area	62.8	18.8
	220.5	304.3

FIGURE VII-2-10 LAYOUT OF IRRIGATION CANAL NETWORK

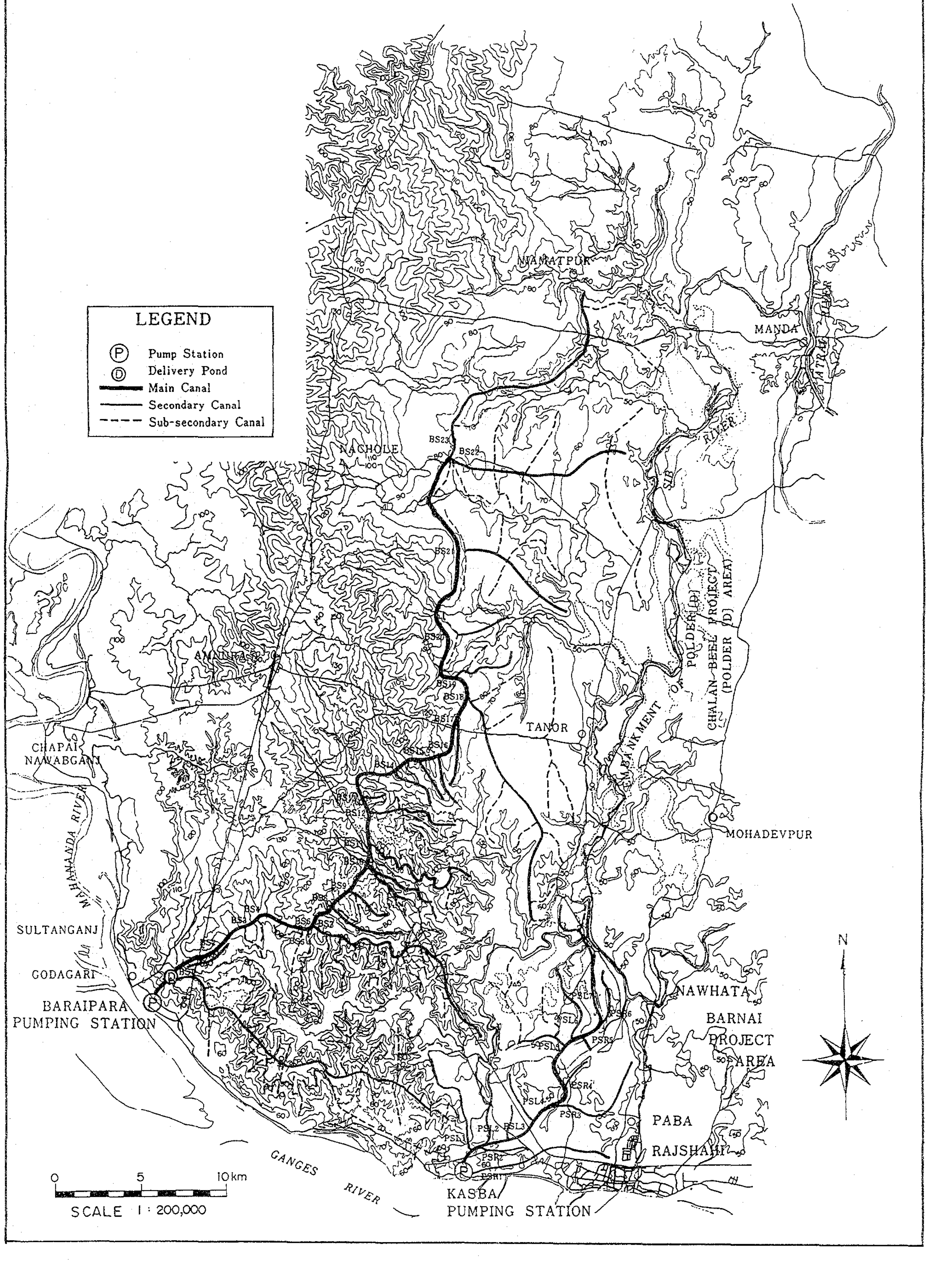


TABLE VII-2-10 SECTIONAL DISCHARGE AND TYPE AND LENGTH OF BARIND MAIN CANALS BARAIPARA PUMPING STATION

$Q = 44.242\ m^3/s$ $A = 42,200$ ha

		Main Canal			Secondary Canal	Sub-secondary Canal
Bifurcation	Net-irrigated area	Discharge	Canal type	Length	Length	Length
	ha	m^3/s		m	m	m
Pumping Station						
BS-1	7,942	44.247			19,500	100,470
-2	341	35.916		3,600	2,800	-
-3	265	35.559		2,134	2,700	-
-4	126	35.281	M-I	579	1,270	-
-5	580	35.149		3,333	4,680	4,220
-6	358	34.541		454	6,050	1,000
-7	3,381	34.165		700	15,000	41,600
-8	185	30.621		1,000	4,900	1,950
-9	257	30.427		2,140	2,920	1,200
-10	329	30.157		1,776	5,070	3,700
-11	1,047	29.812		1,584	13,900	8,050
-12	1,165	28.715		1,866	6,050	12,850
-13	104	27.493	M-II	1,034	1,980	-
-14	308	27.384		4,000	3,170	2,000
-15	365	27.061		2,200	2,900	1,200
-16	281	26.679		1,087	2,950	1,350
-17	451	26.384		3,713	4,700	37,350
-18	7,704	25.911		1,200	15,060	2,150
-19	866	17.834	M-III	900	4,700	3,200
-20	580	16.926		3,354	3,090	15,800
-21	3,532	16.318		5,946	7,900	37,250
-22	8,759	12.615	M-IV	6,170	11,200	10,130
-23	3,274	0		0	15,170	4,750
Total	42,200			48,700	157,660	285,470
Canal Length Density				1.16 m/ha	3.74 m/ha	6.76 m/ha
					(10.50 m/ha)	

TABLE VII-2-11 SECTIONAL DISCHARGE AND TYPE AND LENGTH OF MAIN CANAL KASBA PUMPING STATION

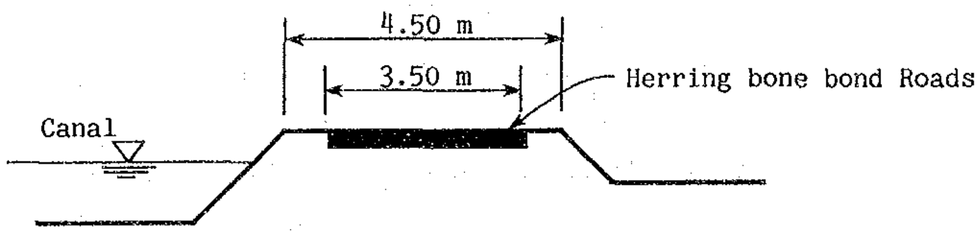
$Q = 9.436\ m^3/s$ A = 9,000 ha

Bifurcation	Net-irrigated area	Main Canal Discharge	Main Canal Canal type	Main Canal Length	Secondary Canal Length	Sub-secondary Canal Length
	ha	m^3/s		m	m	m
Pumping Station						
PSR1	1,208	9.436	M-V	0	9,300	
-L1	654	8.169		1,384	7,060	
-R2	224	7.483		456	3,600	
-L2	643	7.249	M-VI	890	4,670	
-L3	65	6.575		1,270	1,430	
-L4	951	6.506		1,540	4,050	
-R3	1,458	5.509		1,860	8,400	
-R4	354	3.981	M-VII	1,600	2,180	
-L5	1,438	3.610		2,265	2,970	17,010
-L6	620	2.102		395	6,000	
-L1	191	1.452	M-VIII	763	1,000	
-R6	556	1.252		1,485	3,400	
-L7	638	-		0	8,740	1,780
Total	9,000			13,908	62,800	18,790
Canal Length Density				1.55 m/ha	6.98 m/ha	2.09 m/ha
					(9.07 m/ha)	

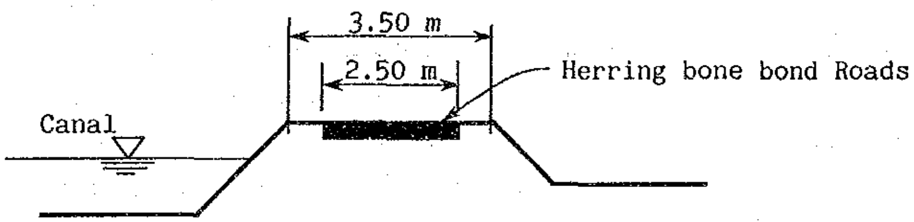
2-4-4. Proposed O & M Roads

Herring bone bond roads are to be provided along the embankment of main, secondary and sub-secondary canals.

Typical cross section of O & M raods are shown below.



Main Canal O & M Road



Secondary and Sub-secondary canal O & M Road

3. DRAINAGE PLAN

3-1. Concept of Drainage Plan

3-1-1. Background of the Drainage Problem

Along the Sib river, a few drainage and flood control projects were implemented or studied, such as Chalan Beel Project, Karnahar Barabila Project and Barnai Project. The flood water in the Sib river was effected by the construction of the Polder D located along the left bank of the Sib river and Barnai river. Recently, the Barnai Project has been started the implementation works and planned to construct a polder dike along the right bank of the Barnai river.

As the result, the flood water level in the Sib river will be risen due to the back water affection from the Barnai river. No flood analysis in the Sib river for the condition of the after implementation of Barnai Project has been made.

There is another difficulty to estimate the flood water level in the Sib river. Because the Sib river water level is affected by not only the rainfall or runoff from its own catchment area but also from the back water from the Brahmaputra, Baral, Gumati and Atrai rivers. Water levels in the rivers located in the down-stream of the Sib river will be controlled by several projects such as Pabna Project, Bogra Project etc.

It will be rather difficult to perform accurate drainage analysis in the Sib river.

About half of the catchment area in the down-stream of the Sib river is located in the Study area. However, the rest of the up-stream catchment area is outside of the Study area. The total catchment area is approximately 1,850 sq.km. It was rather difficult to grasp the characteristics of the whole catchment area.

There is a water level and discharge measuring station at Nawhata in the Sib river. The datum elevation at Nawhata was recently revised to correct the records of water level. In the Sib river, reliable records of the water level at Nawhata is since October 1986.

Accordingly, for the drainage analysis of the Barind area it will required to study the overall catchment area of Atrai river basin or Baral river basin.

3-1-2. Present Drainage Conditions

(1) Water Levels in the Ganges and Sib river

As shown in the FIGURE Ⅷ-3-1,the water level fluctuation in the Ganges river at Rajshahi and in the Sib river at Nawhata shows that the water level at Nawhata from October to December becomes higher than the one in the Ganges river. During the post monsoon period, the water in the Sib river can be drained to the Ganges river, that the inundation period in the flood plain area can be shortened.

According to the topographic map, the elevation of lower portion in the Paba area is approximately 13 meters (43 feet), therefore it will be possible to shortened the inundation period for about one month.

(2) Drainage Networks

The Sib river flows along the eastern boundary of the Project area from north to south functioning as a catch of runoff from the Barind tract. The Sib river is confluenced to the Barnai river at Nawhata which flows from east to west. The Joakhali river is confluence to the Barnai river at Nawhata flowing from south to north along the embankment of Karnahar Barabila Polder. Near the Sitlai railway station, the Joakhali river crosses the railway and the Damkura Khal is confluenced to the Joakhali river near the railway crossing point.

The Damkura Khal was connected to the Ganges river at Kasba but at present the outlet of the Khal is silted and closed by deposit.

In the Paba flood plain area, the drainage networks can be divided into two areas. The northern portion in the Karnahar Barabila area drains to the north. It will be required to facilitate a regulator to drain to the Sib river.

In the surthern portion of the Paba flood plain area, there are two natural drainage rivers. One is Joakhali river which flows from south to north and confluenced to the Sib river. Another is a natural drainage canal which flows through the center of the area from south to north and confluenced at nawhata to the Sib river or Barnai river.

3-1-3. Drainage Improvement Plan

(1) Barind Area

In the Barind Area, the river course is rather steep and the river bank is too much erroded. It will be too costly to perform river training works such as re-excavation, bank protection and drop structures construction. These area has been neglected from the beneficial area.

The drainage improvement in the on-farm level has been planned. The main river course, however, in the Barind area will not be touched.

(2) Paba Flood Plain Area

1) Gravitational Drainage System

During the peak flood in the Ganges river the water level becomes higher than the inland water level. So there is no possibility to drain to the Ganges river by gravity. However, during pre-monsoon and post-monsoon period, there will be a possibility to drain the Sib river through Joakhali river to the Ganges river through Damkura Khal.

Accordingly, the drainage plan is proposed to connect the Joakhali river at Kasba to the Ganges river site with a regulator.

The capacity of the drainage canal can be decided, based on the recorded maximum discharge capacity at Nawhata which is about 160 to 170 cu.m/sec.

The design capacity of the proposed drainage canal has been decided at 150 cu.m./sec.

2) Drainage by Irrigation Pump at Kasba

The outlet of the drainage canal is located quite near to the proposed Kasba pumping station. During the peak flood time, the Ganges water level is higher than the water level in the Paba area. It will be possible to utilize the Kasba pumping station for drainage purpose.

The capacity of pump, however, is about 10 cu.m/sec which is rather small in capacity for drainage purpose. In order to utilize the capacity of the pump effectively, it is necessary to limit the drainage area to meet with the pump capacity. Two regulators are proposed to limit the drainage area at Nawhata and at the railway crossing point of the Joakhali river near the Sitlai. When the Kasba pump is operated for drainage, these regulators should be closed to reduce the water level as low as possible.

3-2. Drainage System Networks

3-2-1. Barind Area

The Sib river flows along the eastern boundary of the Project area from north to south functioning as a catch of run-off from the Barind tract area.

The present river systems, several tributaries of Sib river have been sub-divided into several sub-catchment areas.

The river network system and the sub-catchment area are shown in FIGURE VII-3-2 and the schematic river channel networks that are drainage networks are shown in FIGURE VII-3-3.

3-2-2. Flood Plain Area

Karnahar Barabila drainage cum-flood control scheme embankment exists along the western boundary of the Flood Plain Area, which is bounded by the Sib river to the North.

The Sib river is confluenced to the Barnai river at Nawhata flowing from south to north along the embankment of Karnahar Barabila

Polder Near the Sitlai railway station, the Joakhali river crosses the railway and the Pamkura Khal is confluenced to the Joakhali river near the railway crossing point.

The river network system is shown in FIGURE Ⅶ-3-4.

3-3. Proposed Drainage Improvement Works

The drainage system in the Flood plain area is necessary to be improved.

The improvement plan for re-excavation and extension of drainage canals are shown in FIGURE Ⅶ-3-4.

As shown in the flood water level in 1987 in the Ganges and Brahmaputra rivers (FIGURE Ⅶ-3-1), the peak water level between both rivers appeared in different period. As for the river system in the Project area, the Sib river flows to Barnai river and confluenced Atrai river to Boral river to discharge at Brahmaputra river. Accordingly, the water level in the Sib river is affected by the back water of the Brahaputra river.

During the peak flood in the Ganges river the water level becomes higher than the inland water level. So there is no possibility to drain to the Ganges river by gravity. However, during pre-monsoon and post-monsoon period, there will be a possibility to drain the Sib river through Joakhali river to the Ganges river at Kasba where the proposed pumping station site is.

Accordingly, the drainage plan is proposed to connect the Joakhali river at Kasba to the Ganges river site with a regulator. So that it will be possible to use the proposed irrigation pump as drainage pump during the peak flood as well.

FIGURE VII-3-1 WATER LEVEL FLUCTUATION OF THE GANGES AND BRAHMAPUTRA RIVERS

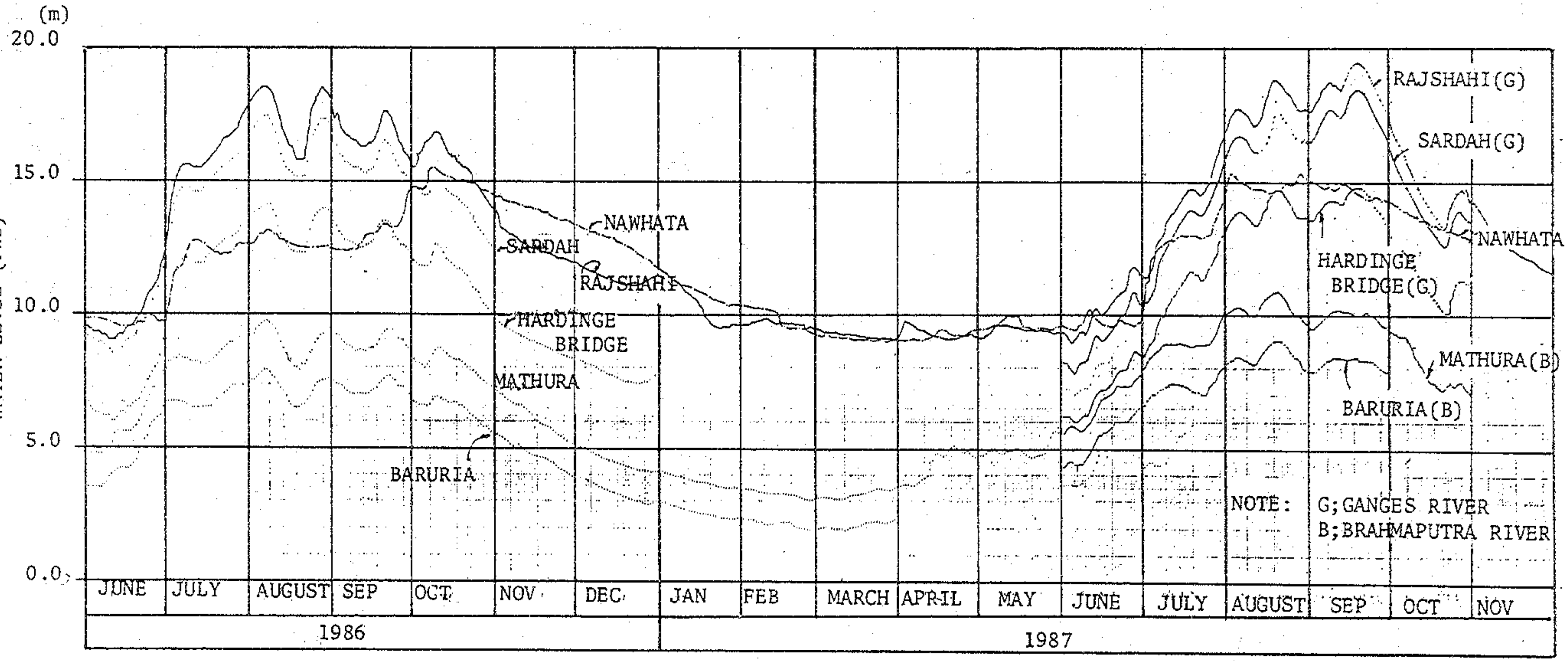


FIGURE VII-3-2

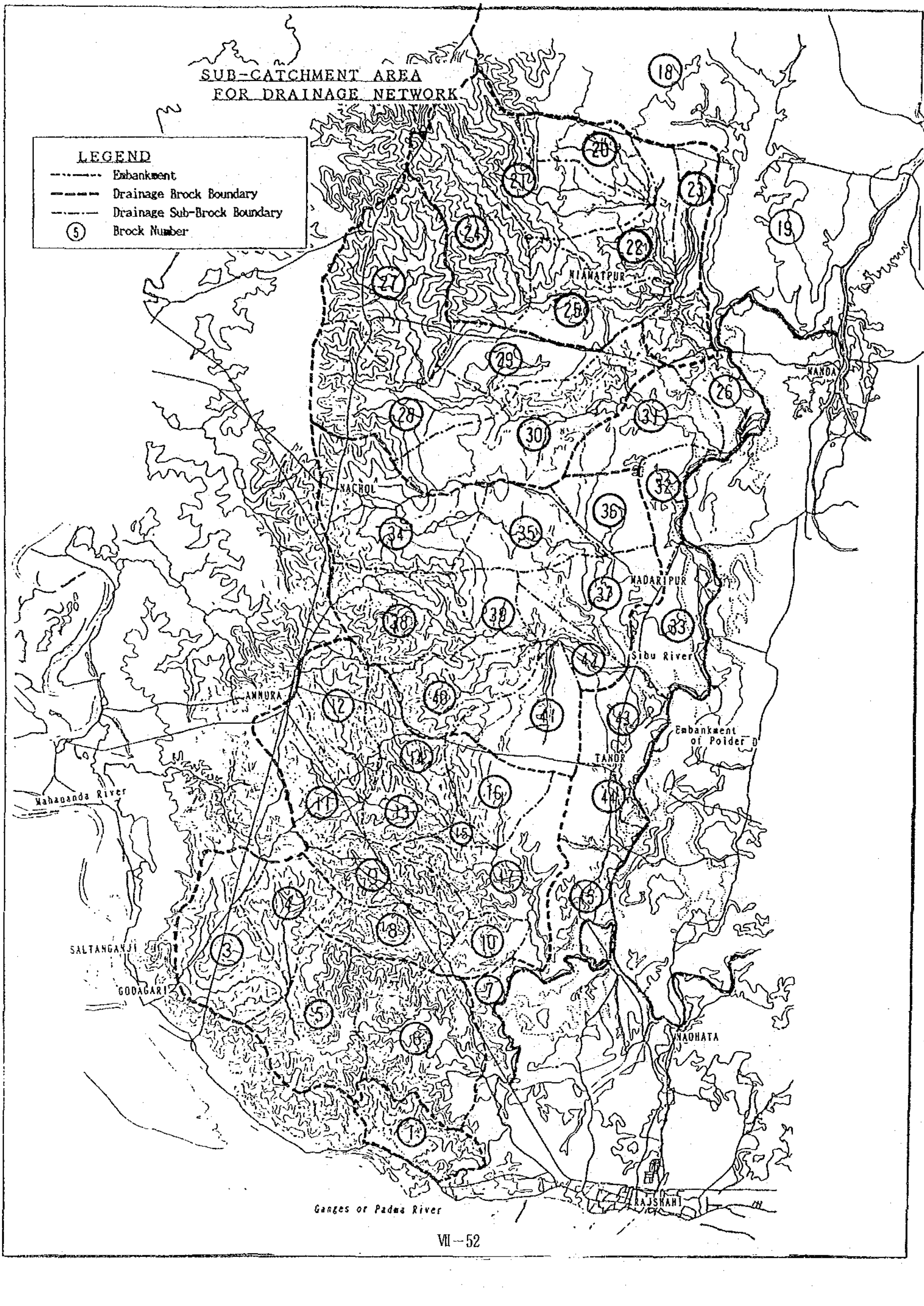
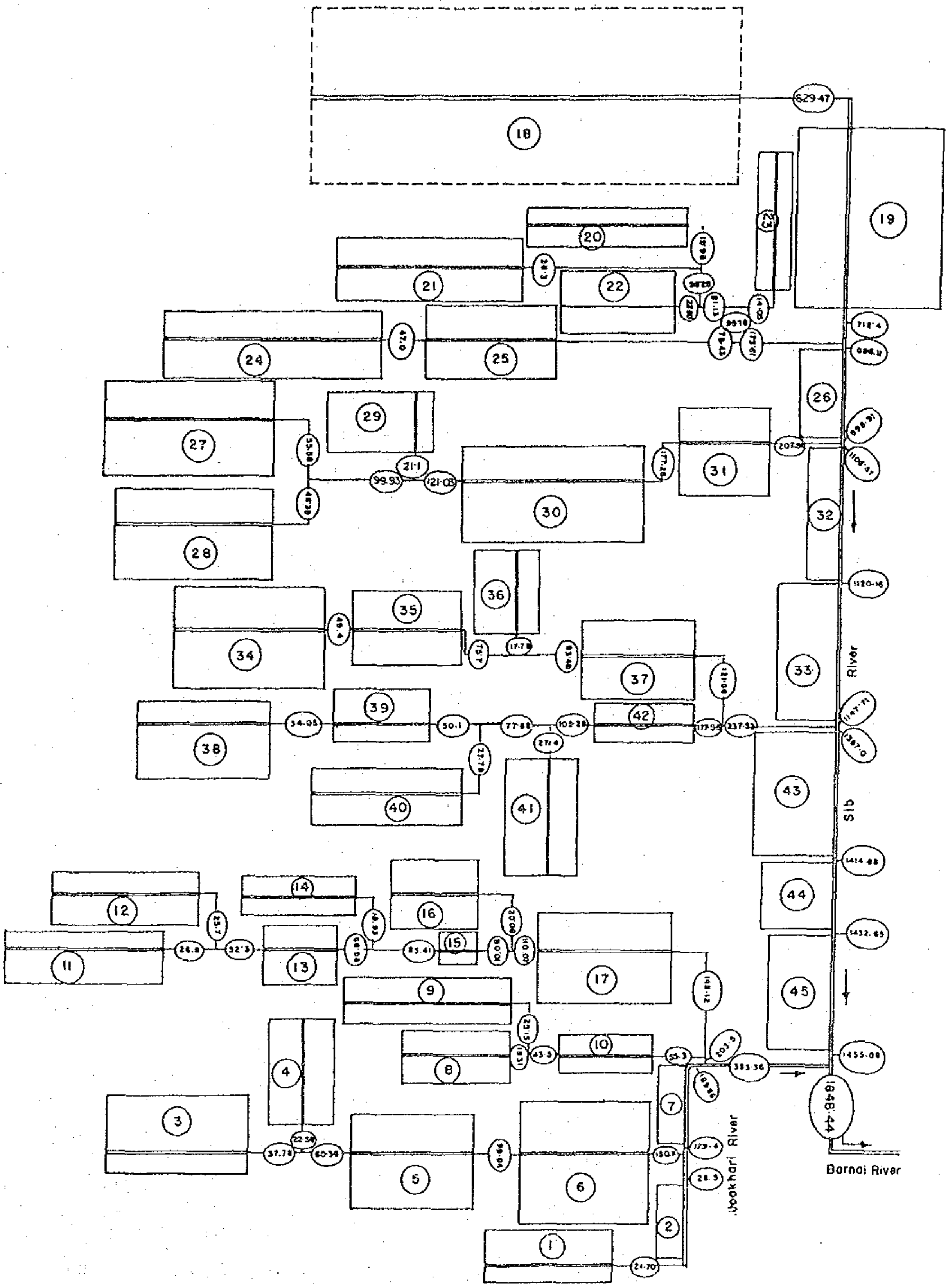


FIGURE VII-3-3 DIAGRAM OF DRAINAGE NETWORKS



Note: (i) ; shows the number of the sub-catchment area.

(i) ; figure shows the accumulated catchment area in sf.km.

FIGURE VII-3-4

DRAINAGE IMPROUVEMENT PLAN

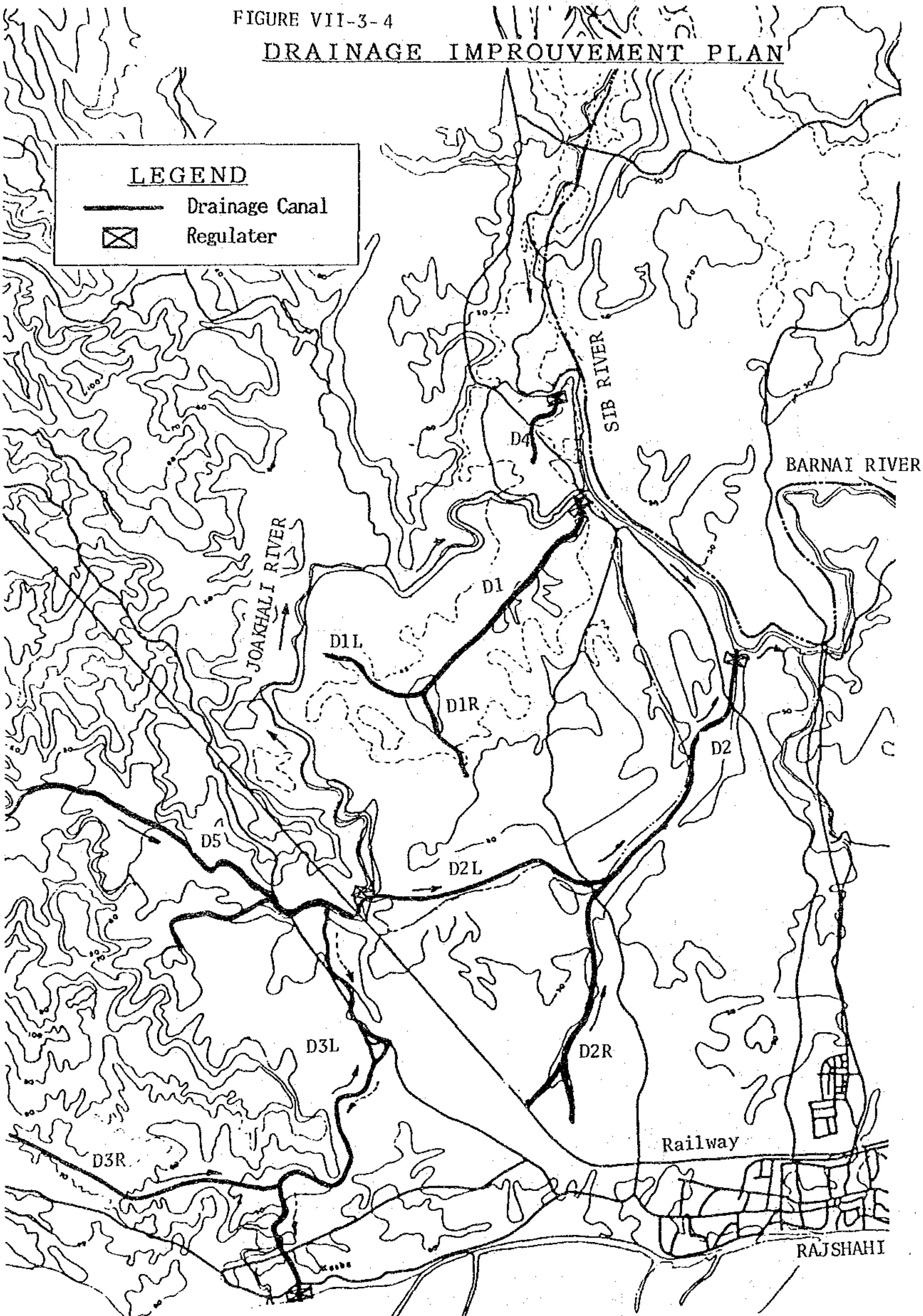
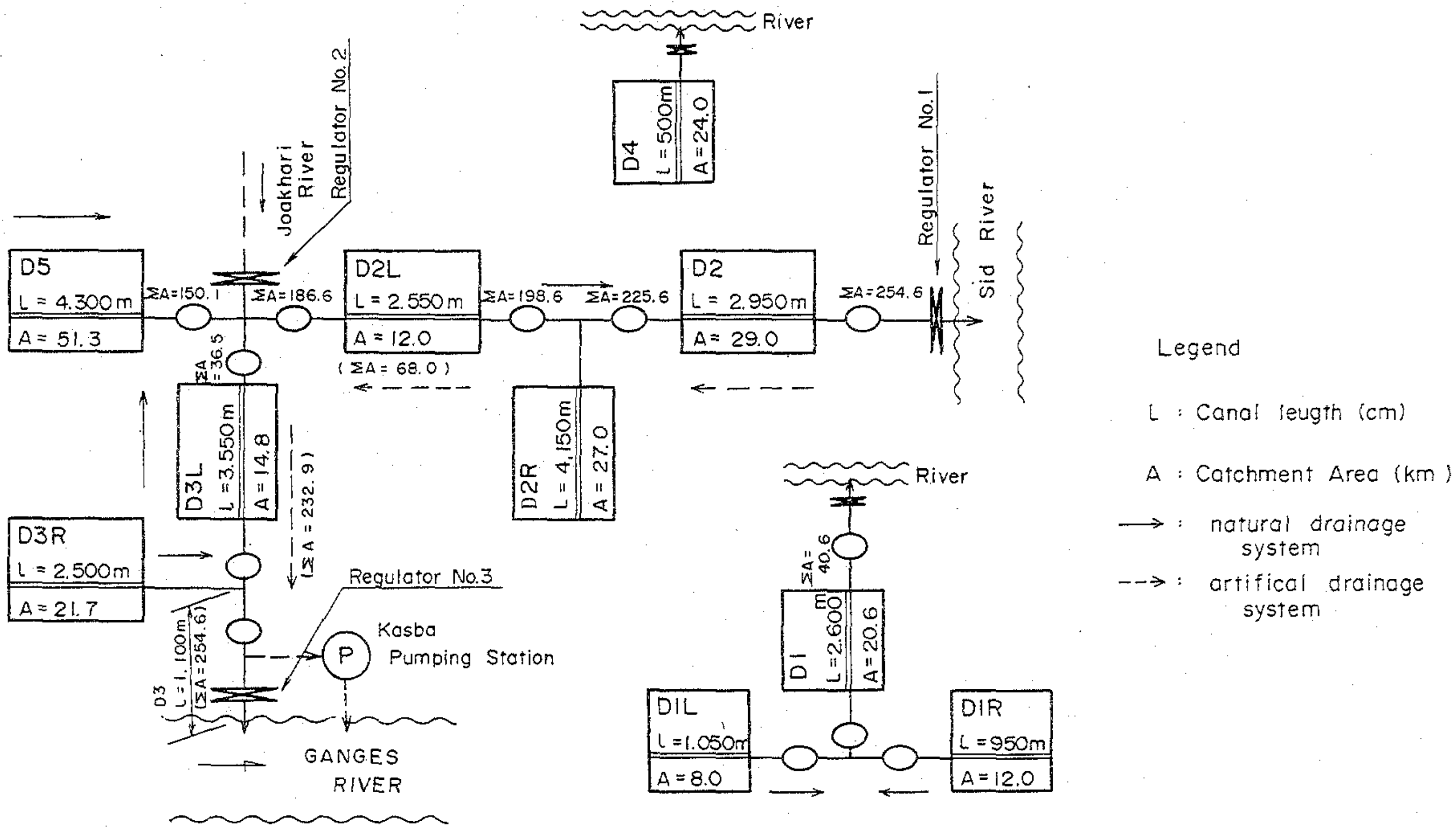


FIGURE VII-3-5 DIAGRAM OF DRAINAGE NETWORKS IN FLOOD PRAIN AREA



4. On-Farm Development Plan

4-1. Concept of On-Farm Development plan

The On-Farm development is the most important factor in the irrigation and drainage development project.

The objective of the development plan is to have the functions for distribution of irrigation water and for collection of excess water in the farm-level in a timely and efficient manner. Therefore, the terminal facilities should be planned taking into consideration the following items;

- Topographical condition
- Soil condition
- Shape of farm-lot
- Acreage of farm-lot
- Present land-use
- Present land-holding
- Water management
- Construction cost

Particularly, the canal densities to tertiary, farm ditch and farm drain are considerable.

Generally, there is no standard criteria to determine the canal densities on-tertiary canals, farm ditch and farm drain, and these are provided based on the long term experience.

On the development plan for this project, four sample areas have been selected as representative area which are divided into four categories depending upon the topographic condition the project area.

The sample area is kept at around 200 hectare, which is covered by topographical ground survey with 50 centimeter contour line inclusive of the cadastral map.

Based on said basic data, the canal lay-out have been carried out for each sample area as shown in drawings.

4-2. Sample Area for on-farm development

In order to grasp the topographical character for the project area, two kind of topo-map with scale of 1:50,000 and 1:7,920 have been utilized respectively and as a additional data, aerial photo have been collected for the analysis of topographical condition of the area.

As a results of the analysis, the project area has been divided into four types based on the land slope, namely the project area divided into two sub-project, one is Barind Tract Area, another one is flood plain area (Paba Area), moreover, Barind Tract Area has classified into three types.

4-2-1. Selection of Sample Area

(1) Sample Area "A" at Barind Hilly Area

The area selected as a representative of hilly area at Barind Tract Area. The area is located along sub-secondary of BS7-2, and the length is 3.0 kilometer, the width is about 400 meter approximately. And the acreage of the area is measured at around 119 hectares. As mentioned in the drawing, the land slope is very steep, which varies from 1/50 to 1/100 approximately.

(2) Sample Area "B" at Barind Slope Area

The Area is located along the secondary canal of BS-5, and the length is 2.5 kilometer, the width is about 900 meter approximately and the acreage is at around 181 hectares. The land slope is comparatively gentle compare to sample area "A". The land slope varies from 1/100 to 1/200 approximately.

(3) Sample Area "C" at Barind Flat Area

The area is located along the secondary canal of BS-18, and the length is about 1.6 kilometer and the width is 2.4 kilometer approximately and the acreage is estimated at about 191 hectares. The land slope is flatter compare to other sample areas, and estimated at 1/500 approximately.

(4) Sample Area "D" at Paba Flood Plain Area

The area prepared as the representative area for Paba flood plain area. The land slope is being flater, however, there are some undulating places here and there . The existing drainage channel net works should be considered for the layouting the on-farm facilities.

The area is located along SL4, the length is 1.9 km, the width is about 800 m, the acreage estimated at around 138 hectares.

The land slope varies 1/200 to 1/400. Above mentioned sample areas are summarized in the following table ;

Sample Area		Items		
		Acreage (ha)	Ground Elevation (m)	Land Slope (Appex)
Barind Hilly Area	"A"	119	23 ~ 28	1/50 ~ 1/100
Barind Slope Area	"B"	181	22 ~ 27	1/100 ~ 1/200
Barind Flat Area	"C"	191	20 ~ 21.5	1/500
Flood Plain Area(Paba)	"D"	138	16 ~ 17	1/200 ~ 1/400

4-2-2. Lay-out of On-Farm Facilities

The lay-out of facilities required for the sample areas have been carried out under the folowing items.

- Land slope (contour line)
- Existing drainage channel, roads and ponds
- Existing road net works
- Codastal maps with spots ground elevation

(1) Tertiary canal

The tertiary canals have been located and arranged to intersect at a right angle for the contour line as much as possible, and to transit the center line at higher portion of a ridge because of covering more irrigable area.

In this case, it has been taken care to have irrigable area of 50 hectares to 60 hectares at one tertiary as a standard criteria for the canal capacities.

(2) Farm-ditch

The farm-ditches have been arranged and located to intersect at a right angle with the tertiary canals and parallel with the contour line.

The end point of a farm-ditch should be connected with the nearest drainage facilities, and the interval of farm-ditches shall be kept 100 meter to 300 meter approximately.

Accordingly, the irrigation methods shall be applied a plot to plot irrigation and drainage between the farm ditches.

(3) Farm drain

Farm drain shall be provided to drain away excess discharge from the paddy field.

The canal alingment shall be carried out to have a right angle with the contour line and it should be installed at the lowest area, and finally, these facilities should be connected with the existing main drainage channels.

(4) Diversion and check structures

From view point of the water management the diversion and check structures should be installed in the tertiary and farm-ditch.

The details are shown in drawing of volume 4.

As mentioned above, the results of lay-out for on-farm facilities are summarised as in the following table.

Sample Area		Canals								
		Items								
		Tertiary Canal			Farm Ditch			Farm Drain		
		Average Irrigable Area (ha)	Average Canal Length (m)	Canal Slpe	Average Irrigable Area (ha)	Average Canal Length (m)	Canal Slope	Average Irrigable Area (ha)	Average Canal Length (m)	Canal Slope
Barind Tract Hilly	A	15	440	1/500	2.4	190	1/500~1/1,000	11	430	1/500
Barind Tract sloped	B	60	750	1/500	7.9	465	〃	21	600	1/500
Barind Tract Flat	C	64	1,130	1/1,000	7.6	434	〃	28	1,000	1/1,300
Flood Plain Paba	D	23	750	1/1,000	11.5	385	〃	17	770	1/1,000

4-3. On-Farm facilities in the Project Area

Percentage and acreage of each category for the project area are shown as follows :

(1) Barind Tract Area

Type "A"	20.7 %	8,735 (ha)
Type "B"	42.0 %	17,724 (ha)
Type "C"	37.3 %	15,471 (ha)
Total	100 %	42,200 (ha)

(2) Flood Plain Area (Paba)

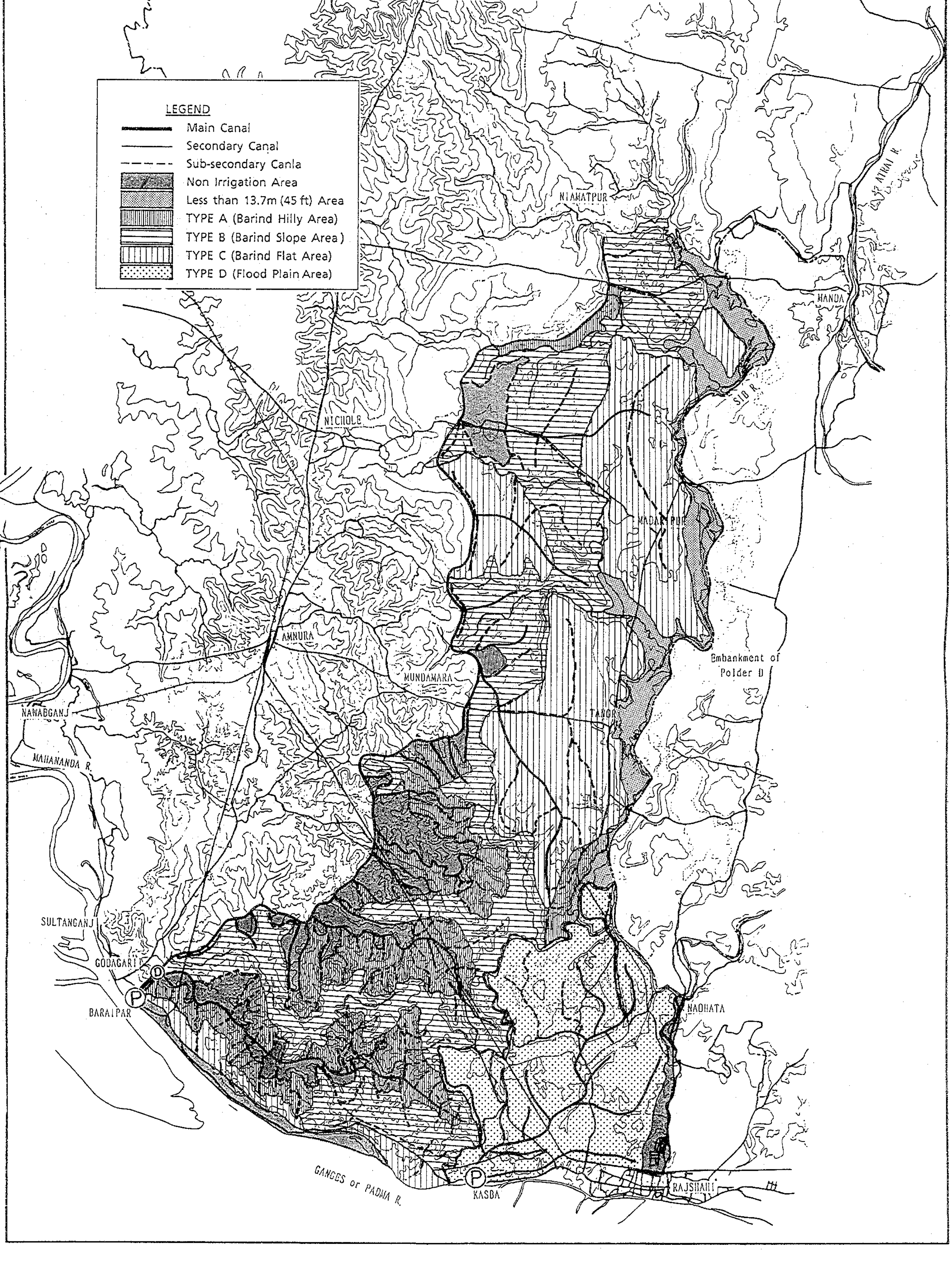
Type "D"	100 %	9,000 (ha)

(3) Facilities required for the project

Tertiary canal, Farm Ditch and Farm Drain which are required for the project area are summarized as following table.

Area	Type	Items					
		Tertiary Canal		Farm Ditch		Farm Drain	
		Canal Desities (m/h)	Total length (km)	Canal Densities (m/h)	total length (km)	Canal Densities (m/h)	Total length (km)
Barind Tract Hilly	A	30	262.1	78	681.3	40	349.4
Barind Tract sloped	B	13	230.4	59	1,045.7	31	549.4
Barind Tract Flat	C	18	283.3	57	897.2	36	566.7
Flood Plain Paba	D	32	288.0	33	297.0	44	396.0
Total			1,063.8		2,921.2		1,861.5

FIGURE VII-4-1 APPLICATION FOR TYPE OF ON-FARM DEVELOPMENT



5. PROPOSED FACILITIES

5-1. Irrigation System

5-1-1. Irrigation Canal

(1) Design Criteria

1) Mean velocity formula

Manning's Formula was used to determine the canal cross section, as presented below.

$$V = 1/n \cdot R^{2/3} \cdot S^{1/2}$$

$$Q = A \cdot V$$

$$= 1/n \cdot A \cdot R^{2/3} \cdot S^{1/2}$$

V	:	Mean velocity (m/s)	
n	:	*Coefficient of roughness*	*0.030*
R	:	Hydraulic mean radius	(m)
S	:	Channel slope	
A	:	Cross sectional area	(m^2)
Q	:	Design discharge	(m^3/s)

2) Coefficient of roughness

Coefficient of roughness of irrigation canal was decided 0.030, taking into account of table "The Values of Manning's roughness coefficient (TABLE 3.1)" in Bangladesh design standard "Chapter 3. Irrigation Canal".

3) Permissible Velocity

Water velocity should be within the minimum velocity of antihydrophyte to growth and maximum velocity in order not to cause erosion or unstable flow.

Factors to identify minimum velocity are indefinite, however generally they are assumed to be in the range of 0.25~0.4 m/s for unlined canals. Usually maximum velocity can be determined by applying kennedy's Formula as provided below :

$$Vc = cd^{m}$$

where, Vc = Kennedy critical velocity (m/sec)

C = Coefficient depending primarily on the characteristics of the material forming the canal (0.5)

d = depth of flow (m)

m = exponent varying with character of flowing water 0.64 for water containing very fine silt 0.50 for clear water

In this project area, maximum velocity is decided 0.7 m/s, according to the investigation of the soil material of this area, which is designed to prevent eroding.

4) Canal Cross Section

Cross Section of canal is planned as a trapezoid type, and designed by the criteria of Irrigation canal in Bangladesh.

Bedwidth-depth ratio

Q (m^3/s)	Preferred b/d ratio
Less than 5.0	b = 3 d
5.0 ~ 9.99	= 4 d
10.0 ~ 49.99	= 5 d
50.0 ~ 100.00	= 6 d

5) Inside slope

To maintain a stable inside canal face, the inside slope is determined by the nature of the soil.

Usually inside slope of canal should be between 1V : 1.5H and 1V : 2H.

In this project, its value was decided at 1 : 1.5 according to the slope stability calculation (method of Fellenius).

Slope Stability Calculation

- Soil Investigation data at Sagona
  1. Cohesion C : 4.12 ℓ/m^2
  2. Angle of Internal Friction (degree) 5.5°
  3. Dry Density 1.57 ℓ/m^3

The method of Fellenius has been adopted for Slope Stability for embankment of irrigation canal.

- Slope Stability is calculated by following terms (see FIGURE. Ⅶ-5-1).

Condition	γ	C	Ø
	KN/m^3	KN/m^2	Degree
Layer I	15.4	40.4	5.5
Layer II	15.4	40.4	5.5

Segment	Vert force	α	W'	W_N	Ø	W_N·tanØ	C	Δℓ	C·Δℓ
W1	38.8	43.86	26.9	28.0	5.5	2.7	40.4	3.3	133.3
W2	147.8	27.85	69.0	130.7	5.5	12.6	40.4	3.4	137.4
W3	85.5	14.44	21.3	82.8	5.5	8.0	40.4	1.5	60.6
W4	46.2	5.88	4.7	46.0	5.5	4.4	40.4	4.4	177.8
W	67.0	-	-	67.0	5.5	6.5	40.4	3.0	121.2
W5	16.2	11.78	3.3	15.9	5.5	1.5	40.4	1.6	64.6
				370.4		37.7			694.9

Moving force W' = 370.4 kN

Resisting Force (WN·tanØ + C·Δℓ) = 730.6 kN

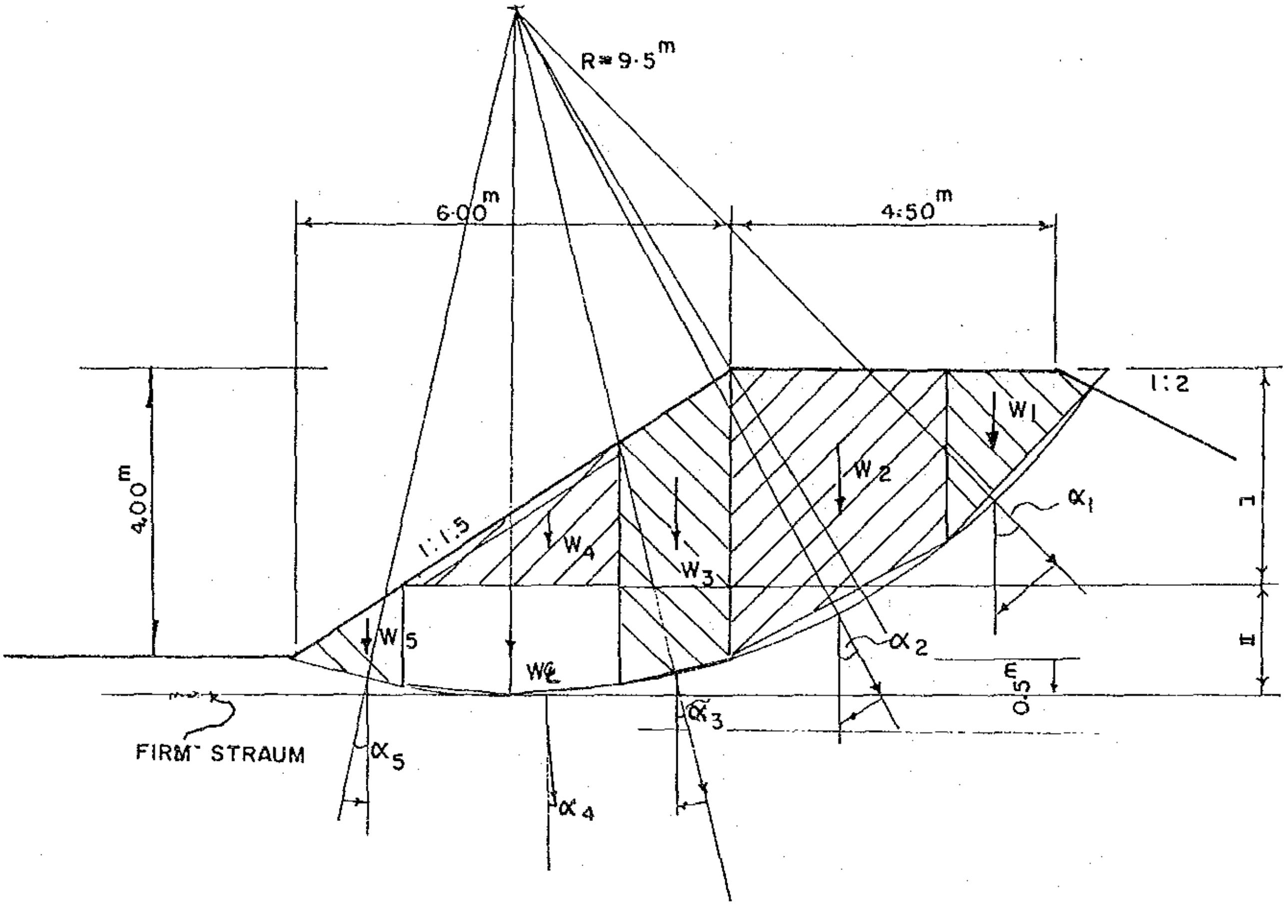
$$\text{Safety against sliding} = \frac{730.6}{370.4} = 1.97$$

6) Outside slope

The outside slope was considered in the light of dike saturation and stability of the embankment.

The outside slope of the canal was determined at 1 : 2.0.

FIGURE VII-5-1 SLOPE STABILITY CALCULATION (Method of Fellentus)



AREA	m^2
W_1	2.52
W_2	9.60
W_3	5.55
W_4	3.00
W_5	1.05

$W_{℄} = 4.35 \, m^2$

α	° deg
α_1	43.86'
α_2	27.85'
α_3	14.44'
α_4	5.88'
α_5	11.78'

7) Bank top width

In principle, one side of the canal bank is planned as an operation and maintenance road, and the other side as an inspection path.

The dimensions of these roads are presented below.

Item	O/M Road (m)	Inspection Road (m)
Main Canal	4.50	1.50
Secondary and sub-secondary canal	3.50	1.50

8) Freeboard

Water level in a canal always has the potential to rise above the designed water level.

Some of the major reasons are :

a) unexpected roughness coefficient caused by improper construction :

b) waving by wind ; and

c) increase in rainfall amount

Therefore, freeboard has been designed as follows with due consideration of the above points :

$$Fb = 0.25 \cdot d + 0.30$$

Fb : Freeboard (m)

d : water depth for design discharge (m)

9) Bed Gradient

Bed gradient of canal should normally be 1/5,000, as it was mentioned in the criteria.

Therefore bed gradient of Flood Plain main canal was determined at 1/5,000.

However, main canal of Barind area passed through fills to serve as a high area at the tail, therefore, the bed gradient was reduced to 1/7,000.

TABLE Ⅶ-5-1, Ⅶ-5-2 and TABLE Ⅶ-5-3 show the relationship of bed gradient and velocity based on the bed width.

The main canal longitudinal profile is shown in volume 4 DRAWINGS.

5-1-2 Canal Related Structures

(1) Bifurcations

Bifurcation structures are proposed to be installed to divert the irrigation water.

Bifurcatoins are to be graded into three types depending on diversion capacity and each of the type is further sub-divided into 1 to 4 types.

(2) Measurement Structures

Diversion of water from the main canal to the secondary canal will be done by a head gate attached with a water level gauge to record the water level in the main canal.

However, diversion from the secondary canal to the sub-secondary canal will be done by a constant head orifice.

(3) Check Gate

In order to control and raise the water level in the irrigation canal, check gate are proposed to be built in the midway of main canal so that the required water can be diverted at headgates and turnouts.

(4) Drop

A drop structure will be constructed to maintain the design bed slope.

The vertical drop is a simple structure well suited for small discharge, not for a large discharge and drop.

Therefore, for secondary canals, a chute type structure will be provided.

(5) Wasteway

In principle, wherever a change occurs in the main canal across section of a wasteway is planned.

(6) Crossing Facilities

An inverted siphon is planned for drainage canals in consideration of the relation between water level in the canal and water level in crossing the drainage canal, and in comparison of the flow amount in the irrigation canal and estimated flood in the drainage canal.

Although irrigation siphons are economical if estimated flood drainage is noticeably larger than the flow amount in the irrigation canal.

If a small drainage canal crosses an irrigation canal, a drainage culvert or drainage culvert pipe is more advantageous.

(7) Road Crossing Facilities

A bridge is planned where irrigation canal crosses the existing road.

If the flow amount is little, a road cross pipe will be constructed in the light of the economical approach.

(8) Over Chute

In case of drainage flow being relatively small, an overchute to convey the drainage water above the irrigation canal is planned rather than a drainage culvert in the view of the economy.

Installation of these structures discussed above is based on the results of field investigation and the numbers of structures are tabulated in Appendix X .

5-2. Drainage System

5-2-1. Kasba Drainage / Irrigation System

The drainage system in Flood Plain area is proposed to connect the Joakhali river at Kasba to the Ganges river site with a regulator and there is a possibility to use the proposed irrigation pump to drain off the flood water during the peak flooding.

Kasba D/I system is shown in FIGURE VII-5-2.

5-2-2. Regulator

Five drainage regulators are provided at the outlet of drainage units. TABLE Ⅶ-5-4 shows the size and location of each regulator.

TABLE Ⅶ-5-4 REGULATOR TYPE

No.	Location	Width	× height	× Nos.	Type
1	Junction of D2 canal and Sib river	3.0	5.0	10	A1
2	Junction of D3R canal and Ganges river	3.0	3.0	10	A2
3	Joakhari river	3.0	5.0	10	A1
4	D1 canal	-	-	-	B
5	D4 canal	-	-	-	B

5-2-3. New Drainage Canals

Location of the newly proposed drainage canals are shown in FIGURE Ⅶ-3-3, and canal lengths are tabulated below.

LENGTH OF NEW DRAINAGE CANALS

Canal	Length (m)
D2L	2,550
D3	1,100
Total	3,650

(1) Design Criteria

1) Mean velocity Formula

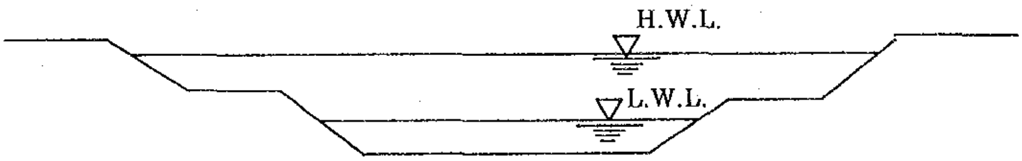
Mean velocity was calculated by the Manning Formula with a roughness coefficient "n" of 0.035.

2) Maximum and Minimum Velocity

Maximum and Minimum flow velocties at design discharge would be adopted as 0.7 m/s and 0.3 m/s.

3) Canal Cross Section

Cross Section of a drainage canal is planned as complex sections shown below.



Typical cross section of a drainage canal is composed of a low water discharge area and a high water discharge area.

TABLE Ⅶ-5-5 shows the relationship of bed gradient and velocity based on the bed width.

4) Freeboard

The design water levels were determined from the following minimum depth below ground level.

Q (m^3/s)	Minimum Freeboard (m)
Less than 8.0	0.20
8.0 - 100.0	0.30

5-2-4. Improvement of Existing Drainage Canals

During the field survey, shortage of drainage capacity in the existing canals and rivers was observed.

Rehabilitation of existing canals are proposed according to the drainage analysis, with emphasis on the following points.

a) expansion of narrow sections ; and

b) improvement of extreme meandering.

The existing canals to be excavated are tabulated below.

Canal	Length(m)
D1	2,600
D1R	950
D1L	1,050
D2	2,950
D2R	1,550
D3R	2,500
D3L	3,550
D4	500
D5	4,300
Total	19,950

TABLE VII-5-1

*** HYDRAULIC DESIGN OF OPEN CANAL BY MANNINGS MEAN FLOW VELOCITY FORMULA ***

SIDE SLOPE S = 1/1.50
COEFFICIENT OF ROUGHNESS N = 0.030

BED WIDTH	I :	1/ 3000	1/ 3500	1/ 4000	1/ 4500	1/ 5000	1/ 5500	1/ 6000	1/ 7000	1/ 8000	1/10000
1.00	H :	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	V :	0.28	0.26	0.24	0.23	0.22	0.21	0.20	0.18	0.17	0.15
	Q :	0.25	0.23	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.13
1.50	H :	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
	V :	0.37	0.34	0.32	0.30	0.28	0.27	0.26	0.24	0.22	0.20
	Q :	0.72	0.67	0.63	0.59	0.56	0.53	0.51	0.47	0.44	0.40
2.00	H :	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	1.00	1.00
	V :	0.36	0.33	0.31	0.29	0.28	0.27	0.25	0.24	0.27	0.24
	Q :	0.72	0.67	0.62	0.59	0.56	0.53	0.51	0.47	0.95	0.85
2.50	H :	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
	V :	0.42	0.39	0.36	0.34	0.32	0.31	0.30	0.27	0.26	0.23
	Q :	1.30	1.21	1.13	1.06	1.01	0.96	0.92	0.85	0.80	0.71
3.00	H :	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	V :	0.47	0.44	0.41	0.38	0.36	0.35	0.33	0.31	0.29	0.26
	Q :	2.12	1.96	1.84	1.73	1.64	1.57	1.50	1.39	1.30	1.16
3.50	H :	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
	V :	0.52	0.48	0.45	0.43	0.40	0.39	0.37	0.34	0.32	0.29
	Q :	3.20	2.96	2.77	2.61	2.48	2.36	2.26	2.09	1.96	1.75
4.00	H :	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
	V :	0.57	0.53	0.49	0.47	0.44	0.42	0.40	0.37	0.35	0.31
	Q :	4.57	4.23	3.95	3.73	3.54	3.37	3.23	2.99	2.80	2.50
4.50	H :	1.13	1.13	1.13	1.13	1.50	1.50	1.50	1.50	1.50	1.50
	V :	0.53	0.49	0.46	0.43	0.48	0.46	0.44	0.40	0.38	0.34
	Q :	3.69	3.42	3.20	3.01	4.84	4.62	4.42	4.09	3.83	3.42
5.00	H :	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.67
	V :	0.57	0.53	0.49	0.46	0.44	0.42	0.40	0.37	0.35	0.36
	Q :	4.89	4.53	4.23	3.99	3.79	3.61	3.46	3.20	2.99	4.53
5.50	H :	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38
	V :	0.61	0.56	0.53	0.50	0.47	0.45	0.43	0.40	0.37	0.33
	Q :	6.30	5.84	5.46	5.15	4.88	4.66	4.46	4.13	3.86	3.45

V > 0.3 m/s

H : WATER DEPTH (M)
V : MEAN VELOCITY (M/SEC)
Q : DISCHARGE (M**3/SEC)

TABLE VII-5-2

*** HYDRAULIC DESIGN OF OPEN CANAL BY MANNINGS MEAN FLOW VELOCITY FORMULA ***

SIDE SLOPE S = 1/1.50
COEFFICIENT OF ROUGHNESS N = 0.030

BED WIDTH	I :	1/ 3000	1/ 3500	1/ 4000	1/ 4500	1/ 5000	1/ 5500	1/ 6000	1/ 7000	1/ 8000	1/10000
6.00	H :	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
	V :	0.64	0.59	0.56	0.52	0.50	0.47	0.45	0.42	0.39	0.35
	Q :	7.95	7.36	6.89	6.49	6.16	5.87	5.62	5.21	4.87	4.35
6.50	H :	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63
	V :	0.68	0.63	0.59	0.55	0.52	0.50	0.48	0.44	0.42	0.37
	Q :	9.84	9.11	8.52	8.04	7.62	7.27	6.96	6.44	6.03	5.39
7.00	H :	1.40	1.40	1.40	1.75	1.75	1.75	1.75	1.75	1.75	1.75
	V :	0.63	0.58	0.55	0.58	0.55	0.53	0.50	0.47	0.44	0.39
	Q :	8.05	7.45	6.97	9.79	9.29	8.86	8.48	7.85	7.34	6.57
7.50	H :	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.88	1.88	1.88
	V :	0.66	0.61	0.57	0.54	0.51	0.49	0.47	0.49	0.46	0.41
	Q :	9.67	8.96	8.38	7.90	7.49	7.14	6.84	9.44	8.83	7.90
8.00	H :	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	2.00
	V :	0.69	0.64	0.60	0.56	0.53	0.51	0.49	0.45	0.42	0.43
	Q :	11.49	10.64	9.95	9.38	8.90	8.49	8.12	7.52	7.04	9.38
8.50	H :	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
	V :	0.72	0.67	0.62	0.59	0.56	0.53	0.51	0.47	0.44	0.39
	Q :	13.51	12.50	11.70	11.03	10.46	9.97	9.55	8.84	8.27	7.40
9.00	H :	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
	V :	0.75	0.69	0.65	0.61	0.58	0.55	0.53	0.49	0.46	0.41
	Q :	15.73	14.56	13.62	12.84	12.18	11.62	11.12	10.30	9.63	8.62
9.50	H :	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
	V :	0.77	0.72	0.67	0.63	0.60	0.57	0.55	0.51	0.47	0.42
	Q :	18.17	16.82	15.73	14.83	14.07	13.42	12.85	11.89	11.13	9.95
10.00	H :	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
	V :	0.80	0.74	0.69	0.65	0.62	0.59	0.57	0.52	0.49	0.44
	Q :	20.83	19.29	18.04	17.01	16.14	15.39	14.73	13.64	12.76	11.41
10.50	H :	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
	V :	0.83	0.77	0.72	0.68	0.64	0.61	0.59	0.54	0.51	0.45
	Q :	23.73	21.97	20.55	19.37	18.38	17.52	16.78	15.53	14.53	13.00

H : WATER DEPTH (M)
V : MEAN VELOCITY (M/SEC)
Q : DISCHARGE (M**3/SEC)

V >0.7 m/s

TABLE VII-5-3

*** HYDRAULIC DESIGN OF OPEN CANAL BY MANNINGS MEAN FLOW VELOCITY FORMULA ***

SIDE SLOPE S = 1/1.50
COEFFICIENT OF ROUGHNESS N = 0.030

BED WIDTH	I :	1/ 3000	1/ 3500	1/ 4000	1/ 4500	1/ 5000	1/ 5500	1/ 6000	1/ 7000	1/ 8000	1/10000
11.00	H :	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
	V :	0.85	0.79	0.74	0.70	0.66	0.63	0.60	0.56	0.52	0.47
	Q :	26.86	24.87	23.26	21.93	20.81	19.84	18.99	17.58	16.45	14.71
11.50	H :	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
	V :	0.88	0.81	0.76	0.72	0.68	0.65	0.62	0.58	0.54	0.48
	Q :	30.24	28.00	26.19	24.69	23.42	22.33	21.38	19.80	18.52	16.56
12.00	H :	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40
	V :	0.90	0.84	0.78	0.74	0.70	0.67	0.64	0.59	0.55	0.50
	Q :	33.88	31.36	29.34	27.66	26.24	25.02	23.95	22.18	20.74	18.55
12.50	H :	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
	V :	0.93	0.86	0.81	0.76	0.72	0.69	0.66	0.61	0.57	0.51
	Q :	37.77	34.97	32.71	30.84	29.26	27.90	26.71	24.73	23.13	20.69
13.00	H :	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60
	V :	0.95	0.88	0.83	0.78	0.74	0.70	0.67	0.62	0.58	0.52
	Q :	41.94	38.82	36.32	34.24	32.48	30.97	29.65	27.45	25.68	22.97
13.50	H :	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70
	V :	0.98	0.91	0.85	0.80	0.76	0.72	0.69	0.64	0.60	0.54
	Q :	46.38	42.94	40.16	37.87	35.92	34.25	32.79	30.36	28.40	25.40
14.00	H :	2.33	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
	V :	0.91	0.93	0.87	0.82	0.78	0.74	0.71	0.66	0.61	0.55
	Q :	37.07	47.31	44.25	41.72	39.58	37.74	36.13	33.45	31.29	27.99
14.50	H :	2.42	2.42	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
	V :	0.93	0.86	0.89	0.84	0.80	0.76	0.73	0.67	0.63	0.56
	Q :	40.71	37.69	48.59	45.81	43.46	41.44	39.68	36.73	34.36	30.73
15.00	H :	2.50	2.50	2.50	2.50	3.00	3.00	3.00	3.00	3.00	3.00
	V :	0.95	0.88	0.82	0.78	0.81	0.78	0.74	0.69	0.64	0.58
	Q :	44.56	41.25	38.59	36.38	47.58	45.36	43.43	40.21	37.61	33.64
15.50	H :	2.58	2.58	2.58	2.58	2.58	3.10	3.10	3.10	3.10	3.10
	V :	0.97	0.90	0.84	0.79	0.75	0.79	0.76	0.70	0.66	0.59
	Q :	48.63	45.02	42.11	39.70	37.67	49.51	47.40	43.88	41.05	36.72

H : WATER DEPTH (M)
V : MEAN VELOCITY (M/SEC)
Q : DISCHARGE (M**3/SEC)

V ≧ 0.7 m/s

TABLE VII-5-4 1/4

*** HYDRAULIC DESIGN OF OPEN CANAL BY MANNINGS MEAN FLOW VELOCITY FORMULA ***

SIDE SLOPE S = 1/1.50
COEFFICIENT OF ROUGHNESS N = 0.030

BED WIDTH	I :	1/ 100	1/ 300	1/ 500	1/ 700	1/ 1000	1/ 1500	1/ 2000	1/ 2500	1/ 3000	1/ 3500
0.30	H :	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
	V :	0.99	0.57	0.44	0.38	0.31	0.26	0.22	0.20	0.18	0.17
	Q :	0.22	0.13	0.10	0.08	0.07	0.06	0.05	0.04	0.04	0.04
0.50	H :	0.25	0.25	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	V :	0.97	0.56	0.62	0.53	0.44	0.36	0.31	0.28	0.26	0.24
	Q :	0.21	0.12	0.39	0.33	0.28	0.23	0.20	0.17	0.16	0.15
1.00	H :	0.33	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	V :	1.24	0.89	0.69	0.58	0.49	0.40	0.34	0.31	0.28	0.26
	Q :	0.62	0.77	0.60	0.51	0.42	0.35	0.30	0.27	0.25	0.23
1.50	H :	0.50	0.50	0.50	0.50	0.50	0.50	0.75	0.75	0.75	0.75
	V :	1.63	0.94	0.73	0.61	0.51	0.42	0.45	0.40	0.37	0.34
	Q :	1.83	1.06	0.82	0.69	0.58	0.47	0.88	0.79	0.72	0.67
2.00	H :	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
	V :	1.97	1.14	0.88	0.74	0.62	0.51	0.44	0.39	0.36	0.33
	Q :	3.94	2.27	1.76	1.49	1.25	1.02	0.88	0.79	0.72	0.67
2.50	H :	0.63	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
	V :	1.96	1.32	1.02	0.86	0.72	0.59	0.51	0.46	0.42	0.39
	Q :	4.22	4.12	3.19	2.70	2.26	1.84	1.60	1.43	1.30	1.21
3.00	H :	0.75	0.75	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	V :	2.22	1.28	0.99	0.98	0.82	0.67	0.58	0.52	0.47	0.44
	Q :	6.86	3.96	3.07	4.39	3.67	3.00	2.60	2.32	2.12	1.96
3.50	H :	0.70	0.88	0.88	0.88	0.88	1.17	1.17	1.17	1.17	1.17
	V :	2.18	1.42	1.10	0.93	0.78	0.74	0.64	0.57	0.52	0.48
	Q :	6.94	5.97	4.63	3.91	3.27	4.52	3.92	3.50	3.20	2.96
4.00	H :	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.33	1.33
	V :	2.38	1.55	1.20	1.02	0.85	0.69	0.60	0.54	0.57	0.53
	Q :	9.91	8.53	6.61	5.58	4.67	3.81	3.30	2.95	4.57	4.23
4.50	H :	0.90	0.90	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13
	V :	2.58	1.49	1.30	1.10	0.92	0.75	0.65	0.58	0.53	0.49
	Q :	13.57	7.83	9.04	7.64	6.39	5.22	4.52	4.04	3.69	3.42

H : WATER DEPTH (M)
V : MEAN VELOCITY (M/SEC)
Q : DISCHARGE (M**3/SEC)

0.3 ~ 0.7 m/s

2/4

*** HYDRAULIC DESIGN OF OPEN CANAL BY MANNINGS MEAN FLOW VELOCITY FORMULA ***

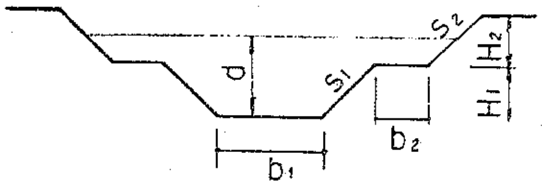
BED SLOP I = 1/10000 SIDE SLOPE (1ST) S1= 1/1.50

COEFFICIENT OF ROUGHNESS N = 0.035 (2ND) S2= 1/1.50

WATER DEPTH	BED WIDTH :	6.00 B2= 5.00 H1= 1.60 H2= 2.00	7.00 B2= 5.00 H1= 1.80 H2= 2.00	11.00 B2= 5.00 H1= 2.20 H2= 2.00	12.00 B2= 5.00 H1= 2.40 H2= 2.00	12.00 B2= 5.00 H1= 2.80 H2= 2.00	24.00 B2=10.00 H1= 4.00 H2= 2.00	30.00 B2=10.00 H1= 4.80 H2= 2.00	32.00 B2=10.00 H1= 4.80 H2= 2.00	35.00 B2=10.00 H1= 4.80 H2= 2.00	36.00 B2=10.00 H1= 4.80 H2= 2.00
0.0	V :	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Q :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2	V :	0.094	0.094	0.095	0.096	0.096	0.097	0.097	0.097	0.097	0.097
	Q :	0.1	0.1	0.2	0.2	0.2	0.5	0.6	0.6	0.7	0.7
0.4	V :	0.143	0.145	0.148	0.149	0.149	0.152	0.152	0.152	0.153	0.153
	Q :	0.4	0.4	0.7	0.7	0.7	1.5	1.9	2.0	2.2	2.2
0.6	V :	0.182	0.184	0.190	0.191	0.191	0.197	0.198	0.198	0.199	0.199
	Q :	0.8	0.9	1.4	1.5	1.5	2.9	3.7	3.9	4.3	4.4
0.8	V :	0.214	0.217	0.226	0.227	0.227	0.236	0.238	0.238	0.239	0.239
	Q :	1.2	1.4	2.2	2.4	2.4	4.8	5.9	6.3	6.9	7.1
1.0	V :	0.242	0.247	0.258	0.259	0.259	0.271	0.274	0.274	0.275	0.275
	Q :	1.8	2.1	3.2	3.5	3.5	6.9	8.6	9.2	10.0	10.3
1.2	V :	0.268	0.273	0.286	0.288	0.288	0.303	0.307	0.308	0.309	0.309
	Q :	2.5	2.9	4.4	4.8	4.8	9.4	11.7	12.5	13.6	14.0
1.4	V :	0.291	0.297	0.312	0.315	0.315	0.333	0.337	0.338	0.340	0.340
	Q :	3.3	3.8	5.7	6.2	6.2	12.2	15.2	16.2	17.6	18.1
1.6	V :	0.312	0.319	0.337	0.340	0.340	0.361	0.366	0.367	0.369	0.370
	Q :	4.2	4.8	7.2	7.8	7.8	15.2	19.0	20.2	22.1	22.7
1.8	V :	0.243	0.339	0.359	0.363	0.363	0.387	0.393	0.395	0.397	0.397
	Q :	4.3	5.9	8.9	9.6	9.6	18.6	23.1	24.6	26.9	27.7

B2 : 2ND BED WIDTH (M)
H1 : 1ST STEP HIGTH (M)

H : WATER DEPTH (M)
V : MEAN VELOCITY (M/SEC)
Q : DISCHARGE (M**3/SEC)



3/4

*** HYDRAULIC DESIGN OF OPEN CANAL BY MANNINGS MEAN FLOW VELOCITY FORMULA ***

BED SLOP I = 1/10000 SIDE SLOPE (1ST) S1= 1/1.50

COEFFICIENT OF ROUGHNESS N = 0.035 (2ND) S2= 1/1.50

WATER DEPTH	BED WIDTH :	6.00 B2= 5.00 H1= 1.60 H2= 2.00	7.00 B2= 5.00 H1= 1.80 H2= 2.00	11.00 B2= 5.00 H1= 2.20 H2= 2.00	12.00 B2= 5.00 H1= 2.40 H2= 2.00	12.00 B2= 5.00 H1= 2.80 H2= 2.00	24.00 B2=10.00 H1= 4.00 H2= 2.00	30.00 B2=10.00 H1= 4.80 H2= 2.00	32.00 B2=10.00 H1= 4.80 H2= 2.00	35.00 B2=10.00 H1= 4.80 H2= 2.00	36.00 B2=10.00 H1= 4.80 H2= 2.00
2.0	V :	0.276	0.268	0.381	0.385	0.385	0.412	0.419	0.420	0.423	0.424
	Q :	6.1	5.9	10.7	11.5	11.5	22.2	27.6	29.4	32.1	33.0
2.2	V :	0.305	0.299	0.401	0.405	0.405	0.435	0.443	0.445	0.448	0.449
	Q :	8.1	8.0	12.6	13.6	13.6	26.1	32.5	34.6	37.7	38.8
2.4	V :	0.333	0.327	0.331	0.425	0.425	0.458	0.466	0.469	0.472	0.473
	Q :	10.3	10.3	12.3	15.9	15.9	30.3	37.6	40.1	43.7	44.9
2.6	V :	0.359	0.354	0.359	0.354	0.444	0.479	0.489	0.491	0.495	0.496
	Q :	12.8	12.9	15.3	15.4	18.3	34.8	43.1	45.9	50.0	51.4
2.8	V :	0.383	0.379	0.385	0.381	0.462	0.500	0.510	0.513	0.517	0.518
	Q :	15.5	15.7	18.7	18.8	20.9	39.5	48.9	52.0	56.7	58.3
3.0	V :	0.406	0.402	0.409	0.406	0.386	0.520	0.531	0.534	0.538	0.540
	Q :	18.5	18.7	22.3	22.5	19.9	44.5	55.0	58.5	63.8	65.6
3.2	V :	0.428	0.425	0.432	0.429	0.411	0.539	0.551	0.555	0.559	0.560
	Q :	21.7	22.0	26.2	26.5	23.7	49.7	61.4	65.3	71.2	73.2
3.4	V :	0.449	0.446	0.455	0.452	0.434	0.558	0.571	0.574	0.579	0.580
	Q :	25.0	25.5	30.3	30.8	27.8	55.2	68.1	72.4	78.9	81.1
3.6	V :	0.469	0.467	0.476	0.474	0.456	0.576	0.590	0.593	0.598	0.600
	Q :	28.7	29.3	34.8	35.3	32.2	61.0	75.2	79.9	87.0	89.4
3.8	V :	*****	0.487	0.496	0.494	0.478	0.593	0.608	0.612	0.617	0.619
	Q :	******	33.2	39.4	40.2	36.9	67.0	82.5	87.7	95.5	98.1

B2 : 2ND BED WIDTH (M)
H1 : 1ST STEP HIGTH (M)

H : WATER DEPTH (M)
V : MEAN VELOCITY (M/SEC)
Q : DISCHARGE (M**3/SEC)

*** HYDRAULIC DESIGN OF OPEN CANAL BY MANNINGS MEAN FLOW VELOCITY FORMULA ***

BED SLOP I = 1/10000 SIDE SLOPE (1ST) S1= 1/1.50

COEFFICIENT OF ROUGHNESS N = 0.035 (2ND) S2= 1/1.50

WATER DEPTH	BED WIDTH :	6.00 B2= 5.00 H1= 1.60 H2= 2.00	7.00 B2= 5.00 H1= 1.80 H2= 2.00	11.00 B2= 5.00 H1= 2.20 H2= 2.00	12.00 B2= 5.00 H1= 2.40 H2= 2.00	12.00 B2= 5.00 H1= 2.80 H2= 2.00	24.00 B2=10.00 H1= 4.00 H2= 2.00	30.00 B2=10.00 H1= 4.80 H2= 2.00	32.00 B2=10.00 H1= 4.80 H2= 2.00	35.00 B2=10.00 H1= 4.80 H2= 2.00	36.00 B2=10.00 H1= 4.80 H2= 2.00
4.0	V : Q :	***** ******	***** ******	0.516 44.4	0.514 45.3	0.499 41.9	0.610 73.3	0.626 90.1	0.630 95.8	0.636 104.2	0.637 107.1
4.2	V : Q :	***** ******	***** ******	0.535 49.6	0.534 50.6	0.519 47.1	0.486 63.8	0.643 98.1	0.648 104.2	0.654 113.4	0.655 116.4
4.4	V : Q :	***** ******	***** ******	***** ******	0.553 56.3	0.538 52.6	0.510 72.7	0.660 106.3	0.665 112.9	0.671 122.8	0.673 126.1
4.6	V : Q :	***** ******	***** ******	***** ******	***** ******	0.557 58.4	0.532 82.1	0.677 114.8	0.681 121.9	0.688 132.6	0.690 136.2
4.8	V : Q :	***** ******	***** ******	***** ******	***** ******	0.575 64.5	0.555 91.9	0.693 123.7	0.698 131.3	0.705 142.7	0.707 146.5
5.0	V : Q :	***** ******	***** ******	***** ******	***** ******	***** ******	0.576 102.2	0.570 109.1	0.578 116.5	0.590 127.7	0.593 131.4
5.2	V : Q :	***** ******	***** ******	***** ******	***** ******	***** ******	0.597 113.0	0.591 120.9	0.599 128.8	0.611 140.8	0.614 144.9
5.4	V : Q :	***** ******	***** ******	***** ******	***** ******	***** ******	0.617 124.2	0.612 133.2	0.620 141.7	0.632 154.6	0.635 158.9
5.6	V : Q :	***** ******	***** ******	***** ******	***** ******	***** ******	0.637 135.9	0.632 146.1	0.640 155.1	0.652 168.8	0.655 173.4
5.8	V : Q :	***** ******	***** ******	***** ******	***** ******	***** ******	0.656 148.0	0.652 159.4	0.660 169.0	0.671 183.6	0.675 188.5

B2 : 2ND BED WIDTH (M)
H1 : 1ST STEP HIGTH (M)

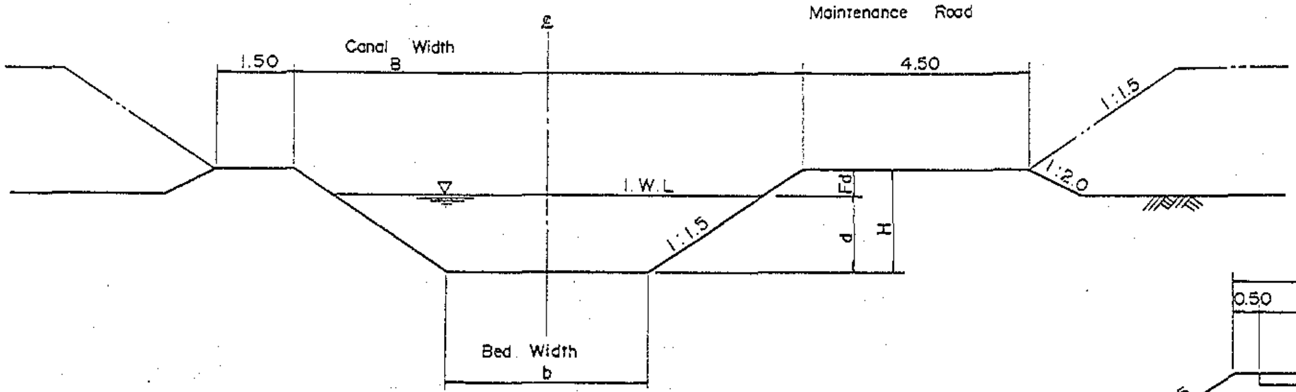
H : WATER DEPTH (M)
V : MEAN VELOCITY (M/SEC)
Q : DISCHARGE (M**3/SEC)

Dimension : m

TYPE	Q (m/s)	b	B	d	Fb	H	Total Length
M - I	36.00	14.5	26.20	2.88	1.02	3.90	10,800
M - II	30.60	13.5	24.90	2.78	1.02	3.80	21,600
M - III	17.85	11.0	20.30	2.22	0.88	3.10	10,200
M - IV	12.65	9.5	17.75	1.96	0.79	2.75	6,170
M - V	8.15	8.0	14.60	1.52	0.68	2.20	1,380
M - VI	7.50	7.5	14.10	1.50	0.70	2.20	6,020
M - VII	4.00	4.5	10.95	1.47	0.68	2.15	3,860
M - VIII	2.10	3.0	8.25	1.14	0.61	1.75	2,640

Note,

1. Slope M-I~IV 1/7,000
M-V~VIII 1/5,000



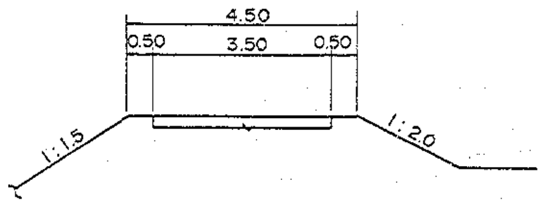


FIGURE VII-5-2 TYPICAL CROSS SECTION OF MAIN IRRIGATION CANAL

Barind Area

Dimension : m

TYPE	b	TYPE	b
BS - 1	9.0	BS - 8	3.5
- 2	8.5	- 9	3.0
- 3	7.0	- 10	2.5
- 4	6.0	- 11	2.0
- 5	5.5	- 12	1.5
- 6	4.5	- 13	1.0
- 7	4.0	- 14	0.5

Flood Plain Paba Area

Dimension ; m

TYPE	b
PS - 1	3.0
- 2	2.5
- 3	2.0
- 4	1.5
- 5	1.0
- 6	0.5

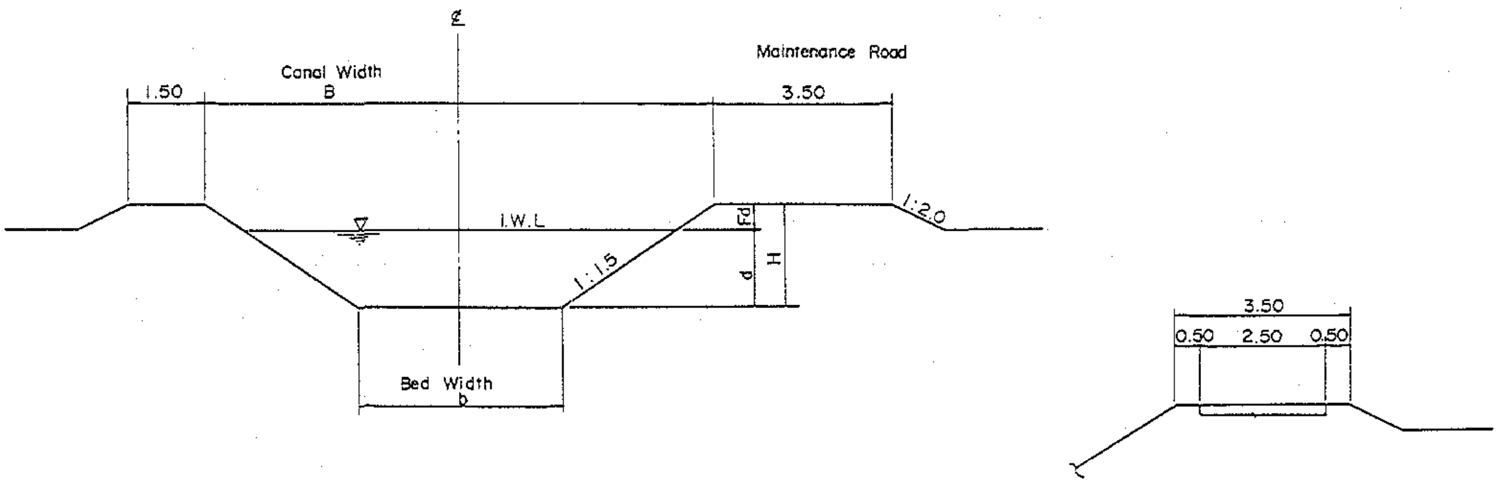


FIGURE VII-5-3 TYPICAL CROSS SECTION OF SECONDARY & SUB-SECONDARY CANAL

Drainge Canal	Q (m³/s) 1/2	Q (m³/s) 1/5	b_1	b_2	d_1	d_2	Fd	H	Length (m)
D 1	20.9	36.9	12.0	5.0	2.8	1.00	0.3	3.9	2,600
- 1 R	5.9	10.3	7.0	5.0	1.8	0.60	0.2	2.6	950
- 1 L	4.2	8.1	6.0	5.0	1.6	0.60	0.2	2.4	1,050
D 2	146.5	188.5	36.0	10.0	4.8	1.00	0.3	6.1	2,950
- 2R	15.4	22.5	12.0	5.0	2.4	0.60	0.3	3.3	1,550
- 2L	131.3	169.0	32.0	10.0	4.8	1.00	0.3	6.1	2,550
D 3	146.5	188.5	36.0	10.0	4.8	1.00	0.3	6.1	1,100
- 3R	12.6	18.7	11.0	5.0	2.2	0.60	0.3	3.1	2,500
- 3L	131.3	169.0	32.0	10.0	4.8	1.00	0.3	6.1	3,550
D 4	12.6	22.3	11.0	5.0	2.2	0.80	0.3	3.3	500
D 5	73.6	124.2	24.0	10.0	4.0	1.40	0.3	5.7	4,300

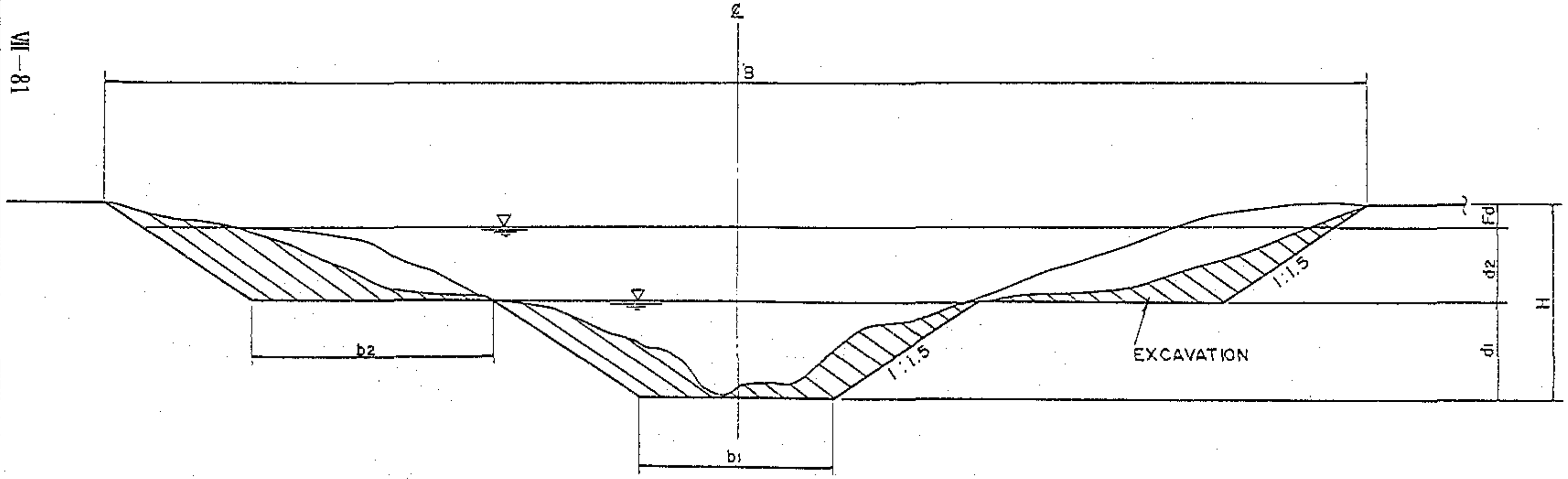


FIGURE VII-5-4 TYPICAL CROSS SECTION OF PROPOSED DRAINAGE CANAL

TABLE VII-5-5 (1) NUMBERS OF STRUCTURES (BARIND AREA)

(1/3)

Canul Name	CHECK		BIFURCATION			INVERT SIPHON			DRAINAGE CULVERT			DOUBLE ORIFICE	FARM TURNOUT	BRIDGE		AQUEDUCT	WAST-WAY		CHUTE		VERTICAL DROP		
	A	B	A	B	C	A	B	C	A	B	C			HIGH WAY	RAIL WAY		A	B	A	B	A	B	C
MAIN	1	1				2	3	1	1	1	1		-	4	1		4						
BS-1																							
BS1-S				2	12								32								29		49
BS-2					1								1										
BS-3					1																1		
BS-4					1																		
BS-5					1																		
BS5-S													2										
BS-6					1																		
BS-6-S													1						1				2
BS-7														1	3								
BS-7-S					2								21	3	2						16		24
BS-8													1										
BS-8-S													1										
BS-9					1																		
BS-9-S													1										
BS-10					1									1	1								2
BS-10-S													2	1							1		

Canul Name	CHECK		BIFURCATION			INVERT SIPHON			DRAINAGE CULVERT			DOUBLE ORIFICE	FARM TURNOUT	BRIDGE		AQUEDUCT	WAST-WAY		CHUTE		VERTICAL DROP		
	A	B	A	B	C	A	B	C	A	B	C			HIGH WAY	RAIL WAY		A	B	A	B	A	B	C
BS-11				1		2	3	1	1	1	1												
BS-11-S					1							1	2								2		3
BS-12				1																			
BS-12-S					1								4								1		
BS-13													1										
BS-14					1																3		
BS-14-S													3										
BS-15					1																		
BS-15-S													1										
BS-16					1																2	1	
BS-16-S													1										
BS-17					1									1									
BS-18			1											1						1			
BS-18-S				2	3							2	5	1							3		
BS-19				1																			
BS-19-S													1								1		
BS-20					1																3		
BS-20-S													2										
BS-21			1																				
BS-21-S				1	3								1								2		

(3/3)

Canul Name	CHECK		BIFURCATION			INVERT SIPHON			DRAINAGE CULVERT			DOUBLE ORIFICE	FARM TURNOUT	BRIDGE		AQUEDUCT	WAST-WAY		CHUTE		VERTICAL DROP		
	A	B	A	B	C	A	B	C	A	B	C			HIGH WAY	RAIL WAY		A	B	A	B	A	B	C
BS-22			1											2									
BS-22-5				3	1							1	5	3									1
BS-23														1									
BS-23-S				1	1								1										
Total	1	1	3	12	36	4	6	2	2	2	2	4	89	19	7	0	4	0	1	1	64	1	81

TABLE VII-5-5 (2) NUMBERS OF STRUCTURES (FLOOD PLAIN AREA)

Canul Name	CHECK		BIFURCATION			INVERT SIPHON			DRAINAGE CULVERT			DOUBLE ORIFICE	FARM TURNOUT	BRIDGE		AQUEDUCT	WAST-WAY		CHUTE		VERTICAL DROP		
	A	B	A	B	C	A	B	C	A	B	C			HIGH WAY	RAIL WAY		A	B	A	B	A	B	C
MAIN		1						2			1		-	4	1	-		4					
PSR-1				-										2	1								
PSL-1			1													1							
PSR-2				-									1	1									
PSL-2					1								-	1									
PSL-3													1	1									
PSL-4				1									-										
PSR-3			1										-	1		1							
PSR-4					1									1									
PSL-5			1											1									
PSL5-S				1	1								3	1							1		
PSL-6			1											1									
PSR-5													1										
PSR-6					1																		
PSL-7			1											2		1							
PSL-7-S													1										
TOTAL	0	1	5	2	4	0	0	2	0	0	1	0	7	16	2	3	0	0	0	0	1	0	0

5-3. Typical Plan for On-Farm Facilities

(1) Tertiary Canal

1) Canal Density

Generally, a tertiary canal shall cover 50~60 hectare as a command area, however, the density is varied depending on the topographic condition, particularly, its land slope, and circumstances of the valley or the ridge in the project area.

2) Canal capacities

The water requirement of tertiary canals has given 1.55 ℓ/s/ha in this project, and the requirement is maximum value in daily water requirement. In case of design of the tertiary canal, the length of canal shall be at around 500 meter to 1,000 meter, furthermore, it should be considered to have rotational irrigation methods in case of shortage of water supply.

Taking into consideration of the above mentioned points, the maximum design capacity is given from the beginning point to the end point of canal.

3) Canal and appurtenance structure

Canal and an appurtenance structure for the tertiary canals are considered as follows ;

- Canals shall be constructed by earth materials and particularly, the compaction works should be performed carefully with proper equipment.
- Intake structures should be constructed at the beginning point of canals and the details lay-out is shown in Drawing No. 301 in Volume 4.
- Check structures
  The structure shall be installed at the downstream of the conjunctions with farm ditches.
  The detail of lay-out for a structure is shown in Drawing No. 301 in Volume 4.

The end point of all tertiary canals shall be connected to existing drainage channels.

(2) Farm Ditch

1) Canal Density

The densities of farm-ditches shall be decided based on topographical condition, particularly, the shapes of farm lot is the most effective for canal alignment.

Generally, the command area of a farm ditch is kept at about 5 hectare to 10 hectare.

2) Canal capacities

In case of design of the farm ditches, the basic factors applied are same as of the tertiary canals.

3) Canals and Appurtenance structure

The basic ideaes for above mentioned subjects to be applied are same as the theories for tertiary canals.

(3) Farm Drain

1) Canal Density

If the shape of farm-lot are arranged and resettled based on some design criteria, the canal density shall be closed to tertiary canals, however, there are no proposals to reshape and resettle for the existing farm-lots. Accordingly, the canal alignment should be carried out depending on the detailed field survey. As a results of lay-out on the sample area, the length of the canal is estimated at about 44 m/ha to 31 m/ha.

2) Canal capacity

According to the hydrological analysis of the project area, the unit discharge of drainage scheme estimated at 8 ℓ/s/ha.

3) Canal and Appurtenance structures

The canal should be constructed at the lowest area of the drainage area, and it shall be located at the right angle to the contour line as much as possible. An appurtenance is considered to be prepared for the protection of erosion in the river bed at the confluence.

TABLE VII-5-6

*** HYDRAULIC DESIGN OF OPEN CANAL BY MANNINGS MEAN FLOW VELOCITY FORMULA ***

SIDE SLOPE S = 1/1.00
COEFFICIENT OF ROUGHNESS N = 0.030

BED WIDTH 'b'	I :	1/ 200	1/ 300	1/ 500	1/ 700	1/ 1000	1/ 2000	1/ 3000	1/ 4000	1/ 5000	1/ 7000
0.10	H :	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	V :	0.33	0.27	0.21	0.18	0.15	0.10	0.09	0.07	0.07	0.06
	Q :	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.15	H :	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	V :	0.43	0.35	0.27	0.23	0.19	0.14	0.11	0.10	0.09	0.07
	Q :	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
0.20	H :	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
	V :	0.52	0.43	0.33	0.28	0.23	0.17	0.14	0.12	0.10	0.09
	Q :	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01
0.25	H :	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	V :	0.61	0.50	0.38	0.32	0.27	0.19	0.16	0.14	0.12	0.10
	Q :	0.08	0.06	0.05	0.04	0.03	0.02	0.02	0.02	0.02	0.01
0.30	H :	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
	V :	0.69	0.56	0.43	0.37	0.31	0.22	0.18	0.15	0.14	0.12
	Q :	0.12	0.10	0.08	0.07	0.06	0.04	0.03	0.03	0.02	0.02
0.35	H :	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	V :	0.76	0.62	0.48	0.41	0.34	0.24	0.20	0.17	0.15	0.13
	Q :	0.19	0.15	0.12	0.10	0.08	0.06	0.05	0.04	0.04	0.03
0.40 Tertiary	H :	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
	V :	0.83	0.68	0.52	0.44	0.37	0.26	0.21	0.19	0.17	0.14
	Q :	0.27	0.22	0.17	0.14	0.12	0.08	0.07	0.06	0.05	0.04
0.45	H :	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
	V :	0.90	0.73	0.57	0.48	0.40	0.28	0.23	0.20	0.18	0.15
	Q :	0.36	0.30	0.23	0.19	0.16	0.11	0.09	0.08	0.07	0.06
0.50 Farm drain	H :	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	V :	0.96	0.79	0.61	0.51	0.43	0.30	0.25	0.22	0.19	0.16
	Q :	0.48	0.39	0.30	0.26	0.22	0.15	0.12	0.11	0.10	0.08

H : WATER DEPTH (M)
V : MEAN VELOCITY (M/SEC)
Q : DISCHARGE (M**3/SEC)

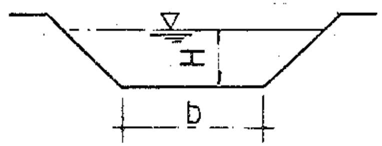
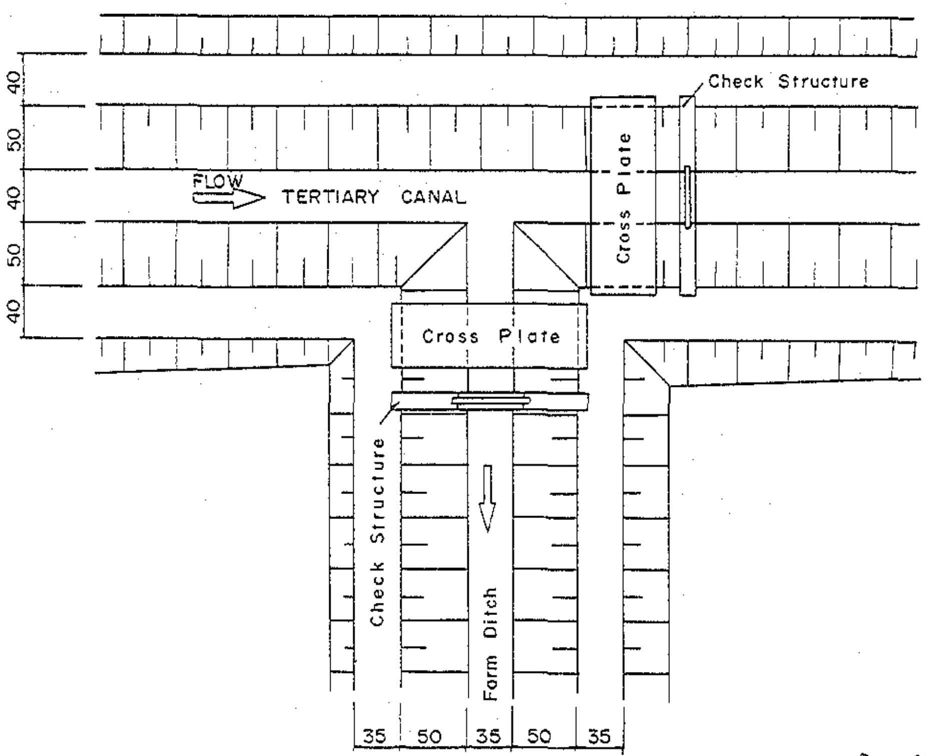
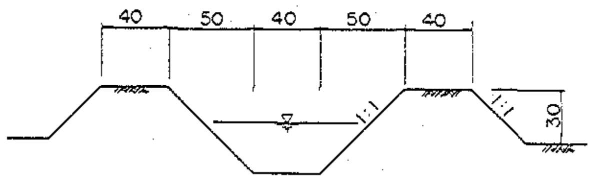


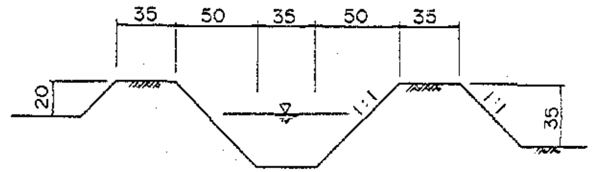
FIGURE VII-5-5 ON-FARM FACILITIES



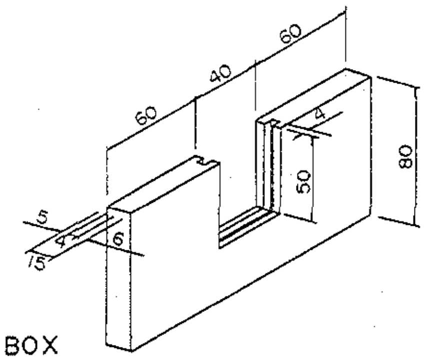
SCHEMATIC PLAN FOR DIVISION BOX



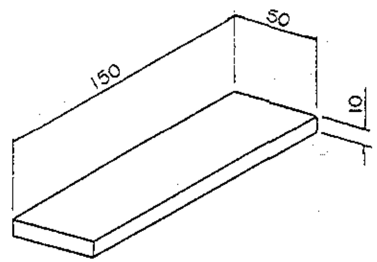
TERTIARY CANAL



FARM DITCH



DIMENSION OF CHECK STRUCTURE



DIMENSION OF CROSS PLATE

DIMENSION ; cm

6. SUPPLEMENTAL CONPONENTS

6-1. Road Network

6-1-1. On-going Road Improvement works

The road networks in the project area are currently improved by Road & Highway division under the plan of Bangladesh Rural Development Corperation (See FIGURE Ⅶ-6-1).

6-1-2. Proposed Link Road and O & M Road

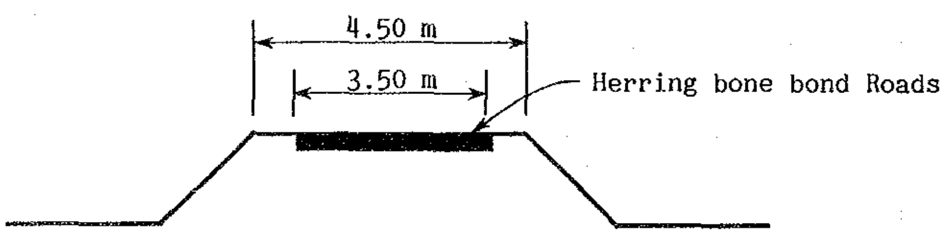
The length of the main canal and secondary canal will be about 56 km from Godagari to Niamatpur, and the O & M road along the canal can be used for rural road by paving the road surface by brick (Herring bone bond road).

The supplemental link roads along the secondary canal will be considered to connect with existing road.

The accessible road networks during rainy season should be established in the Project area.

6-1-3. Design of Link Road

The typical cross section of a Link Road is as follows.



Link Road

FIGURE VII-6-1 THE MAP OF RURAL ROAD NETWORKS