Government of the People's Republic of Bangladesh
Bangladesh Water Development Board
Water Resource Planning Organisation

NORTHEAST REGIONAL WATER MANAGEMENT PROJECT (FAP 6)

DAMPARA WATER MANAGEMENT PROJECT

FEASIBILITY STUDY
ANNEX A: ENGINEERING
FINAL REPORT

February 1997

SNC • LAVALIN International
Northwest Hydraulic Consultants

in association with

Engineering and Planning Consultants Ltd.
Bangladesh Engineering and Technological Services

Canadian International Development Agency

COVER PHOTO: A typical village in the deeply flooded area of the Northeast Region. The earthen village platform is created to keep the houses above water during the flood season which lasts for five to seven months of the year. The platform is threatened by erosion from wave action; bamboo fencing is used as bank protection but often proves ineffective. The single *hijal* tree in front of the village is all that remains of the past lowland forest. The houses on the platform are squeezed together leaving no space for courtyards, gardens or livestock. Water surrounding the platform is used as a source of drinking water and for waste disposal by the hanging latrines. Life in these crowded villages can become very stressful especially for the women, because of the isolation during the flood season. The only form of transport from the village is by small country boats seen in the picture. The Northeast Regional Water Management Plan aims to improve the quality of life for these people.

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ACRONYMS AND ABBREVIATIONS

AST	Agriculture Sector Team
BADC	Bangladesh Agricultural Development Corporation
BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Meteorological Department
BRDB	Bangladesh Rural Development Board
BWDB	Bangladesh Water Development Board
CIDA	Canadian International Development Agency
DAE	Department of Agricultural Extension
DPHE	Department of Public Health Engineering
DSSTW	deep set shallow tube well
DTW	deep tube well
FAO	Food and Agriculture Organization (United Nations Agency)
FAP	Flood Action Plan
FCD	Flood control and drainage
FFW	Food for Works
FPCO	Flood Plan Coordination Organization
FW	future with project scenario
FWO	future without project scenario
GEV	General Extreme Value
ha	hectare
HTW	hand tube well
HYV	high yielding variety
kg	kilogram
km	kilometer
LGED	Local Government Engineering Department
LLP	low lift pump
m	meter
MB	motorized boat
mm	millimetre
Mm^3	million cubic meters
MOSTI	manually operated shallow tube well
NERP	Northeast Regional Water Management Project (FAP 6)
NGO	non-government organization
NMB	non-motorized boat
PWD	Public Works Department
RCC	reinforced cement concrete
STW	shallow tube well
WARPO	Water Resources Planning Organization

GLOSSARY OF TERMS

aman	late monsoon rice crop
aus	early monsoon rice crop
beel	natural depression surrounded by floodplain
boro	dry season rice crop
durba	grass
khal	natural drainage channel
khas	Government-owned land
thana	geo-administrative unit under a district comprising several unions

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A.1 Project Area

A.1.1 General Description

Location
The Dampara Water Management Project lies northwest of Netrokona Town and is located between latitudes 24°56'N and 25°03'N and longitudes 90°23'E and 90°39'E. It is bounded by the Kangsha River to the north, the Phulpur-Netrokona Road to the south, the Kharia River to the west and the Bangladesh Water Development Board's (BWDB) Kangsha River Project's west embankment to the east (Figure A.1). The project covers a gross area of 15,000 ha spread over the Purbadhala and Phulpur *thanas*. About 11,361 ha (76%) of the area lies in Purbadhala Thana and 3,639 ha (24%) in Phulpur Thana.

Accessibility
The area is easily accessible by road and rail from Dhaka via Mymensingh Town. In addition to other seasonally motorable roads, Mymensingh is connected to the project area by the following all-weather roads:

- Mymensingh-Phulpur Road;
- Mymensingh-Shymganj-Purbadhala Road;
- Mymensingh-Netrokona-Purbadhala Road.

The area is also connected by the Mymensingh-Shymganj-Purbadhala-Jaria railway line; the terminal point is at Jaria (Figure A.1).

Population
According to the 1991 census, the project area has a population of about 112,125. The population density is 747 per km^2 which is very close to the national figure of 755. There are 21,548 households in the area with an average of 5.23 members. This is slightly lower than the figure for Bangladesh (5.48). The gender ratio (male/female), which is 103:100, is also lower than the national figure of 106:100.

Population increased at an annual rate of 1.54 percent during the 10-year period from 1981 to 1991. This is much lower than the national figure of 2.01 percent. This may be due to net out-migration.

Topography
The project area is roughly elliptical in shape measuring 23.5 km east to west and 9.0 km north to south at its widest points. The general slope of the land is downwards from west to east, but the land also slopes away from the boundary rivers toward the basin centre. Kalihar and Balia, the two major drainage channels of the area, run from west to east through the basin centre.

Land elevations range from about 13.0 m (PWD) in the west near Phulpur to 6.5 m (PWD) in the east near Jaria (Figure A.2). The area-elevation-storage relation was computed from land levels obtained from water development maps. These maps are drawn at a scale of four inches:one mile and one-foot contour intervals. The data is provided in Table A-1 and illustrated graphically in Figure A.3.

Table A-1: Elevation-Area-Storage Relation

Elevation (m, PWD)	Area (ha)	Storage (ha-m)	Elevation (m, PWD)	Area (ha)	Storage (ha-m)
6.24	6.33	0.00	10.00	6725.01	5710.50
6.50	12.65	2.47	10.50	9559.26	9781.57
7.00	63.26	21.45	11.00	11419.23	15026.19
7.50	170.81	79.97	11.50	12741.46	21066.36
8.00	550.40	260.27	12.00	13892.87	27724.95
8.50	1056.52	662.00	12.50	14626.74	34854.85
9.00	2163.64	1467.04	13.00	15000.00	42261.54
9.50	4042.60	3018.60	-	-	-

Climate

There are no climatological stations within the project area. Though located outside the project area, Mymensingh climatological station collects data relevant to the project area. Data from this station was obtained from the Bangladesh Meteorological Department (BMD). The processed data, based on 45 years of record from 1950-94, are provided in Table A-2 and illustrated in Figure A.4.

As shown in Table A-2, mean monthly temperatures remain fairly stable around 28°C between the months of April and September. After October, temperatures begin to fall and mean monthly temperatures reach a minimum of 21.5°C in January. In April, maximum daily temperatures in the area often exceed 35°C. Increased cloud cover during the June-September period prevents extremes of temperature, though the sun is at its peak maximum decline.

Relative humidity is high throughout the year. Maximum values occur in July, with a mean of 85 percent. February produces the lowest value of 68 percent.

The mean monthly evaporation rate is highest in April (5.9 mm/day) and lowest in January (2.3 mm/day). Potential evapotranspiration is at its maximum in April (162 mm) and minimum in December (87 mm). Potential evapotranspiration exceeds rainfall between November and April. It is clear from the ET_0 and rainfall plot that there is a need for irrigation between the months of November and April under average rainfall conditions.

Rainfall is highly variable in the regions, and that measured at Mymensingh station does not give and accurate representation of rainfall in the project area. The project's rainfall conditions, therefore, are described separately in A.2.

River Systems
The project area is bounded by the Kangsha River to the north and the Kharia River to the west. The Mogra River runs outside the project boundary to the south (Figure A.5).

Kharia River
The Kharia River originates from the Old Brahmaputra River at Char Niamat, travels 40 km northeast along the periphery of project area, and spills into the Kangsha River at Silpur(Figure A.5: Key Plan). About two hundred years ago this river was a major distributary channel of Brahmaputra River. At that time, it dominated the Kangsha flow. With the change of course of the Brahmaputra River, the Kharia has experienced heavy siltation in the upstream reaches. It is now closed at the offtake. Morphologically, the river is inactive, and it receives very little drainage from the adjoining areas. Its water level is now controlled by the Kangsha level at the confluence.

No hydrometric data is collected for this river by any agency.

Kangsha River
The Kangsha River originates at the confluence of the Bhogai and Malijhee, upstream of Sarchapur Bridge, from where it follows an easterly course until it joins the Baulai in the central depression of Northeast Region. The Kangsha River reach between the outfalls of Kharia River at Silpur and Balia Channel at Chorerbhita forms the project's northern boundary.

Two hundred years ago, the Kangsha was a direct continuation of the Kharia River. Therefore, the present Kangsha River is occupying a former distributary spill channel that probably had a different hydrologic regime. The channel is still adjusting to this change, and is very slowly reducing its size and slope by point bar accretion. The tortuous meander pattern and active formation of inner levees within a wide active floodplain are signs of this adjustment as the river forms a channel section that is approximately one-half the width of the original channel.

Near the project area, water levels and discharges in the Kangsha River are observed by BWDB at Sarchapur and Jaria. Their locations are shown in Figure A.5.

Table A-2: Climatological Data

Month	Rain (mm)	Temperature (°C)			Sunshine Hours (hrs/day)	Relative Humidity(%)	Evaporation (mm/day)	Wind Speed (knots)	Potential Evapotranspiration (mm)
		M Max	M Min	Mean					
Jan	11	25.7	9.8	21.5	8.0	74	2.3	6	91
Feb	18	28.4	13.6	23.9	7.5	68	3.3	4	106
Mar	40	32.2	17.3	27.8	8.1	67	4.4	5	149
Apr	103	34.7	20.2	30.2	7.7	71	5.9	6	162
May	327	32.2	20.5	29.4	6.4	79	5.5	6	160
Jun	419	32.2	21.7	29.7	4.5	84	4.7	5	132
Jul	410	32.1	21.7	29.9	3.5	85	4.6	5	134
Aug	367	32.2	21.7	30.2	3.7	84	4.6	5	134
Sep	319	32.1	21.5	29.7	3.9	84	3.9	4	122
Oct	202	32.1	21.3	29.2	7.0	81	3.9	4	124
Nov	23	30.5	15.9	26.7	8.0	75	2.9	3	105
Dec	5	27.3	11.4	23.1	8.4	75	2.4	3	87
Year	2219	30.5	19.1	27.7	6.4	77	4.0	4	1506

Source: BMD

Note: 1. The Bangladesh Meteorological Department uses the standard Weather Bureau Class A pan for estimation of daily evaporation rate. Water surface level is measured by gauge at 6 am and 6 pm daily. Evaporation is computed as the difference between the observed levels, adjusted for any precipitation measured in a standard rain gauge.

2. Potential evapotranspiration estimates were computed using the Penman Method.

Mogra River
Mogra River originates on the floodplain south of the project area and flows eastward to fall on Baulai in the central depression. Netrokona gauging site, where BWDB measures water level and discharge, is the nearest site to the project area. Northeast Regional Project (NERP) in its 1994 hydrometric data collection programme, installed a water-level gauge at Trimohoni. Hydrometric data collection sites are shown in Figure A.5.

Drainage Channels
Kalihar, Balia and Dhalai are the three major drainage channels of the project area. Mohespatti is a minor drainage channel (see Figure A.5).

Kalihar Channel originates from Kuma Beel and flows into the Kangsha River at Khatuair above Jaria after travelling 22 km over the project land. Balia Channel originates at Shadhupara and falls on the Kangsha at Chorerbhita below Jaria after travelling 15.5 km over the project land. Dhalai Channel originates from Saljan Beel and flows into the Mogra at Tarakanda. Its length is about 15.5 km. Moheshpatti Channel flows into the Kangsha at Moheshpatti Village and mainly drains Moheshpatti Beel.

A.1.2 Hydrometeorology

Rainfall
Data Sources: The Bangladesh Water Development Board, BMD and Wallingford database are the sources for rainfall data. Data for the period 1901 - 1950 were obtained from the UK Meteorological Office and processed for NERP by the UK Institute of Hydrology, Wallingford. This data comes from both Bangladesh and Indian rainfall stations.

Data from the Bangladesh stations for the period 1951-60 are relatively scanty. There are no data available for the Indian stations.

Plentiful data exist for the period 1961-90 from Bangladesh stations but no data are available from Indian stations.

Data Analysis: The approach to analysing the data involved the use of double-mass analysis to fill in gaps, to adjust for any inconsistencies and to extend the records to predict future trends.

Isohyetal Map: Rainfall over the study area is extremely variable over both space and time. The spatial variation of rainfall is shown in Figure A.6. The regional isohyetal map was prepared based on mean annual rainfall data from 51 stations over the period 1961-90. Of the 51 stations, 23 are located in Bangladesh and 28 in India. Their locations are shown in Figure A.6 (Key Plan).

The mean annual rainfall for the 51 stations for the period 1961-90 is presented in Table A-3.

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Table A-3: Mean Annual Rainfall (mm)

Bangladeshi Stations

Serial	Station	Rainfall	Serial	Station	Rainfall
1.	Kishoreganj	2275	13.	Lallakhal	5733
2.	Mymensingh	2462	14.	Langla	2796
3.	Netrokona	2971	15.	Moulvibazar	2615
4.	B'baria	2136	16.	Munshiganj	2159
5.	Chandpur	1984	17.	Nalitabari	2474
6.	Ch.bagan	2439	18.	Narayanganj	2105
7.	Dakhinbag	3435	19.	Narsingdi	2319
8.	Dewanganj	2085	20.	Sharishabari	1858
9.	Durgapur	3570	21.	Sherpur	2169
10.	Habiganj	2422	22.	Sunamganj	5811
11.	Jamalpur	2008	23.	Sylhet	4260
12.	Joydebpur	2016			

Indian Stations

Serial	Station	Rainfall	Serial	Station	Rainfall
1.	Goalpara	2586	15.	Jafferbund	3156
2.	Dibrugarh	3277	16.	Jowai	3945
3.	Gauhati	1753	17.	Karimganj	4129
4.	Silchar	3820	18.	Kohima	2051
5.	Jorhat	2403	19.	Kolosib	3156
6.	Demagiri	3006	20.	Koyah	3156
7.	Dimapur	1747	21.	Lungleh	3945
8.	Aijal	2312	22.	Mokohchung	2814
9.	Bikrampur	4471	23.	Monierkhal	3498
10.	Champai	2209	24.	Sairang	2630
11.	Cherapunji	11599	25.	Sherkawn	3419
12.	Dewan	3419	26.	Shillong	2630
13.	Dullabchara	2959	27.	Tura	3524
14.	Hailakandi	3261	28.	Wokha	3682

The spatial distribution of these stations is considered adequate for the preparation of an isohyetal map.

As shown in Figure A.6, rainfall shows an increasing trend from southwest to northeast. The mean annual rainfall varies from 2800 mm near Phulpur to 3400 mm near Jaria.

Project Rainfall: Within the project area, there are two rainfall stations maintained by BWDB. Their locations, at Jaria and Phulpur, are shown in Figure A.5. Project rainfall was analysed based on data from these stations. The mean monthly rainfall and mean monthly maximums and minimums are presented in Table A-4. The seasonal distribution of rainfall is given in Table A-5.

Table A-4: Monthly Rainfall Statistics

Month	Rainfall (mm):Period of Record: 1961-1993					
	Station: Phulpur			Station: Jaria		
	M Max	M Min	Mean	M Max	M Min	Mean
Jan	67.00	0.00	7.00	55.70	0.00	6.70
Feb	89.40	0.00	15.10	80.70	0.00	16.70
Mar	66.80	0.00	18.10	101.10	3.10	36.80
Apr	307.40	0.80	114.30	498.50	16.80	164.00
May	1032.50	3.00	337.80	1028.30	163.00	411.20
Jun	1612.90	67.30	519.40	1365.00	191.70	656.50
Jul	1424.00	114.00	587.80	1161.40	442.10	755.70
Aug	980.60	71.60	367.80	1184.40	237.90	537.00
Sep	723.00	110.80	376.40	1177.10	162.40	527.60
Oct	500.70	0.30	210.60	529.70	0.00	201.60
Nov	129.50	0.00	19.10	82.60	0.00	16.80
Dec	74.90	0.00	7.20	67.30	0.00	9.70
Ann	5831.40	1104.50	2658.80	4951.60	2296.40	3368.70

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As seen in the Table A-5, there is little rain in the dry season (December-March). More than 84 percent of the annual rainfall occurs during the monsoon (May-September) when flash floods are regular and frequent. The post monsoon season (October-November) is characterised by decreasing rainfall, and the draining of flood water that accumulated during the monsoon season.

Table A-5: Seasonal Distribution of Rainfall

Station	Rainfall (Jan-Dec)	Seasonal Rainfall (mm)					
		Dry (Dec-Mar)		Monsoon (May-Sep)		Post-Monsoon (Oct-Nov)	
		Amount	%	Amount	%	Amount	%
Phulpur	2580.6	47.40	1.84	2189.20	84.83	229.70	8.90
Jaria	3340.3	69.90	2.09	2888.00	86.46	218.40	6.54

The total annual rainfall for various return periods is given in Table A-6. Maximum annual rainfall intensity (mm/day) for various intervals is provided in Table A-7. These data were obtained by fitting station data with GEV Distribution.

The rainfall depth-duration-frequency for maximum rainfall for one to ten consecutive days occurring in April-May is given in Table A-8.

Table A-6: Rainfall Totals (July-October) for Various Return Period

Station	Period of Record	Rainfall Totals (mm)			
		2-yr	5-yr	10-yr	20-yr
Phulpur	1961-1993	1445	1945	2289	2630
Jaria	1961-1993	1969	2350	2604	2847

Table A-7: Maximum Annual Rainfall Intensity (mm/day) for Various Return Period

Station: Jaria; Period of Record: 1961-93

Station	Maximum One-day Annual Rainfall (mm/day)				
	2-yr	5-yr	10-yr	20-yr	50-yr
Jaria	182	240	273	300	330

Table A-8: Rainfall Depth-Duration-Frequency for April-May

Return Period	Station: Phulpur ; Rainfall (mm)									
	1 day	2 day	3 day	4 day	5 day	6 day	7 day	8 day	9 day	10 day
2	67	90	106	121	135	145	159	169	180	190
5	97	133	158	177	201	217	242	257	271	291
10	124	165	200	231	257	282	304	327	357	376
20	144	221	257	278	320	348	389	411	433	478
Station: Jaria; Rainfall (mm)										
2	78	107	135	146	170	180	192	205	214	223
5	107	151	188	199	231	249	272	289	308	322
10	137	174	209	242	272	301	328	352	375	396
20	142	218	259	271	305	347	385	406	450	480

Dependable Rainfall: The 1 in 5 year dependable rainfall is generally used to design irrigation systems. The 1 in 5 year, or 80 percent of the dependable rainfall, is the amount of rainfall which can be depended upon in 4 out of 5 years or with an 80 percent probability of exceedance.

Dependable rainfall was assessed using the methodologies developed for the CROPWAT computer programme (Manual and Guidelines for CROPWAT, FAO, Rome 1991). The CROPWAT method derives an estimate of the 80 percent dependable rainfall by factoring the average decade rainfall by the ratio of the 80 percent annual dependable rainfall to the annual average rainfall. However, while computing the dependable rainfall this study considers only the irrigation period of the year. The results of the analyses are given in Table A-9.

Effective Rainfall: Effective rainfall was assumed to be 80 percent of the dependable rainfall, and 70 percent when monthly values are in excess of 100 mm. This is in accordance with the Manual and Guidelines for CROPWAT, FAO, Rome 1991,

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Table A-9: Rainfall Availability for Irrigation Season

Station	Average Seasonal Rainfall	80% Dependable Seasonal Rainfall	Ratio
Phulpur	443 mm	223 mm	0.50
Jaria	635 mm	410 mm	0.65

Month	Decade	Dependable Rainfall (mm)				Mean of 5-yr Rainfall	Effective Rainfall
		Phulpur		Jaria			
		Average	5-yr	Average	5-yr		
Jan	I	4.7	2.4	3.6	2.3	2.4	1.9
	II	0.0	0.0	0.8	0.5	0.3	0.2
	III	1.8	0.9	2.2	1.4	1.2	1.0
Feb	I	4.4	2.2	5.6	3.6	2.9	2.3
	II	1.2	0.6	4.0	2.6	1.6	1.3
	III	4.2	2.1	7.0	4.6	3.4	2.7
Mar	I	1.3	0.7	5.5	3.6	2.2	1.8
	II	8.8	4.4	12.4	8.1	6.3	5.0
	III	6.9	3.5	18.9	12.3	7.9	6.3
Apr	I	14.9	7.5	31.0	20.2	13.9	11.1
	II	34.8	17.4	61.1	39.7	28.6	22.9
	III	58.4	29.2	71.9	46.7	50.6	30.4
May	I	80.3	40.2	105.9	68.8	54.5	38.2
	II	95.6	47.8	127.8	83.1	65.5	45.9
	III	118.5	59.3	177.6	115.4	87.4	61.2

Water Levels

Data Source: The BWDB measures water levels at Sarchapur and Jaria on the Kangsha River and at Netrokona on the Mogra River. Water level data are taken five times a day: 6:00 am, 9:00 am, 12:00 pm, 3:00 pm and 6:00 pm. These five values are then averaged to obtain mean daily water levels.

NERP monitored the Mogra River at Trimohoni during the 1994 monsoon period. At Meda, water levels were derived through linear interpolation from data at Jaria and Sarchapur, since there is no monitoring gauge at Meda. The distance between Jaria and Sarchapur along the

Kangsha River is 61.87 km and that between Jaria and Meda is 30.0 km. The locations of these five sites are shown in Figure A.5.

Data Analysis: The analysis of water level data involves listing observed maximums, minimums and ranges at the three long-term recording sites (Table A-10). The analysis also includes the computation of pre-monsoon (April-May) and annual maximum water levels for the different recurrence intervals. The values for the five sites are given in Tables A-11 and A-12.

In the absence of long-term data for Trimohoni Station, the water levels at this location for different return periods were obtained by regression analysis using the Netrokona data.

Table A-10: Historical Observed Maximum and Minimum Water Levels

Station	River	Period of Record	Years of Record	Observed Water Levels (m, PWD)		
				Maximum	Minimum	Range (m)
Sarchapur	Kangsha	1964-94	31	14.30	12.16	2.14
Jaria	Kangsha	1964-94	31	11.33	9.70	1.63
Netrokona	Mogra	1977-94	16	9.47	7.51	1.96

Table A-11: Pre-monsoon (April-May) Maximum Water Levels

Station	River	Period of Record	Pre-monsoon Maximum Water Levels (m, PWD)				
			2-yr	5-yr	10-yr	20-yr	50-yr
Sarchapur	Kangsha	1964-94	9.28	10.18	10.73	11.23	11.84
Meda	Kangsha	-	7.85	8.90	9.49	10.0	10.57
Jaria	Kangsha	1964-95	6.50	7.70	8.33	8.84	9.37
Netrokona	Mogra	1977-94	5.06	5.81	6.11	6.31	6.47
Trimohoni	Mogra	1994	5.23	5.96	6.25	6.45	6.61

Table A-12: Annual Maximum Water Levels

Station	River	Period of Record	Annual Maximum Water Levels (m, PWD)				
			2-yr	5-yr	10-yr	20-yr	50-yr
Sarchapur	Kangsha	1964-95	13.39	13.79	13.99	14.14	14.29
Meda	Kangsha	-	12.11	12.43	12.57	12.67	12.78
Jaria	Kangsha	1964-95	10.91	11.15	11.24	11.30	11.36
Netrokona	Mogra	1977-94	8.94	9.28	9.40	9.46	9.51
Trimohoni	Mogra	1994	9.44	9.83	9.96	10.03	10.09

Discharge

Data Source: All discharge data was obtained from the BWDB. The only long-term discharge record for the Kangsha River has been monitoring at Jaria. Flow measurements for the Kangsha at Sarchapur and for the Mogra at Netrokona are available from 1991.

Field measurements of the flow are taken fortnightly. Rating curves were developed based on discharge and water levels recorded at the time of flow measurement. Mean daily discharges are computed from the mean daily water levels using the rating curve. All other analyses related to discharges were based on the mean daily values.

Data Analysis: Discharge data analysis involves listing the maximum, minimum and range of the mean daily discharge at Jaria on the Kangsha River (Table A-13). The analysis also includes computation of the annual maximum discharge for different recurrence intervals of Kangsha River at Jaria. These values are given in Table A-14.

Table A-13: Maximum and Minimum Mean Daily Discharge

Station	River	Period of Record	Years of Record	Mean Daily Discharge (m^3 /sec)		
				Maximum	Minimum	Range
Jaria	Kangsha	1964-93	27	1430 (1989)	0.0 (1979)	1430

Surface Water Availability

Boundary Rivers: Dependable surface water availability in the Kangsha River at Jaria is given in Table A-15. Since the data period at Sarchapur and Netrokona are too short to make any frequency analysis, only the mean values of the available data for these two stations are given (Table A-16).

Table A-14: Annual Maximum Discharge

Station	River	Period of Record	Annual Maximum Discharge (m^3 /sec)				
			2-yr	5-yr	10-yr	20-yr	50-yr
Jaria	Kangsha	1983-93	1324	1400	1440	1460	1490

One hundred percent of the dry flow of the Kangsha River at Jaria is received from the Someswari River through Shibganj Dhala. As seen from Sarchapur data, the Kangsha River becomes dry above the Kangsha-Shibganj Dhala confluence during the winter period. The upstream reach of the Mogra River in the project area also becomes dry during the winter period.

Table A-15: Dependable Surface Water Availability-Kangsha River at Jaria
Period of Record: 1983-93

Percent	Dependable Surface Water Availability (m^3 /sec)									
	Jan			Feb			Mar			Apr
	I	II	III	I	II	III	I	II	III	I
50	49	41	31	25	21	21	18	21	23	18
80	31	36	21	15	13	12	11	10	14	12
90	29	29	19	14	13	11	10	8	10	10

Table A-16: Dependable Surface Water Availability (Mean Value)
Kangsha River at Sarchapur and Mogra River at Netrokona
Period of Record: 1991-93

Station	Dependable Surface Water Availability -Mean Value (m^3 /sec)									
	Jan			Feb			Mar			Apr
	I	II	III	I	II	III	I	II	III	I
Sarchapur	14	14	8	7	6	5	4	3	4	3
Netrokona	1	1	1	1	1	1	0	0	0	0

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Internal Channels and Beels: Approximately 1.0 Mm^3 of water is available in the Kalihar and Balia Channels. This was computed from the measured cross-sections of the channels and pond levels at the existing cross-dams. The pond levels are so fixed that low croplands are not inundated.

Another 1.0 Mm^3 of water is assumed to be available in the project's *beel* areas.

Groundwater

Groundwater Conditions: The project area lies in the Old Brahmaputra floodplain. The alluvial sediments range from coarse, poorly sorted sands to silts and clays and are distributed in complex patterns. From the lithologies of borehole logs of Bangladesh Agriculture Development Corporation (BADC) deep tube wells (DTW), a geological cross-section was drawn through the middle of the project from the northwest to the southeast(Figure A.7). The cross-section depicts three major sequences of sedimentation pattern. The top layer consists of clay and silt with thicknesses varying from three to ten metres. This is underlain by a transitional layer composed largely of fine to very fine sand and alternating with silty sand and clay. The average thickness of the transitional layer is 30 metres. The main formation consists of fine to medium sand with coarse sands and gravel forming the aquifer materials at a depth of 50 to 100 metres.

As shown in Figure A.7, excepting a few localized clay deposits, very fine to fine sand deposits exist within the upper 10 m of the reservoir, having a medium to high specific-yield values in the range of 10-13 percent, which partly explains a very good storage condition in the upper aquifer.

Groundwater Monitoring Station: In the project area, there are three monitoring wells: Purbadhala (MY-04), Jaria (MY-06) and Hatibanda (My-49). Their locations are shown in Figure A.5. These wells are operated by BWDB.

Groundwater Users: Groundwater use can be divided into three categories: agriculture, domestic and industrial. Agriculture is the major user of groundwater, principally for the irrigation of the dry season *boro* crop: a major crop of the area. The entire population (112,125 according to the 1991 census) uses groundwater for domestic purposes. The only industry in the project area comprises five small ice plants. Their use of groundwater resources is negligible; therefore, industrial use is not considered in the resource evaluation.

Resource Availability: The assessment of groundwater resource availability depends on an accurate determination of groundwater recharge. Recharge is the replenishment of groundwater storage depleted by groundwater discharge. Discharge is the amount of water flowing out of the aquifer through natural flows and withdrawal from wells. On an annual cycle, if the discharge and recharge are equal, extraction will be sustained in the long term.

Besides the soil properties, two other external parameters, namely rainfall and river flooding, influence the recharge rate. Potential recharge in the project area, based on 17 years of recharge simulation with average rainfall over the area and flooding from Kangsha River, was estimated by the Water Resources Planning Organisation (WARPO) to be 818 mm. The mean annual rainfall over this 17 years of rainfall record is 2982 mm. Therefore, the recharge is equal to 27 percent of mean annual rainfall (Table A-17). Available groundwater is assumed to be 75 percent of the potential recharge, thus 614 mm equivalent to 92.1 Mm^3. A reduction in the base figure was made to cover uncertainties in the model calibration and input data.

Table A-17: Annual Rainfall and Recharge for Dampara Project

Year	Annual Recharge	Annual Rainfall
1972-73	607	2026
1973-74	905	3448
1974-75	946	3534
1975-76	706	2391
1976-77	763	2964
1977-78	930	3180
1978-79	778	2765
1979-80	748	2988
1980-81	876	2783
1981-82	811	2743
1982-83	725	2533
1983-84	848	3539
1984-85	869	3319
1985-86	730	2373
1986-87	847	2890
1987-88	827	2962
1988-89	996	4255
Annual Mean	818	2982

Present Use: Before the privatisation of minor irrigation, most data on groundwater irrigation were collected by BADC. After privatisation, data collection has become inherently more difficult. In 1990-91, and again in 1992-93, the CIDA-funded Agriculture Sector Team (AST) surveyed minor irrigation development in the country. Their results for the Dampara Project area are given in Table A-18.

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Table A-18: Irrigation Mode and Irrigation Area

Mode	1990-91		1992-93	
	No.	Irrigated Area (ha)	No.	Irrigated Area (ha)
STW	328	1525	631	2700
DSSTW	22	8	4	2
DTW	50	678	204	2946
MOSTI	12	3	18	5
Total	412	2214	857	5653

Quantification of groundwater use from wells is not reliable since farmers do not keep records of discharge or operating hours. Groundwater use is quantified using theoretically computed crop water requirements.

Irrigation Water Requirements: Irrigation water requirements were assessed (Table A-19) using the methodologies developed for the CROPWAT computer programme (Manual and Guidelines for CROPWAT, FAO, Rome 1991). The basic assumptions are as follows:

- Irrigated *boro* dominates all other crops. The water requirements have therefore been calculated for this crop alone. In this study, it was assumed that water requirement for local *boro* is 75 percent of that of HYV *boro*.
- Reference evaporation values for Mymensingh were used, since this is the nearest climatic station.
- The stations used for rainfall calculations are Phulpur and Jaria. The effective rainfall is assumed to be 80 percent of the dependable rainfall, and 70 percent for monthly rainfall values in excess of 100 mm.
- An overall transmission efficiency of 70 percent was adopted to determine the quantity of groundwater withdrawal.

The irrigation requirement for *boro* crop is 75.0 Mm^3. The available surface water in *beels* and channels is 2.0 Mm^3 indicating there is 73.0 Mm^3 of groundwater used for irrigation in the area.

According to The Department of Public Health Engineering DPHE/UNICEF *Rural Water Supply and Sanitation Programme 1992-95*, groundwater consumption for domestic purposes in rural

Table A-19: Crop Water Requirement for HYV boro

	January			February			March			April			May	
	1	2	3	1	2	3	1	2	3	1	2	3	1	2
ETo (mm)	30	30	31	35	35	36	49	50	50	54	54	54	53	53
Effective Rainfall	2	0	1	2	1	3	2	5	6	11	23	30	38	46
Land Preparation /Transplantation														
% area entered LP/T stage														
% area left LP/T stage	30	80	100	100										
% area at LP/T stage	0	30	80	100										
Land Preparation	30	50	20	0										
Equivalent over whole area	15	150	150	150										
	0	75	30	0										
	45													
Establishment and Development														
% area entered E & D														
% area left E & D		30	80	100	100	10	10	100						
% area at E & D stage		0	0	0	0	0	0	100						
Crop co-efficient Kc		30	80	100	100	30	80	0						
Evapotranspiration		1.1	1.1	1.1	1.1	70	20	1.1						
Net irrigation requirement		33	34	38	38	1.	1.	55						
- over area at E & D stage						1	1							
- equivalent over whole area		33	33	36	37	40	54	50						
		10	26	36	37			0						
						37	52							
						26	10							

	January			February			March			April			May	
	1	2	3	1	2	3	1	2	3	1	2	3	1	2
Reproductive Stage														
% area entered R- stage						30	80	100	10	100	100	100		
% area left reproductive stage						0	0	0	0	30	80	100		
% area at reproductive stage						30	80	100	0	70	20	0		
Crop co-efficient Kc						1.	1.	1.05	10	1.05	1.05	1.05		
Evapotranspiration						05	05	52	0	57	57	-		
Net irrigation requirement						38	51		1.					
- over area at R-S								47	05	46	34	-		
- over whole area						35	49	47	52	32	7	-		
						11	39							
									46					
									46					
Mature Stage														
% area entered mature stage										30	80	100	100	100
% area left mature stage										0	0	0	30	80
% area at mature stage										30	80	100	70	20
Crop co-efficient Kc										0.8	0.8	0.8	0.8	0.8
Evapotranspiration										43	43	43	42	42
Net irrigation requirement														
- over area at R-S										32	20	13	4	0
- over whole area										10	16	13	4	0
Total Requirement over whole area (mm)	45	85	56	36	37	37	49	47	46	42	23	13	4	0

Total: 520 mm
Overall Transmission Efficiency: 70%
Total Withdrawal: 743 mm
HYV *boro* Area: 7856 ha.
Local *boro* Area: 2927 ha.

Water Requirement
HYV *boro*: 58.37 Mm^3
Local *boro*: 16.31 Mm^3
Total: 74.68 Mm^3 ; say 75.0 Mm^3

areas is 12.5 litres per person per day. Figures from the 1991 census show an area population of 112,125. The total groundwater consumption for domestic purposes would therefore be about 0.0016 Mm^3. This is not considered significant in comparison to the figures for agricultural use. The present groundwater use is thus 73.0 Mm^3.

Future Potential: When exploring the possibility of future groundwater development, priority should be given to domestic use. By 2015, the population of the area will be 155,710, and domestic need will increase to 0.002 Mm^3. Since the available groundwater resource is 92.1 Mm^3, there remains about 92.0 Mm^3 of groundwater for use by other sectors.

The development of industries based on large scale groundwater in the project area is not foreseen. Only agriculture remains as a potential future user.

The potential for future groundwater development for irrigation depends upon two factors:

- the availability of irrigable area, and

- the availability of water for irrigation.

According to NERP's 1995 land use survey, about 94 percent of the cultivated area is under winter crops. This indicates that there is very little scope for areal expansion of winter cropping. Thus irrigation is limited by the availability of irrigable land. This contention is supported by the stability of the lowest levels of groundwater (Figure A.8) that shows abstraction reaches the potential demand of the area.

It is predicted, therefore, that the future groundwater need for irrigation will remain at 75.0 Mm^3. Since the available groundwater is 92.0 Mm^3 it would seem that groundwater resource is adequate to meet future needs.

A.1.3 Communication

Roadway

Data on existing motorable roads and road structures were collected from the Local Government Engineering Department (LGED) and during field visits. In addition to many kilometres of village roads, there are about 10.0 km of metalled and 76.0 km of unmetalled roads in the project area.

As shown in Figure A.1, almost all the motorable roads run north-south and are intercepted by the Purbadhala-Phulpur Road. The north-south roads lead either to Phulpur or Purbadhala, the two *thana* centres of the area. All these roads were constructed under Food for Works Programme. The LGED has earmarked the roads for further development in their programme to connect all growth centres of the area by metalled roads. Details of road infrastructures are given in Table A-20.

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Table A-20: Road Infrastructures

	Name of Road	Type	Length			Culvert	Res. Agency
			From	To	km		
1.	Purbadhala-Jaria	Metalled	Purbadhala	Jaria	10.	4	R & H
	Subtotal	**Metalled**			**10.**	4	
2.	Purbadhala-Phulpur	Unmetalled	Purbadhala	Phulpur	30.	16	LGED
	Purbadhala-Gagra	Unmetalled	Kaldura	Gagra	11.	3	UP
4.	Purbadhala-Guatala	Unmetalled	Hogla	Guatala	10.	2	LGED
5	Jaria-Gagra	Unmetalled	Jaria	Gagra	11.	-	UP
6	Phulpur-Guatala	Unmetalled	Baola	Guatala	6.0	2	LGED
7	Phulpur-Bilasati	Unmetalled	Balia	Bilasati	4.5	3	UP
8	Phulpur-N.Patti	Unmetalled	J.Pur	N.Patti	3.5	2	UP
	Subtotal	**Unmetalled**			**76.**	**28**	

Railway

In the project area, there are 9.9 km of metre gauge railway line and six railway bridges between Purbadhala and Jaria. It is a part of the Mymensingh-Shymganj-Purbadhala-Jaria railway line, with the north terminus at Jaria (Figure A.1). Before road development, it was the only transport route for the northern area. It is still the most dependable route during floods when road communication is frequently disrupted. Country boats connecting the different growth centres of the region coordinate their schedules with the trains' arrivals and departures.

Waterway

Navigation is seasonally and geographically limited within the project area. Of the three main drainage channels, there is water transportation only in the Kalihar Khal during the monsoon season (late June to October).

Balia Khal runs over low lands and beels. The homesteads are far from this channel making it difficult to reach and the Channel becomes unattractive for navigation. Dhalai Khal flows over high land. Road development using low bridges has rendered this channel non-navigable.

Kalihar Khal connects the project's interior with Jaria and Jhanjail, situated across the Kangsha River from one another. Jhanjail is an important market, operating on Saturdays and Wednesdays. Jaria is a landing centre with a railway terminus and road connection with Netrokona and Mymensingh.

During the monsoon season two mechanized boats ply this channel on market days (Saturday and Wednesday) and one boat on non-market days. They travel between Jaria-Jhanjail and the project area with passengers and merchandise. Non-mechanized country boats also ply this channel. Non-mechanized boats carry mainly cargo to and from the project area. The findings of the NERP 1995 boat traffic survey on this route are given in Table A.21.

The main water transportation takes place on the Kangsha River that borders the project area on the north (The Project has no intervention across the Kangsha River). This transport route is also seasonal. People living on or near the banks of this river use the waterway extensively. Jaria, Jhanjail, Kapasia, Gagra, Porakandulia and Goatala are some growth centres situated on the banks of the river. A NERP 1995 field survey revealed that fertilizers, petroleum, oils, lubricants, cement, mild steel rods and other manufactured goods are imported to this region from Bhairab Bazaar, Ashuganj, Narayanganj, etc. and items like paddy, timber, oilseed, etc. are exported from this area on mechanized boats. Estimated volume of the export and import traffic is 10,560 tons.

Table A-21: Estimated Annual Inflow and Outflow of Traffic through Kalihar Channel

Inflow				Outflow			
Boat		Traffic		Boat		Traffic	
NMB (No)	MB (No)	Cargo (ton)	Passenger (No)	NMB (No)	MB (No)	Cargo (ton)	Passenger
843	193	280	8000	713	193	780	7400

A.1.4 Existing Flood Control and Drainage Infrastructure

Drainage Regulator

There are two drainage regulators in the area. One regulator with five vents on the Kalihar Nadi outfall at Khatuair, and another with ten vents on the Balia Nadi outfall at Chorerbhita (Figure A.9). Vent size is 1.52m x 1.83m for both regulators. The structures' invert levels are given in Table A-22.

Table A-22: Existing Drainage Regulators

Regulator	Channel	Location	Vent	Height (m)	Width (m)	Invert Level (m, PWD)
R-1	Kalihar	Khatuair	5	1.83	1.52	3.35
R-2	Balia	Chorerbhita	10	1.83	1.52	4.27

The Khatuair Regulator was built in 1989 on a proposed diversion channel under small scale project. But excavation of the diversion channel and closing of the original Kalihar Channel are yet to be done.

The structure is fitted with vertical lift gates in the upstream and has provision for flap gates in the downstream. The downstream flap gates have not been fitted yet. The erosion protection work around the structure and the concrete work are seen in good conditions.

The Chorerbhita Regulator was constructed in 1992 with IDA fund. The structure is in good condition and operationable.

According to the BWDB Netrokona Division Office, these two structures have been built as a part of the flood control works for the Dampara Project. But the structures are not in operation as the project embankment is yet to be constructed.

Embankment from Chorerbhita Regulator (0.0 km) to Khatuair Regulator (9.3 km)
In 1992 about 1.8 km of embankment has been constructed to connect the Chorerbhita Regulator with Jaria. In the 1995-96 dry season, BWDB undertook to extend the embankment towards upstream with WFP resources and built 1.4 km of embankment over a distance of 7.5 km between Jaria and Khatuair but constructed it haphazardly in 12 segments varying in length from 30 m to 450 m. The reason behind this piecemeal approach is the non-availability of land as the compensation money could not be paid to the land owners in time.

Phulpur-Purbadhala Road
Phulpur-Purbadhala Road is acting as the southern boundary of the project area. There are 15 culverts and bridges on this road. About 3440 ha of the project area is drained through these openings to the Mogra River. During flood time, flood waters from the Kangsha River also flow to the Mogra River through these openings. Hydraulically the Road has no role but it encloses the affected area and the project boundary line is identifiable physically.

A.2 Proposed Project

A.2.1 Problems

Flooding is perceived to be the main water resource problem in the project area, though there are also problems of adequate surface drainage during the pre-monsoons. Flooding results from the inability of the Kangsha River channel to carry peak flows. More than 71 percent of the project area is inundated by the annual floods. Flood waters from the Kangsha start entering the area through the Kalihar and Balia channels; but with the rise of flood levels, it spills over the banks.

The major impact of flooding is on agriculture, especially the *t.aman* crop. Floods also damage homesteads, infrastructure and fish ponds. In response to deepening flood waters, area residents cut the west embankment of the neighbouring BWDB's Kangsha Project, draining their homesteads, but flooding those of the Kangsha Project and ultimately threatening Netrokona Town. Road transportation, the main communication system in the area, is totally disrupted by floods.

In general, water shortage does not pose a problem for the area. About 94 percent of the cultivated area is under crops during winter when irrigation is necessary. As described in A.1, sufficient water is available for irrigation, and with modified pumps, for other purposes. This project, therefore, does not propose interventions for irrigation purposes. However, it is recommending the continuation of monitoring of groundwater levels at three sites: Purbadhala (MY-04), Jaria (MY-06) and Hatibandha (MY-49). Their locations are shown in Figure A.5.

A.2.2 Project Concept

The purpose of this project is to protect the major monsoon crops and secure the safety of homesteads and infrastructure through flood management.

The two major monsoon crops are the rice varieties *aus* and *aman*. *Aus* is grown in the early monsoon and *aman* is the late monsoon crop. They cover 12 and 88 percent of the cultivated land respectively. The coverage of *aman* is not only higher in comparison to *aus* but its production is substantially greater. Moreover, much of the aus area is located on flood-free highlands. For these reasons, the main thrust of this project is to protect the *aman* crop. Aman crop protection may be achieved by reducing flood depths in the project area from July to October which is the flood-vulnerable period for this crop.

Flooding will be allowed through the regulating structures, but will be restricted to the April-June period and the depths will be controlled so that homesteads, infrastructure and fish ponds are not threatened. Though this will negatively affect the *aus* crop, it will allow the area to derive beneficial aspects of flooding, i.e., improvement of floodplain fisheries, regeneration of wetlands and improvement in soil fertility. April-June flooding is particularly important to the fisheries, because of the timing of fish migration and spawning.

A.2.3 Project Description

As shown in Figure A.9, this study is proposing the following interventions to manage floods and drainage problems of the project area:

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Embankment
In response to the area's flooding problems, this project proposes the construction of a 29.7 km embankment from Jaria to Meda along the right bank of the Kangsha River. Field surveys indicate that there are no spills above Meda. The proposed embankment will connect to the existing Kangsha Project embankment which ends near Jaria.

The Flood Plan Coordination Organisation's (FPCO) guidelines recommend the utilization of existing roads as embankment wherever possible. Around Naterkona Village, there are two potential roads for embankment use - one to the north of the village and the other to the south. The north road (Caritas Road) is close to the river, but it is not safe for use as an embankment; the south road leaves the entire village on the river side (Figure A.9). The development of a third embankment between the two roads is opposed by the people of the village. Since they have already relinquished land for the two roads, they are not prepared to give up more land for an embankment. The study therefore recommends the development of the southern road as the embankment.

To prevent the flooding of the village, it is proposed to improve Caritas Road. As well, three small drainage outlets will be installed on the southern embankment to allow the drainage of the village. This proposal was agreed upon by the people of the village.

Drainage Regulators
There are two existing drainage regulators - one at Khatuair on the outfall of Kalihar Channel and the other at Chorerbhita on the outfall of Balia Channel. This study examines the adequacy of these two structures for draining their catchments. It should be mentioned that the Khatuair Regulator has to be fitted with flap gates on the downstream side . The Kalihar Channel will be closed at the outfall and the diversion channel will be excavated.

Mohespatti Beel is an isolated *beel* and drains to the Kangsha through Mohespatti Khal. It is proposed to construct a small drainage outlet at Mohespatti on the outfall of that *khal*.

Re-excavation of Drainage Channels
Young *aus* and *boro* crops are damaged by drainage congestion caused by pre-monsoon rainfall-runoff. Kalihar, Balia and Dhalai are the three major drainage channels of the project area. Analysis was carried out to check the adequacy of these three channels to discharge rainfall-runoff without damaging crops (See Section A.2.4: Design of Drainage Channel). It was found that the Kalihar and Balia channels adequately drain their respective catchments but the Dhalai Channel needs re-excavation over a stretch of approximately 9.6 km.

Summary of Proposed Project Interventions
The main components of the proposed project include the following:

- construction of 29.7 km full flood embankment along the Kangsha right bank from Jaria to Meda;
- re-sectioning of 2.01 km of Caritas Road along Naterkona to be used as embankment;
- utilization of existing two regulators at the outfall of Kalihar and Balia Channels;
- rehabilitation of Khatuair Regulator;
- closing off the Kalihar Channel at the outfall;

- excavation of diversion channel;
- construction of three small drainage outlets south of Naterkona Village and one drainage outlet at the outfall of Mohespatti Khal;
- provision of thirty LLP inlet structures; and
- re-excavation over 9.6 km of Dhalai Channel.

The proposed interventions will:

- protect the project area's crops from damage caused by floods and drainage congestion;
- rehabilitate the Kangsha Project;
- protect the Netrokona-Purbadhala and Netrokona-Durgapur roads and the project's internal infrastructure;
- protect Netrokona Town, and
- protect ponds from flooding.

A.2.4 Design of Project Components

Embankment from Jaria to Meda
The main purpose of the embankment is to protect the agriculture of the area. BWDB's criteria in such cases is to provide protection for a 20-year flood with a free board of 0.91 m. An additional 10% of fill height was added to the design elevations to compensate for consolidation.

A hydrodynamic model calibrated for the area by NERP showed that the proposed embankment would raise the outside water level by 5 and 10 cms respectively for the 1991 and 1988 hydrological conditions. The 1991 and 1988 peak water levels at Jaria are close to 2- and 20-year flood levels respectively. Since the modelled water level rise is not considered appreciable, the confinement effect was omitted from the embankment design.

The embankment crest elevations at Jaria and Meda are given in Table A-23. The 20-year flood levels at Jaria and Meda are in Table A-12. A 0.91 m freeboard was added to determine the design crest level and another 0.25 m was added for shrinkage (maximum fill height is about 2.5 m) to fix the embankment crest level to be constructed.

Table A-23: Embankment Crest Elevations

Location	Section (km)	20-yr Flood Level (m, PWD)	Design Crest Level (m, PWD)	Crest Level to be Constructed (m, PWD)
Jaria	0.0	11.30	12.21	12.46
Meda	29.7	12.67	13.58	13.83

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Following BWDB's guidelines, the top width is 4.27 m with a river-side slope of 3:1 and a country-side slope of 2:1. A typical cross-section and longitudinal profile are shown in Figure A.10.

Jaria-Meda Embankment Alignment

Selection of a proper alignment is a key to the success of any embankment project. The alignment must be technically safe as well as socially acceptable. These aspects were seriously considered while planning the alignment of the proposed embankment.

The local preference is for an embankment on the bank of the river so that the maximum amount of land and homesteads come under its protection. Unfortunately, morphological processes dictate that the best alignment is that which is furthest away from the river bank. When too many people are left unprotected the safety of the embankment can not be assured. Therefore a compromise must be made whereas homesteads and farm lands are protected without sacrificing the safety of the embankment.

A social survey, conducted by NERP in villages along the river's right bank, found that many farmers are willing to "sacrifice" homesteads rather than crop land. This is particularly true for those who own both homestead and cropland. The implicit assumption is that if one loses a crop, one loses their means of living. But when the homestead is inundated, the people suffer for a few weeks and then "everything becomes normal" again. These views were considered in aligning the proposed embankment.

The Kangsha River reach through the project area is a depositional zone. This implies there is little bank erosion taking place. Because of this, the proposed embankment can safely be aligned with the minimum setback distance of six metres from the river bank. In the few places where erosion has regularly occurred, the setback was fixed based on the erosion rate. An extra margin, equivalent to five years of the present erosion rate, will be added to the minimum setback figures.

Past channel shifting was estimated by comparing the 1990 channel alignment (from 1:50,000 scale SPOT imagery) and the alignment in 1961 (shown on 1:15,480 scale water development maps). It was found that the overall channel pattern has remained unchanged, but erosion has occurred along the concave banks of river meanders. Erosion rates are difficult to assess accurately, given the lack of precision of small scale mapping. However, it appears that many bends have shifted 90 to 120 m and some have shifted up to 250 m over the last 30 years. An average erosion rate on the meanders was estimated to be about four metres per year. Thus the minimum setback required at the concave bend is 20.0 m.

A setback of 15.0 to 30.0 m from the top of the river bank was designed and is shown on the *mauza* maps in Figure A.11 (see this Figure after Figure A.32). While planning the alignment, the following additional considerations were made:

- wherever possible, all available roads were used as a part of the embankment;
- homesteads and farmlands were kept in the protected area as much as possible;
- to avoid displacement of homesteads, alignment was detoured, and
- the acquisition of poor family's land was avoided as far as possible.

The preliminary layout plan indicates no displacement of homesteads.

Re-sectioning of Caritas Road along Naterkona
The Caritas Road by Naterkona Village takes off the proposed embankment at km 1.118 and meets again at km 2.65 of the embankment. Design consideration for the road embankment is the same as that for the Jaria - Meda embankment. Design elevations are given in Table A-24, and the longitudinal profile is shown in Figure A.10.

Table A-24: Design Crest Elevations of Caritas Road

Location on Jaria-Meda Embankment	Section (km)	20-yr Flood Level (m, PWD)	Design Crest Level (m, PWD)	Crest Level to be Constructed (m, PWD)
Km 1.118	0.00	11.30	12.21	12.46
Km 2.650	2.01	11.33	12.24	12.49

Drainage Regulator
The construction of an embankment along the Kangsha will close the openings of Balia, Kalihar and Mohespatti channels in order to stop the entry of flood water into the area. Since these channels drain about 11560 ha (77%) of the project area the closures will significantly impound rainfall-runoff in the project area. After flood protection, the management of internal drainage is a major hydrologic consideration for reducing crop loss and bringing more lands under monsoon crops. Therefore, as a mitigation measure, regulating structures are required to make passage for draining rainfall-runoff to the Kangsha River when river levels permit.

Two drainage regulators exist in the project area: one of 5 vents (vent size: 1.52 m x 1.83 m) located at Khatuair (R-1) at the outfall of Kalihar Channel and the other of 10 vents (same vent size) situated at Chorerbhita (R-2) at the outfall of Balia Channel (Figure A.9). The objective of this analysis is to assess the adequacy of these regulators and propose enlargement of the structures if required.

Methodology
A flood routing technique was used to determine the size of the drainage structure and to compute the polder water level under project conditions. The analysis was carried out for both pre-monsoon, monsoon and post-monsoon situations.

The routing analysis followed the approach described in the BWDB's *Hydrologic and Hydraulic Procedures for Drainage Structures.* Computer programmes were developed to perform the pre-monsoon, monsoon and post-monsoon flood routing. Monsoon and post-monsoon situations were covered with one programme.

Design Criteria
Following BWDB's guidelines, the 1 in 5 year return period of 10-day pre-monsoon rainfall and 1 in 5 year pre-monsoon river level are used to obtain the ventage requirements to satisfy the following crop damage criterion:

- The incremental area inundated to a depth greater than 300 mm for a period of 3 days should be less than 5 percent of the drainage area.

The adequacy of the regulator capacity with respect to the polder inundation level is required to be checked for a post-monsoon simulation using the 5- year rainfall within the polder and 5- year water level in the outfall channel. The head difference across the regulator during post- monsoon drainage should be within the acceptable limit. This is usually assumed as 230 mm for a prolonged period or up to 300 mm for not more than three days.

Drainage Pattern
The catchment areas of the drainage channels were delineated and verified in the field (Figure A.12). The areas drained by the different channels are: Kalihar, 7270 ha (49%); Balia, 4090 ha (27%); Mogra, 1800 ha (12%); Dhalai, 1640 ha (11%), and Mohespatti, 200 ha (1%).

Flood routing was carried out for the Kalihar and Balia Catchments only. The area drained by the Dhalai and the Mogra will remain open since there is no backflow into the project area. The Moheshpatti Khal drains only 200 ha of area and flood routing is not necessary to design an outlet structure for that catchment.

Pre-monsoon Flood Routing
Pre-monsoon routing mainly considers the damage to standing *boro* and young plants of the *aus* crop. For this analysis, rainfall and outfall river levels up to 31 May were considered. Flood routing was carried out for the Kalihar and the Balia catchments to check the adequacy of the existing structures at the outfall of these two channels. Analysis was done under two conditions:

> **Condition 1:** Kalihar and Balia catchments as two separate watersheds draining through their respective channels;
>
> **Condition 2:** Kalihar and Balia catchments as a single watershed draining through Balia Channel only.

The following input data were used in the analysis:

- one to ten day 5-year rainfall for Phulpur and Jaria rainfall stations (Table A-8);
- area-elevation-storage data for Kalihar and Balia catchments from Figure A.13;
- catchment characteristics.

Kalihar Catchment
Area= 72.70 km^2; Length=26.16 km; Length of outfall from centroid=14.50 km;
slope (%)=0.008; Manning's n = 0.04;

Balia Catchment
Area= 40.90 km^2; Length=16.14 km; Length of outfall from centroid=9.50 km;
slope (%)=0.014; Manning's n=0.04;

Kalihar and Balia Catchments
Area = 113.60 km^2; Length = 28.0 km; Length of outfall from centroid=11.50 km;
slope (%)=0.011; Manning's n=0.04;

- paddy land and non-paddy land; 75% and 25% respectively;
- vent characteristics-height, width and entrance co-efficient: as given in Table A-22;

- regulator invert level: as given in Table A-22;
- outfall river level: one in 5- year April-May level at the structure sites;
  - at R1: 8.45 m, PWD
  - at R2: 8.00 m, PWD
- initial polder level: same as outfall river level;

Condition 1: Kalihar and Balia catchments as two separate water sheds and draining through their respective channels

Regulator R-1 and Kalihar Catchment
Summary of Results:

Maximum polder water level= 8.76 m, PWD
Maximum regulator discharge=27.50 m^3/sec

The incremental area inundated to a depth greater than 300 mm for a period of 3 days is far less than 5 percent of the drainage area (Table A-25 and Figure A.14a). The structure R-1 on Kalihar Channel is adequate to drain pre-monsoon rainfall-runoff from Kalihar catchment.

Regulator R-2 and Balia Catchment
Summary of Results:

Maximum polder water level= 8.07 m, PWD
Maximum regulator discharge=25.86 m^3/sec

No area above the river level (river level: 8.0 m, PWD) remains inundated for a period more than 72 hours (Table A-26 and Figure A.14b). As such the structure R-2 on Balia Channel is adequate to drain pre-monsoon rainfall-runoff from Balia catchment.

Table A-25: Polder Inundation Analysis

Polder El.	Polder El.-0.30 m	Inundation Period	Area	Percent of
8.47	8.17	102	151	2.1
8.51	8.21	90	157	2.2
8.54	8.24	78	163	2.2
8.60	8.30	66	164	2.3
8.71	8.41	36	164	2.3
8.74	8.44	24	164	2.3
8.75	8.45	12	164	2.3

Table A-26: Polder Inundation Analysis

Polder El. (m, PWD)	Polder El.-0.30 m (m, PWD)	Inundation Period (Hours)	Area (ha)	Percent of Basin Area
8.04	7.74	30	213	5.2
8.06	7.76	18	220	5.4

Condition 2: Kalihar and Balia catchments as a single watershed and draining through Balia Channel only.

Regulator R-2 and Kalihar and Balia Catchments
Summary of Results:

Maximum polder water level = 8.21 m, PWD
Maximum regulator discharge = 44.91 m^3/sec

The incremental area inundated to a depth greater than 300 mm for a period of 3 days is far less than 5 percent of the drainage area (Table A-27 and Figure A.14c). As such the R-2 structure alone is adequate to drain pre-monsoon rainfall-runoff from the Kalihar and Balia catchments.

Table A-27: Polder Inundation Analysis

Polder El. (m, PWD)	Polder El.- 0.30 m (m, PWD)	Inundation Period (Hours)	Area (ha)	Percent of Basin Area
8.04	7.74	78	280	2.5
8.07	7.77	66	295	2.6
8.12	7.82	54	295	2.6
8.16	7.86	36	295	2.6
8.19	7.89	18	295	2.6
8.21	7.91	12	295	2.6

Conclusion
The existing structures are adequate to drain pre-monsoon rainfall-runoff from the Kalihar and Balia catchments.

Monsoon Flood Routing

The purpose of this routing analysis is to check the adequacy of the existing regulators for rapid drainage of monsoon and post-monsoon rainfall-runoff with the fall of outfall river levels. This routing also determines the polder water level, which dictates the cropping pattern of the area.

The analysis covers rainfall and outfall river levels for the period July to October in accordance with the project's concepts (section A.2.2). However, additional analysis was done using rainfall and river levels for the period April to November.

As stated above, the adequacy of the existing regulators is to be checked for a post-monsoon simulation using 5-year rainfall within the polder and 5-year outfall river levels.

Considering that the Kangsha is subject to frequent flash floods, any design hydrograph drawn from frequency analysis will not truly define the monsoon hydrograph. The flash-flood characteristic of the river is better represented in the annual hydrograph. In this analysis, therefore, an annual hydrograph in which the peak level is close to 5-yr return period of annual maximum water levels was selected for routing.

Frequency analyses with rainfall totals (July-October) and peak Kangsha River level at Jaria for all available years show that 5-year rainfall and 5-year river levels do not occur in the same year. In consideration of this the routing analysis was carried out for the following two cases:

Case 1: A rainfall year when rainfall totals (July-October) at Jaria is close to 5-year rainfall. The outfall river level at Jaria is taken for the corresponding year.

A comparison of 5-year rainfall (Table A-6) with the measured rainfalls of all available years at Jaria found that rainfall year 1991 was close to 5-year rainfall.

Case 2: The Kangsha level at Jaria for such a year when its peak level is close to 5-year peak level. The rainfall is taken for the corresponding year.

A comparison of 5-year water levels (Table A-12) with the measured water levels of all available years at Jaria found that levels in the year 1990 were close to 5-year water levels.

Flood routing analyses with Case 1 and Case 2 conditions revealed that Case 1 conditions (rainfall year 1991) are more critical in respect to polder levels and head difference across the regulator. Because of these findings only Case 1 results are presented in this report.

In the absence of any overland gauge, it cannot be ascertained whether in the monsoon, Kalihar and Balia catchments act as a single basin or a separate basin. As such, analysis was carried out for both situations:

Situation 1: Kalihar and Balia as Separate Catchments

R-1 Regulator and Kalihar Catchment

Flood routing was carried out for Kalihar catchment with the existing 5-vent regulator at the outfall of Kalihar Channel. Analysis was done for Case 1 conditions for the July-October period.

The following input data were used in the analysis:

- area-elevation-storage relation for Kalihar catchment (Figure A.13);
- The 1991 average of daily rainfall of Jaria and Phulpur Stations;
- The 1991 daily water levels at R-1 structure site (Kalihar outfall) computed from daily water levels of Jaria and Sarchapur by linear interpolation;
- evapotranspiration rates based on Mymensingh climatic station data (Table A-2);
- regulator size and invert level (Table A-22); and
- percolation at the rate of 3.80 mm/day considering clay loamy soil until the end of July and zero thereafter due to saturation of the underlying aquifer.

Computation
The routing programme estimates the water balance in the polder on a daily basis. Net changes in stored volume were calculated from the inflow due to effective rainfall, corrected for the outflow (when it occurs) at the regulators and calculated on the basis of previous day's internal (polder) level and external (river) level. The regulator discharge was computed according to the hydraulic flow conditions through the culvert.

Results
The output is shown graphically in Figure A-15. As computed, the maximum polder level is 10.21 m, PWD with the existing 5-vent regulator. A head difference of more than 300 mm across the structure prevails for 5 days in late October.

The analysis was repeated for a 12-vent regulator (an increase of 7-vents). The maximum polder level was computed at 10.21 m, PWD. A head difference of more than 300 mm across the structure prevails for one day in the month of October. The output is given graphically in Figure A-15.

The analysis indicates that an increase in vents would increase the drainage efficiency only marginally and there would be virtually no change in the maximum polder level. Delayed drainage by a few days in the month of October would not affect agricultural output. Moreover, discussions with farmers indicate that they wish to retain water in October to benefit their t. *aman* crops. Slow drainage in late October is beneficial to the area. Therefore, the current drainage structure is considered adequate for this situation.

R-2 Regulator and Balia Catchment
Flood routing was carried out for the Balia catchment with the existing 10-vent regulator at Chorerbhita. The following inputs were made in the analysis:

- area-elevation-storage relation for Balia catchment (Figure A.13);

- The 1991 daily water levels at the R-2 structure site (Balia outfall) were computed from daily water levels of Jaria and Thakurakona by linear interpolation;

- regulator size and invert level as given in Table A-22; and

- all other input data are same as for Kalihar catchment.

Results
The outputs are shown graphically in Figure A.16 for 1991 hydrological conditions. As computed, the maximum polder level is 9.50 m, PWD. The maximum head difference across the structure is 12.5 cm. Thus the structure is considered to be adequate to serve the Balia catchment.

Situation 2: Kalihar and Balia as one Catchment

Flood routing was carried out for the catchments of Kalihar and Balia channels as a single unit with the existing 5-vent regulator at Khatuair and 10-vents at Chorerbhita. Analysis was done for Case 1 conditions for the July- October period. Area-elevation-storage relation for the combined catchments of Kalihar and Balia were used (Figure A-13). Other input data remain the same.

Results
The outputs are shown graphically in Figure A-17. As computed, the maximum polder level is 9.88 m, PWD. Maximum head difference across R-2 is 400 mm. A head difference of more than 300 mm across the R-2 structure prevails for 3 days in the month of October.

The analysis was repeated increasing the number of vents to 15 at the R-2 Regulator at the Balia outfall, and keeping the existing ventage at the Kalihar outfall. The results show that the maximum polder level is 9.93 m, PWD. A head difference of more than 300 mm across the R-2 structure prevails for 2 days in the month of October (Figure A-17).

As seen in the analysis, increasing the size of regulators does not improve the situation. Moreover, as mentioned before, discussions with the farmers indicate that they want to retain water in October since it benefits their t. *aman* crops. Since slow drainage in late October is beneficial to the area, the structure will not be considered for enlargement.

There will be a 0.62 m head difference across the Kalihar and Balia catchments if they are considered separate. There are a few minor channels connecting the two catchments. Thus it will be reasonable to assume that pond level between the two catchments will be same.

An additional check was made for the April-November period with the existing regulators R-1 and R-2 and considering the two catchments as one unit. The maximum polder level is computed as 9.94 m, PWD. Maximum head difference at R-2 is 500 mm. A head difference of more than 300 mm across the R-2 structure prevails for 5 days in the month of October. The results are in Figure A.18.

The analysis was repeated with an increase in the number of vents at R-2 to 15. As given in Figure A.18, the maximum polder level as computed is 9.94 m, PWD. The maximum head difference across R-2 is 354 mm. A head difference of more than 300 mm across the R-2 structure prevails for 2 days in the month of October.

The polder water level is slightly higher under these constraints. To be safe, the proposed cropping pattern is based on this level of 9.94 m, PWD.

Alternate Drainage Routes for the Project Area
Under existing conditions, both the Kalihar and the Balia catchments drain to the Kangsha River. A review of the hydrology of the boundary rivers suggests that the Mogra is a better channel for draining the project area. A comparison of 1994 water levels measured at Chorerbhita (on the

Kangsha) and Trimohoni (on the Mogra) shows that the Mogra level is about 1.5 m lower than that of the Kangsha River (Figure A.19). This situation tempted the investigation of diverting a portion of the drainage flow from the Kalihar and Balia catchments to the Mogra River.

Under existing conditions, the maximum Kangsha polder level was computed to be 9.03 m, PWD. As given earlier, the Dampara polder level is 9.94 m, PWD.

There is no direct channel from Kalihar-Balia catchment to the Mogra River. Part of the Kangsha Project catchment drained to the Mogra through Lauari Channel (Figure A.20), but with the development of the Kangsha Project, the channel was closed at Balurghat.

The investigation carried monsoon routing assuming that Lauari Channel been re-opened and an enlargement of the structure at Trimohoni from four vents to sixteen vents. The results are shown graphically in Figure A.21. As the Figure indicates, the Project's maximum water level under this condition is computed to be 9.20 m, PWD.

The Dampara Project would benefit from lower water levels (-0.74 m) from the diversion but the Kangsha Project's water level would rise by 0.25 m. The benefit to the Dampara Project would come at a cost to the Kangsha Project. Moreover, any breaches in the embankment of either project would affect the other project. In view of these considerations, it is recommended to keep the two projects separate. Therefore, the diversion over the Kangsha Project is not proposed.

Conclusion
The existing R-1 and R-2 Regulators are considered adequate for monsoon conditions. No additional structure is proposed for the outfall of Kalihar and Balia Channels.

Small Drainage Outlet Structures

Outlet Structure at Naterkona
Three pipe drainage structures (0.50 m diameter) with steel fall boards were proposed to drain the Naterkona Village south to the *beel* areas. The adequacy of these structures was checked for monsoon rainfall-runoff. The total area between Caritas Road and the proposed embankment is 36.0 ha. The drainage volume (Q) is given by:

$Q = ciA$, where
$c = 0.30$ for unimproved area
$i =$ intensity of rainfall, 240 mm/day (Table A-7)
$A = 12.0$ ha per structure
Runoff $Q = 0.10$ m^3/sec

The afflux ΔH is given by:

$\Delta H = Q^2 / (2gC^2 A^2)$ where,
$Q = 0.10$, $g = 9.81$, $C = 0.80$, $A = 0.785x(0.50)^2$
$\Delta H = 2.0$ cm which is insignificant and the structure is O.K.

The structure is shown in Figure A.22.

Outlet Structure at Moheshpatti
One 0.90 m diameter pipe drainage structure with a steel gate is proposed at the outfall of Mohespatti Channel at the crossing of the proposed channel. This channel drains the pre-monsoon rainfall-runoff when the *boro* crop is in the *Moheshpatti Beel*. The adequacy of this structure should be checked for pre-monsoon rainfall-runoff.

The pre-monsoon rainfall-runoff drainage modulus is 30.6 mm/day based on rainfall record at Jaria (see section A.2.4.5 below). The drainage area is 200 ha. Thus, discharge = 0.71 m^3/sec.

The afflux ΔH is given by:

$\Delta H = Q^2 / (2gC^2 A^2)$ where,
$Q = 0.71$, $g=9.81$, $C=0.80$, $A=0.785x(0.90)^2$
$\Delta H = 0.10$ m only and the structure is considered adequate.

The structure is shown in Figure A.23.

Drainage Channels
Kalihar, Balia and Dhalai are the three major drainage channels in the area - draining about 87 percent of the project. There are also many minor channels connecting the *beels* with these major channels. This study is confined to considering the re-excavation of major channels only. Once the major channels are re-excavated, local bodies will re-excavate the minor channels if necessary.

Design Procedure
Design discharge was calculated by multiplying the area draining to the channel with drainage modulus. The drainage modulus was computed to be 30.6 mm/day. The detailed computation for the drainage modulus is given below.

The water level in the drainage channel at the outfall was calculated as that required to pass the design discharge through the sluice with the 5-year river level used for pre-monsoon flood routing.

Existing cross-sections were used to check the adequacy of the channels. Since existing cross-sections are not uniform, the backwater analysis using the Step Method was used to compute the water-level profile in the drains. The maximum (0.70 m/sec) and minimum (0.30 m/sec) flow velocities were checked while defining the re-excavated sections.

Drainage Modulus
Drainage modulus for Kalihar and Balia catchments were computed based on data from the Jaria Rainfall Station and that for Dhalai catchment based on data from the Phulpur Station. The computations are given in Tables A-28 and 29.

Drainage Modulus Based on Jaria Rainfall Station

Evapotranspiration : 5.15 mm/day (May)
Percolation : 3.81 mm/day
Losses (Et*0.50 +percolation) : 6.45 mm/day
Pre-storage : 50 mm

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Long-term flood depth : 150 mm
One to ten-day 10-year rainfall: From Table A-8

Table A-28 : Computation of Drainage Modulus

Rainfall Station: Jaria

Day	Cum. rain (mm)	Inc. rain (mm)	Cum. loss (mm)	Net rain (mm)	ResidualFlood (mm)	
					Case A	Case B
1	137	137	6	131	150	150
2	174	37	13	161	150	150
3	209	35	19	190	148	148
4	242	33	26	216	144	144
5	272	30	32	240	137	137
6	301	29	39	262	129	129
7	328	27	45	283	119	119
8	352	24	52	300	106	106
9	375	23	58	317	92	92
10	396	21	64	332	76	76

Drainage Modulus (mm/day)

Residual Flood (mm) = Net Rain (mm) + Pre-storage (mm) - Drainage Modulus (mm/day) x No. of Days

1. Case A : 30.6 (Based on day 1 and day 2 rainfall)
2. Case B : 30.6 (Based on limiting residual flooding to within approximately 150 mm).

Recommended Drainage Modulus: 30.6 mm/day

Drainage Modulus Based on Phulpur Rainfall Station

Evapotranspiration (Et) : 5.15 mm/day (May)
Percolation : 3.81 mm/day
Losses (Et*0.50 +percolation) : 6.45 mm/day
Pre-storage : 50 mm
Long-term flood depth : 150 mm
One to ten-day 10-yr rainfall: From Table A-8

Table A-29: Computation of Drainage Modulus

Rainfall Station: Phulpur

Day	Cum. rain (mm)	Inc. rain (mm)	Cum. loss (mm)	Net rain (mm)	Residual Case A	Flood (mm) Case B
1	124	124	6	117	141	138
2	165	41	13	152	150	144
3	200	35	19	187	159	150
4	231	30	26	205	151	139
5	257	27	32	225	145	130
6	282	24	39	243	136	119
7	304	23	45	259	126	106
8	327	23	52	275	116	93
9	357	24	58	293	108	82
10	376	26	64	312	101	72

Drainage Modulus (mm/day)

1. Case A : 26.1 (Based on day 1 and day 2 rainfall)
2. Case B : 29.0 (Based on limiting residual flooding to within approximately 150 mm).

Recommended Drainage Modulus: 29.0 mm/day

Design of Kalihar Channel
Kalihar channel was divided into seven reaches taking into consideration the tributary locations and road networks that guide the drainage patterns. The catchment area was subdivided for each reach and is shown in Figure A-24. A design discharge for each reach was computed from the

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area draining to the reach and the drainage modulus of 30.6 mm/day based on recorded rainfall at Jaria. The discharge computation is given in Table A-30.

Table A-30: Computation of Design Discharge for Kalihar Channel

Reach	Distance		Tributary Channel	Area (ha)	Cum. Area (ha)	Discharge (m^3 /sec)
	From	To				
7	17.50	22.20	Self	1897	1897	6.72
6	13.10	17.50	Self KS5	91 952	2940	10.41
5	8.95	13.10	Self	344	3284	11.63
4	5.60	8.95	Self KS4	178 2109	5571	19.73
3	3.50	5.60	Self KS3	201 398	6170	21.85
2	2.50	3.50	Self KS2	98 486	6754	23.92
1	0.0	2.50	Self KS1	122 394	7270	25.75

Design Water Level at 0.0 km of Channel

Structure invert level : 5.13 m, PWD
Soffit level: 6.96 m, PWD
River water level: 8.45 m, PWD
The structure is running full

Head loss (ΔH) across the structure is given by:

$\Delta H = Q^2 /(2gC^2 A^2)$ where,
$Q = 25.75$, $g=9.81$, $C=0.80$, $A=5\times1.52\times1.83$
$\Delta H = 0.20$ m

Water level in the channel = 8.45 m, PWD + 0.20 m = 8.65 m, PWD

The backwater programme was run for each of the seven reaches with the existing cross-sections surveyed by NERP at intervals of 100 m. The computed water levels and the critical land levels are shown in Figure A.25. The plot shows no inundation, therefore, no re-excavation of this Channel is proposed.

Balia Channel

Balia Channel was divided into seven reaches taking into consideration the tributary locations and road networks that influence drainage patterns. The catchment area was subdivided for each reach and is shown in Figure A-26. A design discharge for each reach was computed from the area draining to the reach and the drainage modulus of 30.6 mm/day based on recorded rainfall at Jaria. The discharge computation is given in Table A-31.

Table A-31: Computation of Design Discharge for Balia Channel

Reach	Distance		Tributary Channel	Area (ha)	Cum. Area (ha)	Discharge (m^3 /sec)
	From	To				
7	14.9	15.5	Self	348	348	1.23
6	13.0	14.9	Self	115	998	3.53
5	10.2	13.0	Self	171	1633	5.78
	8.7	10.2	Self	195	2494	8.83
3	3.1	8.7	Self	660	3232	11.45
2	2.3	3.1	Self	575	3807	13.48
1	0.0	2.3	Self	283	4090	14.49

Design Water Level at 0.0 km of Channel

Structure invert level : 4.27 m, PWD
Soffit level: 6.10 m, PWD
River water level : 8.00 m, PWD
The structure is running full

Head loss (ΔH) across the structure is given by:

$\Delta H = Q^2 / (2g\, C^2\, A^2)$ where,
$Q = 14.49$, $g=9.81$, $C=0.80$, $A=10 \times 1.52 m \times 1.83 m$
$\Delta H = 0.02$ m

Water level in the channel = 8.00 m, PWD + 0.02 m = 8.02 m, PWD

The backwater programme was run for each of the seven reaches with the existing cross-sections surveyed by NERP at intervals of 100 m. The computed water levels and the critical land levels are shown in Figure A.27. The plot shows no inundation, therefore, no re-excavation of this Channel is proposed.

Dhalai Channel

Dhalai falls on Mogra near Tarakanda. NERP measured cross-sections from Dakua, about 4.9 km downstream of the outfall. A review of these cross-sections and field inspections suggested no improvement downstream of the Dhalai outfall.

The channel was divided into four reaches according to the drainage pattern. The catchment area was subdivided for each reach and is shown in Figure A.28. A design discharge for each reach was computed from the area draining to the reach and the drainage modulus of 29.0 mm/day based on recorded rainfall at Phulpur Station. The computation is given in Table A-32.

Table A-32: Computation of Design Discharge for Dhalai Channel

Reach	Distance		Tributary Channel	Area (ha)	Cum. Area (ha)	Discharge (m^3 /sec)
	From	To				
4	16.0	20.4	Self	1369	1369	4.60
3	13.6	16.0	Self	133	1502	5.04
2	9.6	13.6	Self	366	1868	6.27
1	4.9	9.6	Self	426	2294	7.70

Design Water Level at 4.9 km of Channel

In absence of measured data, the design water level at the Dhalai outfall was computed from the slope between Netrokona and Trimohoni on 31 May 1994. The same slope was extended to the outfall of Dhalai channel. The resulting water level is 8.54 m, PWD.

The backwater programme was run for each of the four reaches with the existing cross-sections surveyed by NERP at intervals of 100 m. It was found that the channel sections are not adequate to drain the design discharge. The sections were enlarged and the programme re-run. The computed water level is given in Figure A.29. Checks were made for velocities and found within permissible limit. The design water levels were compared with the cultivable land levels and no inundation of the cultivable lands occurred. As such, proposed sections are considered adequate.

A.3 Project Impact

A.3.1 Impact on Project Water Level

As a result of flood protection measures, monsoon season water levels in the project area will be reduced by more than 86 cm. This, in turn, will mean reduced depths of inundation. The maximum polder water level for 5-year rainfall conditions is 9.94 m, PWD and the river level at Jaria is 10.80 m, PWD.

The cultivable area under different flood depths for pre- and post-project conditions are given in Table A-33. Flood depth maps were prepared for pre-project conditions (Figure A-30) based on 1:5 year maximum Kangsha River levels and for post-project conditions (Figure A-31) based on a design polder water level of 9.94 m, PWD. Net cultivated areas under different flood depths were computed by superimposing the land use map over the flood depth maps taking into consideration the change of land use in future (see Annex B for details).

Table A-33 Monsoon Depth of Flooding

Flood Depth (m)	Net Cultivated Area (ha)		
	Present	Future Without	Future With
0.00-0.30	777	650	8517
0.30-0.90	1319	1300	1582
0.90-1.80	4708	4705	1339
>1.80	5721	5722	854
Total	12525	12377	12292

A.3.2 Impact on Flood Levels on the Left Bank Area

There is an apprehension that an embankment on the right bank of Kangsha River from Jaria to Meda will raise water levels on the left bank floodplain. An analysis by hydrodynamic model reveals that the intervention will raise water levels by 5 cm and 10 cm respectively under 2-year and 20-year flooding conditions. This rise of water levels will not change the cropping patterns of that area. It would appear, therefore, that the impact of the Dampara Project embankment on the Kangsha River left bank water levels will be negligible and, for the most part, impossible to detect.

A.3.3 Impact on the Area between the Proposed Embankment and the Kangsha River Right Bank

From Naterkona to Bisharadpur, an estimated 516 households are living between the proposed embankment alignment and the Kangsha River right bank (Table A-34). Their total homestead area is 35.14 ha. This includes a mosque and a graveyard on 0.81 ha of land in Kapasia Village. Many people living in those villages have no land in the area protected by the proposed embankment. If there is a flood, they may wish to cut the embankment to drain flood waters quickly. People who benefit from the embankment would try to defend it. Thus the embankment could become an object of contention between these two groups, which would threaten the harmony of the community.

Table A-34: Distribution of Households Having Homestead Outside the Proposed Embankment Alignment

Village	Number of households	Homestead area (ha)
Khatuair	19	0.87
Gangerbera	24	1.10
Letirkanda	118	6.69
Sonaikanda	19	0.85
Kapasia	15	2.04
Giriasha	60	2.78
Ghagra	72	2.86
Bainja	7	0.49
Roghurampur	15	0.99
Dampara	24	1.77
Purbo Pathera	37	3.57
Pathera	25	4.90
Kashimala	27	3.09
Projapotkhila	7	0.42
Moheshpatti	5	0.45
Bisharadpur	17	2.27
Total	516	35.14

A.3.4 Impact on Groundwater Recharge

The proposed embankment would reduce flood depths in the project area. At NERP's request, WARPO run the Recharge Model and found that the reduced flooding will reduce recharge by six percent. The WARPO Recharge Model was run with 1988 hydrological conditions with and without flooding conditions. The output is presented in Table A-35.

With reduced recharge, available groundwater is 86.2 Mm^3. As given in section A.1.8.3, the need is 73.0 Mm^3. Thus even with reduced recharge, groundwater is sufficient to meet the demand of the area.

Table A-35: Recharge under 1988 Hydrological Conditions With and Without Project

Project	Recharge (mm)												Total
	J	F	M	A	M	J	J	A	S	O	N	D	
Without	3	1	1	11	74	112	137	137	137	121	60	24	818
With	2	1	1	11	74	112	121	129	132	118	47	18	766

A.3.5 Impact on Hand Tube Well due to Reduced Recharge

At present, groundwater withdrawal for irrigation lowers the water level to the extent that in many areas the No. 6 suction mode hand tube wells upon which area people are dependent for domestic water supply, are running dry. These hand tube wells cannot operate beyond 7.0 m of suction head. The reduced recharge will lower the groundwater level further and make more hand tube wells out of operation. The impact in terms of the number of wells and their locations that will cease functioning is not quantifiable and identifiable without further study.

To cope with the situation, DPHE/UNICEF is gradually replacing the suction mode tube wells by forced mode Tara Pumps. The Tara Pumps can operate up to 15.0 m of suction head. The development of Tara Pumps under DPHE/UNICEF programme in the last few years is given in Table A-36. As seen in the Table, by 1995 there were 408 Tara Pumps in the area. Since one pump can service 100 persons, more than 36 percent of the project population are covered by these pumps.

Table A-36: Development of Tara Pumps

Tara Pump	Year			
	1992	1993	1994	1995
No.	166	222	304	408

A.3.6 Impact on Kangsha River Project

The Kangsha Project, covering an area of 11,000 ha, lies to the east of the Dampara Project (Figure A.19) and was developed by BWDB in 1990. Prior to its development, this area was used as floodway for the Daopara area. Since project development, flood flow is obstructed and homesteads in the Dampara Project area that were not flooded before, are now flooded. This leads the Dampara Project people to cut open the Jaria Road that acts as the Kangsha Project west embankment. As a result, the Kangsha Project cannot function and the investment is being lost. Social tension is also high between the people of the Kangsha and Dampara Project areas.

The proposed project will rehabilitate the Kangsha Project and reduce prevailing social tensions in the area.

A.3.7 Impact on Navigation

In the Dampara Project area, Kalihar Channel is the only navigational route. The 1995 NERP boat traffic survey revealed that total inflow and outflow for this channel is about 1060 tons of cargo.

The project embankment will close this channel at its outfall at Khatuair (Existing Regulator is on a diversion channel). This will require transhipment of cargo across the structure. Transhipment costs are estimated to be Tk. 26,500.00 annually at the rate of Tk 25.0 per ton.

A.4 Project Cost

A.4.1 Quantity Estimate

The estimates of the physical works are based on feasibility-level design and engineering surveys by consultants.

Embankment Works

Embankment from Jaria to Meda

Earthwork The quantity of earthwork infilling for 29.7 km of embankment was estimated based on pre- and constructed sections. About 1647 cross-sections (pre-sections) at intervals of 20 m and at critical locations were taken by NERP over the proposed alignment.

The longitudinal profile of the embankment and the typical design section are shown in Figure A.10. The estimated quantity of earthwork infilling is 742,740 m^3.

Turfing. Turfing was proposed on the embankment slopes and 0.30 m of the crest on both sides. The estimated quantity is 410,080 m^2.

Land Acquisition. About 51.0 ha of land will be required for the construction of the embankment. This is estimated based on base width of 17.0 m considering an average height of the embankment to 2.5 m. To minimise land acquisition, it is proposed to procure suitable earth for the embankment construction from private land with the payment of royalties.

Dismantling and resoling of Brick Work. About 1.0 km of brick soling road in Jaria requires heightening to put it above the 20-year flood level. This requires dismantling the existing soling and then resoling after heightening the road. It is assumed that 50 percent of road will be soled by available bricks and the remaining 50 percent will be done using new bricks. The total quantity of work is 4700 m^2.

Re-sectioning of Caritas Road along Naterkona
Earthwork The quantity of earthwork infilling for re-sectioning of this 2.01 km road (used as embankment) was estimated based on pre-constructed sections. About 138 cross-sections (pre-sections) at intervals of 15 m and at critical locations were taken by NERP over the proposed alignment.

The longitudinal profile of the embankment and the typical design section to be constructed are shown in Figure A.10. The estimated quantity of earthwork infilling is 24,400 m^3.

Turfing Turfing was proposed on the embankment slopes and 0.30 m of the crest on both sides. The estimated quantity is 24,310 m^2.

Land Acquisition There will be no land acquisition for the re-sectioning of the existing roads. The re-sectioning will increase the base width by a metre or so and the Naterkona Village residents have promised not to claim any compensation.

Closure and Diversion Channel

Estimate for closure
(Reference Drawing: Figure A-32)

a. Cross-sectional area of the closure: (21.02m+3.5x5.5m)x5.5m+(4.27m+2.5x2.15m)x2.15m = 250.0 m^2
b. Effective length of the closure: ((10m+30m)x2m/2+(30m+50m)x3.5m/2)/5.5m=40.0m

Eartwork in fillinig including shrinkage: 250 m^2 x 40m x 1.20=**12,000 m^3**

Turfing: (0.60m+5.4x2.15m+6.0m)x50.0m+7.28x5.5mx40.0m = **2600 m^2**

Estimate for Diversion Channel

a. Cross-sectional area: (12.0m+1.5x3.75m)x3.75m+(26.25m+1.5x1.75m)x1.75m=117 m^2
b. Length =400m (u/s+d/s)
Earthwork in excavation: 117m^2 x400m = **46,800 m^3**

Structure

Estimate for 500 mm diameter one Reinforced Cement Concrete (RCC) Pipe Sluice at Naterkona
(Reference Drawing: Figure A.22)

a. Earthwork in excavation: (9.50 - 8.695)x(900+1000)/1000 x 18.30+(9.50 - 8.20) x (3.0 + 1.0) x(5.9+1.0)+(9.50 - 8.20) x (3.0+1.0) x(7.1+1.0)= 28 m^3 + 36 m^3 + 42 m^3 = 106 m^3; say **115 m^3**

b. 500 mm diameter and 50 mm thick RCC pipe with single layer reinforcement = **18.30 m**

c. Lean concrete (1:3:6)

- C/S Apron, R/S Apron & Central Part: 3.50 x 1.4 x 0.08+0.9 x 0.9 x18.3 x0.08 + (3.5+1.10)/2 x 2.85 x 0.08 = 2.23 m^3 ; say **2.50 m^3**

d. RCC Work (1:2:4)

- Central Part base slab: 0.90 x0.275x18.30 - 0.15x0.40x18.30 = 3.43 m^3

- Collar: 0.15 x 0.25 x 0.90 x 9 = 0.304 m^3

- C/S Apron, Wing Wall, Base Slab & Cut-off Wall: (0.7+0)/2 x 0.9 x 0.25 x 2+.50 x.25 x 1.0 x2+1.2 x 1.0 x 0.25 x 2+0.30 x 0.25 x 0.6+0.25 x 1.65 x 3.50+1.50 x 0.25 x 3.50=3.80 m^3

- R/S Apron, Wing Wall, Base Slab & Cut-off Wall: 1.20 x 1.25 x 0.25 x 2+2 x 0.25 x 0.70 x2+(3.5 + 1.1)/2 x 1.6 x 0.25 +1.1 x 1.25 x 0.25+0.25 x 1.50 x 3.50 = 4.02 m^3

Total = 3.43 m^3+ 0.304 m^3+ 3.80 m^3+ 4.02 m^3 = 11.55 m^3 say = **14 m^3**

e. Reinforcement: 0.60 % x14 x 35.28 x 490 /2.204 = 658 kg say **700 kg**

f. Shuttering : say 30 m^2

g. Protective Works

- Loose Apron

  CC blocks (300 mm x 300 mm x 300 mm): (3.00x 1 + 3.00 x 2 + 1.56 x 2 x 2 + 1.56 x 1.0 x 2)/ (0.30 x 0.30)= 204 nos; say 210 nos

  Sand: .15 x 3.0 x 1+1.56 x 1 x .15 x 2+.15 x 3 x 2+1.56 x 2 x .15 x 2= 2.75 m^3 ; say 3 m^3

  Khoa: 0.15 x 3.00 x 1+1.56 x 1 x 0.15 x 2+0.15 x 3 x 2+1.56 x 2 x 0.15 x 2= 2.75 m3; say 3.0 m^3

- Launching Apron: (3 x 2 x 0.60 x 2 + 1.56 x 2 x 0.60 x 2 x 2) = 14.69 m^3; say 15 m^3

  CC blocks (300 mm x 300 mm x 300 mm): (60% x 15) / (0.3 x 0.3 x 0.3) = 333 nos.

  CC blocks (250 mm x 250 mm x 250 mm): (40% x 15) / (0.3 x 0.3 x 0.3) = 222 nos.

Total

CC blocks (300x300x300) =210 + 333 = 543 nos. say **550 nos.**

CC blocks (250x250x250) = 222nos. say **225 nos.**

Sand = **3 m^3**

Khoa = **3 m^3**

Estimate for 900 mm diameter RCC Pipe Sluice at Moheshpatti
(Reference Drawing: Figure A.23)

a. Earthwork in excavation: (1/2 x 2.22 x 1.48) x (18.40 x 2 + 35.40 x 2 + (1/2 x 1.68 x 1.12) x (11.96 x 2 + 35.40 x 2)+(1/2 x 3.50 x1.75) x (6.60 x 2 + 35.40 x 2) = 523.13 m^3 ; **say 525 m^3**

b. 900 mm diameter and 90 mm thick RCC pipe with Double layer Reinforcement = **18.30 m**

c. Lean concrete (1:3:6)

- C/S Apron, R/S Apron & Central Part : 2.50 x 0.5 x 0.08 + 1 x 2.30 x 0.08 x 2 + (3.0 +1.7)/2 x 2.74 x 0.08 + 1.70 x 1 x 0.08 + 1.30 x 18.30 x 0.08 + 3 0 x 0.50 x 0.08 + 2.30 x 10.08 x 2 + (3.50 + 1.78) /2 x 3.86 x 0.08 + 1.78 x 1 x 0.08 = 4.46 m^3 = **5.00 m^3**

d. RCC Work (1:2:4)

- Central Part base slab: 1.30 x 0.5 x 18.30 - 0.5x 0.454 x 0.275 x2 x18.30 = 9.61 m3

- Collar: 0.15 x 0.25 x 1.30 x 9 = 0.44 m^3

- C/S Return Wall, Base Slab, Wing Wall, Apron & Cut-off Wall: 0.25 x 1.15 x 2.30 x 2+0.30 x 1.0 x 2.30 x 2+1.46 x 0.25 x 2.82 x 2 + 2.27 x 0.25 x 1 x 2+2.50 x 0.50 x 0.30 + (3.00+1.20)/2 x 2.74 x 0.30+1 x 1.70 x 0.30 +1.20 x 0.25 x 7.10 = 10.63 m^3

- R/S Return Wall, Base Slab, Wing Wall, Apron, Cut-off Wall: 0.25 x 1.15 x 2.30 x 2+0.40 x1.0 x 2.30 x 2+1.54 x 0.25 x 3.95 x2 + 2.27 x 0.25 x 1 x 2+3.00 x 0.50 x 0.40 + (3.50+1.78)/2 x 3.86 x 0.40+1.00 x 1.78 x 0.50+0.40 x1.00 x 2.30 x 2+1.10 x 0.25 x7.60 = 16.84 m^3

Total = 9.61 m^3+ 0.44 m^3+ 10.63 m^3+ 16.84 m^3 = 37.52 m^3 ; say = **38 m^3**

e. Reinforcement: 0.60 % x38 x 35.28 x 490 /2.204 = 1788 kg; say **1800 kg**

f. Shuttering

- Base slab & Cut off wall: 1.40 x0.70 x 2 x 2 + 0.70 x 1.40 x 2 x 2 + 0.50 x 1 x 2 x 2+1.20 x 1.0 x 2 x 2 = 14.64 m^2 say 20 m^2

- R/S Wall: 1.15 x 2.30 x 4 + 0.25 x 1.15 x2 + 3.95 x 1.54 x4+2.27 x 1 x 4 = 44.57 m^2

- C/S Wall: 1.15 x 2.30 x 4+0.25 x 1.15 x 2+2.82 x 1.46 x 4 + 2.27 x 1 x 4 = 27.62 m^2

Total: 58.24 m^2 + 44.57 m^2 + 27.57 m^2 = 130.38 m^2 say **130 m^2**

g. Protective Works

- Loose Apron :

  CC blocks (300 mm x 300 mm x 300 mm): (2.57x 2 x 2 x 2 + 2.5 x 2 + 3 x2) / (0.30 x 0.30)= 350 nos.

  Sand: 0.15 x 2.50 x 1.75+0.15 x 2.57 x1.75 x 2+0.15 x 1.75 x 3+0.15 x 2.57 x 1.75 x 2 = 4.14 m^3 ; say 4 m^3

  Khoa: 0.15 x 2.50 x 1.75 + 0.15 x 2.57 x1.75 x 2+0.15 x 1.75 x 3+0.15 x 2.57 x 1.75 x 2 = 4.14 m^3 ; say **4 m^3**

- Launching Apron: (2.57 x 2 x 2 x 2 + 2.5 x 2 + 3 x2) x 0.60 = 18.94 m^3 say 20 m^3

  CC blocks (300 mm x 300 mm x 300 mm): (60% x 20) / (0.3 x 0.3 x 0.3) = 444 nos.

  CC blocks (250 mm x 250 mm x 250 mm): (40% x 20) / (0.3 x 0.3 x 0.3) = 296 nos.

Total

CC blocks (300x300x300) =350 + 444 = 794 nos. say **800 nos.**

CC blocks (250x250x250) = 296 nos. say **300 nos.**

Sand = **4 m^3**

Khoa = **4 m^3**

Table A-37: Summary of Structure Quantity Estimate

Description of Item	Unit	Quantities			
		500 mm diameter pipe structures		900mm diameter pipe structure	Total
		1 No	3 No		
1.Earthwork excavation	m^3	115	345	525	870
2.Supply of pipes	m	18.3	54.9	18.3	73.2
3. Lean concrete (1:3:6)	m^3	2.5	7.5	5.0	12.5
4. RCC work (1:2:4)	m^3	14	42	38	80
5.Reinforcement	kg	700	2100	1800	3900
6. Shuttering	m^2	30	90	130	220
7. CC blocks					
300mmx300mmx300mm	no	550	1650	800	2450
250mmx250mmx250mm	no	225	675	300	975
8. Sand	m^3	3	9	4	13
9. Khoa	m^3	3	9	4	13
10. Gate					
- Wooden	no	1	3	-	3
- Steel	no	-	-	1	1

Channel Re-excavation

Earthwork. Of the 15.5 km of Dhalai Channel length, re-excavation is needed for 9.6 km. The quantity of earthwork in excavation was estimated based on pre- and design sections. About 158 cross-sections (pre-sections) at intervals of 100 m were taken by NERP over 15.5 km of the Dhalai Channel.

The longitudinal profile of the channel and a typical design section are shown in Figure A.27. The estimated quantity of earthwork for excavation is 92,350 m^3.

Land Acquisition. Dhalai River was once a big channel. The channel sections have been reduced mainly by human encroachment. Since there is sufficient *khas* (government) land on both banks of the channel, there will be no need for land acquisition to re-excavate this channel.

A.4.2 Cost for FCD Works

The base cost for the FCD works is Tk. 16.8 million. As per FPCO's guidelines, all cost estimates should be derived from the most recent version of BWDB's Standard Schedule of Rates. Accordingly, earthwork and structure costs are based on BWDB's 1994 Schedule of Rates for Mymensingh O & M Circle.

It is assumed that diversion channel and the closure will be done under one contract so that earth available from the excavation of the diversion channel can be used in the closure.

It is assumed that embankment alignment will pass over land, 50 percent of which is double cropped and 50 percent homestead and garden. The current land prices were obtained from field interviews:

double cropped - Tk. 300,000/ha
homesteads and gardens (including high ridges along the river) - Tk. 500,000/ha

A lump sum of Tk. 86,600.00 was assumed to be the cost for the construction of each of the 30 LLP inlet structures.

The bill of quantities is given in Table A-38.

Physical contingencies equal to 15 percent of base construction costs as per *FPCO guidelines* were used to cover unforeseen costs. Engineering costs (survey, design, preparation of tender documents, supervision of construction and administration) were taken as 9 percent of the base construction costs plus physical contingencies. The breakdown of engineering costs are given below:

- survey, detailed design and preparation of tender document 2%
- supervision of construction 5%
- administration costs 2%

The cost summary is presented in Table A-39.

Table A-38: Bill of Quantities

Item	Description of Item	Unit	Quantity	RateTk/unit	Amount (Tk)
Embankment	1.Earthwork in filling: - Earth work by manual labour in construction of embankment with carried earth and as per BWDB's specifications for a lift of 0 to 3 m	m^3	767,140	15.20	11660530
	2.Royalty of specified earth: - Royalty of specified earth taken from private land from the area to be selected by the contractor with agreement of the land owner	m^3	767,140	3.44	2638962
	3.Turfing - Fine dressing and close turfing of the slopes and the crest of embankment with 75 mm thich good quality durba	m^2	434,390	3.94	1711497
	4.Dismantling and re-soling of brick work				
	- Dismantling existing brick pavement	m^2	4700	1.82	8554
	- resoling with available bricks	m^2	2350	28.43	66811
	- resoling with new bricks	m^2	2350	88.43	207810
Subtotal					**16294164**
Closure	1. Earthwork - Earthwork by manual labour in all kinds of soils for closing channel, with all leads and lifts, as per BWDB's specifications and for a channel width upto 60 m.	m^3	12,000	16.30	195,600
	2. Turfing - Fine dressing and close turfing of the slopes and the crest of embankment with 75 mm thich good quality durba	m^2	2,600	3.94	10,244
Diversion Channel	Earth work in excavation - Earth work by manual labour in all kinds of soil in excavation of channel including spreading the spoils over the bank area	m^3	46,800	14.10	659,880

Subtotal					865,724
Structure	a. Drainage Structure 1. Earthwork in excavation 2. Supply of pipes - 500 mm dia - 900 mm dia 3. Lean concrete (1:3:6) 4. R.C.C work (1:2:4) 5. Reinforcement 6. Shuttering 7. CC block -300mmx300mmx300mm -250mmx250mmx250mm 8. Sand 9. Khoa 10. Gate - Steel gate - Wooden gate	m^3 m m m^3 m^3 Kg m^2 nos nos m^3 m^3 no .no	870 54.90 18.30 12.50 80 3900 220 2450 975 13 13 1 3	19.85 925.39 4163.22 2372.29 2839.68 30.32 180.48 65.46 45.52 439.97 1622.51 35,000 500.00	17270 50804 76187 29654 227174 118248 39706 160377 44382 5720 21093 35000 500
	b. LLP Inlet Structure	no	30	86,600	2598000
	c. Rehabilitation of Khatuair Regulator	l.s			100000
Subtotal					**3524115**
Channel	1. Earth work in re-excavation - Earth work by manual labour in all kinds of soil in re-excavation of channel including spreading the spoils over the bank area	m^3	92,350	14.10	1302135
Subtotal					**1302135**
Land acquisition	1. Land acquisition - Double cropped land - Homesteads and gardens	 ha. ha.	 25 26	 300,000 500,000	 7500000 13000000
Sub total					**20500000**

Table A-39: Cost Summary

Item	Cost ('000 Tk)
Embankments	16,294
Closure and Diversion Channel	866
Structure	3,524
Channel	1,302
Land Acquisition	20,500
Base Cost	**42,486**
Physical Contingencies (15% of Base Cost)	6,373
SUBTOTAL	**48,859**
Study Cost (9% of Subtotal)	4,397
TOTAL	**53,256**

A.4.3 O&M Cost

O&M costs in financial prices have been given in Table A-40. FPCO Guidelines (Table 2 of Annex 7) have been followed in estimating the O&M costs. Data collected from different BWDB existing projects indicate that percent costs shown in Table A-40 is adequate to cover the O&M cost of the project.

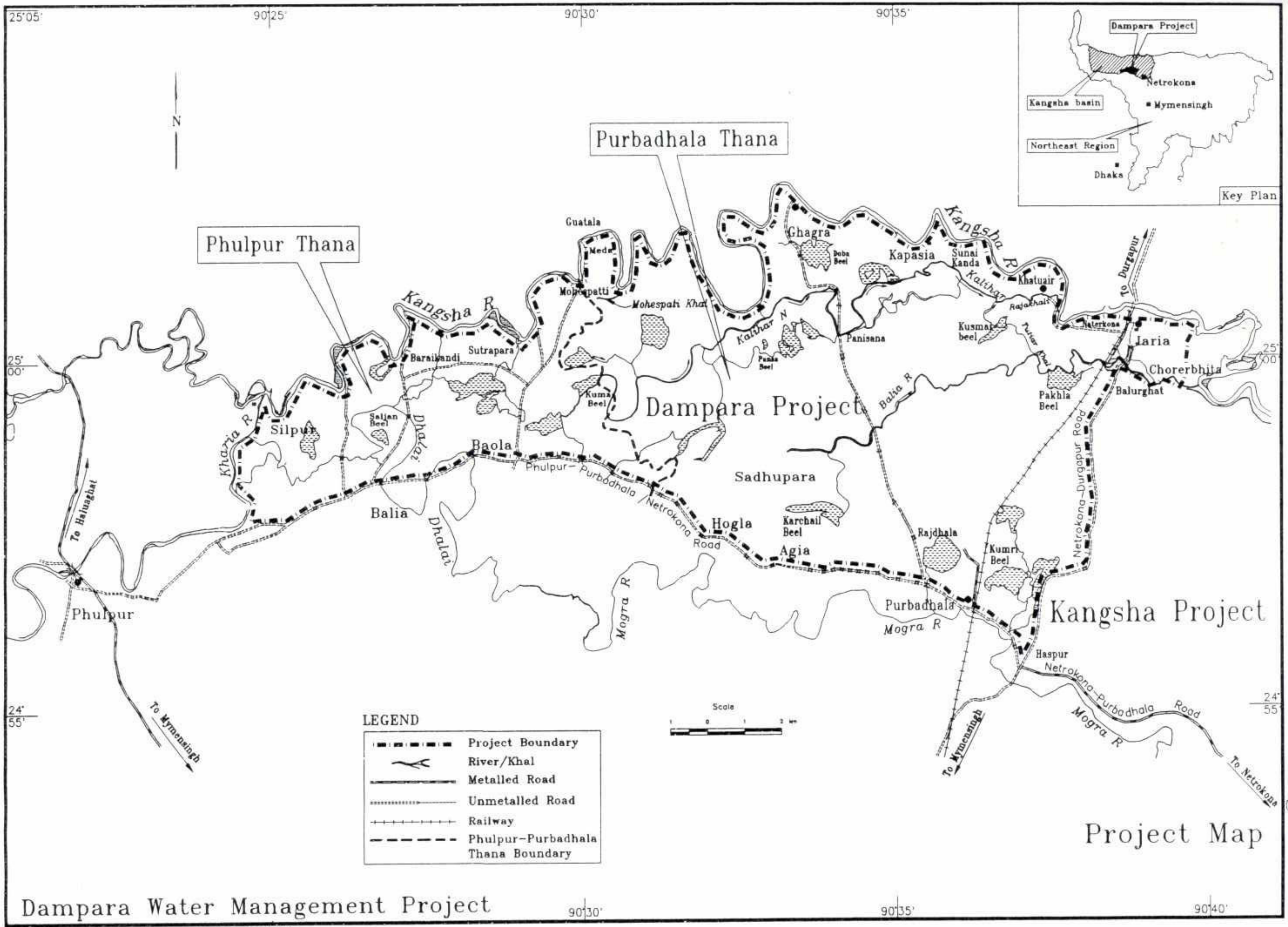
Table A-40: Annual Operation and Maintenance Costs

Item	Capital Cost ('000 Tk)	Annual O&M	
		%	Cost ('000 Tk)
Embankments	16,294	6	978
Closure and Diversion Channel	866	6	52
Structure	3,524[1]	3	886
Channel	1,302	6	78
Base Cost	**21,986**	-	**1,994**
Physical Contingencies (15%)	3,298	-	299
Total	**25,284**	-	**2,293**

[1] An amount of Tk 26.0 million is added to the structure item as cost of the two existing structures to cover their O&M.

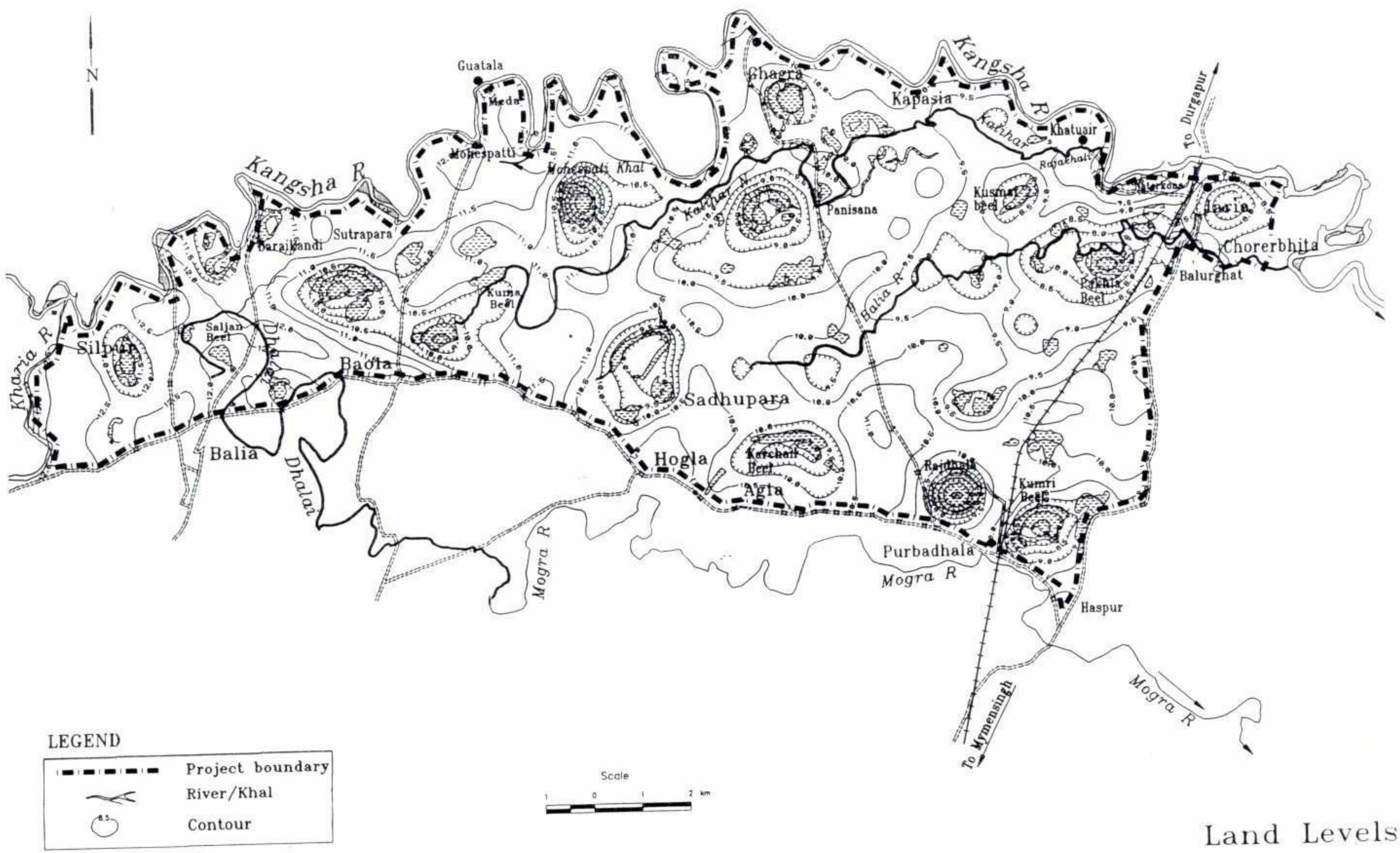
FIGURES

Figure A.1



FILE: ANEX–1.DWG Prepared by: Jalal, Oct/1995

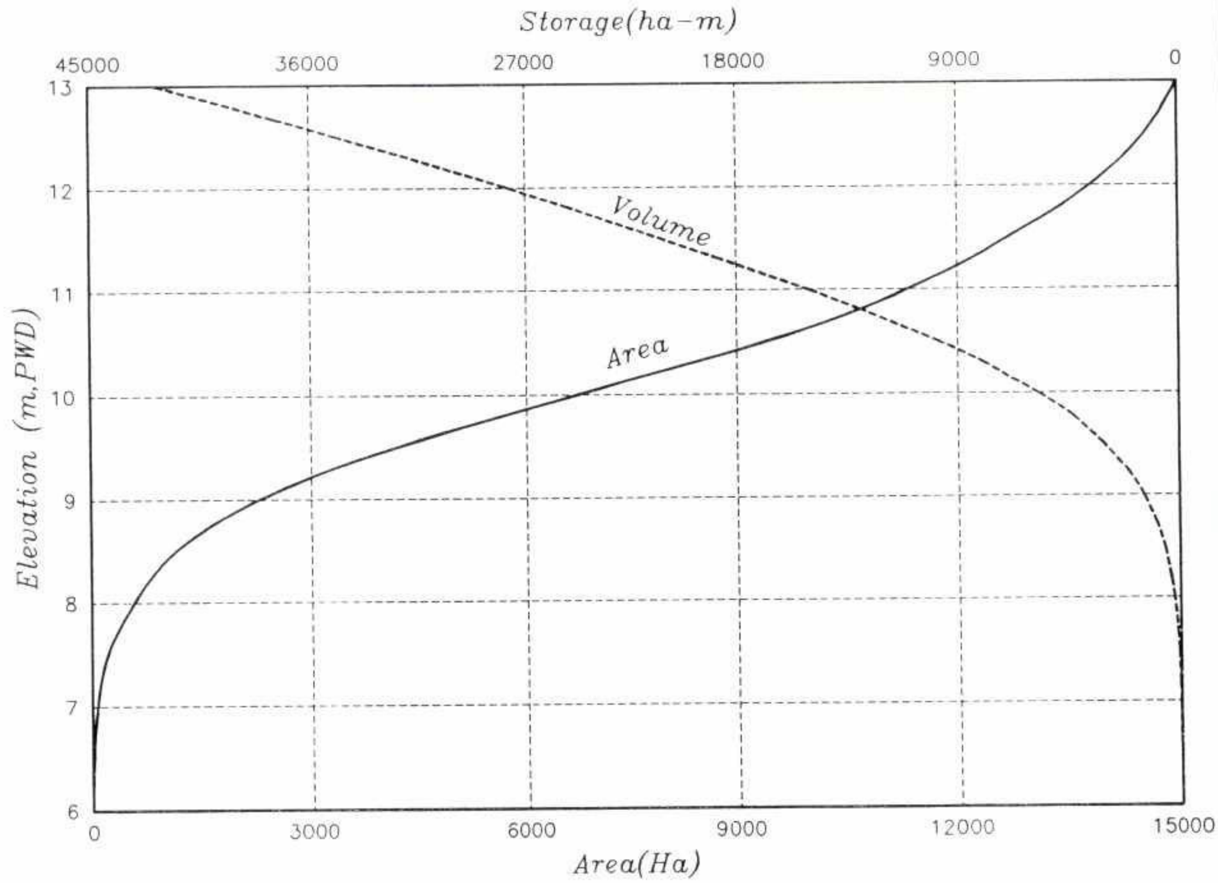
Figure A.2



Land Levels

Dampara Water Management Project

FILE: ANEX-2.DWG Prepared by: Jalal, Oct/1995



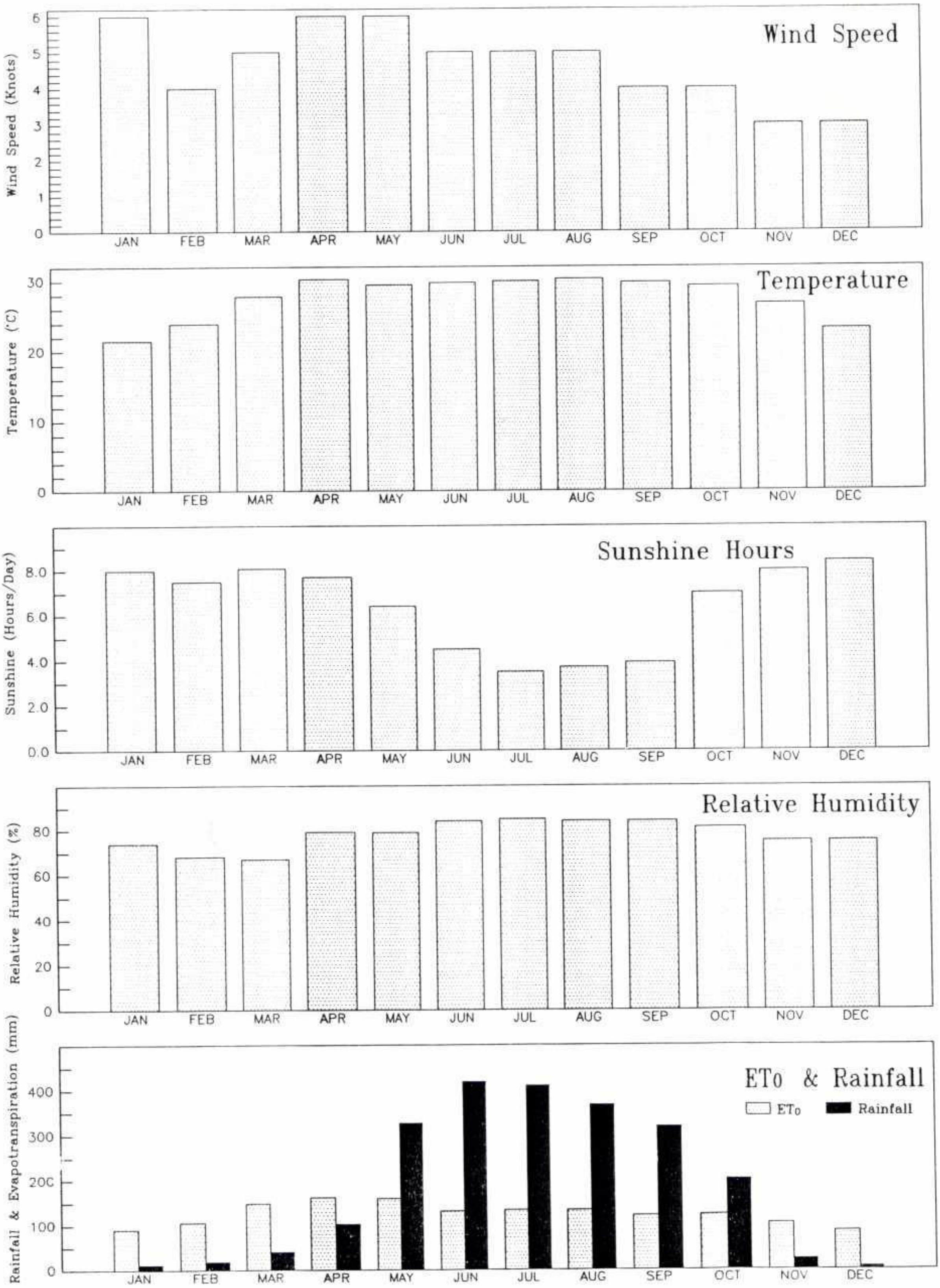
EL(m,PWD)	Area(ha)	Storage(ha-m)
6.24	6.326	0.000
6.50	12.653	2.467
7.00	63.264	21.447
7.50	170.814	79.966
8.00	550.401	260.270
8.50	1056.516	661.999
9.00	2163.644	1467.039
9.50	4042.598	3018.600
10.00	6725.011	5710.502
10.50	9559.258	9781.569
11.00	11419.232	15026.191
11.50	12741.459	21066.364
12.00	13892.872	27724.947
12.50	14626.740	34854.850
13.00	15000.000	42261.535

Elevation - Area - Storage
Dampara Project Area

Dampara Water Management Project

FILE: ANEX-3.DWG Prepared by: Awlad, Oct/1995

Figure A.4

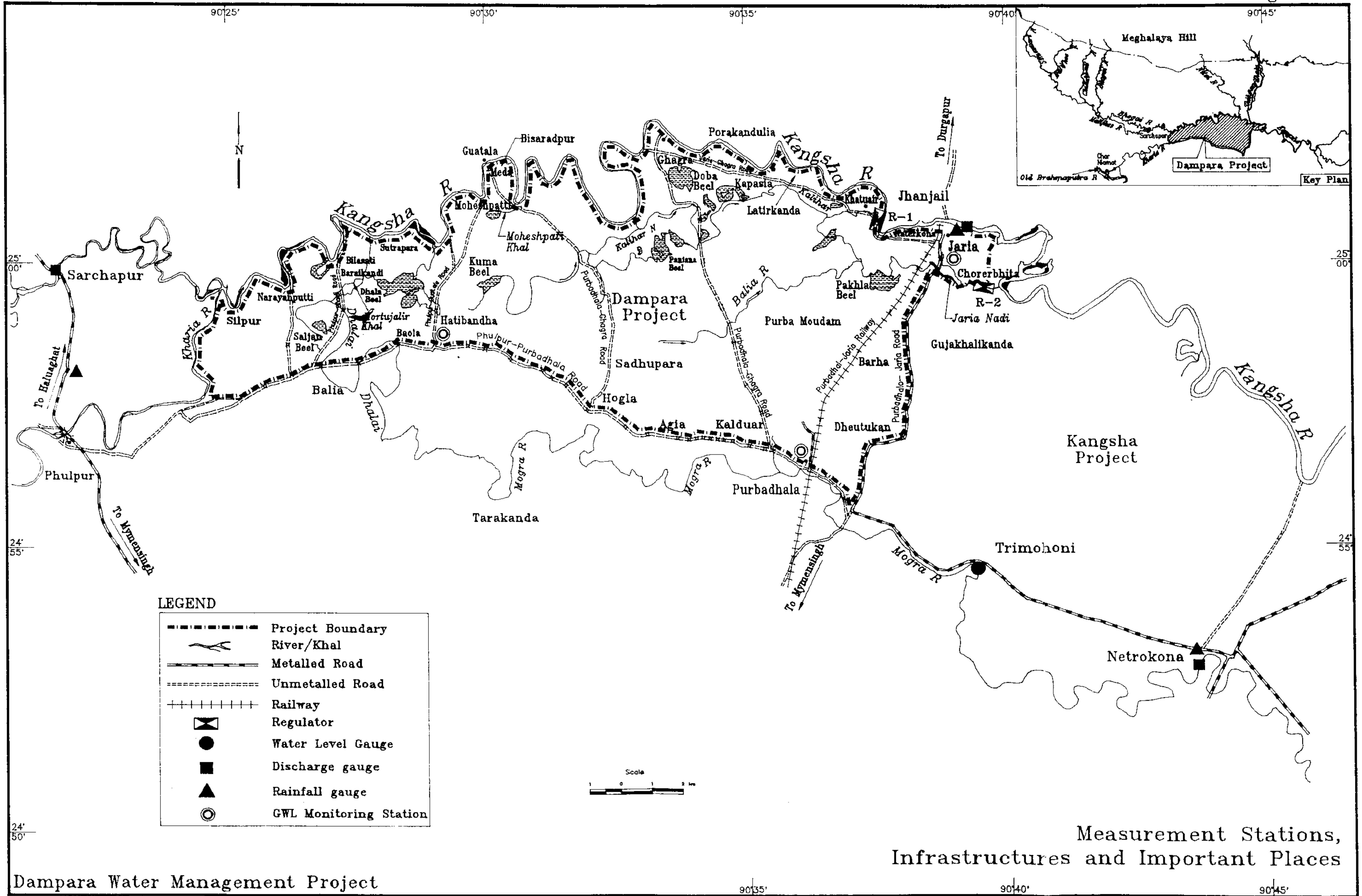


Climatic Condition
at Mymensingh

Dampara Water Management Project

FILE: ANEX-4 Prepared by: FR

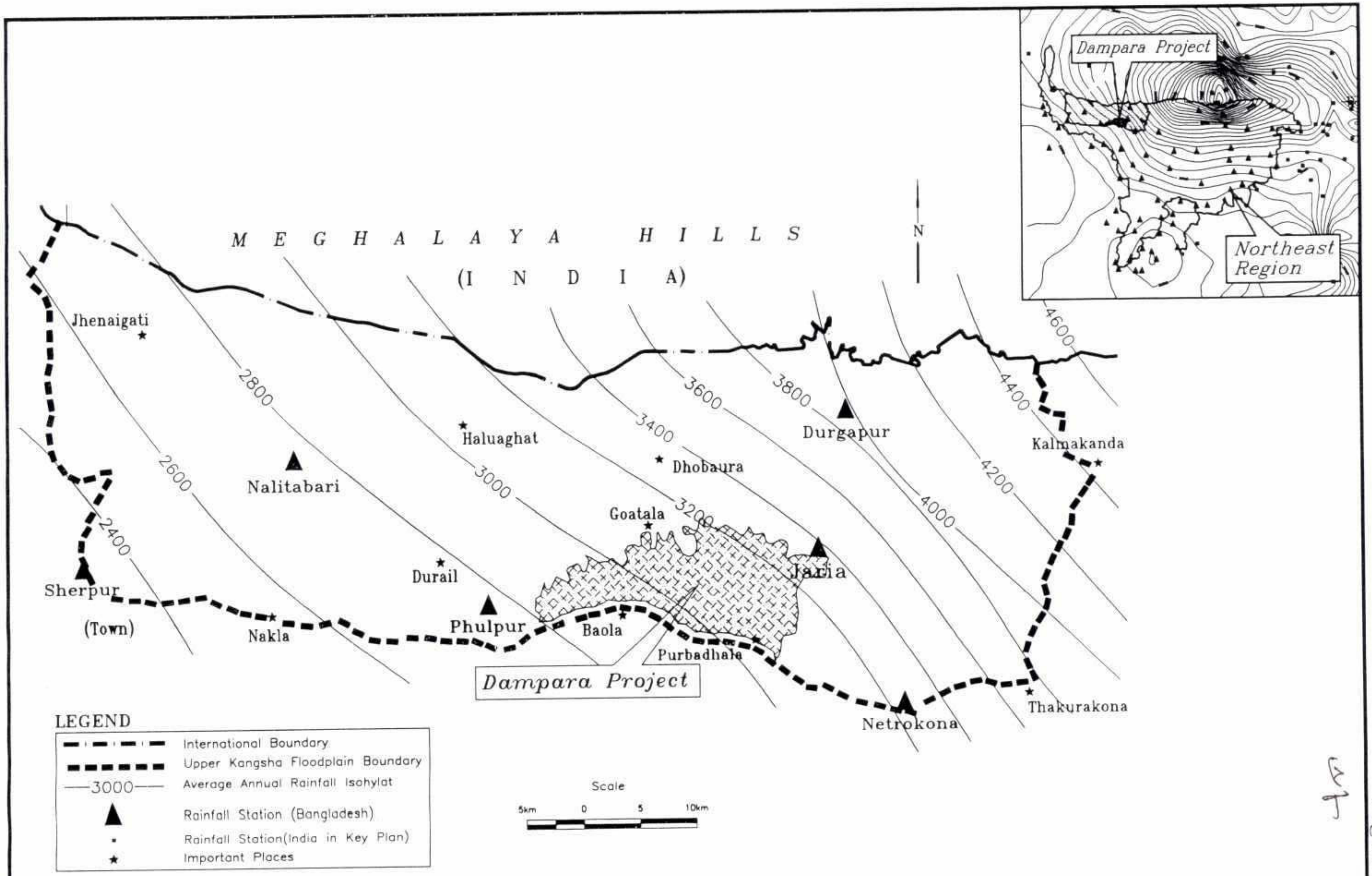
Figure A.5



Measurement Stations, Infrastructures and Important Places

Dampara Water Management Project

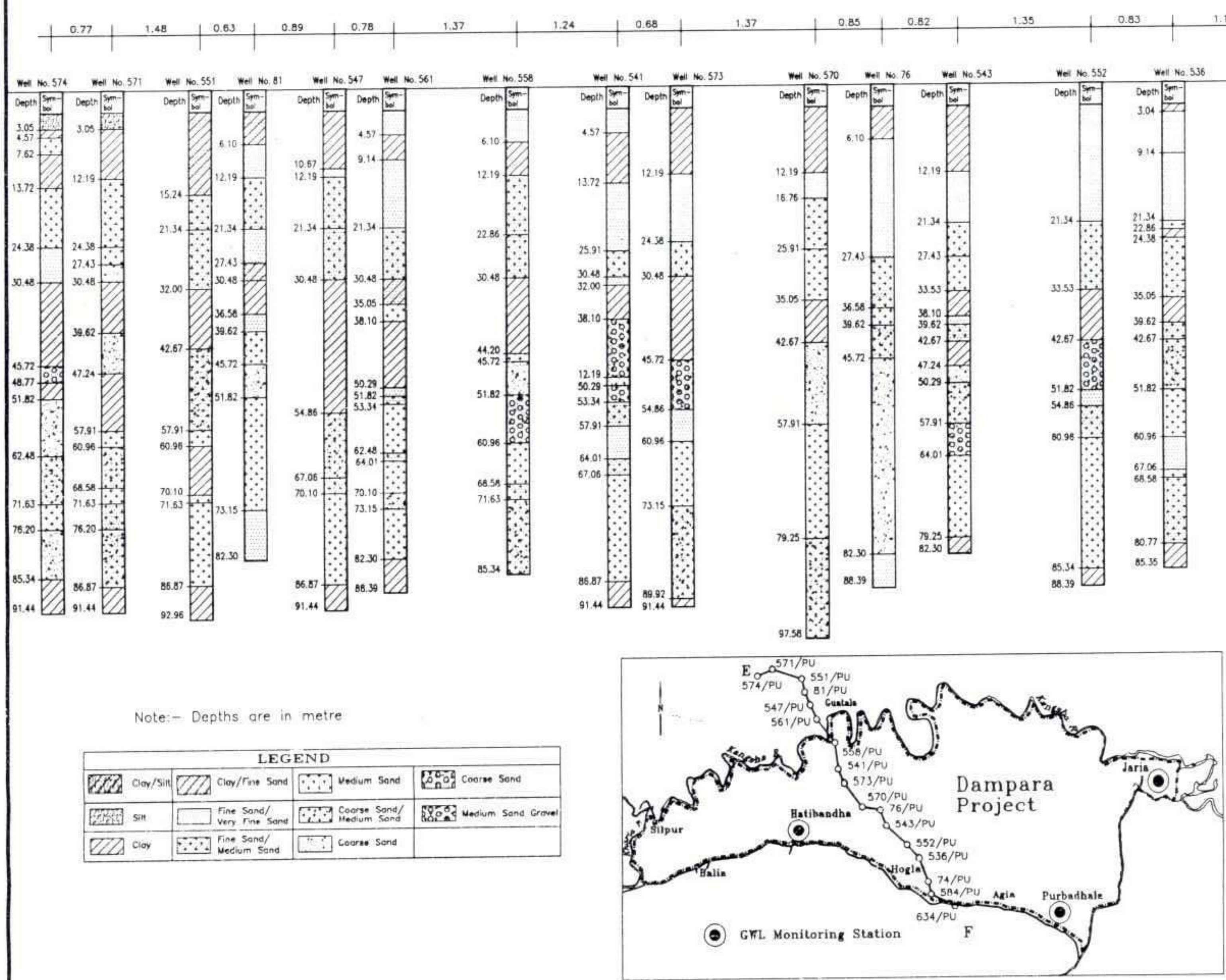
FILE: ANEX-6



Annual Rainfall Isohyet

Dampara Water Management Project

FILE: ANEX-6.DWG Prepared by: Jalal, Oct/1995

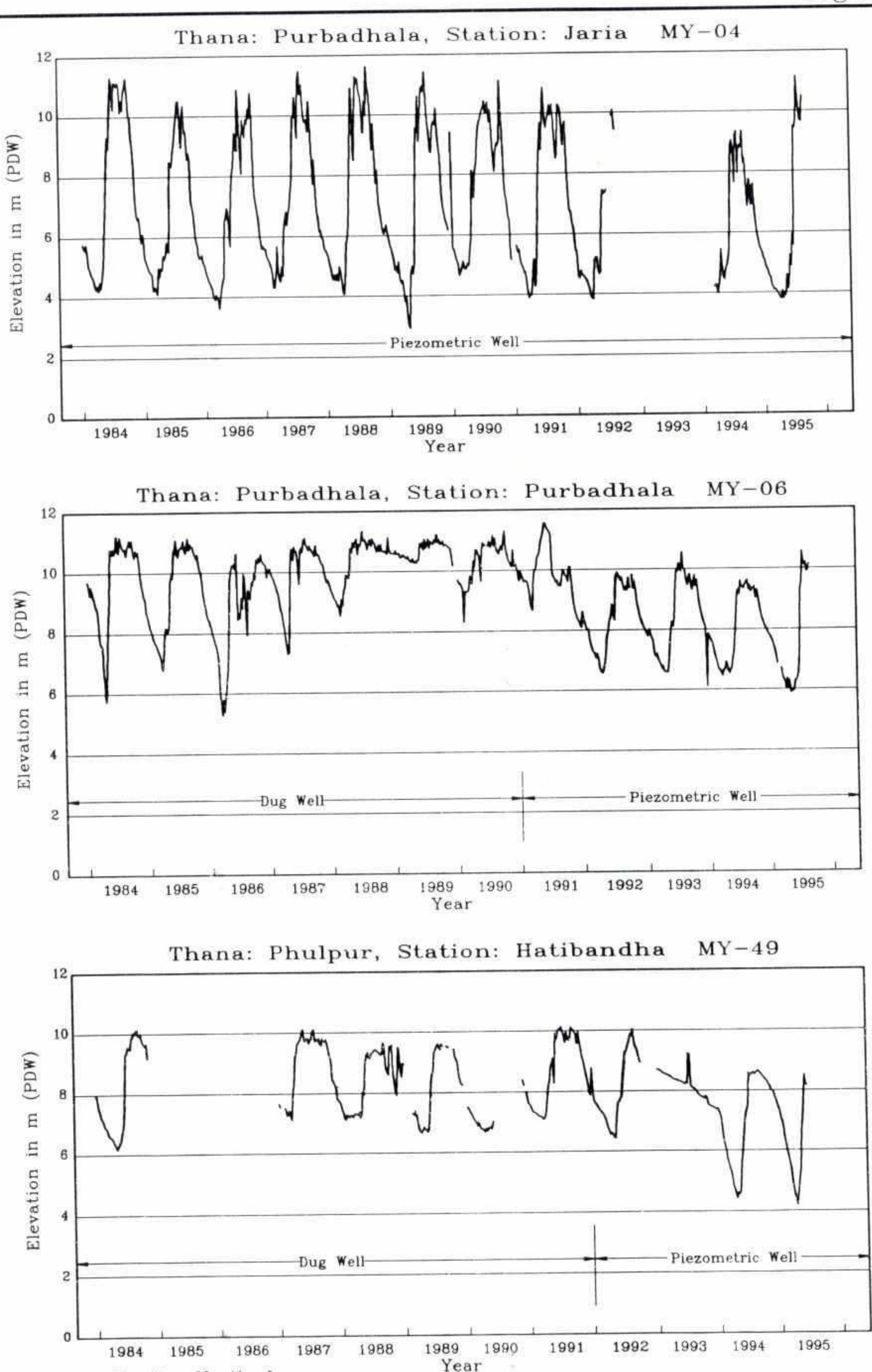


Lithology

Dampara Water Management Project

FILE: ANEX-7 Prepared by: Jalal

Figure A.8



Starting Month: January

Groundwater Level Hydrograph

Dampara Water Management Project

FILE: ANEX-8 Prepared by: MCR

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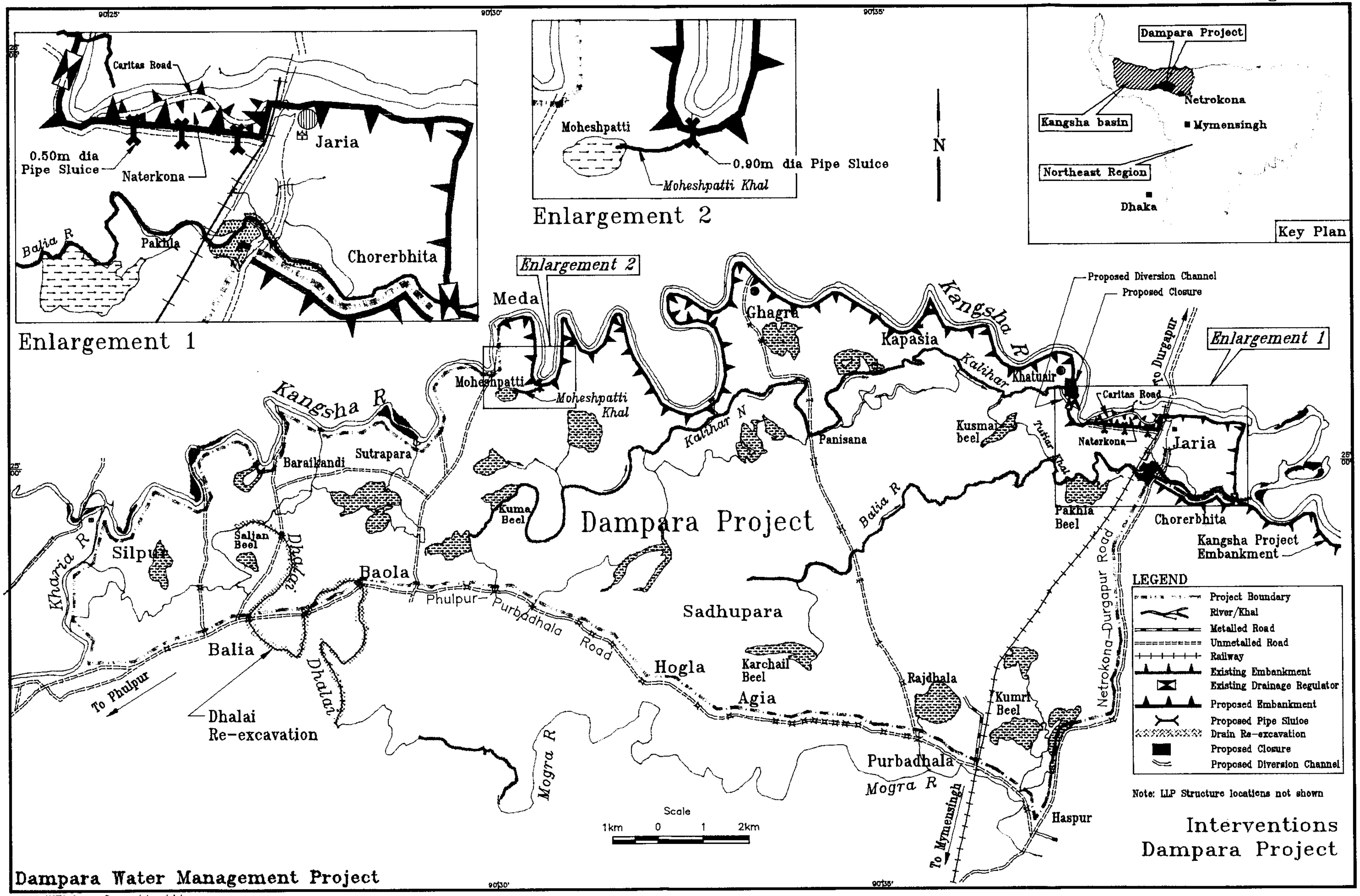
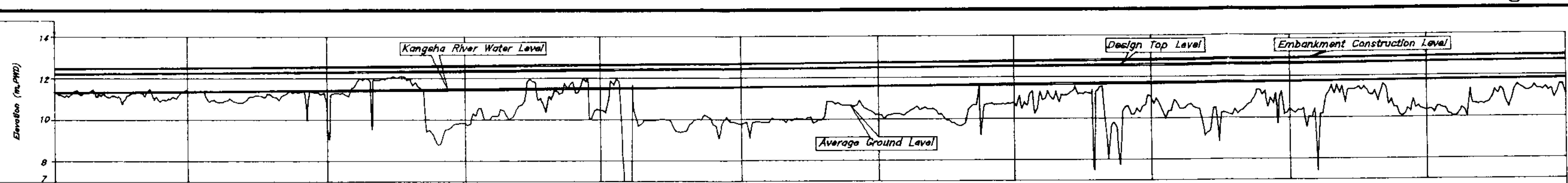
Figure A.9



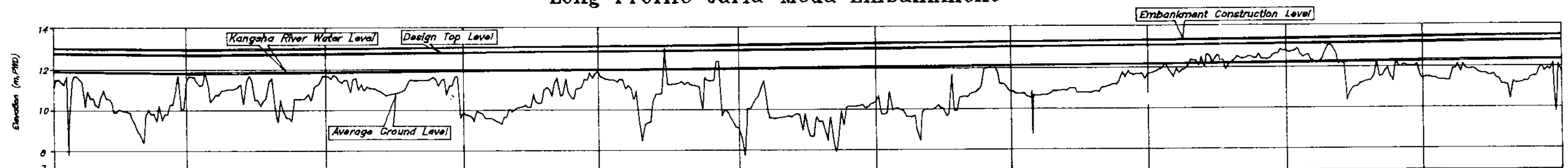
FILE: ANEX-9 Prepared by: Jalal

Figure A.10



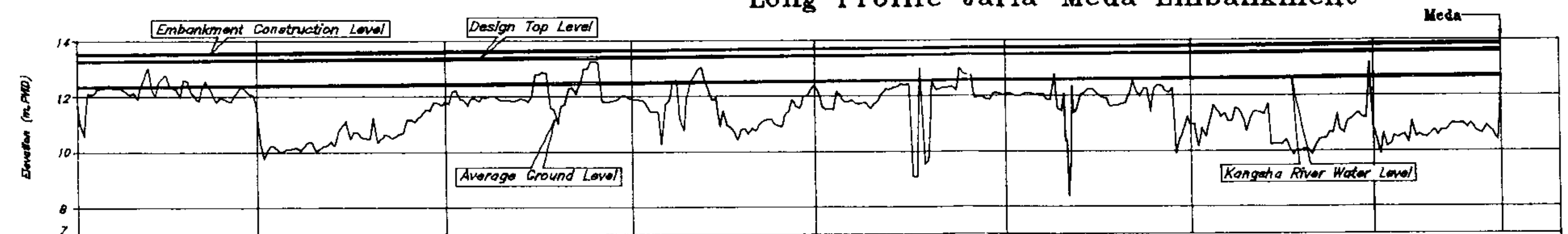
Distance (Km)	00	01	02	03	04	05	06	07	08	09	10	11
Ground Level (m,PWD)	11.35	11.39	9.23	9.83	10.44	9.81	10.23	10.76	11.03	10.41	10.35	11.45
Design Water Level (m,PWD)	11.30	11.35	11.39	11.44	11.48	11.53	11.58	11.62	11.67	11.71	11.76	11.81
Design Crest Level (m,PWD)	12.21	12.26	12.30	12.35	12.39	12.44	12.49	12.53	12.58	12.62	12.67	12.72
Construction Level (m,PWD)	12.46	12.51	12.55	12.60	12.64	12.69	12.74	12.78	12.83	12.87	12.92	12.87

Long Profile Jaria-Meda Embankment



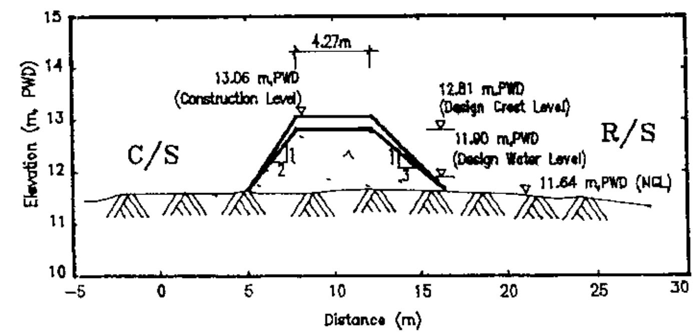
Distance (Km)	11	12	13	14	15	16	17	18	19	20	21	22
Ground Level (m,PWD)	11.45	11.66	11.64	9.67	11.88	9.07	10.66	10.85	11.72	12.70	11.48	10.89
Design Water Level (m,PWD)	11.81	11.85	11.90	11.95	11.99	12.04	12.08	12.13	12.18	12.22	12.27	12.31
Design Crest Level (m,PWD)	12.72	12.76	12.81	12.86	12.90	12.95	12.99	13.04	13.09	13.13	13.18	13.22
Construction Level (m,PWD)	12.97	13.01	13.06	13.11	13.15	13.20	13.24	13.29	13.34	13.38	13.43	13.47

Long Profile Jaria-Meda Embankment



Distance (Km)	22	23	24	25	26	27	28	29	29.7	30
Ground Level (m,PWD)	10.89	10.15	11.72	11.81	12.16	12.08	10.96	10.49	12.65	
Design Water Level (m,PWD)	12.31	12.36	12.41	12.45	12.50	12.55	12.59	12.64	12.67	
Design Crest Level (m,PWD)	13.22	13.27	13.32	13.36	13.41	13.46	13.50	13.55	13.58	
Construction Level (m,PWD)	13.47	13.52	13.57	13.61	13.66	13.71	13.75	13.80	13.83	

Long Profile Jaria-Meda Embankment



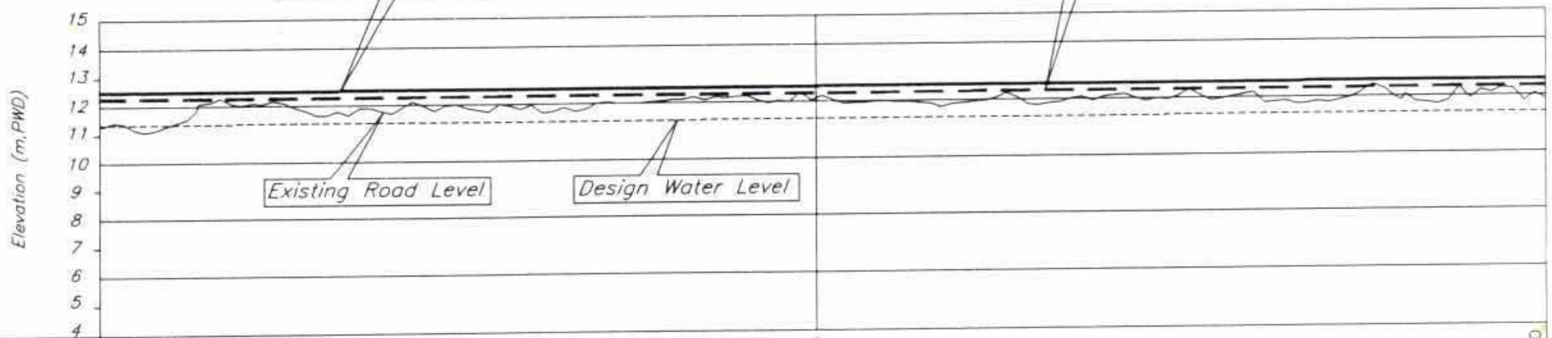
Typical Emabankment Cross section (Ch-13000 m)

Jaria-Meda Embankment Longitudinal Profile

Dampara Water Management Project

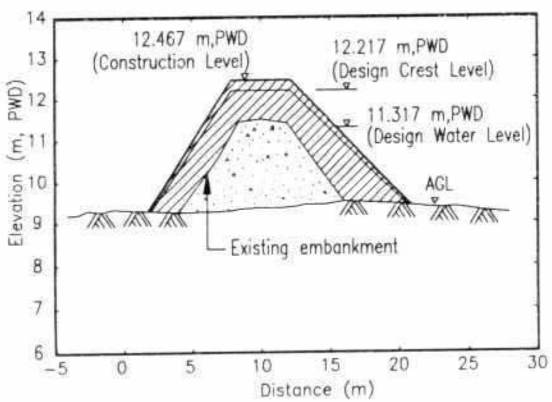
FILE: ANEX-10

Figure A.10(Cont'd)



Ground Level (m,PWD)	11.372	12.200	11.830
Design Water Level (m,PWD)	11.351	11.386	11.420
Design Crest Level (m,PWD)	12.257	12.286	11.830
Construction Level (m,PWD)	12.501	12.536	13.091
Distance (Km)	0	1.0	2.01

Caritas Road



Typical Emabankment Cross section
(Ch-1.358 m)

Typical Cross-section and Longitudinal Profile of Embankment Re-sectioning of Caritas Road

Dampara Water Management Project

FILE: ANEX-10A Prepared by: Awlad

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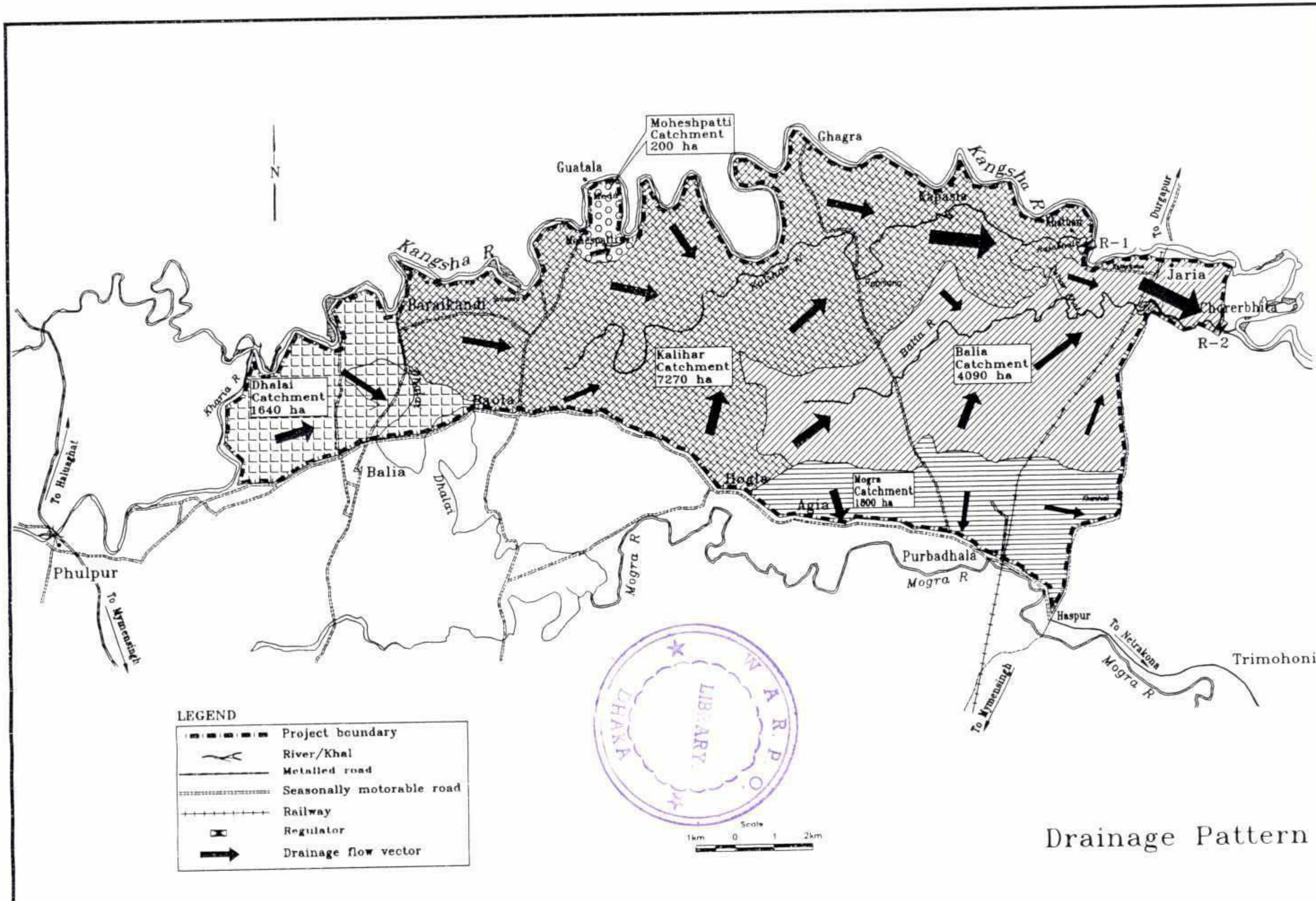


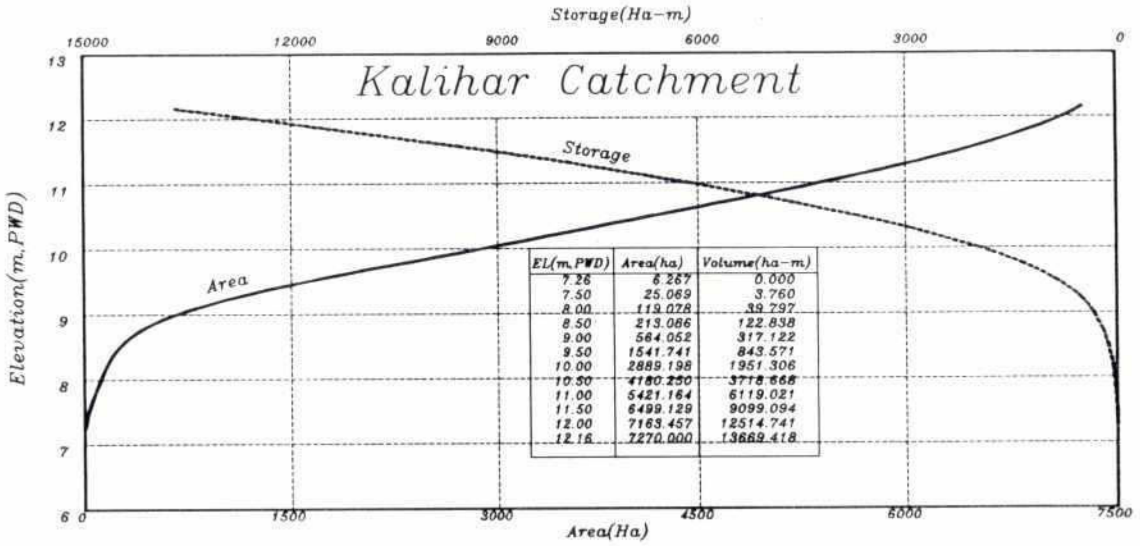
Drainage Pattern

Figure A.12

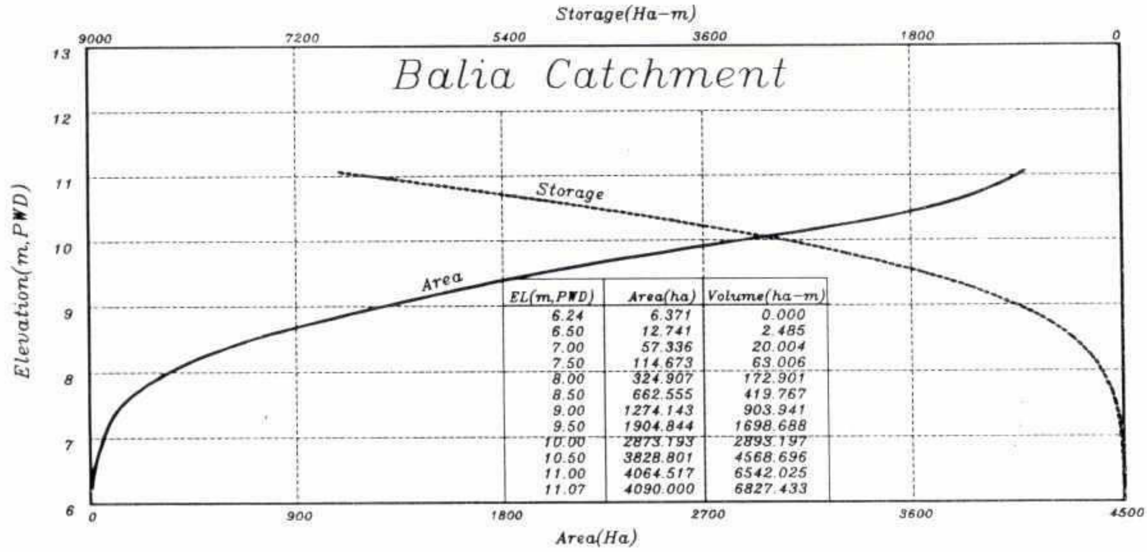
Dampara Water Management Project

FILE: DRP-18.DWG Prepared by: Jalal

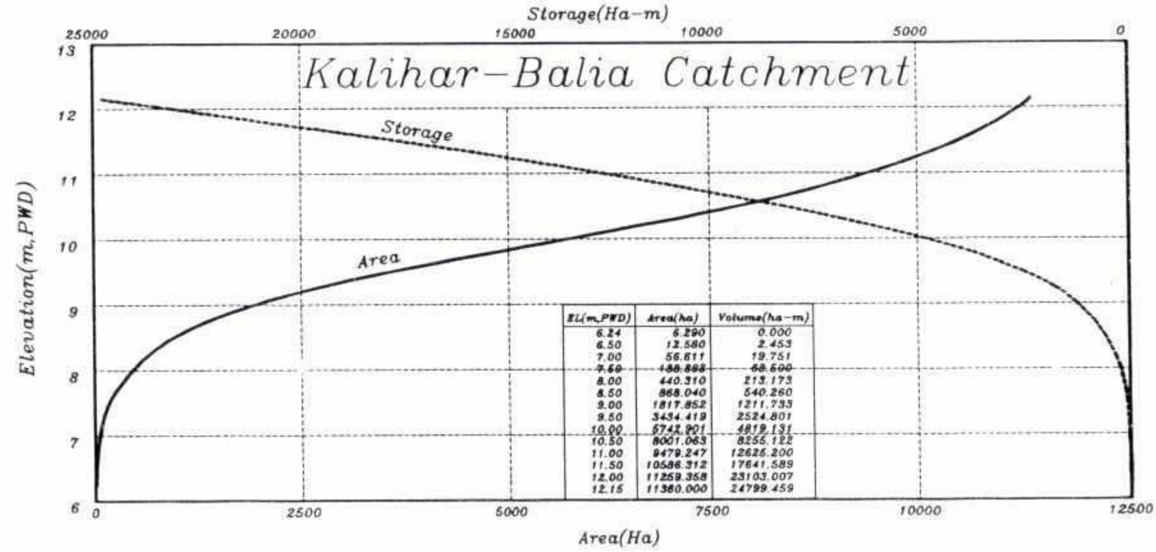
Figure A.13



EL(m,PWD)	Area(ha)	Volume(ha−m)
7.26	6.267	0.000
7.50	25.069	3.760
8.00	119.078	39.797
8.50	213.086	122.838
9.00	564.052	317.122
9.50	1541.741	843.571
10.00	2889.198	1951.306
10.50	4180.250	3718.668
11.00	5421.164	6119.021
11.50	6499.129	9099.094
12.00	7163.457	12514.741
12.16	7270.000	13669.418



EL(m,PWD)	Area(ha)	Volume(ha−m)
6.24	6.371	0.000
6.50	12.741	2.485
7.00	57.336	20.004
7.50	114.673	63.006
8.00	324.907	172.901
8.50	662.555	419.767
9.00	1274.143	903.941
9.50	1904.844	1698.688
10.00	2873.193	2893.197
10.50	3828.801	4568.696
11.00	4064.517	6542.025
11.07	4090.000	6827.433



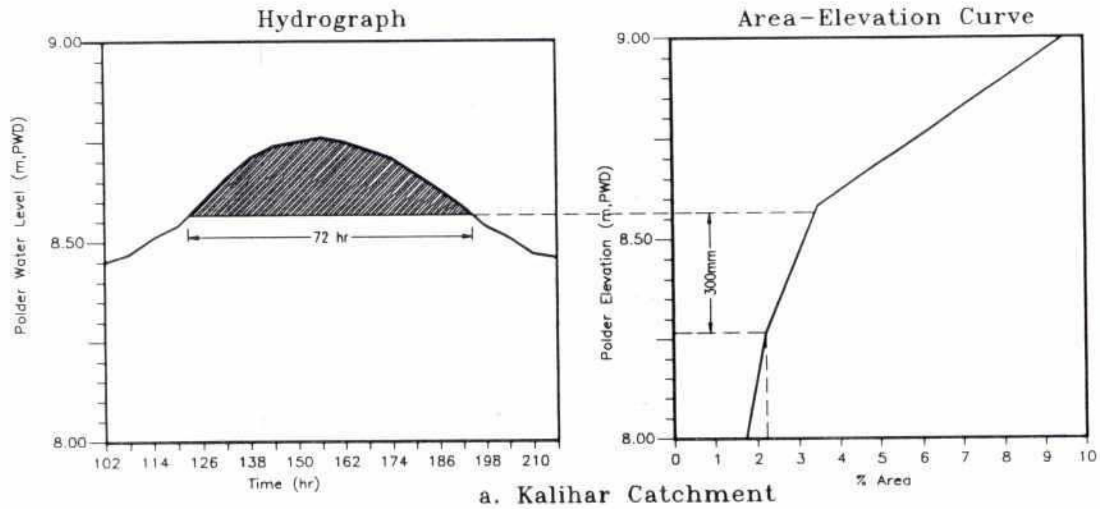
EL(m,PWD)	Area(ha)	Volume(ha−m)
6.24	6.290	0.000
6.50	12.580	2.453
7.00	56.611	19.751
7.50	[illegible]	[illegible]
8.00	440.310	213.173
8.50	868.040	540.260
9.00	1817.852	1211.733
9.50	3434.419	2524.801
10.00	5742.901	4819.131
10.50	8001.063	8255.122
11.00	9479.247	12626.200
11.50	10586.312	17641.589
12.00	11259.358	23103.007
12.15	11360.000	24799.459

Elevation − Area − Storage

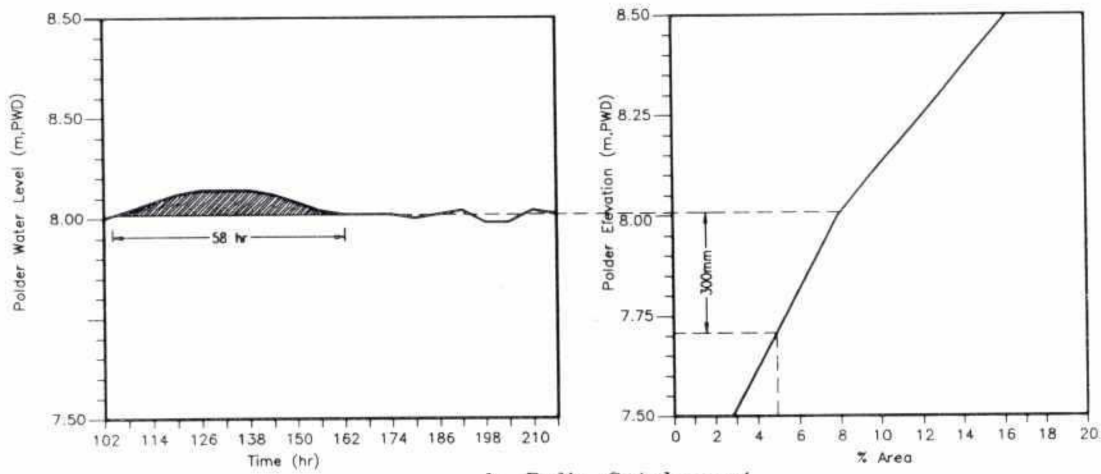
Dampara Water Management Project

FILE: ANEX-13.DWG Prepared by: Awlad, Oct/1995

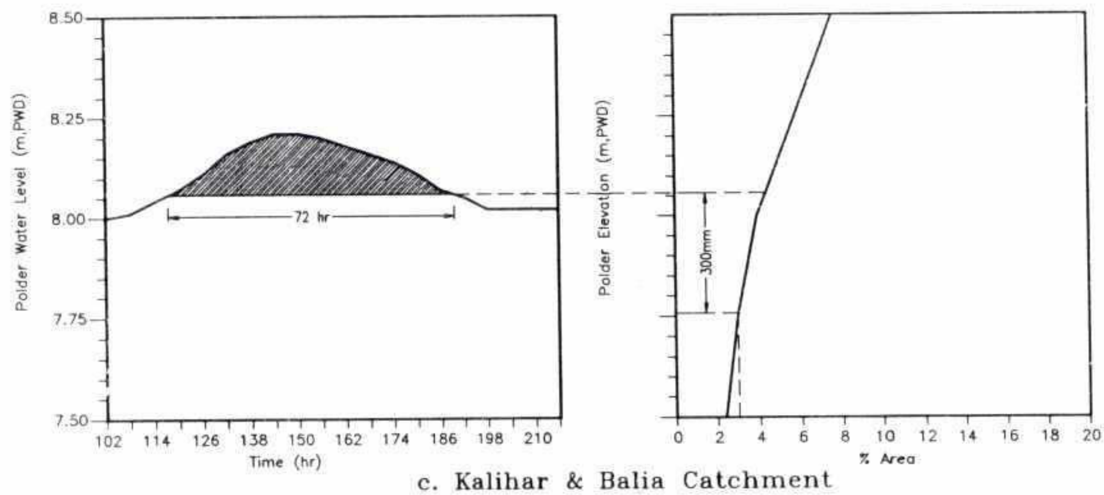
Figure A.14



a. Kalihar Catchment



b. Balia Catchment



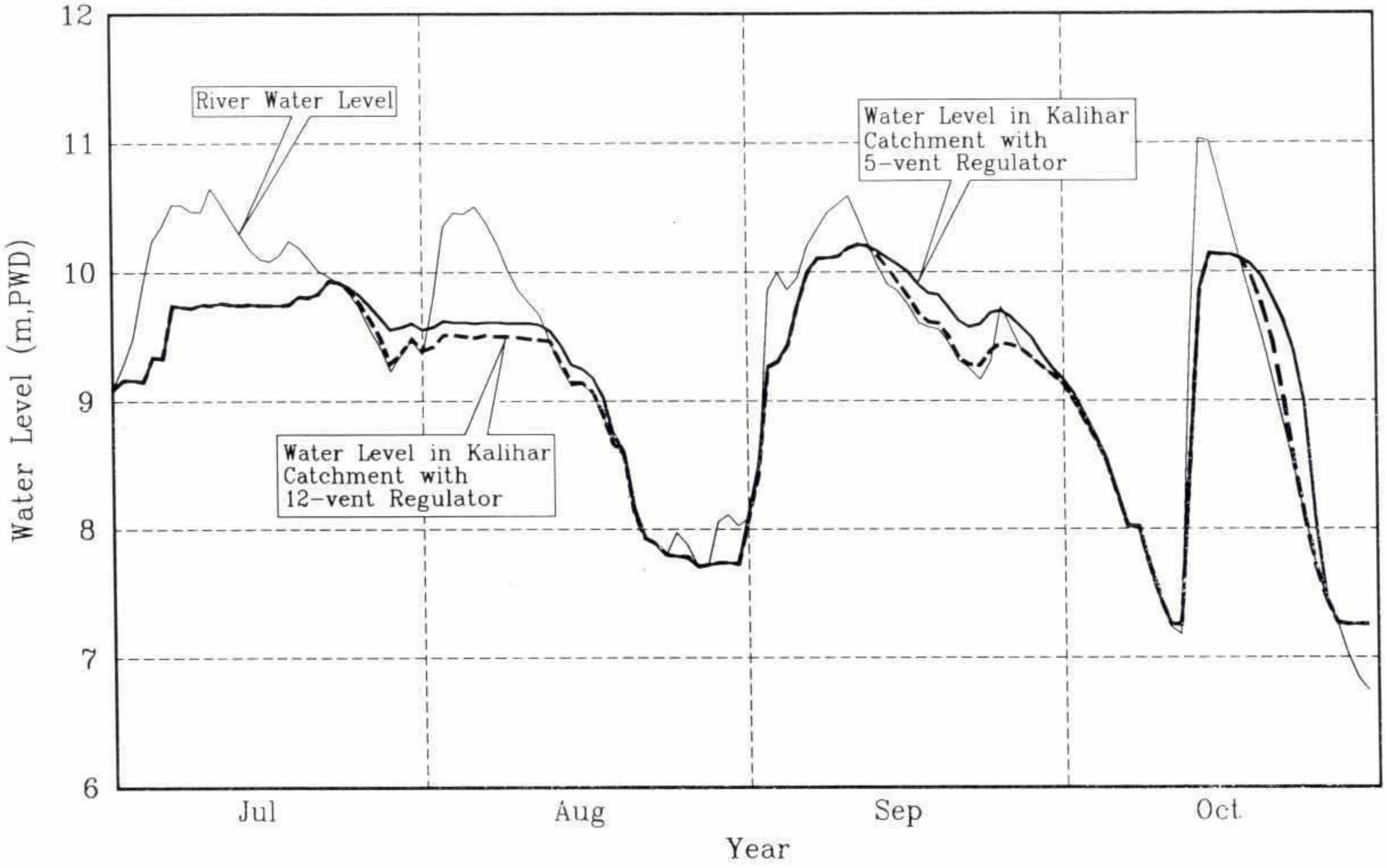
c. Kalihar & Balia Catchment

Pre-monsoon Flood Routing
Check for Regulator Adequacy

Dampara Water Management Project

FILE: ANEX-14 Prepared by: FR

Figure A.15

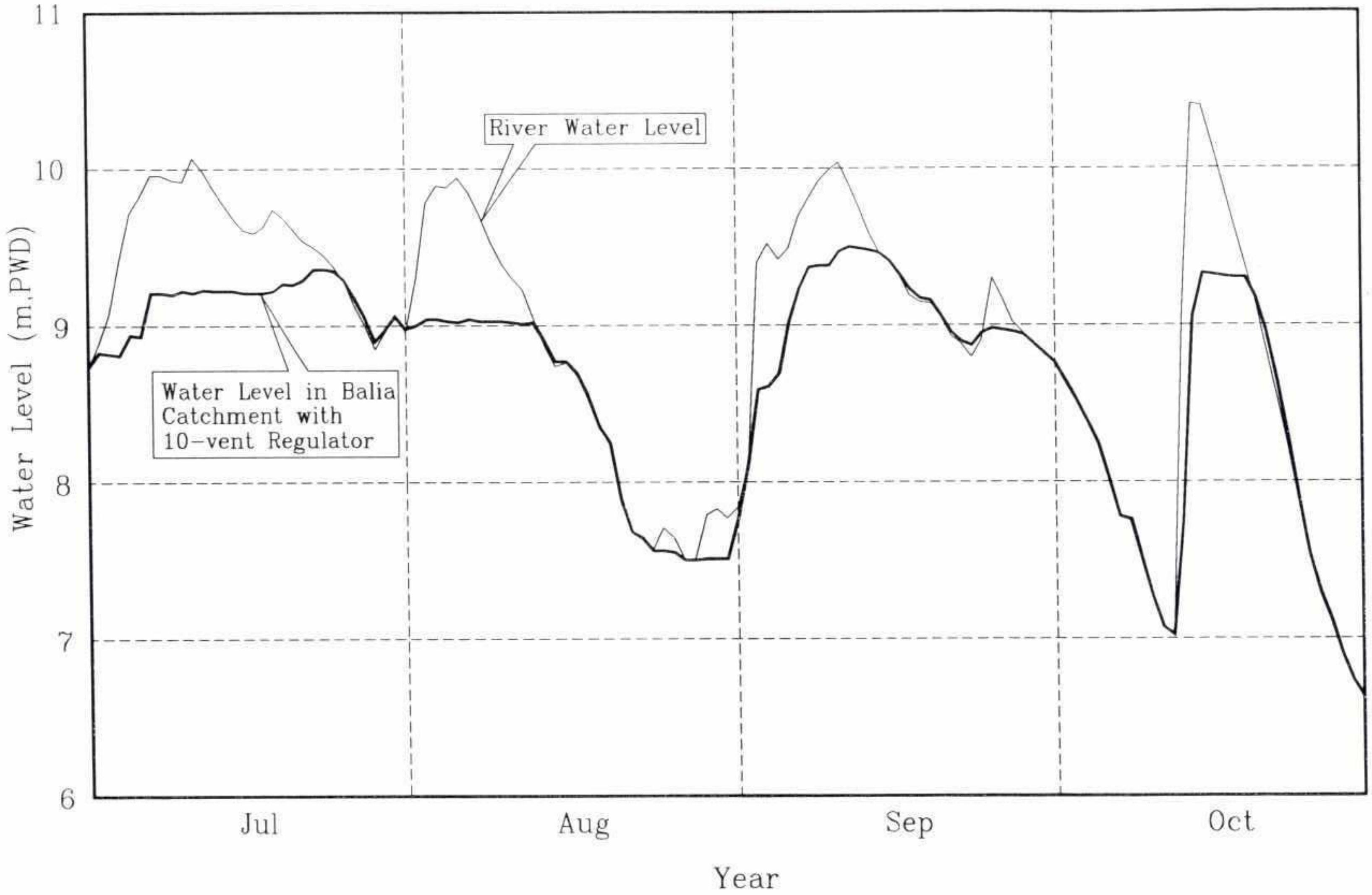


Monsoon Water Level
(Post-Project Condition)
Kalihar Catchment

Dampara Water Management Project

FILE: ANEX-15 Prepared by: Awlad, Nov/1995

Figure A.16

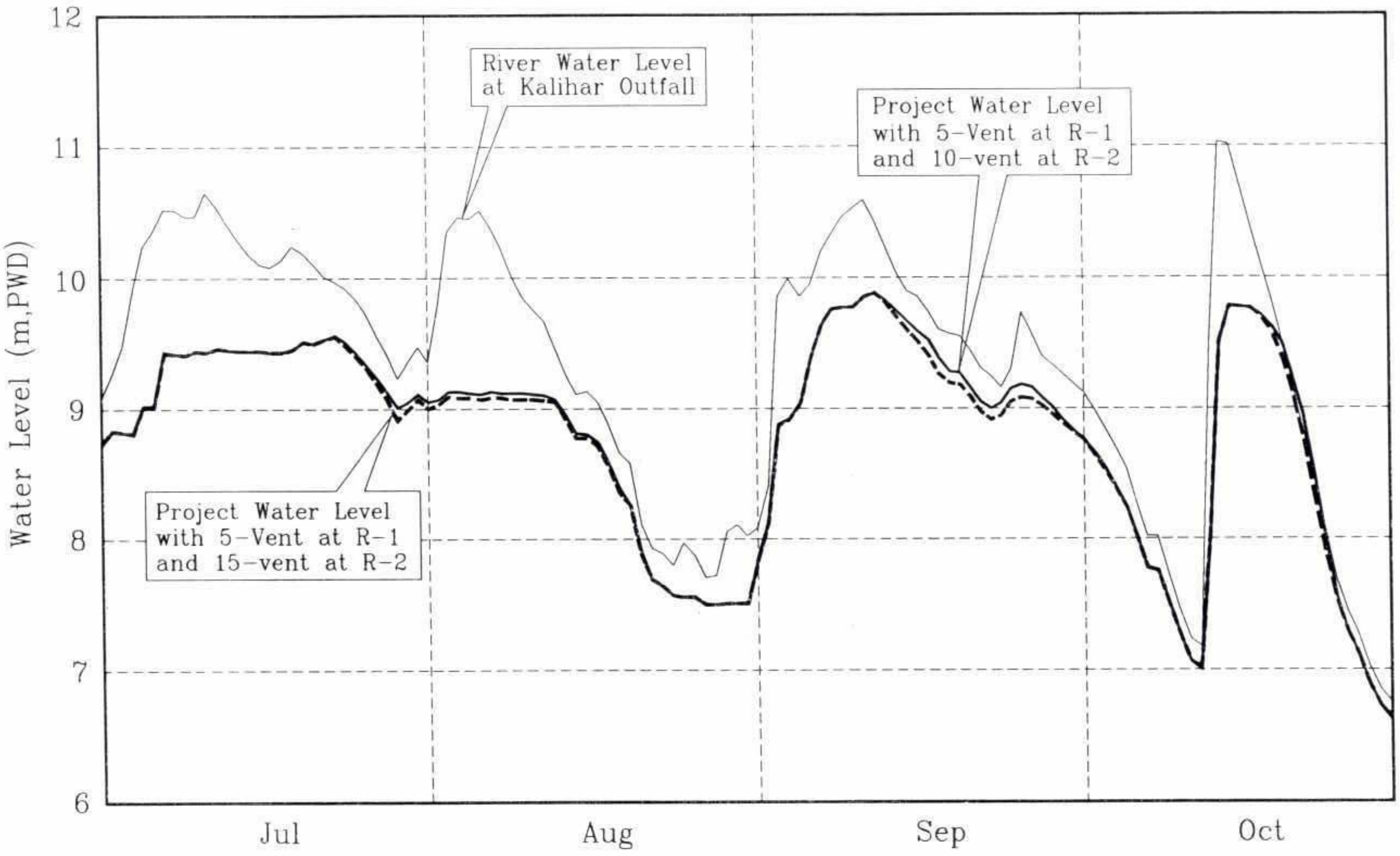


Monsoon Water Level
(Post-Project Condition)
Balia Catchment

Dampara Water Management Project

FILE: ANEX-16 Prepared by: Awlad, Nov/1995

Figure A.17



Period: July-October

Monsoon Water Level
(Post-Project Condition)
Kalihar-Balia Catchment

Dampara Water Management Project

FILE: ANEX-17 Prepared by: Awlad, Oct/1995

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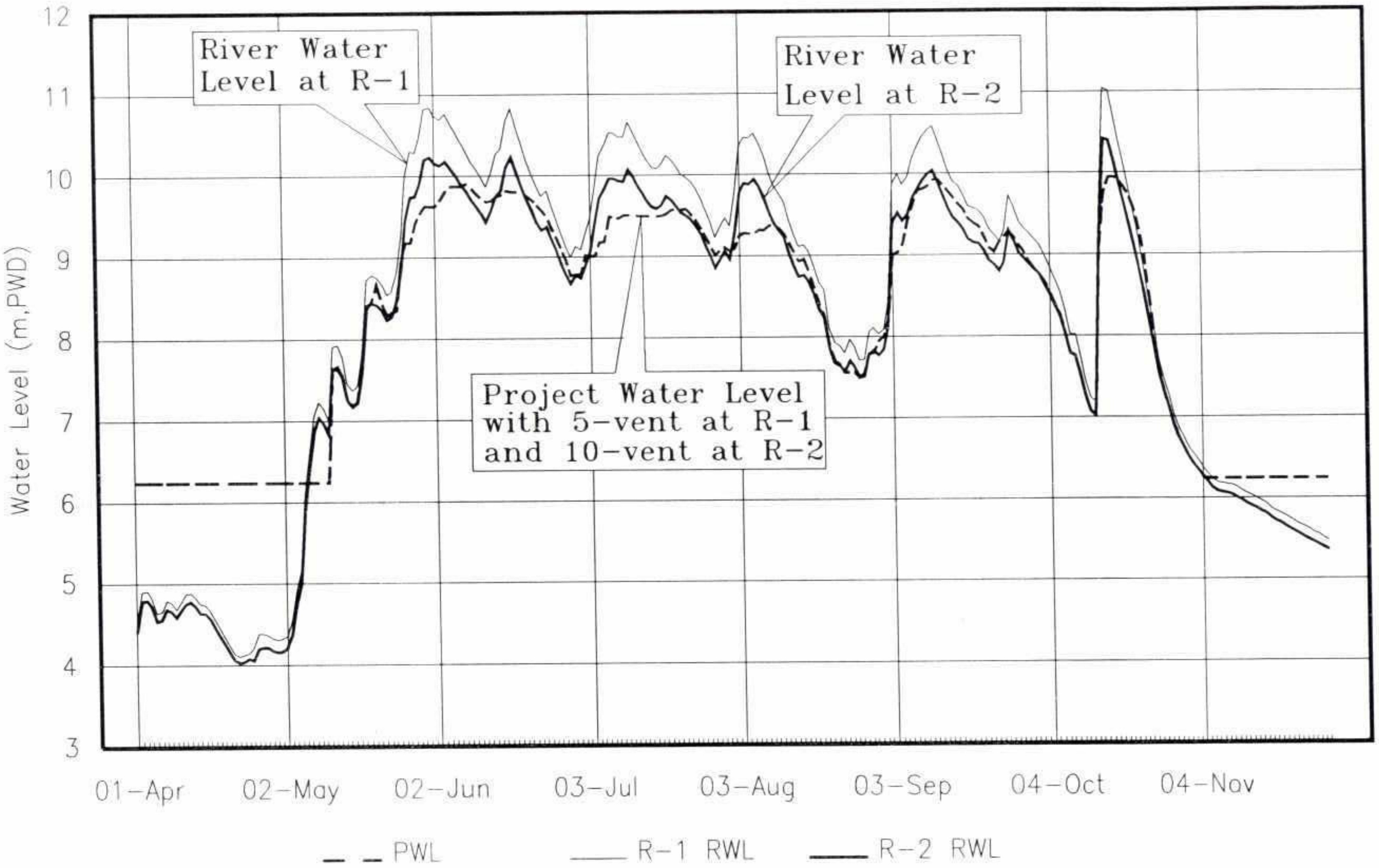
Figure A.18

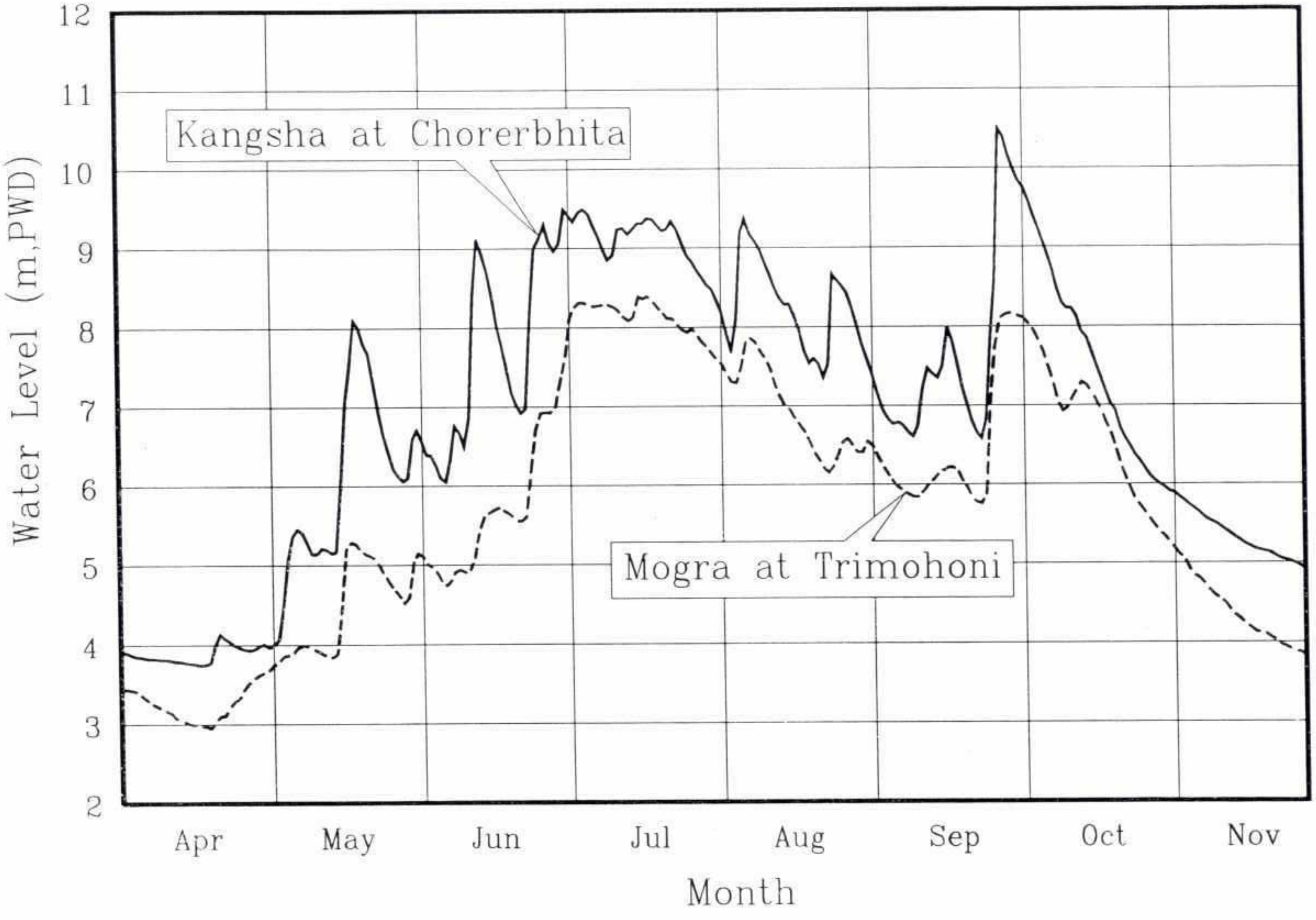


Monsoon Routing
Kalihar and Balia catchment
(April-November Period)

Dampara Water Management Project

FILE: ANEX-18 Prepared by: Awlad

Figure A.19

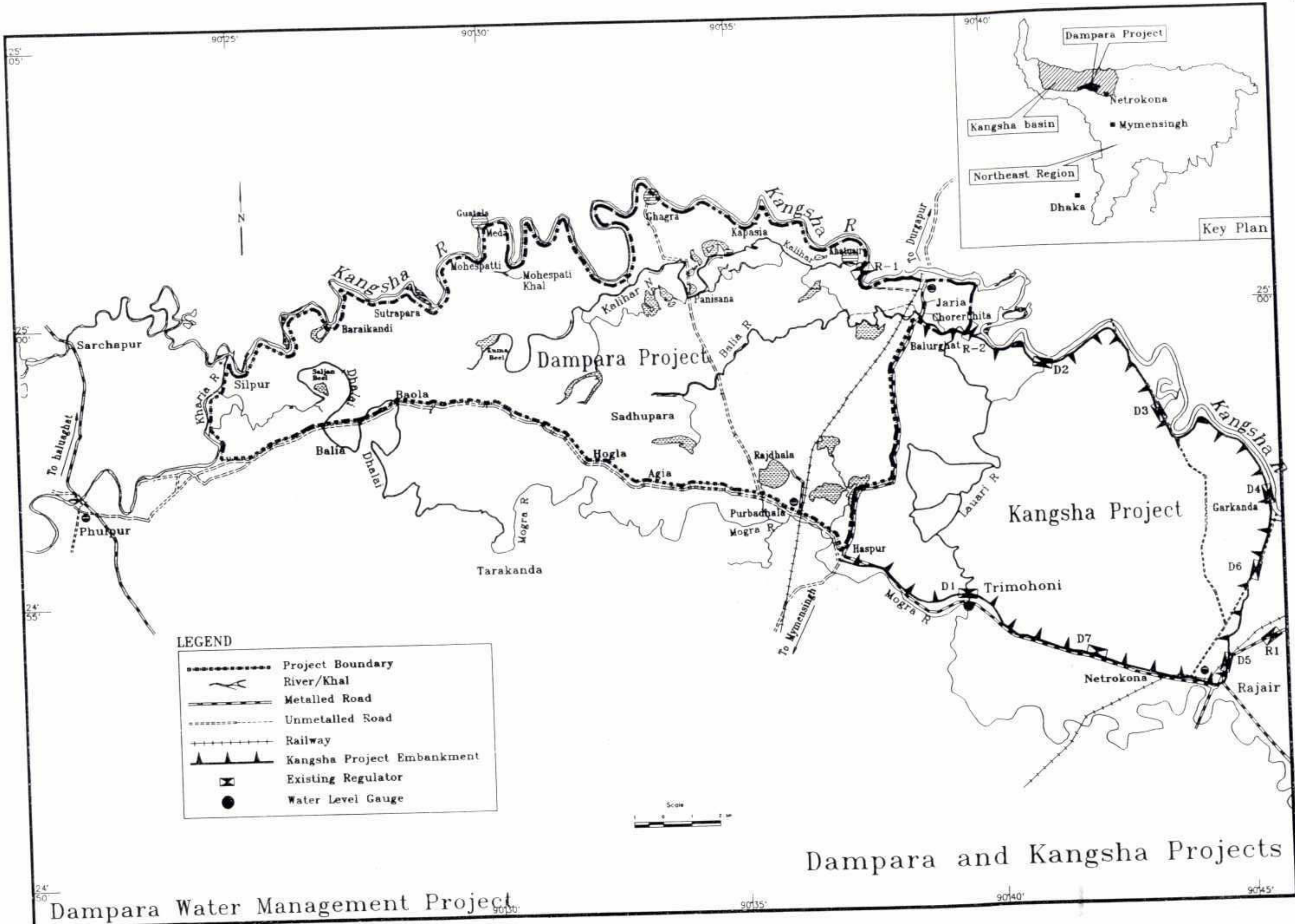


1994 Kangsha & Mogra Water Levels

Dampara Water Management Project

FILE: ANEX-19 Prepared by: Awlad

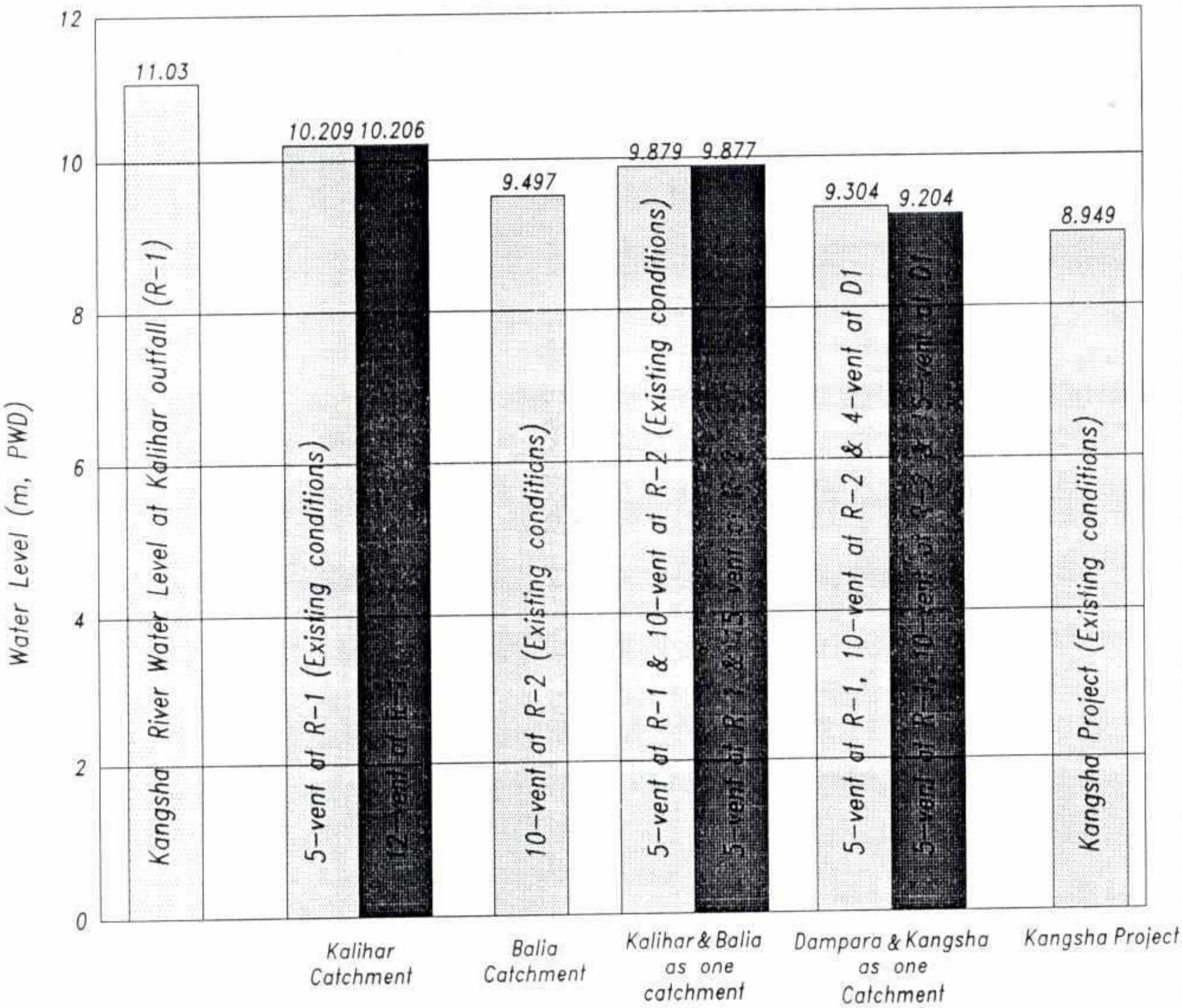
Figure A.20



Dampara and Kangsha Projects

Dampara Water Management Project

FILE: ANEX-20 Prepared by: Jalal, Oct/1995



R-1 Regulator on Kalihar Outfall(Rajakhali)

R-2 Regulator on Balia Outfall(Chorerbhita)

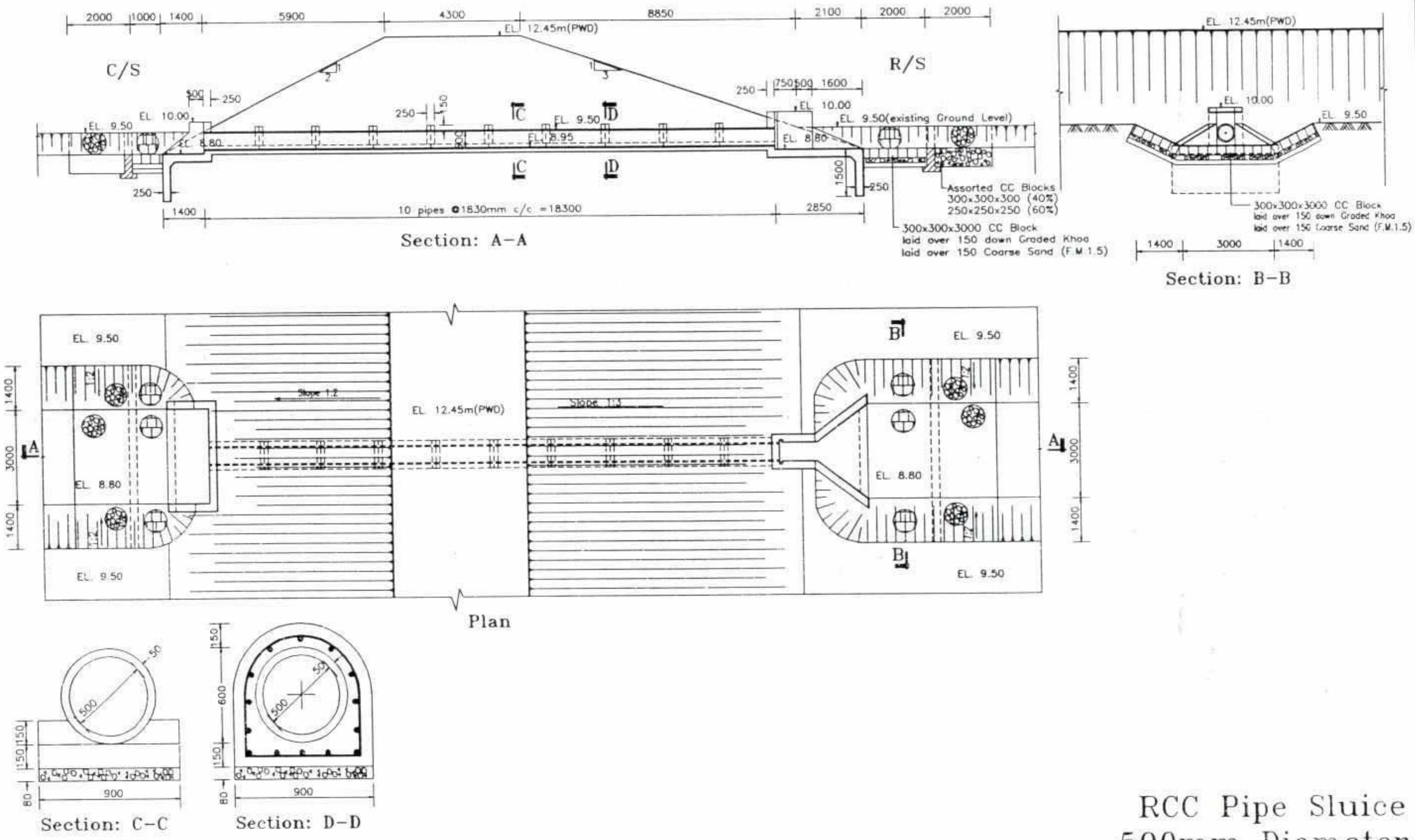
D1 Regulator on Lauari R. at Trimohoni

Maximum Project Water Levels with Different Sizes of Regulators

Dampara Water Management Project

FILE: ANEX-21 Prepared by: Jalal

Figure A.22

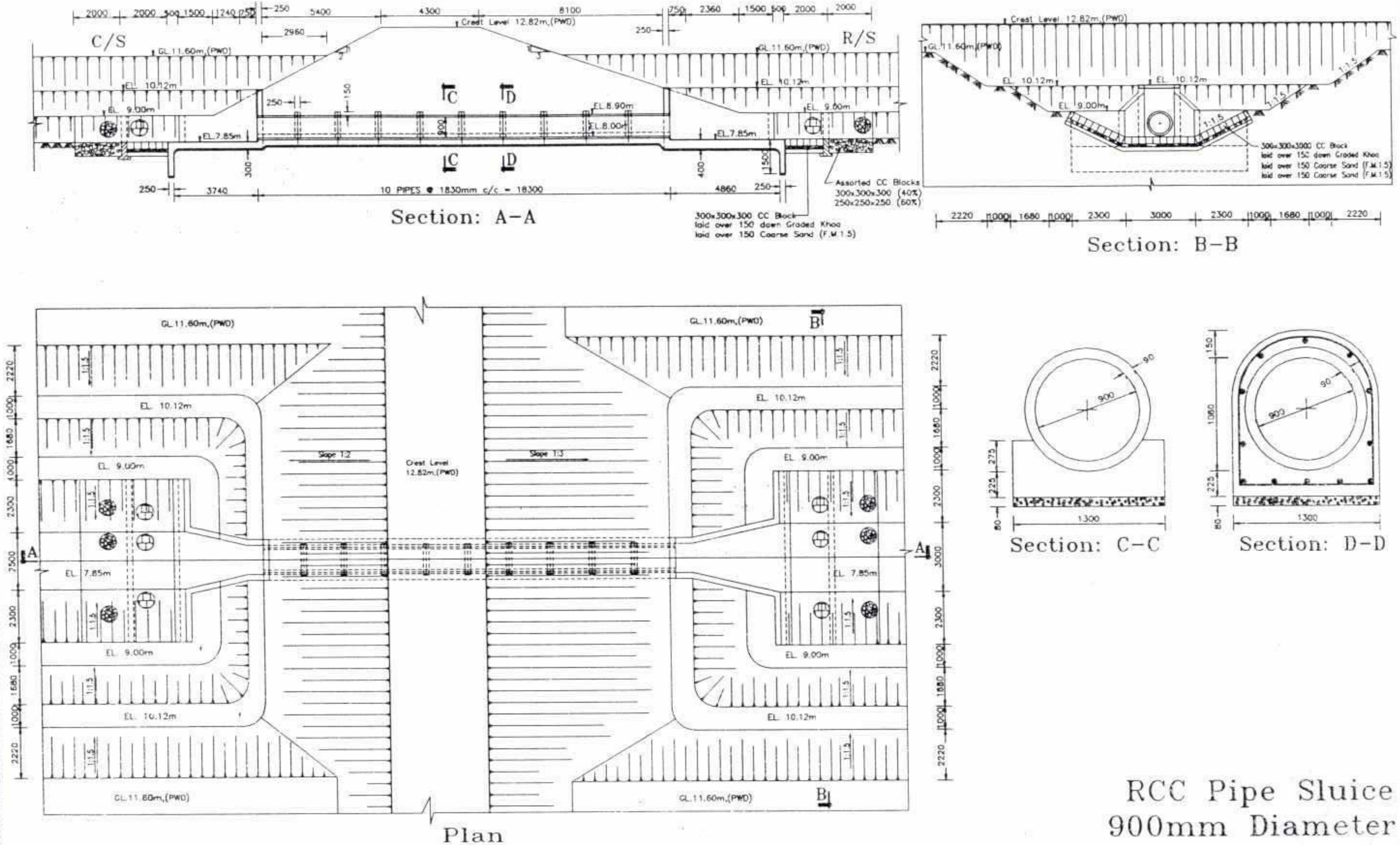


RCC Pipe Sluice
500mm Diameter

Dampara Water Management Project

FILE: ANEX-22 Prepared by: FR/MCR/Jalal

Figure A.23



RCC Pipe Sluice
900mm Diameter

Dampara Water Management Project

FILE: ANEX-23 Prepared by: FR/MCR/Jalal

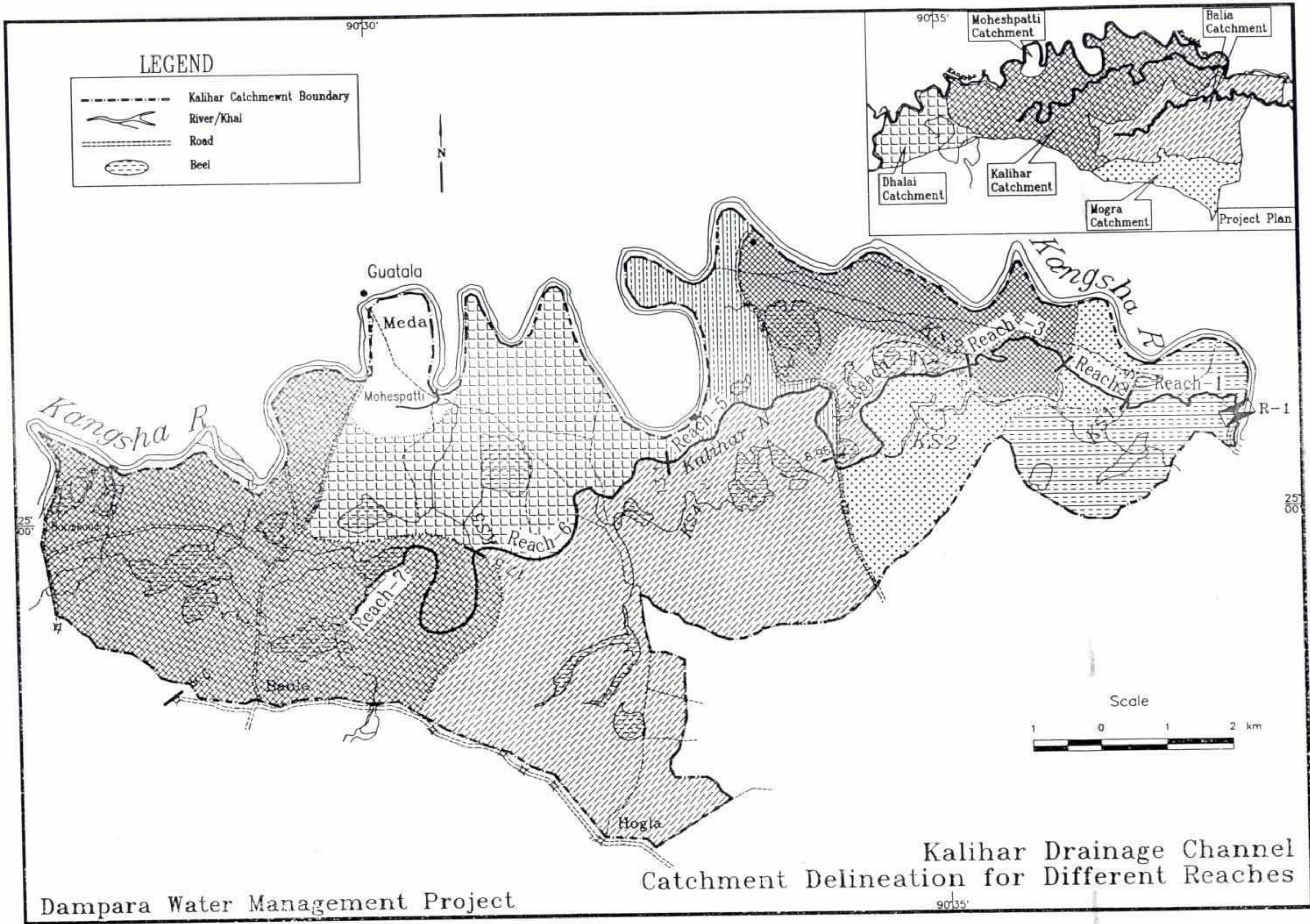


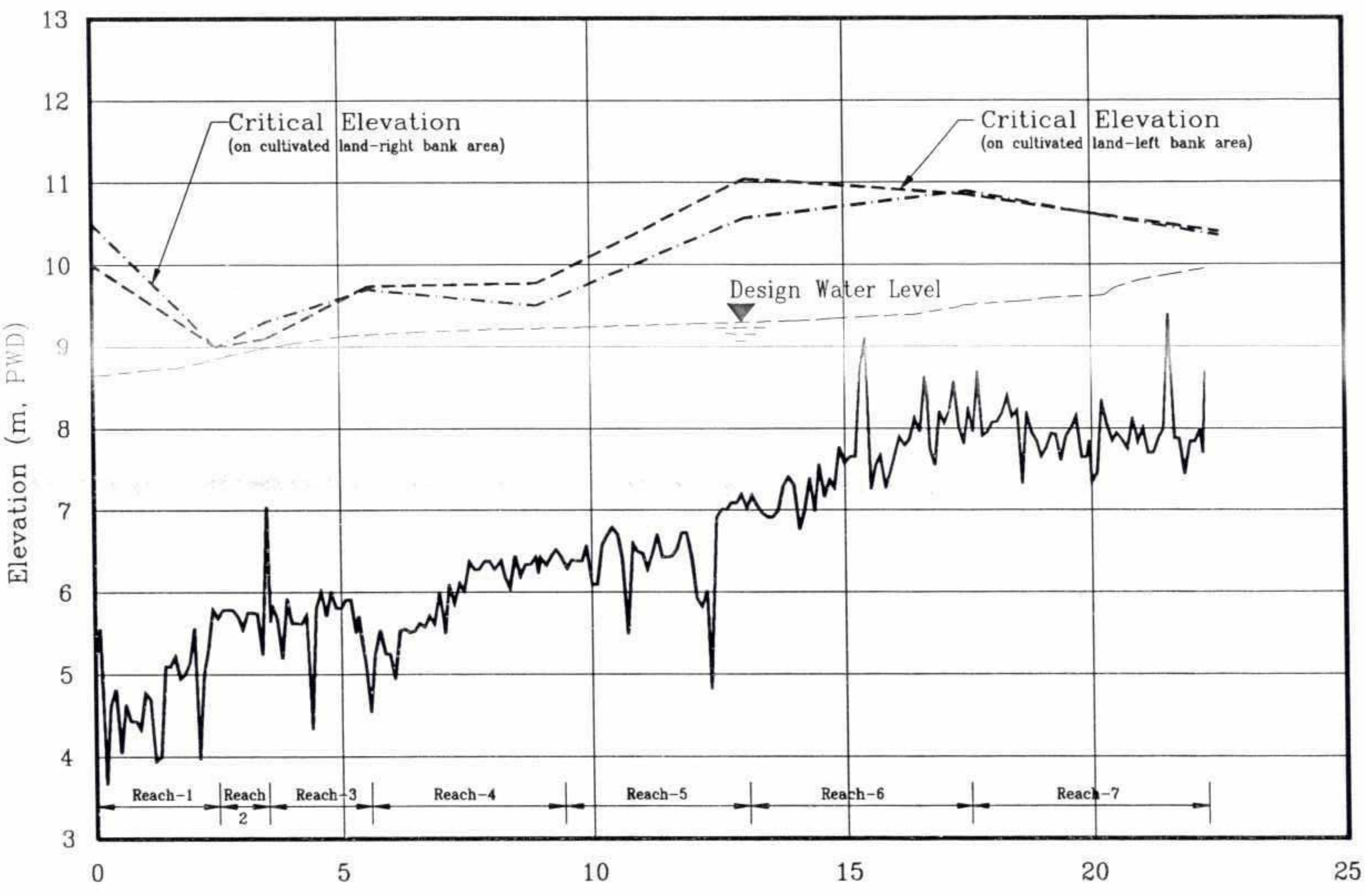
Figure A.24

Kalihar Drainage Channel
Catchment Delineation for Different Reaches

Dampara Water Management Project

FILE: ANEX-24 Prepared by: Jalal, Jan/1996

Figure A.25

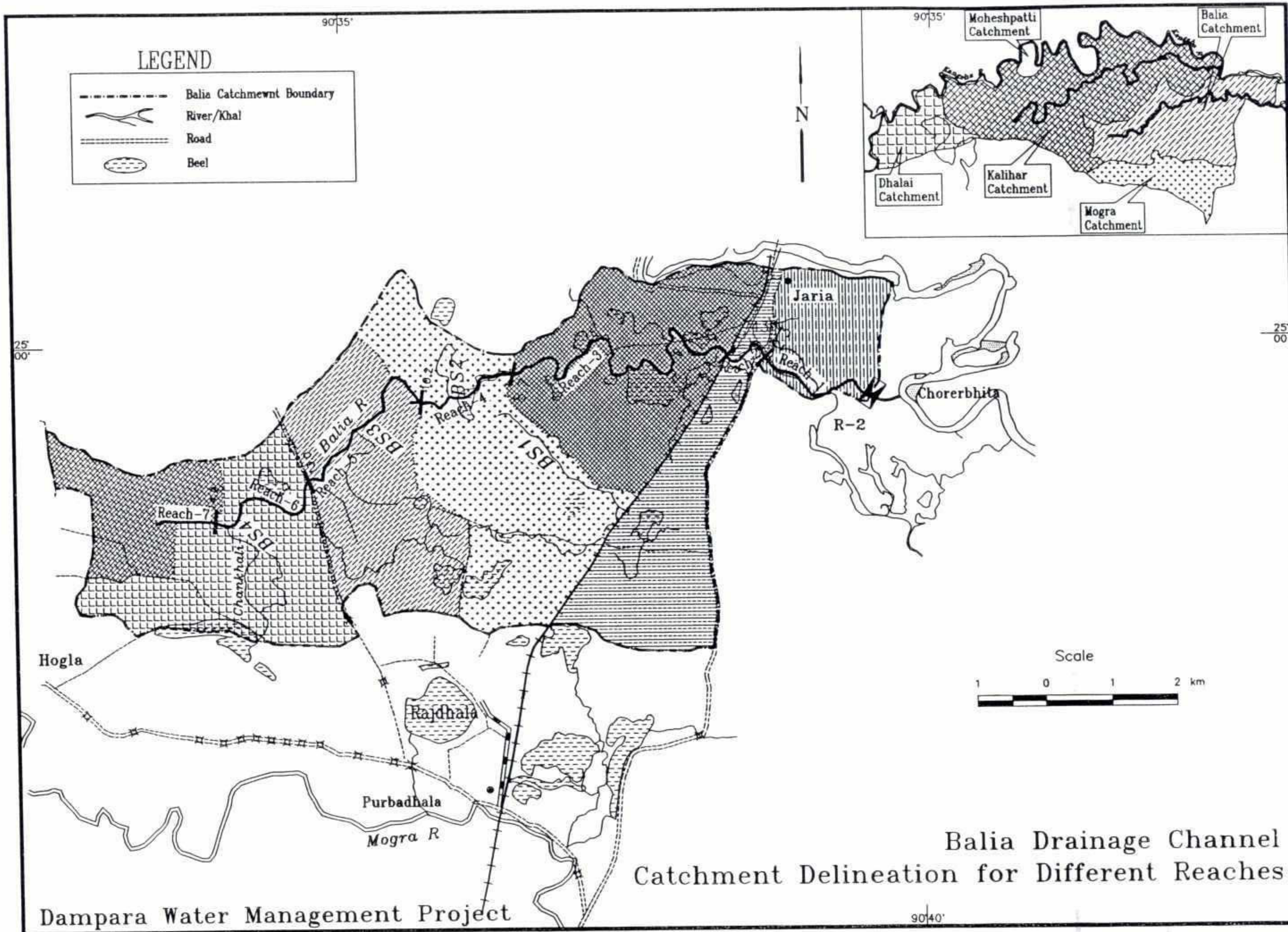


Kalihar Drainage Channel
Design Water Level Profile

Dampara Water Management Project

FILE: ANEX-25 Prepared by: Awlad

Figure A.26

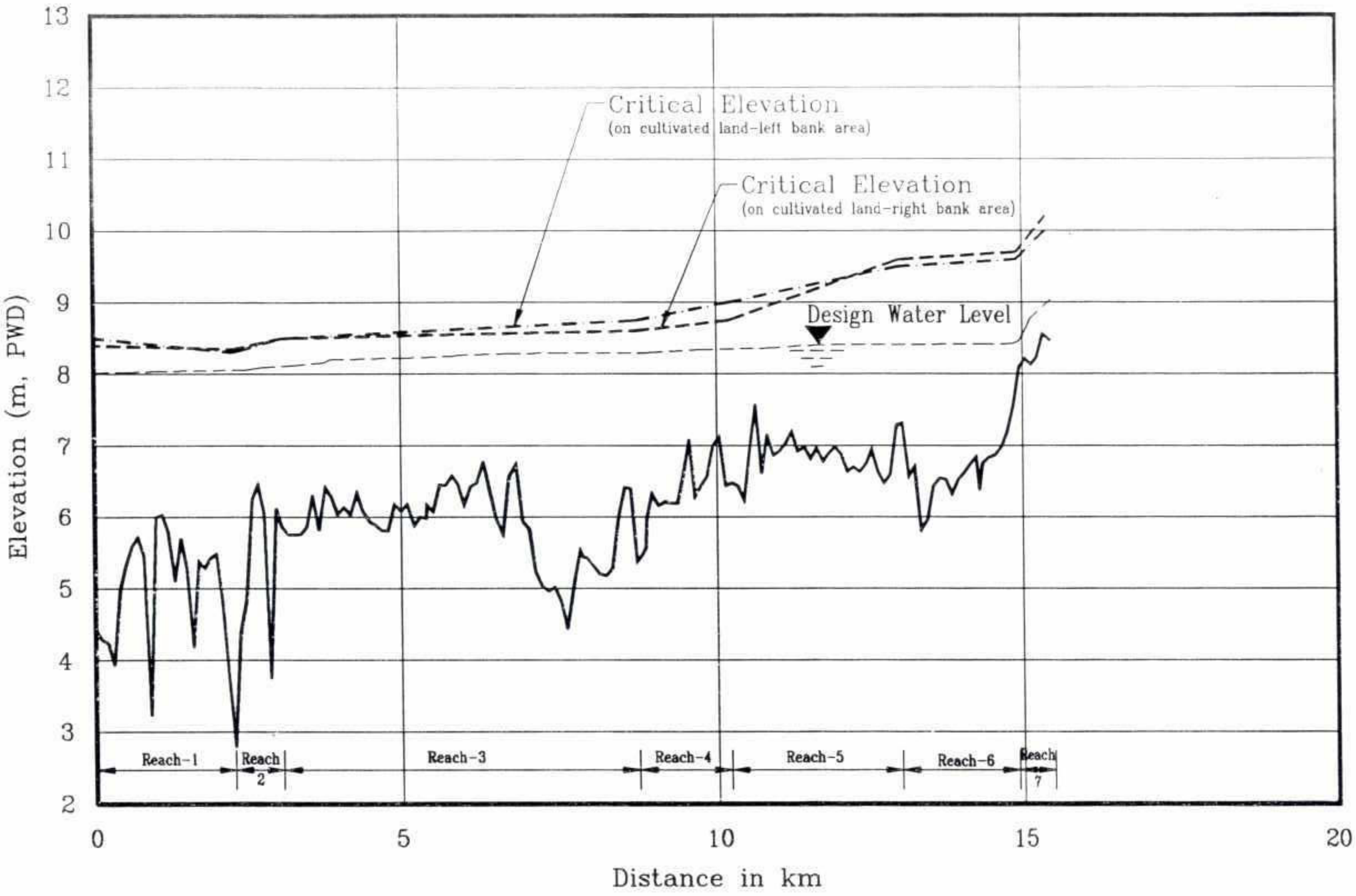


Balia Drainage Channel
Catchment Delineation for Different Reaches

Dampara Water Management Project

FILE: ANEX-26 Prepared by: Jalal, Jan/1996

Figure A.27

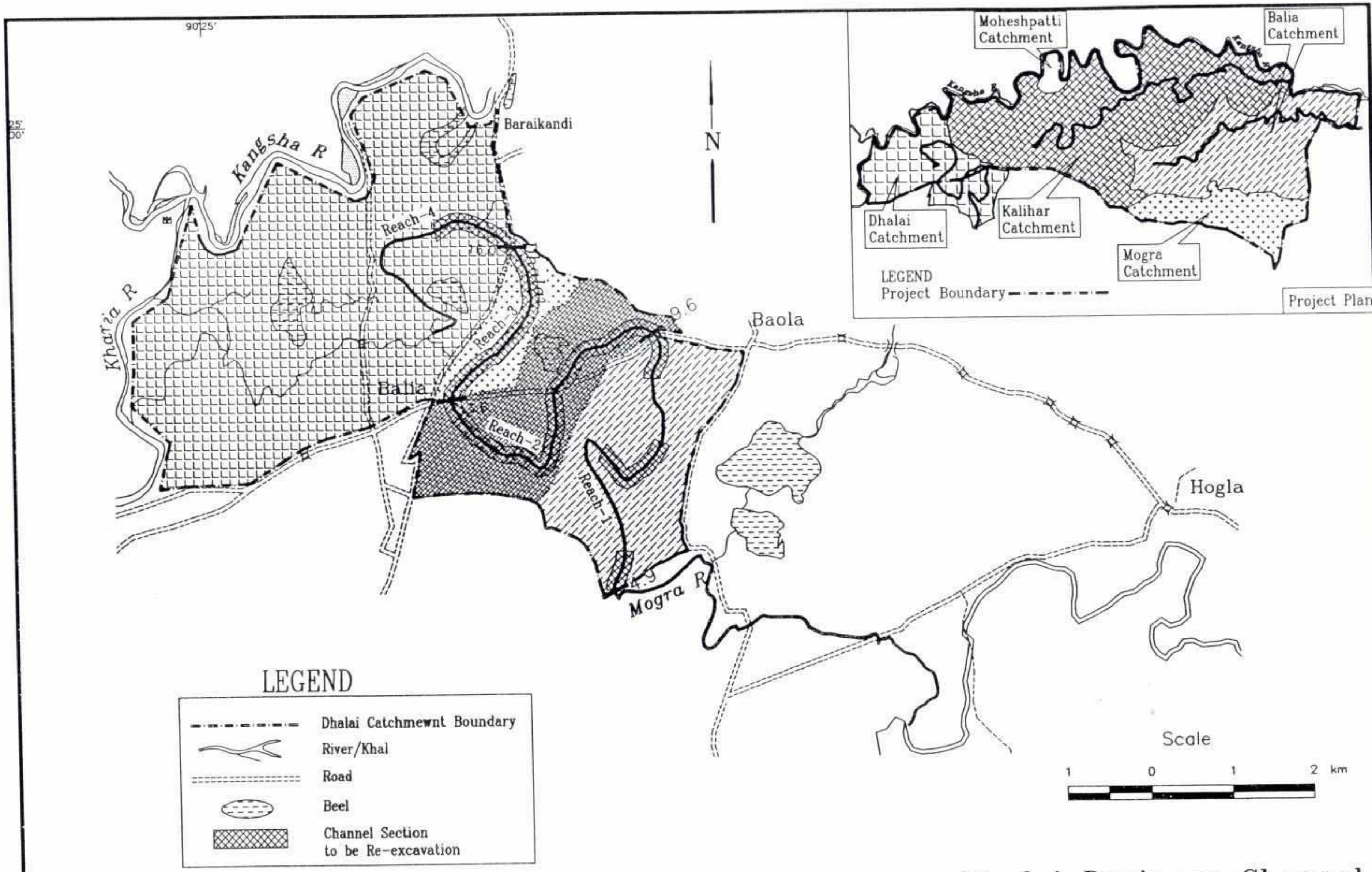


Balia Drainage Channel
Design Water Level Profile

Dampara Water Management Project

FILE: ANEX-27 Prepared by: Awlad

Figure A.28

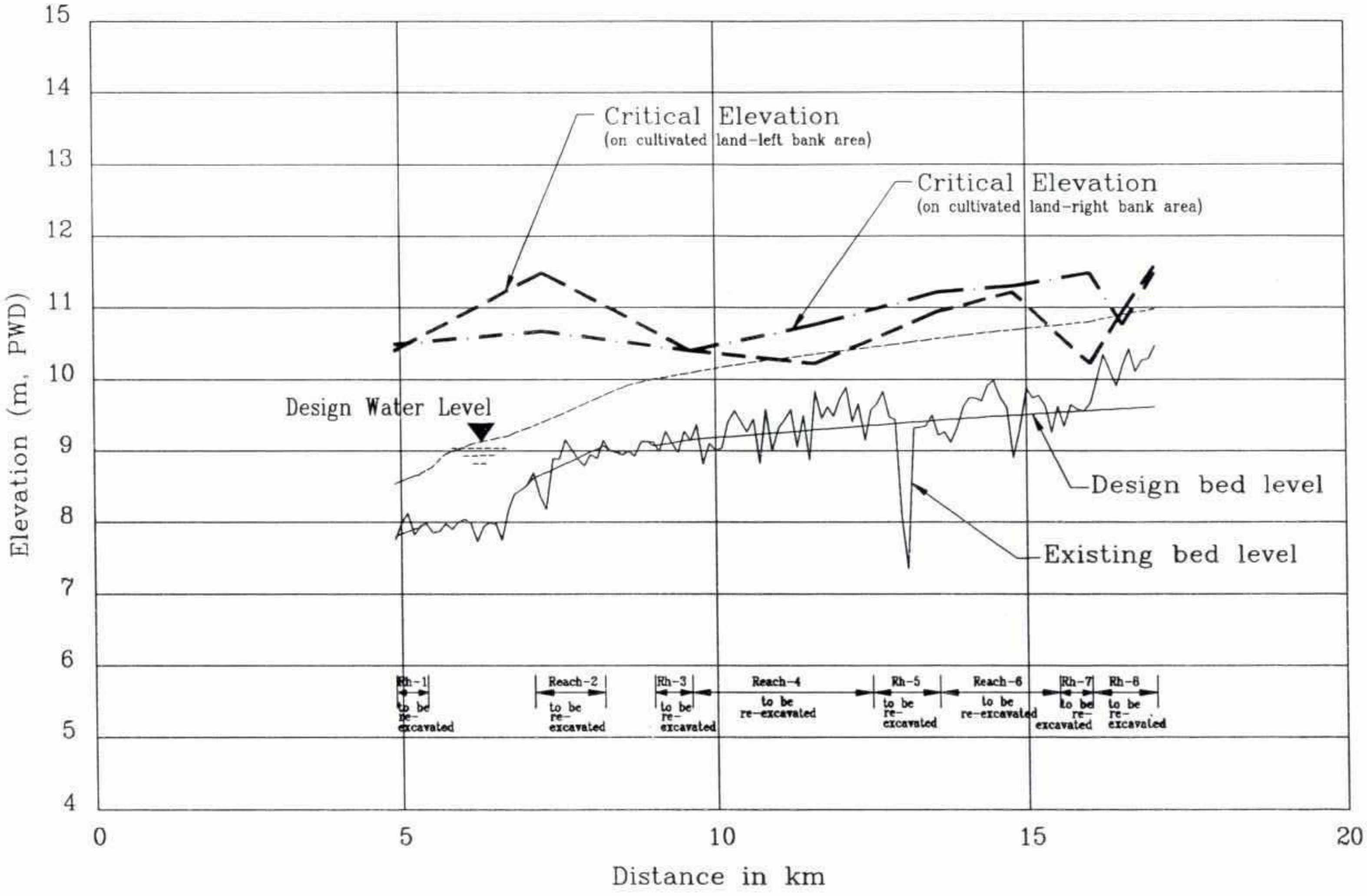


Dhalai Drainage Channel
Catchment Delineation for Different Reaches

Dampara Water Management Project

FILE: ANEX-28 Prepared by: Jalal

Figure A.29

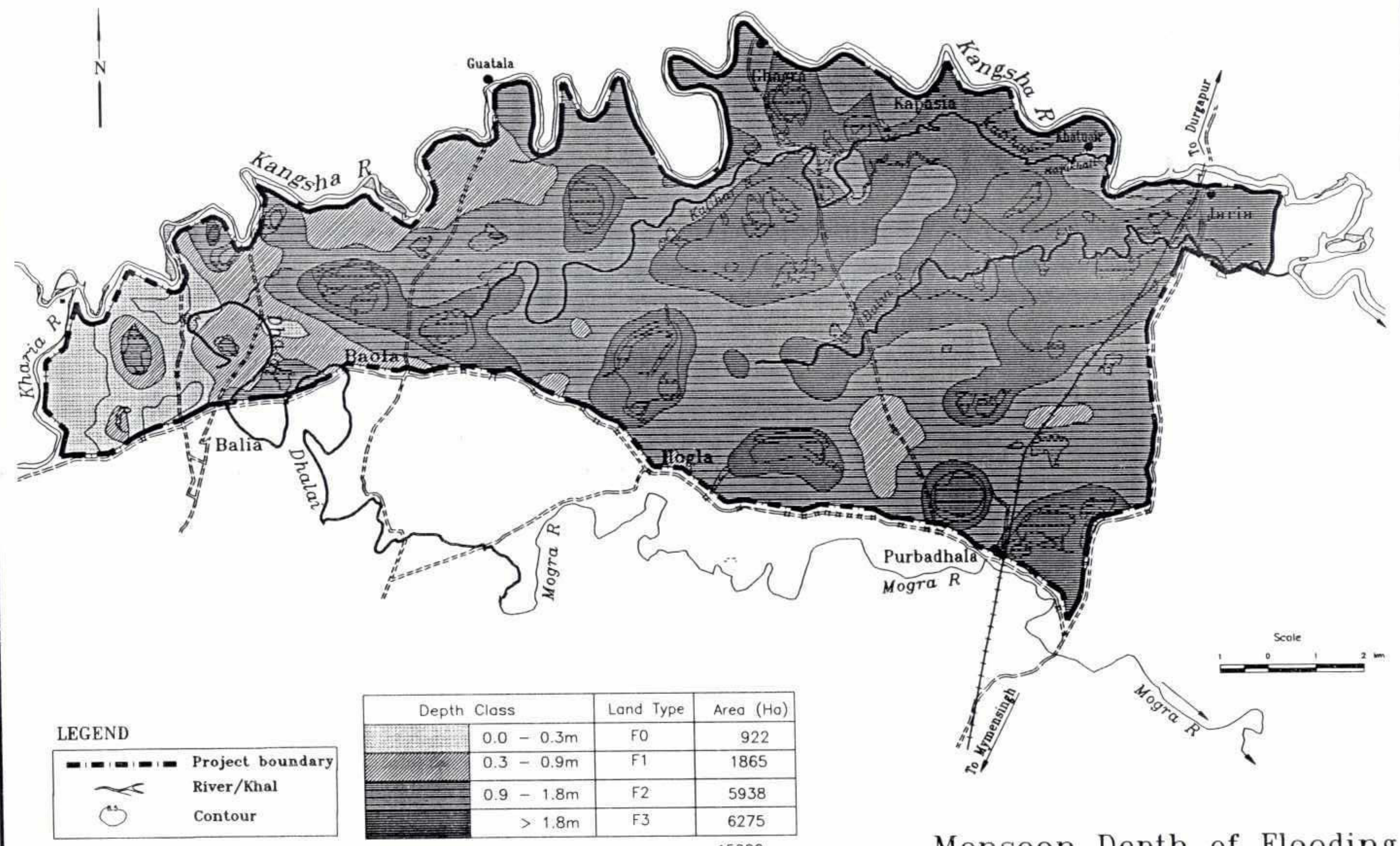


Dhalai Drainage Channel
Design Water Level Profile

Dampara Water Management Project

FILE: ANEX-29 Prepared by: Awlad

Figure A.30



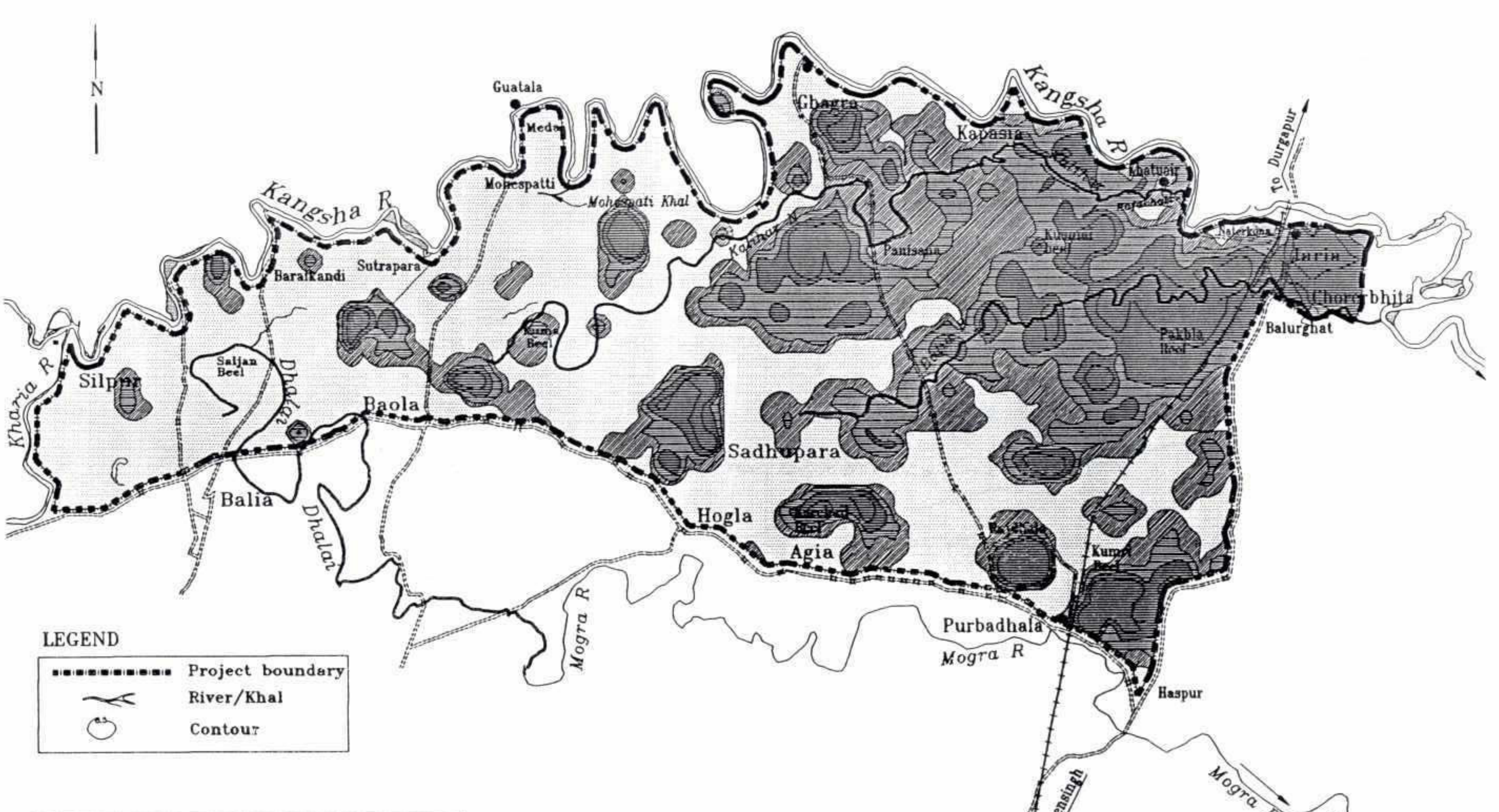
Depth Class		Land Type	Area (Ha)
	0.0 – 0.3m	F0	922
	0.3 – 0.9m	F1	1865
	0.9 – 1.8m	F2	5938
	> 1.8m	F3	6275
			15000

Monsoon Depth of Flooding
1:5 Year Maximum Annual Flood

Dampara Water Management Project

FILE: ANEX-30.DWG Prepared by: Jalal, Oct/1995

Figure A.31



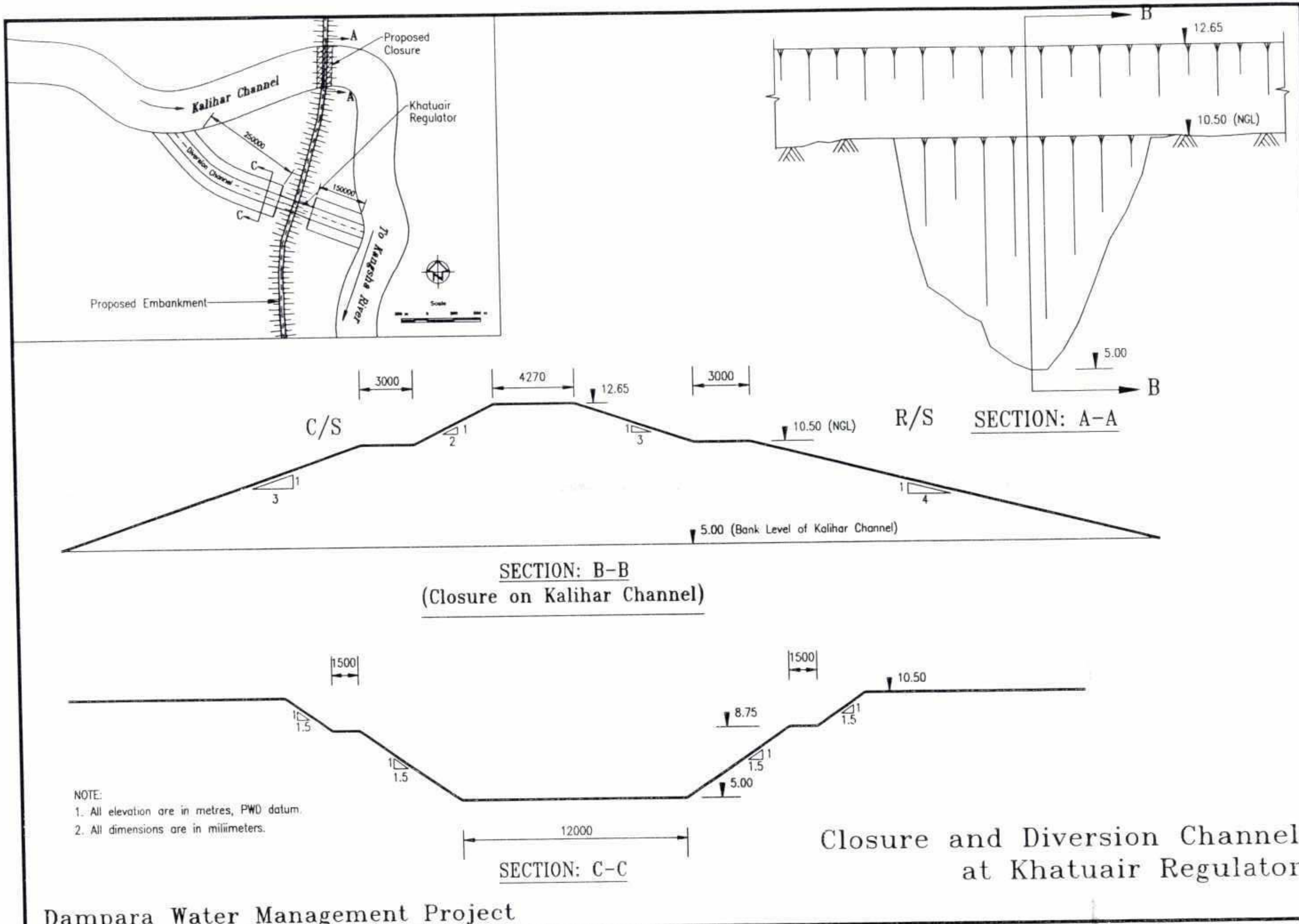
Depth Class		Land Type	Area (Ha)
	0.0 – 0.3m	F0	10523
	0.3 – 0.9m	F1	2004
	0.9 – 1.8m	F2	1486
	> 1.8m	F3	987
			15000

Flood Depth Map
(Based on Post–Project 1:5 yr Design Water Level)

Dampara Water Management Project

FILE: ANEX–31.DWG Prepared by: Awlad, Oct/1995

Figure A.32



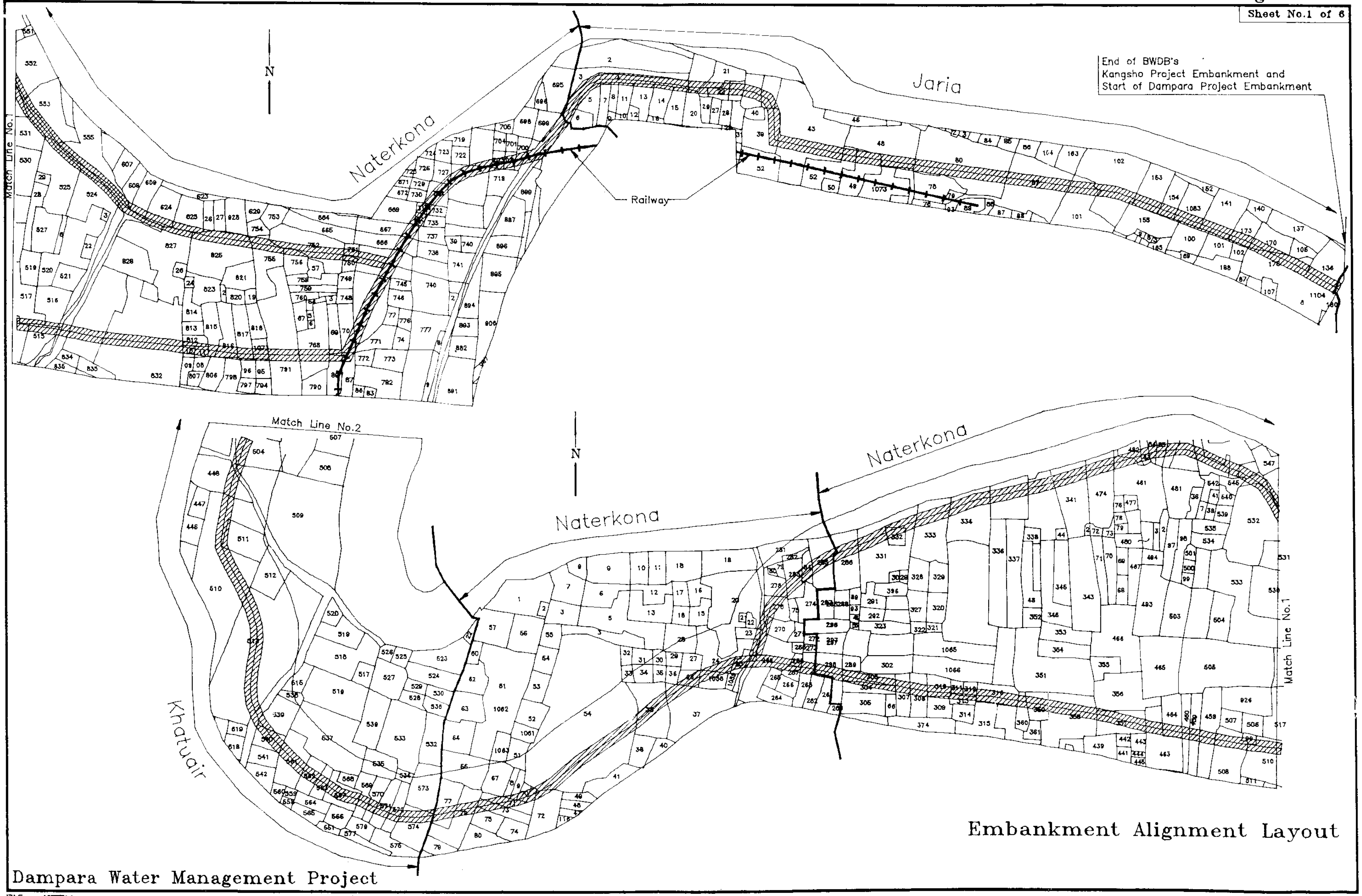
Closure and Diversion Channel at Khatuair Regulator

Dampara Water Management Project

FILE: ANEX-32 Prepared by: Jalal

Figure A.11

Sheet No.1 of 6



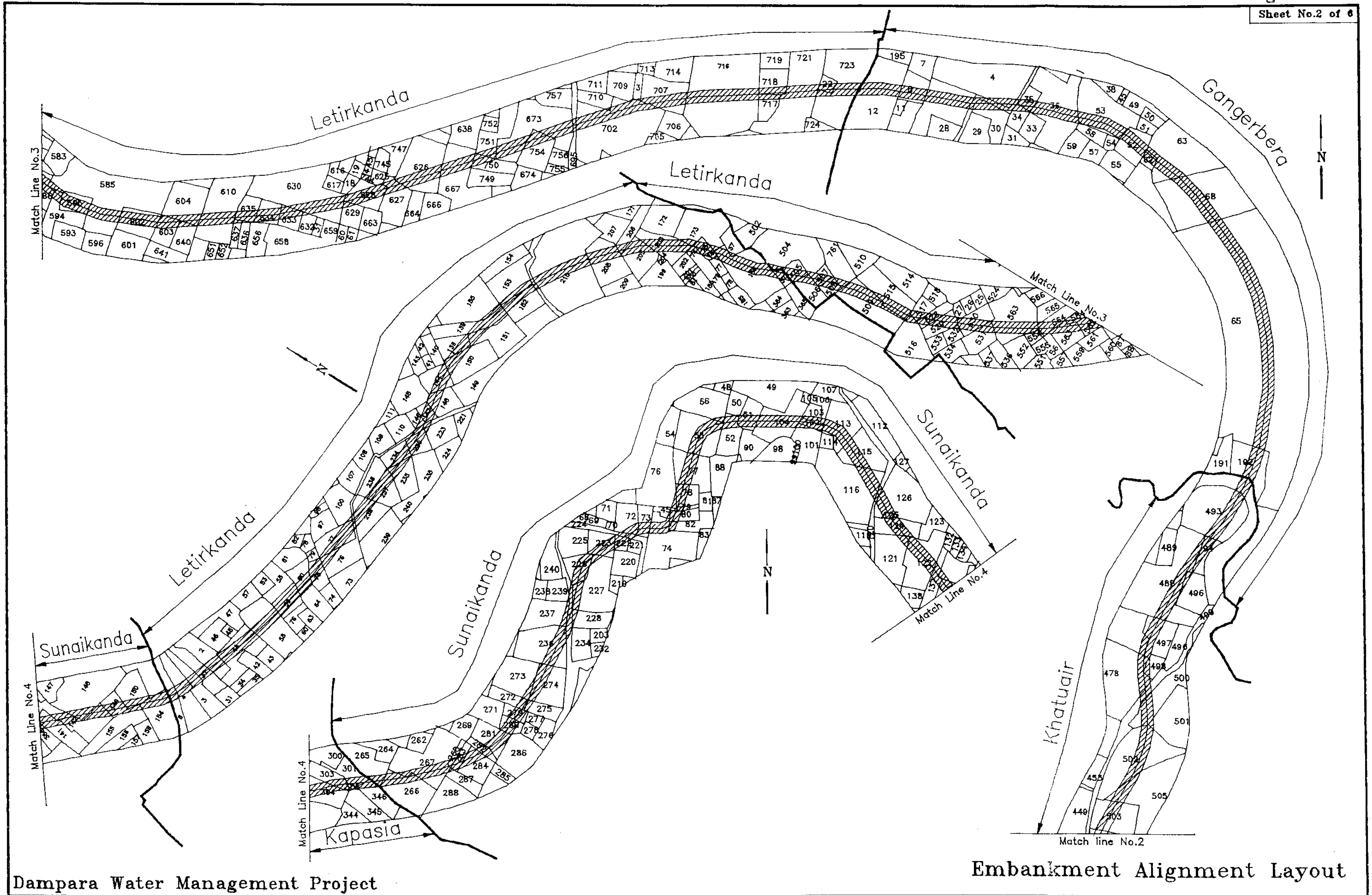
Embankment Alignment Layout

Dampara Water Management Project

FILE: ANEX11a

Figure A.11

Sheet No.2 of 6



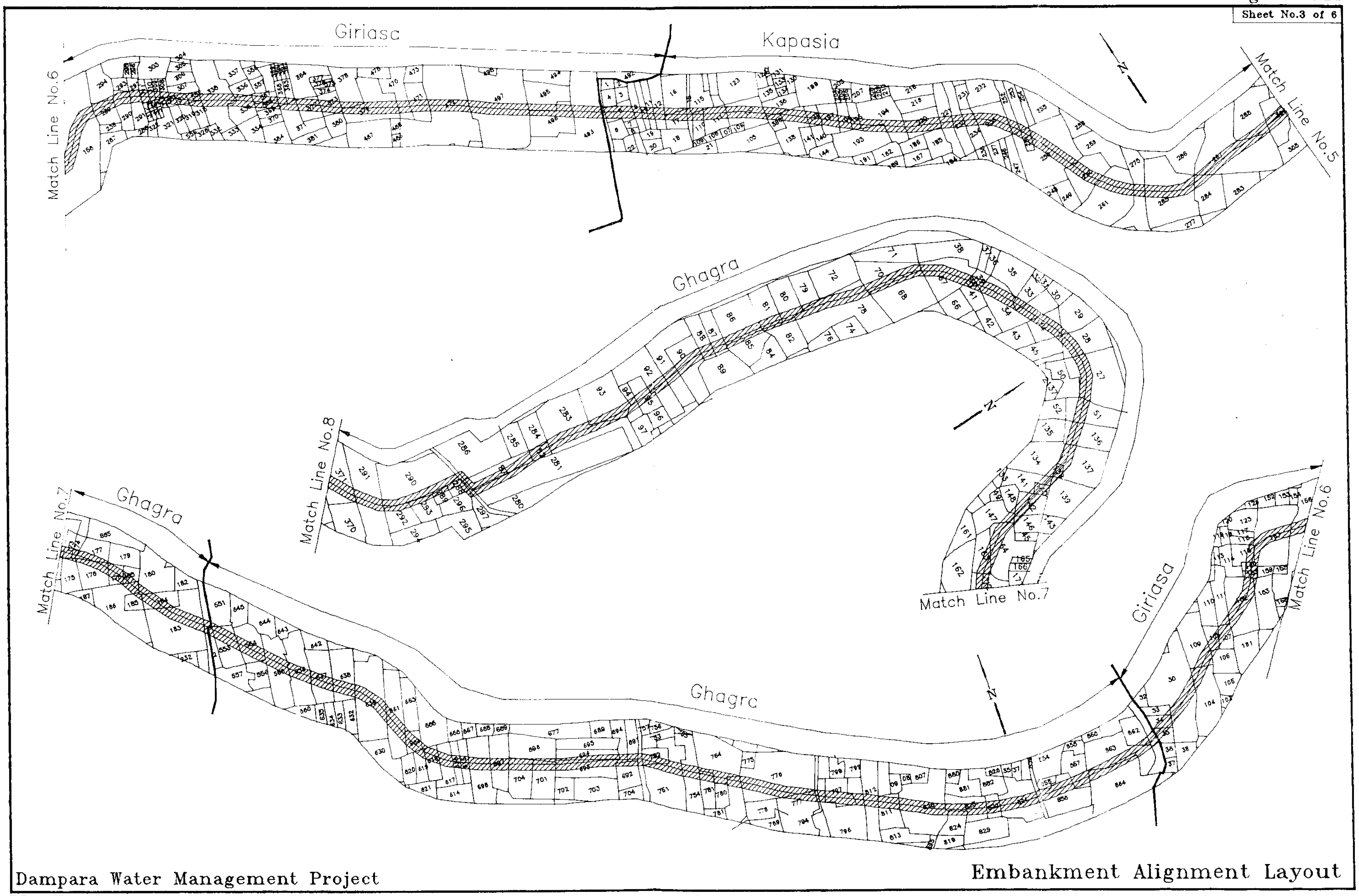
Dampara Water Management Project

Embankment Alignment Layout

FILE: ANXI11a

২৭

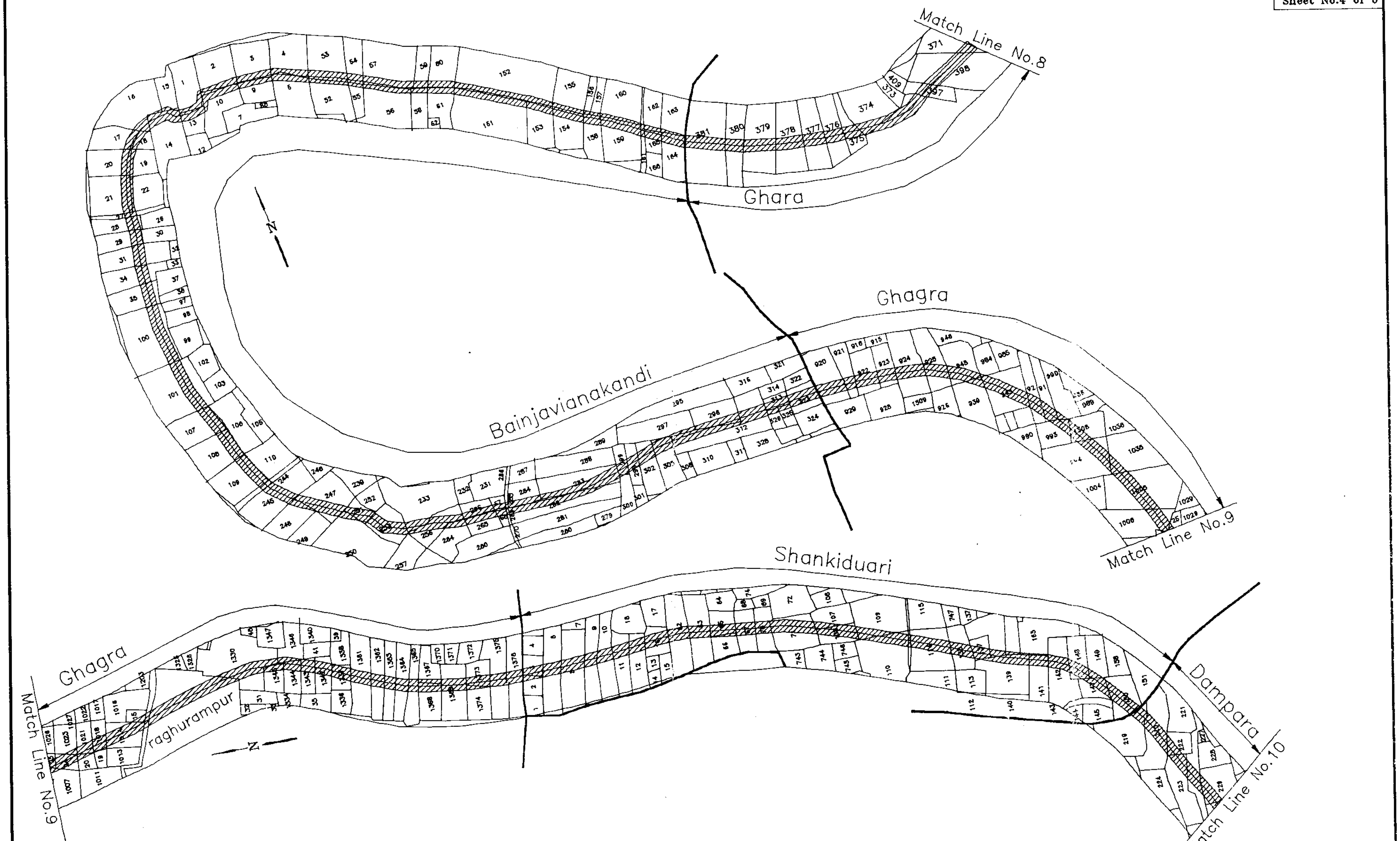
Figure A.11



FILE: ANEX11c

Figure A.11

Sheet No.4 of 6



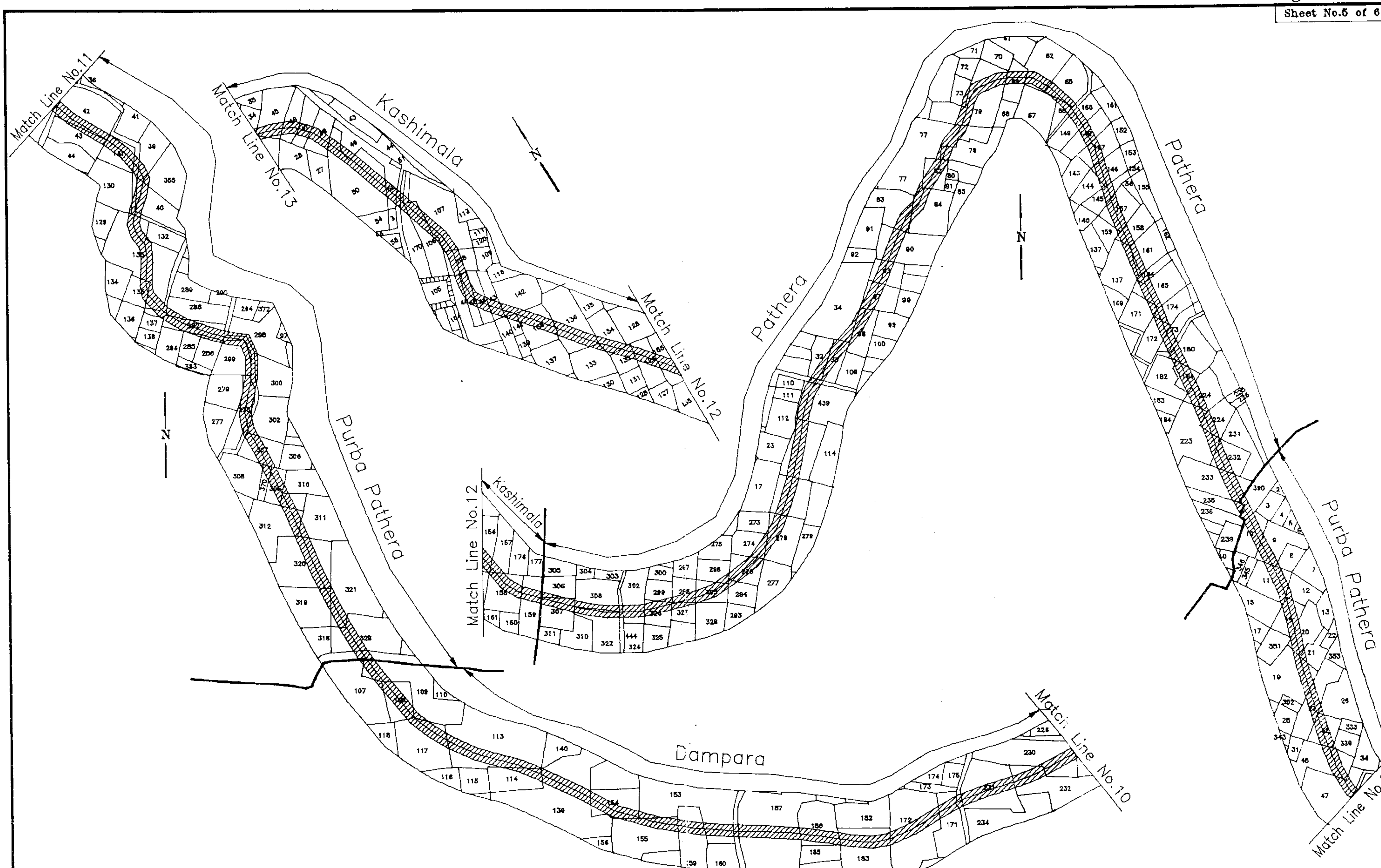
Embankment Alignment Layout

Dampara Water Management Project

FILE: ANEX11d

Figure A.11

Sheet No.5 of 6



Embankment Alignment Layout

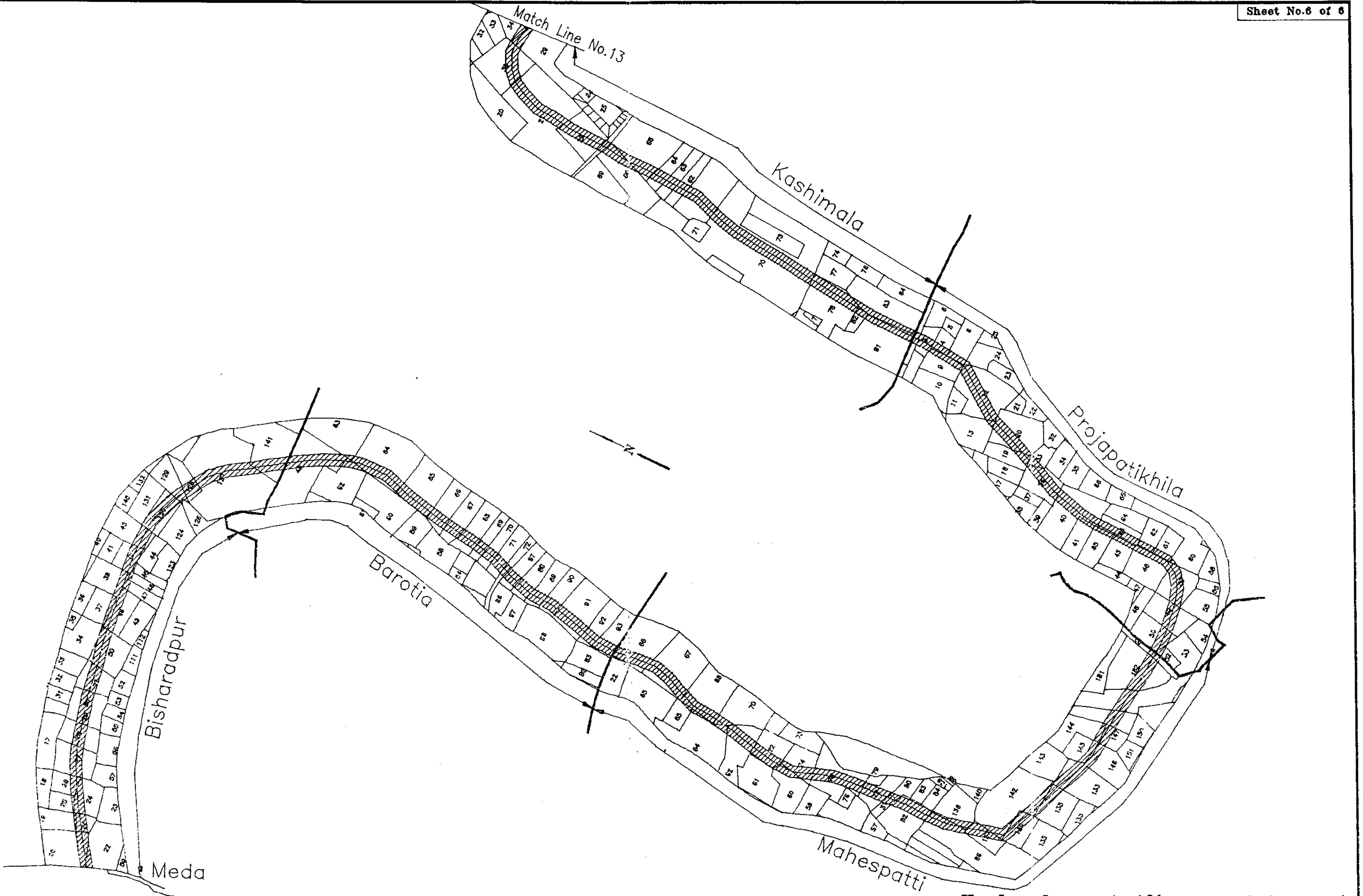
Dampara Water Management Project

FILE: ANEX11e

388

Figure A.11

Sheet No.6 of 6



Dampara Water Management Project

Embankment Alignment Layout

FILE: ANEX11S