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Gumti Phase II
Sub-Project Feasibility Study

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DRAFT FINAL REPORT

ANNEX I

ENGINEERING

VOLUME 1

BN-146
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June, 1993

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ANNEX I

ENGINEERING

VOLUME 1

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GUMTI PHASE II SUB-PROJECT FEASIBILITY STUDY
DRAFT FINAL REPORT

ANNEX I - ENGINEERING

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CHAPTER I.1

TOPOGRAPHIC DATA, SURVEYS AND FIELD INVESTIGATIONS

I.1.1 Available Topographic Data

The following topographic survey data are available associated with the project area:

(i) 4 inch to 1 mile (1:15 840) Water Development Maps, prepared from 1963 aerial photography, verified in the field in 1967 to 1968, with 1 foot interval contours and spot levels on a 250 m x 220 m approx. grid.

(ii) 1:16 000 Water Development Maps, based upon 1987 aerial photography and field work, with 0.5 m interval contours, spot levels on a 100 m x 300 m approx. grid and bench-marks on a 2 500 m approx. square grid. These maps are also available at 1:8 000 scale.

(iii) Some 738 channel cross-sections, with longitudinal sections, covering 579km of channel length, prepared for the 1990 Feasibility Study, together with some of the associated survey field books, including those relating to the establishment of a bench-mark network.

(iv) A further 171 channel cross-sections incorporated in the South East Regional Model (SERM) by the Surface Water Modelling Centre (SWMC). These cross-sections are assumed to be based upon the same datum as the water level records from the 21 gauge stations within the project area.

(v) A network of about 70 Survey of Bangladesh (SOB) maintained bench-marks.

Further details of the data, together with details of aerial photography and satellite imagery available, are given in Appendix I.I to this Annex.

Elevations on the Water Development Maps, and those assigned to the SOB bench-marks, are all to the Survey of Bangladesh (or its precursor the Survey of Pakistan) datum. Both sets of channel cross-sections, as well as all BWDB and SWMC water level gauge records and simulated water levels, are to the Bangladesh Public Works Datum (PWD). To convert an elevation based upon the SOB datum to PWD, 0.46 m must be added. In accordance with standard BWDB practice, all elevations on drawings etc for this study are quoted to PWD datum unless otherwise stated.

The terms of reference require that the latest available large scale maps of the project area be compared with the old 4 inch to 1 mile maps used in the 1990 feasibility study, including a check on their datum consistency. Area-elevation curves for the three drainage units (West and South Block, North Buri Nadi Block and Bijni Block) are required to be prepared on the basis of the latest maps, and compared with the curves assumed in the 1990 study. The datums of the key hydrological gauges of the project are also required to be checked for consistency with the other topographic data. The required analyses are included in Section I.1.2 below.

I.1.2 Comparison of Available Topographic Data

I.1.2.1 Introduction

The 1990 feasibility study used the 4 inch to 1 mile (1:15 840) Water Development Maps prepared in 1968 on the basis of aerial photographs taken in 1963 and verified in the field during the late sixties (1967-68). The latest available Water Development Maps were prepared in 1989, based upon aerial photography and field surveys done in 1987 by FINNMAP Oy. FINNMAP prepared the maps to two scales, 1:16 000 and 1:8 000, from the same aerial photography and field surveys. Since the 1:8 000 maps would not contain additional detail appropriate to the feasibility stage, and the 1:16 000 maps already require 34 sheets to cover the project area, the latter have been used for planning purposes, and as the basis for comparison with the old 4 inch maps. The 1:8 000 maps will however be invaluable during any future detailed design stage.

The objectives of this comparison are:

- to assess the accuracy of both the older and newer maps in representing the topography and significant landmarks of the project area,
- to assess the general nature and extent of land form changes in the project area, and
- to check the datum consistency of all important topographic data within the project area.

The following methods were adopted:

- comparison of selected sheets of the 4 inch maps with the corresponding FINNMAP sheets,
- comparison of the area-elevation curves assumed in the 1990 study for the three drainage units with those derived from the FINNMAP maps,
- detailed topographic survey of small sample areas, for comparison with the two map series, and
- comparison of Survey of Bangladesh, FINNMAP and hydrological gauge station bench-marks.

I.1.2.2 Comparison of Selected Map Sheets

(a) Sheet Selection

Particulars of the two map series are given in Table I.1.1. From this Table it may be observed that the intensity of spot levels on the FINNMAP series is higher, and covers the villages and depressions. However, the FINNMAP mapping is not available in restricted areas, especially near the Indian border; for instance the coverage of sheet 79M-1/9 is incomplete, even within Bangladesh. An index to the FINNMAP maps is given in Figure I.I.1 of Appendix I.I to this Annex. The 4 inch maps follow the same indexing system.For the purposes of comparison three sample sheets were selected, to be representative of the project area from the following points of view:

- distribution over the project area,
- flood phase,
- proximity to the major rivers, and
- proximity to the Tripura Hills.

TABLE I.1.1

Particulars of 4 Inch and FINNMAP Maps

Particulars	4 Inch Maps	FINNMAP Maps
Year of preparation	1968	1989
Agency	SOP (NOW SOB)	BWDB
Data Source:		
Year of Aerial Photography	1963	1987
Year of Field Verification	1967-68	1987
Surveyed by	Pakistan Air Force (aerial photography)	FINNMAP
Scale	1:15 840 (4 inches to 1 mile)	1:16 000
Contour Interval	30 cm (1 foot)	50 cm
Interval of spot levels		
Normal cultivated/uninhabited areas.		
Longitude (m)	222	288
Latitude (m)	253	112
Villages, orchards and depressions	very few (irregular intervals)	more intensive (but not regular)

Note: SOP - Survey of Pakistan
SOB - Survey of Bangladesh

The locations of the selected sheets are shown in Figure I.1.1, and the characteristics of the areas covered by each sheet are as follows:

Sheet Nr 79M-1/9 - Gross Area 30 km2

This area is on the Indian border close to the Tripura Hills, and consists mostly of F0 and F1 land. It is expected that the area should have a tendency towards general accretion, due to the heavy sediment loads carried by the small rivers from the hills during flash floods. Only part of the sheet is available in the FINNMAP mapping.

Sheet Nr 79I-13/9 - Gross Area 78 km^2

This area is in the centre of the project area, quite far from the influence of the major rivers and the hills, and consists mostly of F1 and F2 land. It is expected that the topography of this area should have undergone little significant change.

Figure I.1.1

Selected Areas for Comparison of Available Topographic Mapping

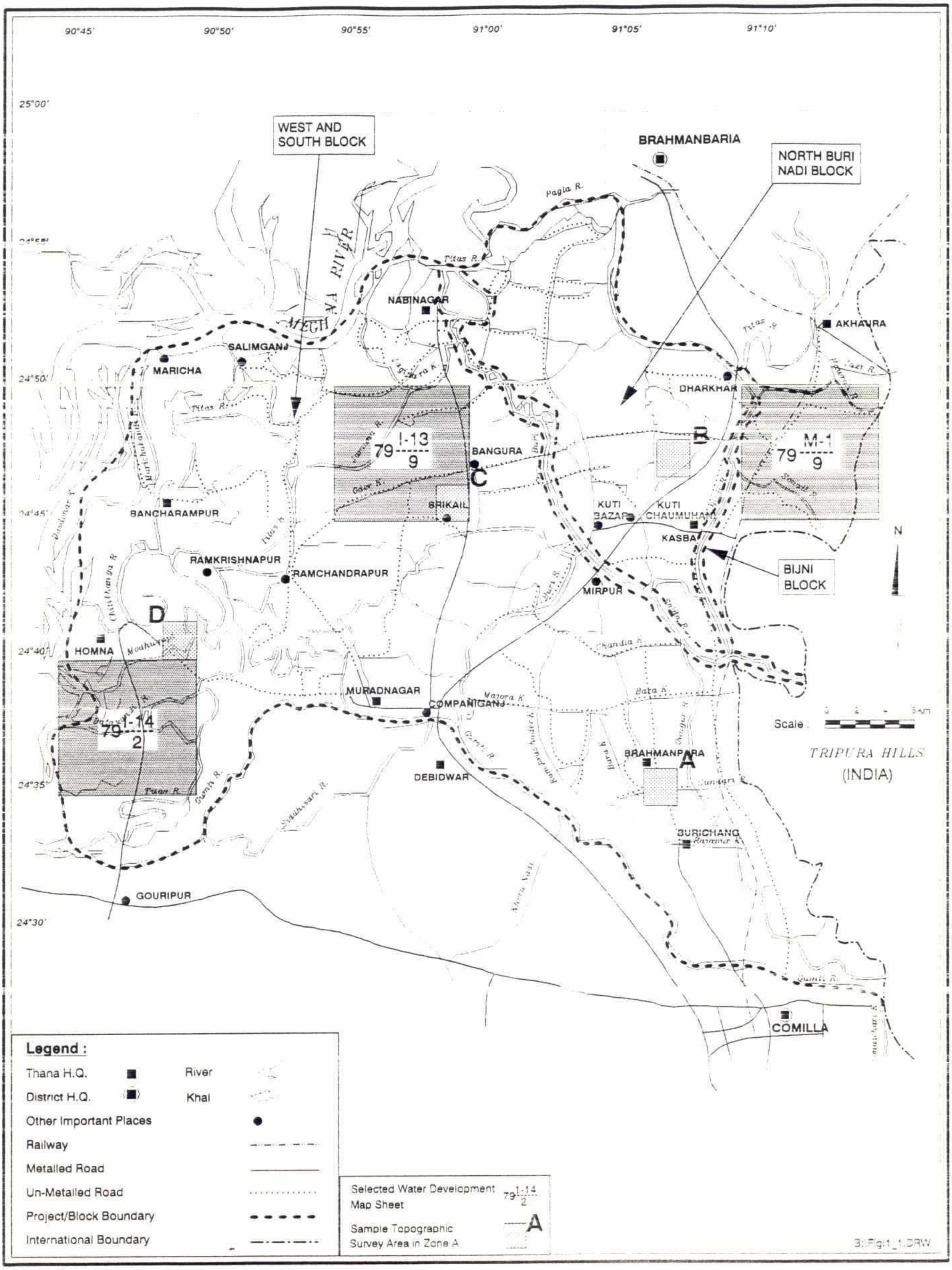


Figure I.1.2

Typical Topographic Changes Between 4 inch and FINNMAP Maps

Sheet No. 79 $\frac{1\text{-}14}{2}$ (Part)

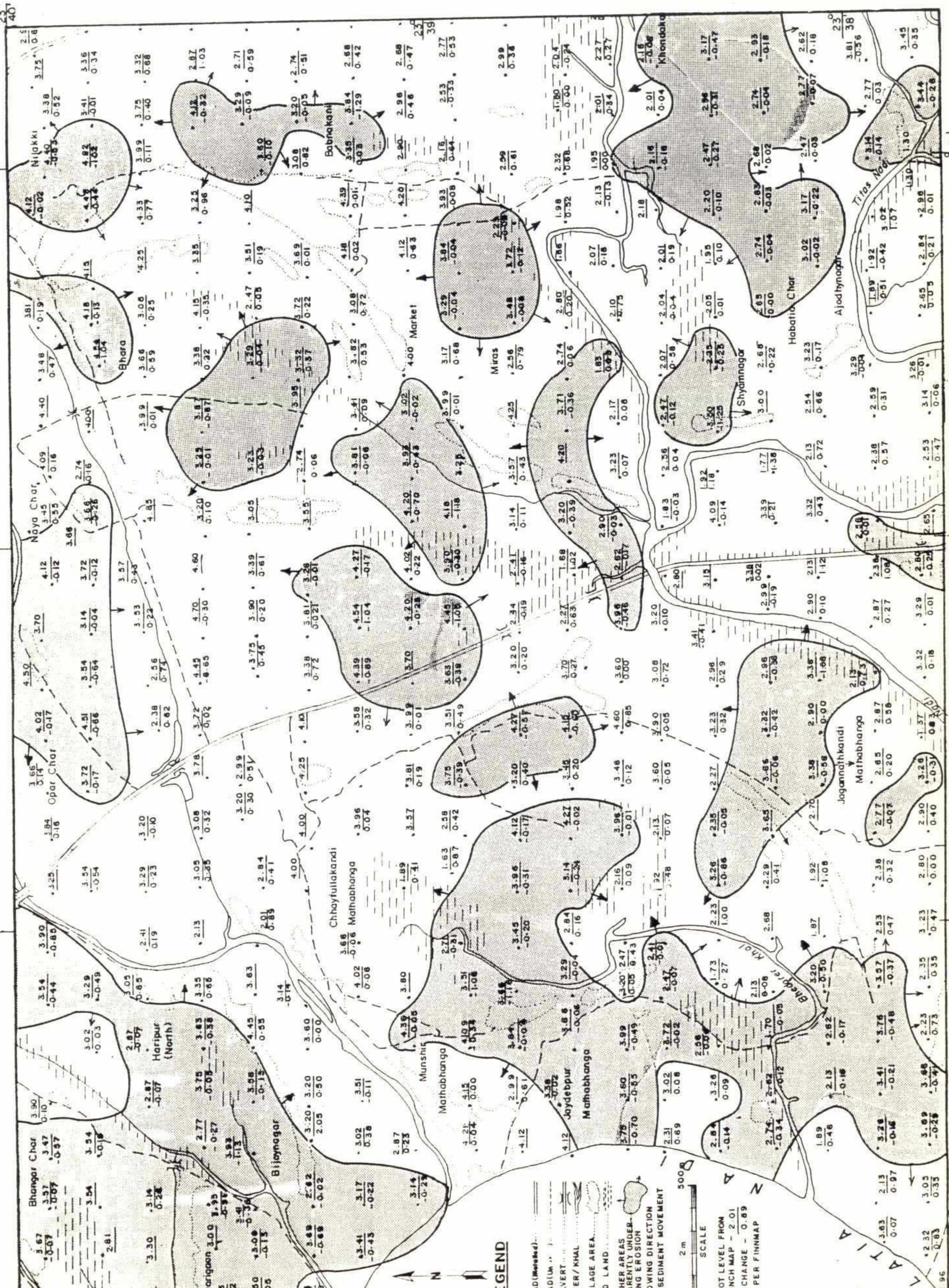


Figure I.1.3

Comparison of Area-Elevation Curves

Water Development Map Sheet Nr 79M-1/9

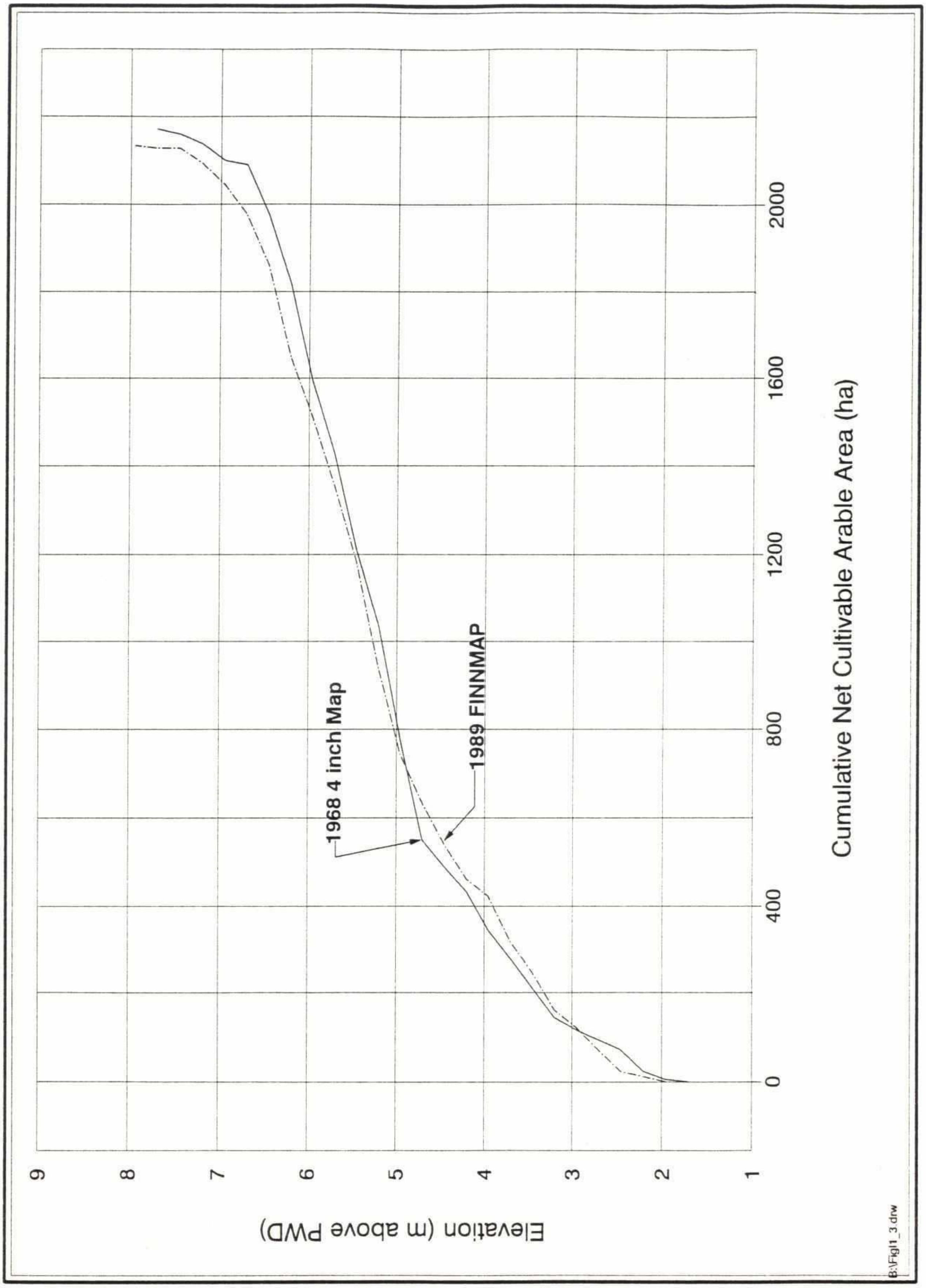


Figure I.1.4
Comparison of Area-Elevation Curves
Water Development Map Sheet Nr 79I-13/9

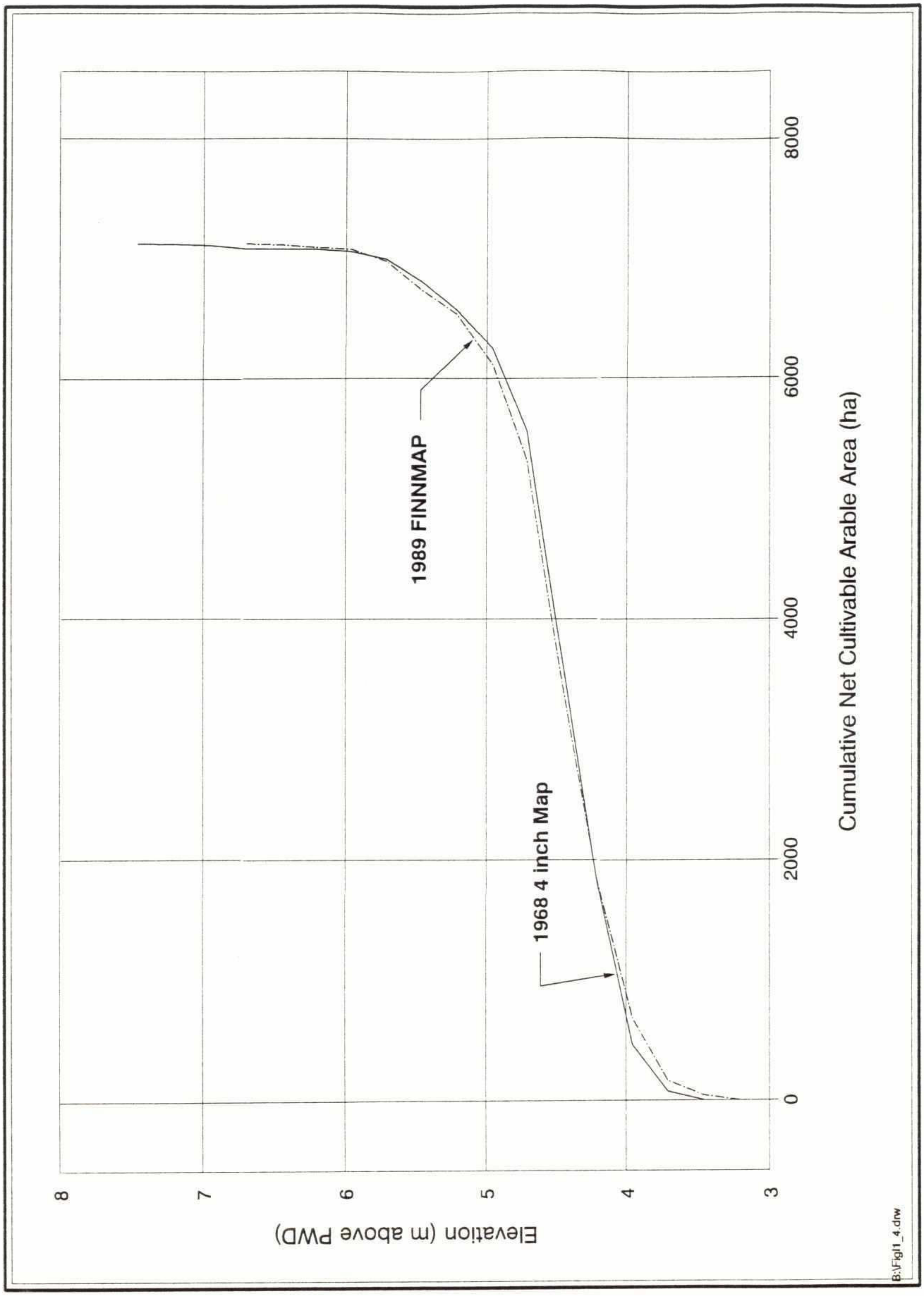
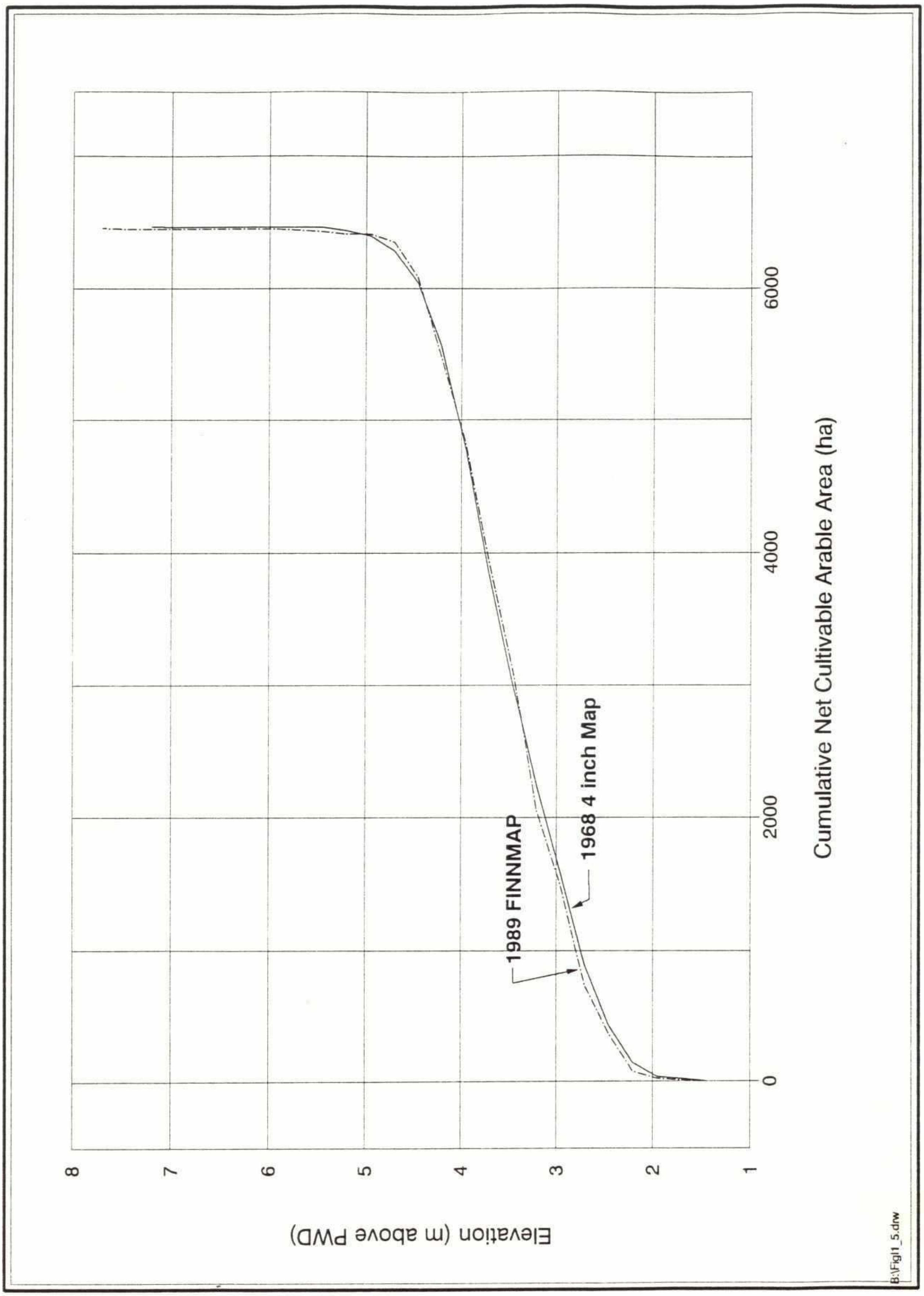


Figure I.1.5

Comparison of Area-Elevation Curves

Water Development Map Sheet Nr 79I-14/2



Sheet Nr 79I-14/2 - Gross Area 78 km²

This area is exposed to the influence of the Meghna, Gumti and Titas Rivers, and is mostly deeply flooded (F3) land. It could be expected that the south-eastern part of the area might undergo some accretion under the influence of the Gumti River, while the north-western part may not have any significant topographic change as the major influencing river, the Meghna, carries little silt.

(b) Methods of Analysis

The following two approaches were adopted:

(i) The spot levels of the 4 inch and FINNMAP maps were compared by superimposing one upon the other. As the number and location of the spots were not identical, the old map was considered as the base map. The levels from the new maps were superimposed on this base map by interpolation. Where the FINNMAP elevation was higher than that on the 4 inch map the difference was regarded as positive, and where lower, negative. Areas showing a negative difference were shaded as indicated in Figure I.1.2, and the results examined to see whether the differences in elevation could reasonably be attributed to the processes of erosion and accretion, bearing in mind the land form, location of villages and roads etc. A tentative interpretation is also given in Figure I.1.2, showing the apparent movement of soil from higher to lower areas in the Meghna flood plain in the west of the project area.

(ii) Area-elevation curves were prepared for the selected map sheets from each series, on the basis of the spot levels compared as above. The curves were superimposed as presented in Figures I.1.3 to I.1.5, and checked to see if they supported the tentative conclusions on erosion and accretion, and for signs of any overall survey datum discrepancy. The area-elevation curves exclude villages as the data from the old maps were meagre and not adequate for any comparison. This is however consistent with the approach adopted for inundation analysis under the present study, which is based upon the area-elevation curves for arable agricultural land, excluding settlements and orchards.

(c) Observations

The following observations are made:

(i) There are numerous high and low pockets in the areas, although the general topography may be flat.

(ii) There is a general tendency towards erosion in the higher land and accretion in the neighbouring low land.

(iii) This phenomenon of erosion and accretion depends only on relative elevations, and cannot be correlated with absolute elevation. For example, even in the beel (low) areas there is erosion from one place to another depending on the relative heights.

(iv) There is evidence of human interference in cutting some high lands or mounds; this may be for cultivation or dwelling purposes.

(v) There is some evidence of a decrease of elevation near to the villages, possibly due to the borrowing of soil for building up settlement areas.

(vi) In the east (sheet Nr 79M-1/9) there is a net accretion, in spite of erosion in the undulating higher land, possibly due to the deposition of sediment carried from the neighbouring hills by flash floods.

(vii) Neither the Meghna nor the lower Gumti Rivers appear to have caused significant accretion within their flood plains in the west of the project area over the period in question.

(viii) The area-elevation curves do not show any major differences between the two series. However, Figure I.1.5 (Sheet Nr 79I-14/2) does support the suggestion of a slight levelling tendency in the west of the project area, through the erosion of higher land and accretion in the lower, whilst Figure I.1.3 (Sheet Nr 79M-1/9) points to an accentuation of relief in the east, possibly because the higher land is first to receive sediment from the runoff from the Tripura Hills.

(ix) There is no evidence of a significant shift or inconsistency in survey elevation datum between the two map series.

I.1.2.3 Area-Elevation Curves for the three Drainage Units in the 1990 Feasibility Study

(a) Description of the Units

The 1990 feasibility study identified three drainage units (or blocks) within the project area, and performed inundation analyses on these, based upon area-elevation curves prepared from the 1968 4 inch maps. The three blocks are described below, and identified in Figure I.1.1.

- **Bijni Block, 10 529 ha.** The Bijni Block is located on the eastern boundary of the project area, close to the Tripura Hills. The land is undulating, having the highest average elevation of the three blocks.

- **North Buri Block, 24 082 ha.** The North Buri Block is on the western side of the Bijni Block, lying between the Bijni and Buri Rivers. The land is comparatively flat, with average ground level lying between that of the Bijni and the West and South Blocks.

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- **West and South Block, 103 019 ha.** The West South Block is the largest of the three drainage units, having a varied topography ranging from flood free land in the south-east corner to deeply flooded land in the west.

(b) Method of Analysis

The area-elevation curves for the three drainage units have been prepared from the 1989 FINNMAP maps, and these are presented together with those extracted from the 1990 study in Figures I.1.6 to I.1.8. This comparison enables an assessment to be made of whether the area-elevation curves used in the 1990 study were adequately representative of the present topography. It should be noted that the curves in the 1990 feasibility study are based upon the gross mapped area, and presumably also include the elevations of settlement areas, although the spot heights for these are very sparse and their influence on the curves therefore relatively minor. The curves prepared from the FINNMAP maps, and used in the present study for inundation analysis, are based upon the net cultivable arable area (NCA) only, as discussed in Section I.1.3 below. These correspond with the curves labelled 'NCA' in Figures I.1.6 to I.1.8. Adjusted curves labelled 'GA' are also presented, calculated by factoring the cumulative area by the ratio of net cultivable to gross area within the drainage unit. Since, as already noted, the effect of the settlement spot heights in the 1990 study curves is minimal, they should be directly comparable with these adjusted curves.

(c) Observations

The following observations are made from a comparison of the curves:

(i) The gross areas of the North Buri Nadi and the West and South Blocks (Figures I.1.7 and I.1.8 respectively) are in reasonable agreement, bearing in mind the limitations on measurement accuracy and the fact that the blocks have been delineated on the FINNMAP mapping for this exercise in terms of whole one minute squares. The gross area for the Bijni Block (Figure I.1.6) is very much smaller in the case of FINNMAP. This is because not all of the area has been mapped, as already noted above.

(ii) The correspondence between the curves is reasonable over most of the area in each case, and especially for the elevation range of most interest for the purpose of inundation analysis (up to about 6 m or 7 m above Public Works Datum). Inspection of map sheet 79M-1/9 for each series, which covers most of the Bijni Block, reveals that although unlike the FINNMAP series the 4 inch map covers all of the area within Bangladesh, the actual area for which spot levels are shown is substantially less, and excludes most of the high ground. It must therefore be presumed that the 1990 study curve for this block was extended to the whole area by some form of extrapolation. Even in the case of this block, the discrepancy is almost entirely confined to land higher than 7 m above Public Works Datum, and is therefore of little significance to the inundation analysis.

Figure I.1.6
Comparison of Area-Elevation Curves
Bijni Block

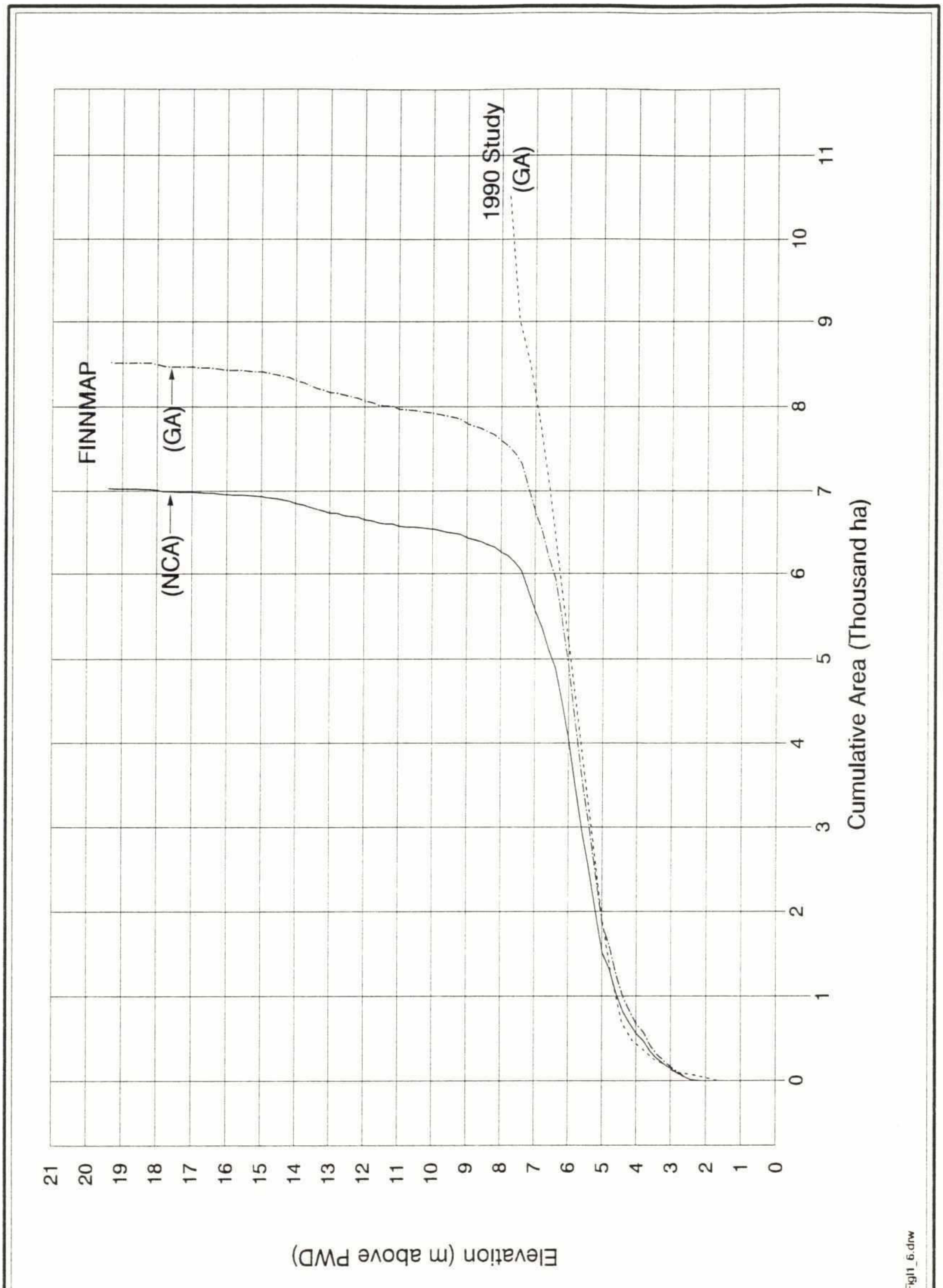


Figure I.1.7

Comparison of Area-Elevation Curves

North Buri Nadi Block

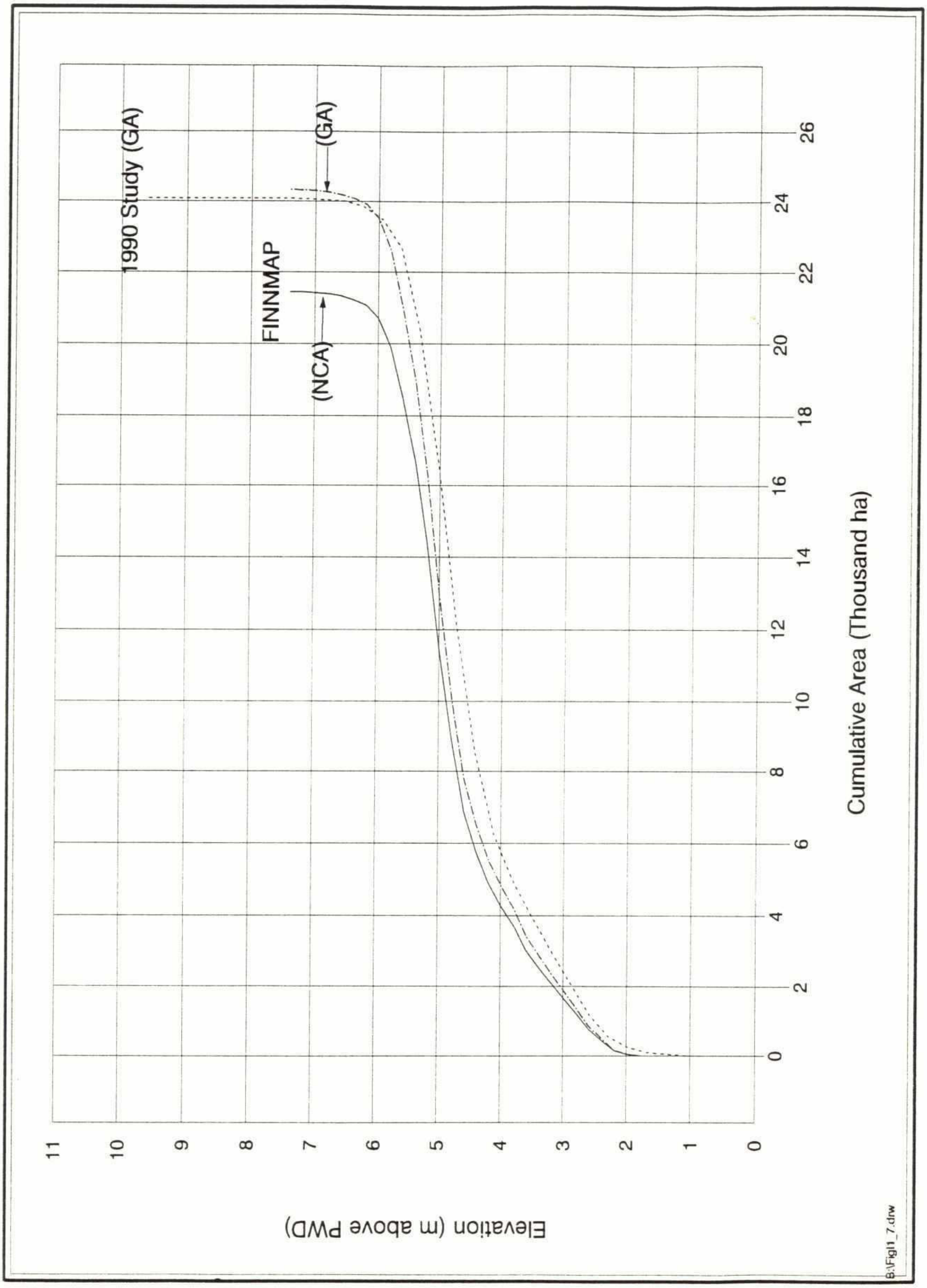
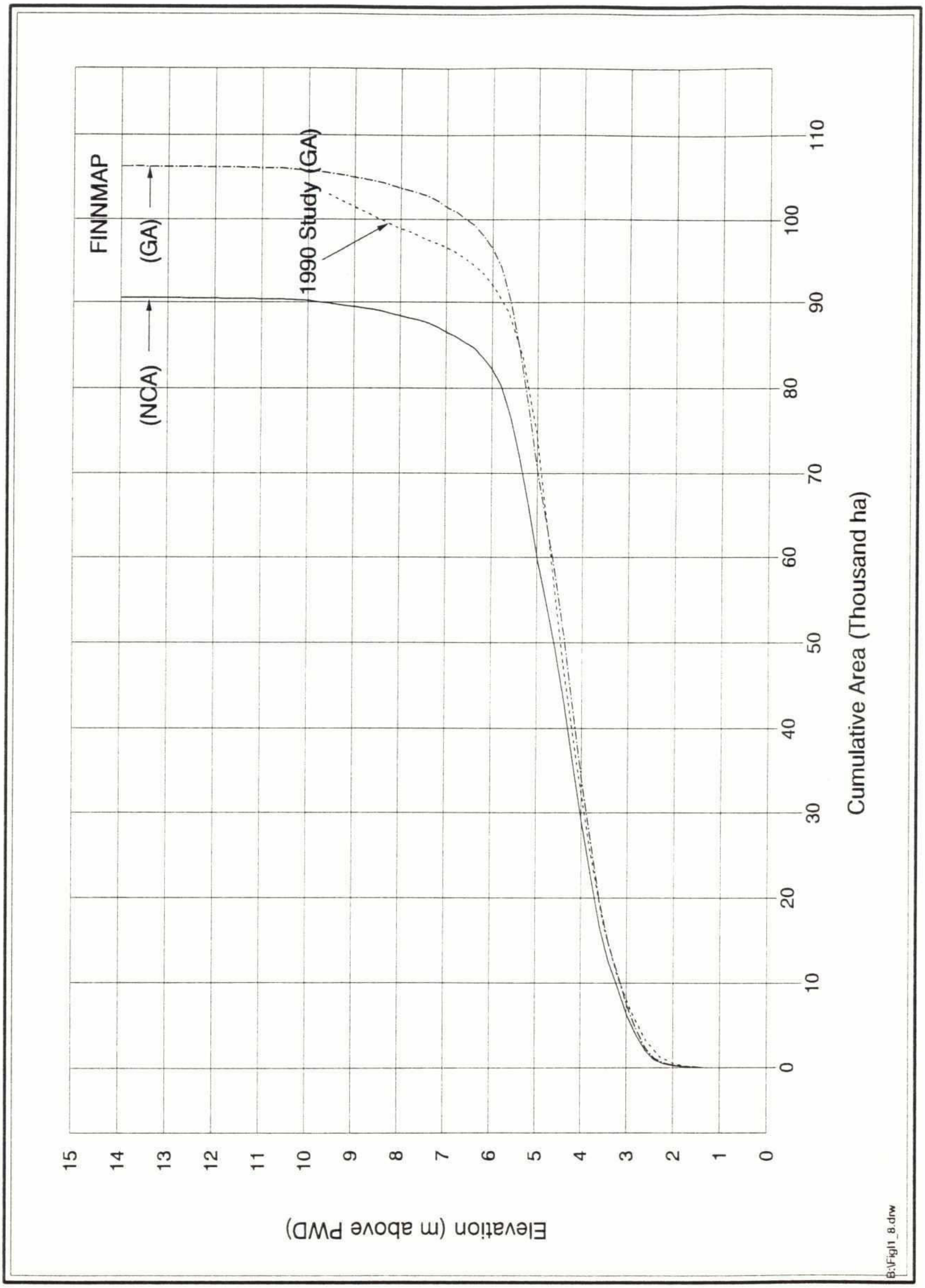


Figure I.1.8

Comparison of Area-Elevation Curves

West and South Block



(iii) In the case of the North Buri Nadi Block, the more recent map gives elevations about 20 cm to 25 cm higher over most of the range. This may possibly be attributed to sedimentation, as discussed above. Otherwise, there are no obvious signs of morphological change, although it is probable that these would in any case cancel one another out, particularly over the large and diverse South and West Block.

(iv) There are unlikely to be major differences between inundation analyses based upon the two map series, at least for areas of the size examined. The curves derived from the 1968 4 inch maps can therefore be regarded as adequately representative of present topography for the purposes for which they were used, although naturally the more recent FINNMAP information is to be preferred, and is used in the present study.

I.1.2.4 Sample Topographic Survey Areas

(a) Sample Area Selection and Purpose

One 2 km square sample area was selected for detailed topographic survey in each of the four agro-socioeconomic survey zones, as representative of its topography, inundation conditions etc. The sample area locations are indicated in Figure I.1.1. Their purpose was as follows:

(i) To assess whether the 1989 FINNMAP mapping adequately represents the topography for the purpose of inundation analysis, particularly from the point of view of the frequency of spot levels.

(ii) To check whether the estimate of net cultivable arable area incorporated in the land level database is reasonable.

(iii) To enable the elevations of selected plots to be determined, and hence the inundation from simulated or observed water levels. This information was then to be used in conjunction with the plot agricultural surveys, to assist in confirming the relationships between cropping and flood characteristics.

(iv) To provide detailed information on non-arable land use (homestead/orchards, ponds and khals) representative of each of the four agro-socioeconomic survey zones.

Water levels were also monitored at points within each sample area throughout the 1992 monsoon season, as discussed in Section I.1.5 below.

(b) Methodology

Each 2 km square sample area is centred on a 1 minute map grid square (about 1.8 km square, or 311 ha), and may therefore be directly related to the corresponding square within the land level database prepared for the present study and discussed in Section I.1.3 below. Individual spot levels from the FINNMAP and the 4 inch

2a

sheets (except in the case of Area A, for which the 4 inch sheet was not available) were compared with the 50 m interval spot levels from the detailed survey, in a similar manner to that described in Section I.1.2.2(b), to see whether any further insight could be gained on recent morphological changes. For each square the area-elevation curve for the net cultivable arable area (NCA) was then prepared from the survey data, and compared with that extracted from the land level database. The 1 in 5 000 surveys were sufficiently detailed to permit separate measurement of homestead/orchard, pond and khal areas, and these were all deducted in arriving at the net cultivable arable area. For completeness, the corresponding curve was also prepared from the 4 inch sheet, except for Area A. The results are presented in Figures I.1.9 to I.1.12.

(c) Observations

The following observations are made:

(i) It is less easy to identify the mechanisms of morphological change in these smaller areas than it was for the whole map sheets (Section I.1.2.2 above). Nevertheless localised erosion and deposition are still apparent.

(ii) The correspondence between the area-elevation curves from the land level database (FINNMAP) and the sample area survey is fairly good for Areas B and C, with a discrepancy generally of between 5 cm and 15 cm. In the case of Area A the discrepancy is larger, increasing from 15 cm to 50 cm at higher elevations. This is probably largely due to the discrepancy in net cultivable arable area, as discussed in (iii) below, although some erosion is conceivable. In the case of Area D, the sample area survey data is between 25 cm and 30 cm higher than the land level database, which is itself higher than the 1968 4 inch map. This would suggest a tendency towards accretion, although this was not apparent for map sheet Nr 79I-14/2, as discussed in Section I.1.2.2(c) above. In general, the sample area surveys do show a greater range of relief, as would be expected from a more detailed survey. It may be that some of the other discrepancies also relate to differences in survey detail.

(iii) The correspondence between net cultivable arable areas for the land level database and the sample area survey is reasonable (within about 10%) except for Area A. In this case there are substantial non-arable areas, and it appears that when these were measured from 1 in 16 000 maps, inclusions of arable land within the settlements could not be distinguished. The 1 in 5 000 sample survey shows the settlements to be quite 'porous'. In the other more sparsely settled areas the land level database tends slightly to underestimate the non-arable area, so over larger mixed areas the errors will tend to compensate.

(iv) Although the comparison of the sample area surveys with the land level database is slightly disappointing, it is concluded from all of the area-elevation curve comparisons carried out that the land level database does adequately represent the topography of the project area for the purposes of inundation analysis, at least when aggregated over large areas.

Figure I.1.9

Comparison of Area-Elevation Curves

Sample Area A

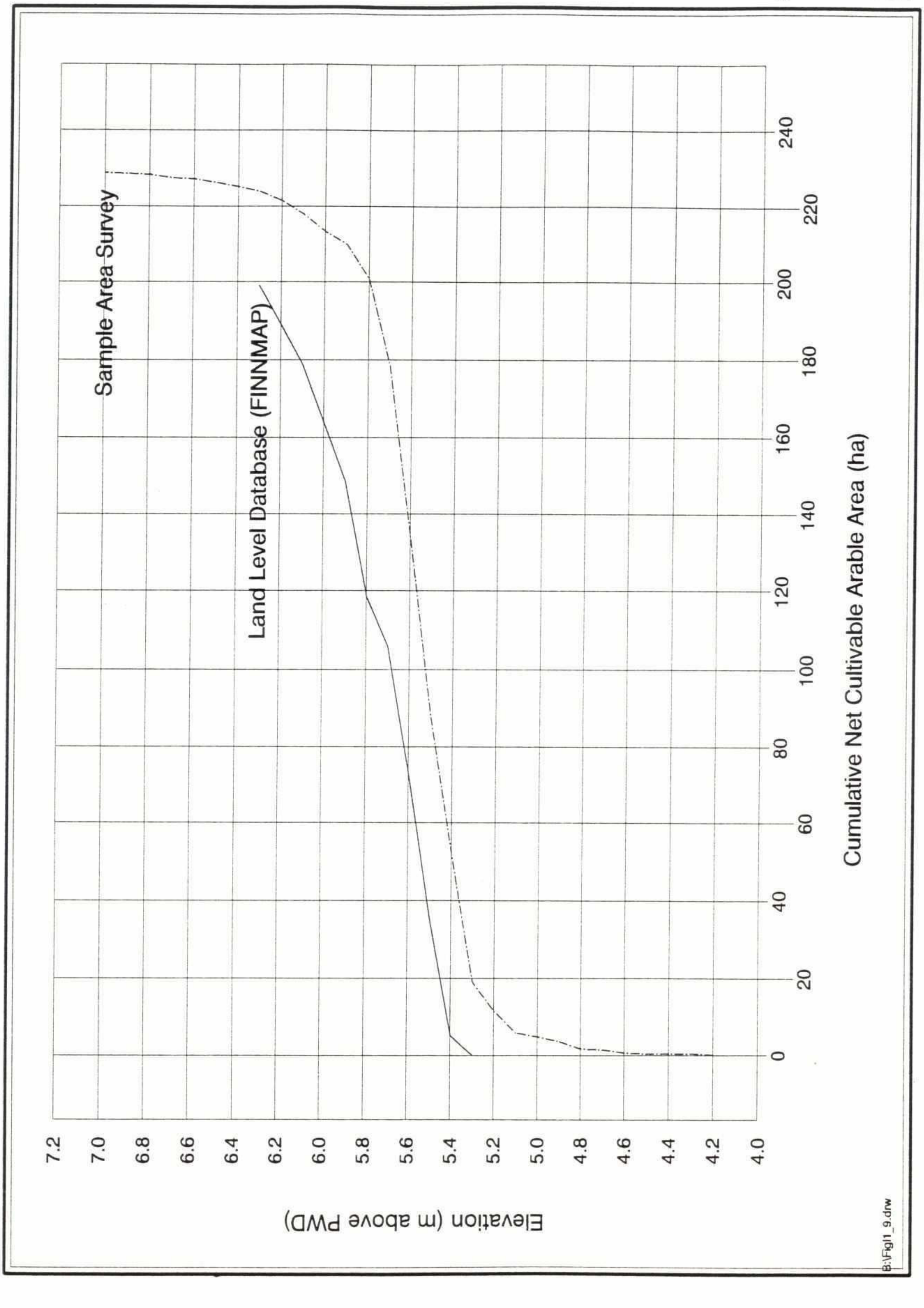


Figure I.1.10

Comparison of Area-Elevation Curves

Sample Area B

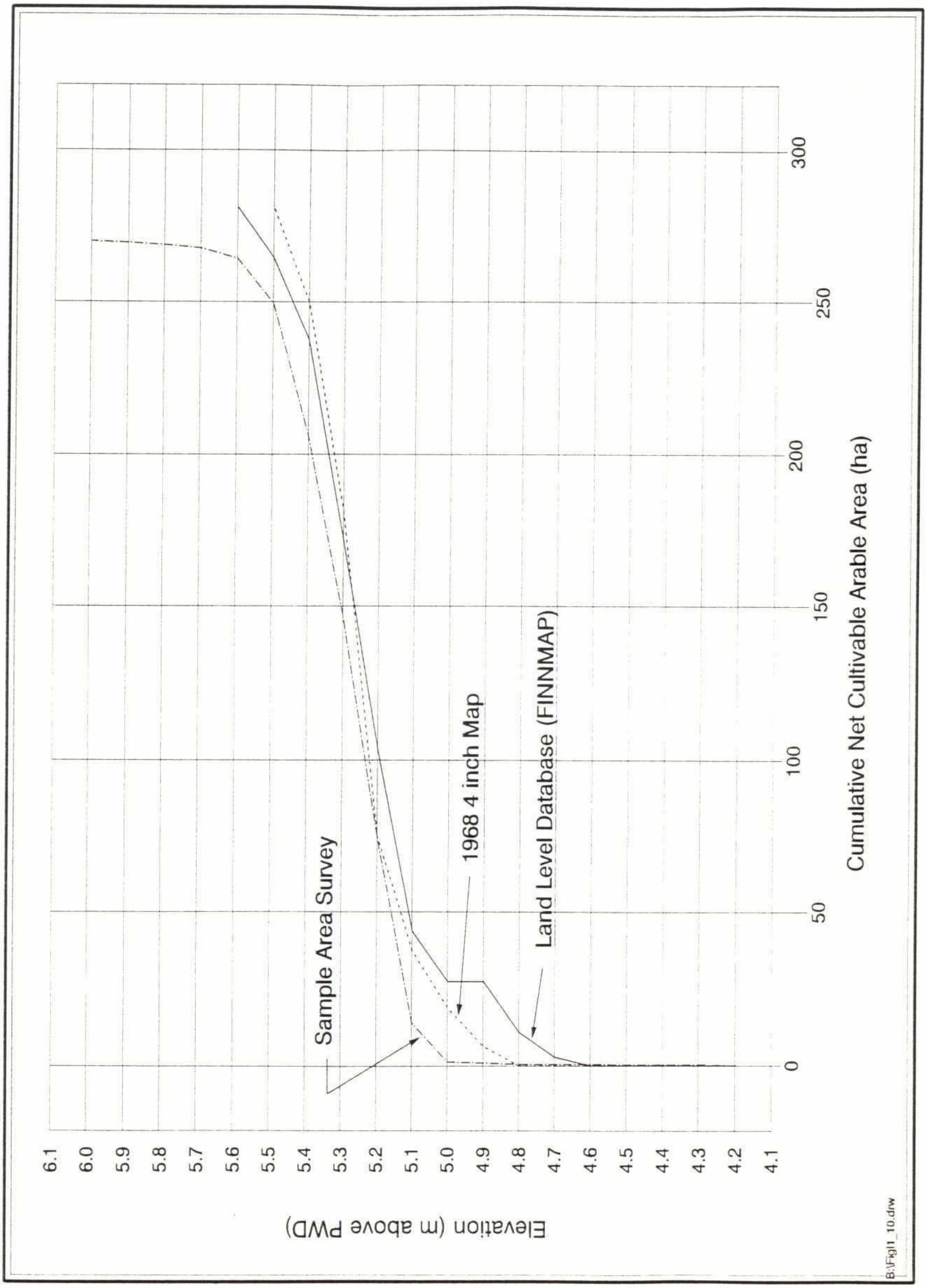


Figure I.1.11

Comparison of Area-Elevation Curves

Sample Area C

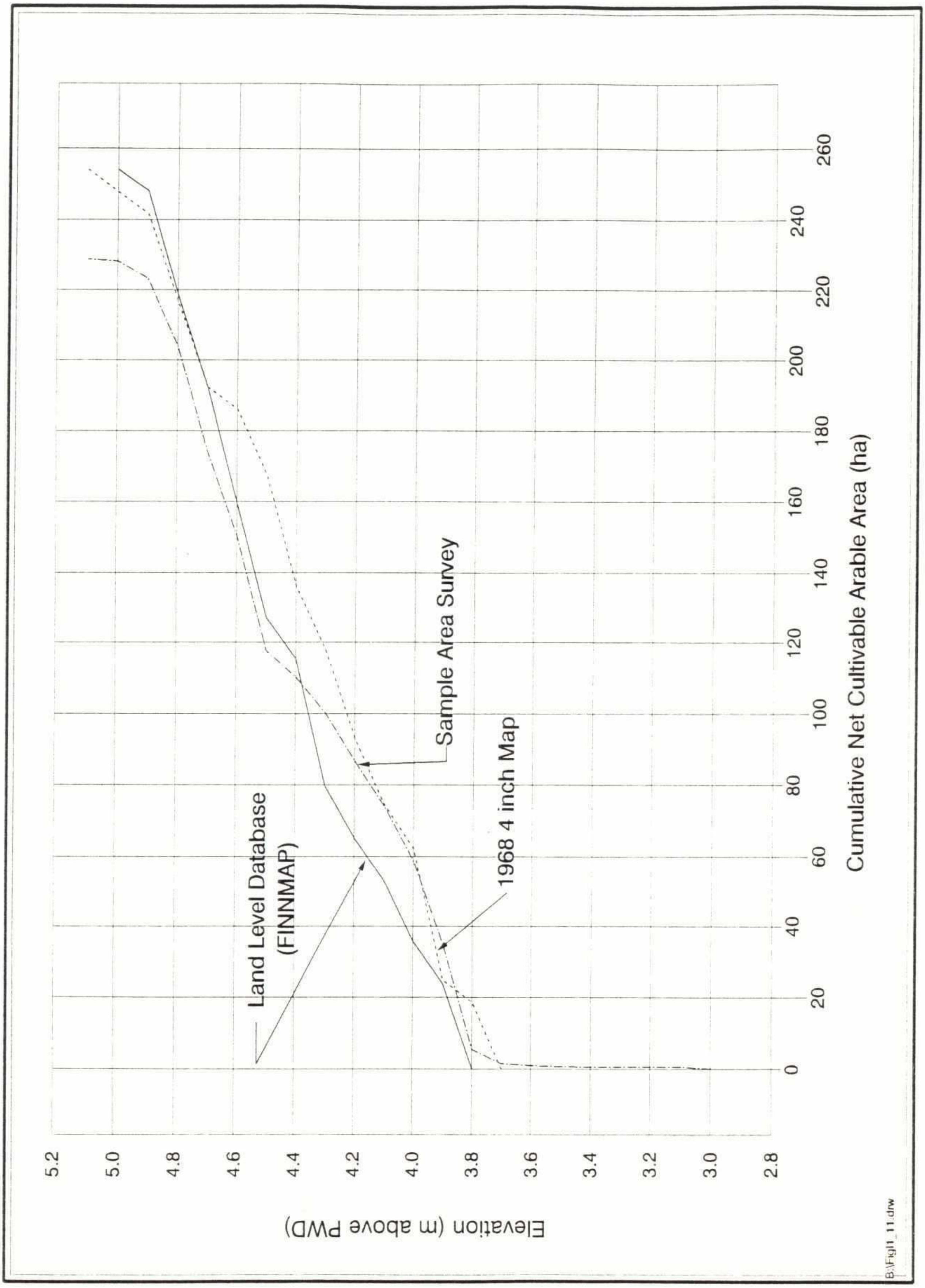
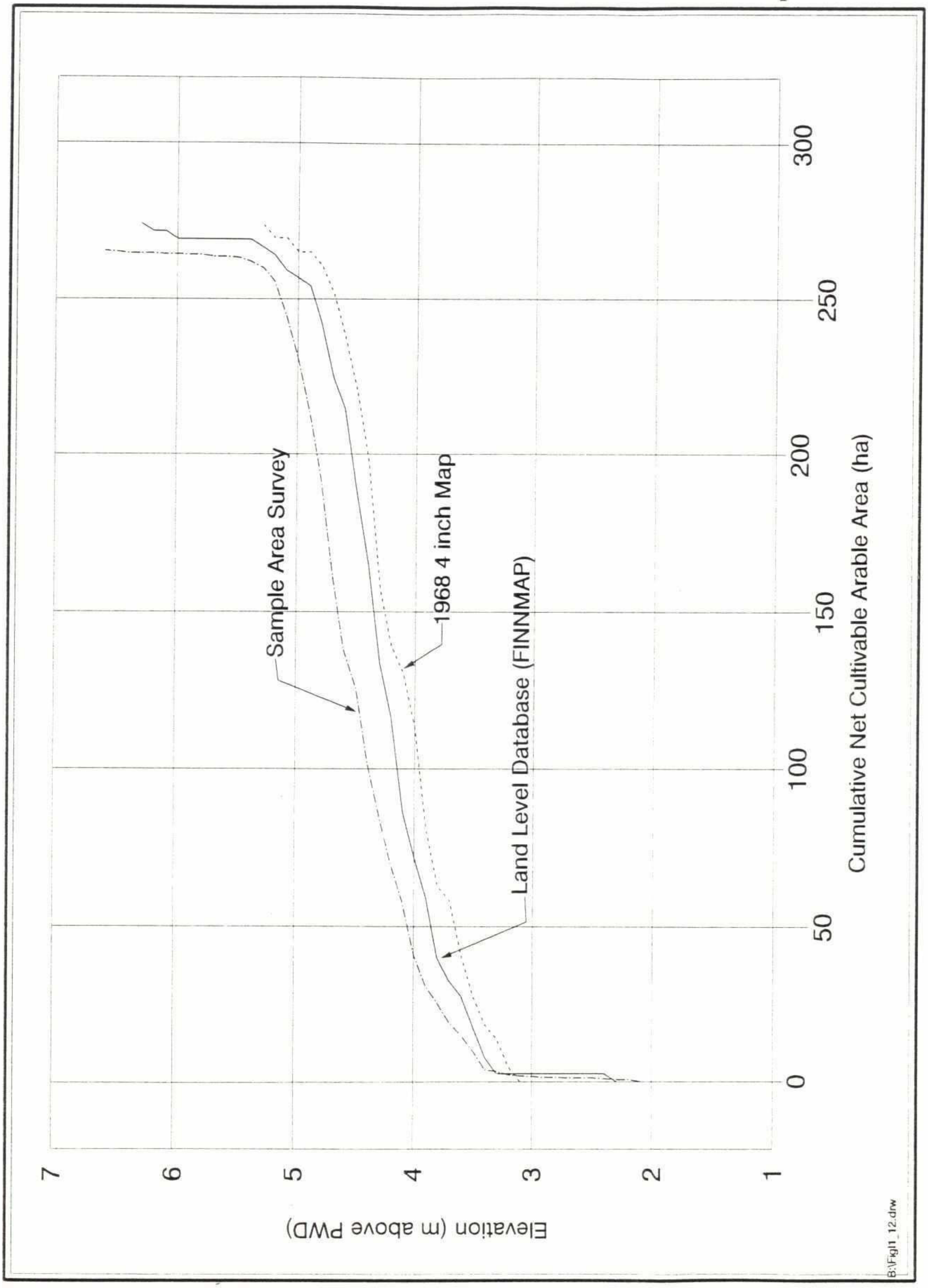


Figure I.1.12

Comparison of Area-Elevation Curves

Sample Area D



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(v) The breakdown of the various uses of the non-arable land within each sample square is given in Table I.1.2. Roads are included within the homestead/orchard area or, where they are beside khals, within the khal area. The pond area has been expressed as a percentage of the total non-arable area. On the assumption that this percentage will be more or less fixed within an agro-socioeconomic survey zone, it has been used to provide an estimate of the total pond area within each zone.

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TABLE I.1.2

Non-arable Land Use by Sample Area

Sample Area	Homestead/ Orchards (ha)	Khals (ha)	Ponds		Total non-arable area in Zone (ha)	Estimated pond area in Zone (ha)
			(ha)	% of non-arable area		
A	48.4	13.2	20.8	25.2%	7 470	1 882
B	24.5	3.4	13.1	32.0%	4 370	1 398
C	50.4	15.0	17.0	20.6%	6 360	1 310
D	25.5	16.3	3.8	8.3%	4 616	383
				TOTAL	22 816	4 973

I.1.2.5 Comparison of SOB, FINNMAP and Hydrological Gauge Station Bench-Marks.

Bench-marks were installed at approximately 2 500 m intervals for the preparation of the 1989 FINNMAP mapping. Most of these are still available in undisturbed condition, at least where they are away from roads and other developments. Since the land level database for flood analysis is based upon these maps, it was decided to check all other topographic data against this bench-mark system.

The following bench-marks were checked against the nearest available 1989 FINNMAP bench-marks:

- two bench-marks, which also happen to be SOB maintained, selected from the field books associated with the channel surveys prepared for the 1990 feasibility study,
- the gauge zeros and associated local bench-marks for all Surface Water Modelling Centre (SWMC) and BWDB hydrological gauge stations, and
- one new (1991) bench-mark from the current FINNMAP Oy survey programme for Bangladesh Inland Water Transport Authority (BIWTA). This bench-mark has not yet been officially assigned an elevation, but once this is known, including the effect of any regional level datum correction, the whole project topographic database could then be adjusted to the corrected national datum if desired.

The detailed results are presented in Appendix I.I to this Annex. The datum consistency was found to be generally very good, but discrepancies in excess of 0.1 m were found at four of the gauge stations; these were double-checked and confirmed.

I.1.3 The Land Level Database

Inundation analysis has been carried out by relating simulated water levels to a land level database prepared from the 1989 1 in 16 000 FINNMAP mapping. In the case of sheet 79M-3/7 (see Figure I.I.1 in Appendix I.I to this Annex) the FINNMAP sheet is not available, and therefore the 1968 4 inch sheet was used. It was considered important that the inundation analysis should relate to the net cultivable arable land, since it is to this that the agricultural benefits relate. Therefore settlement, orchard and other non-arable areas have been omitted from the database, along with the elevations associated with them. Based upon the topographic map sheets, FINNMAP also prepared four series of land use and land type maps to the same scale (see Appendix I.I to this annex), and the non-arable areas were measured from these by one minute square.

The database includes a separate file for each map sheet (36 in all). Within each file the data is separated into a list of elevations for each of the 25 Nr one minute squares within the sheet, with each list preceded by the square number, the gross area, the net cultivable arable area and the number of elevations. The whole file is headed by the map sheet number and the grid reference of the north-west corner.

Minute squares falling outside the project area have a single zero elevation entry. At the boundaries of the project area, elevation data is often available for only a part of a square, either because of a lack of data or because the boundary is marked by a major river. In other locations, particularly along the southern boundary formed by the Gumti right bank embankment, the elevations within the boundary square but outside the project area were not considered representative of the project, and were therefore omitted. In both cases the gross area of the minute square was reduced by an appropriate amount in the database. The gross area was also adjusted to take account of the larger channels within the project area, especially in the west. Otherwise, the gross area of each one minute square was taken as 311 ha.

The land level database was used in post-processing the output of the South East Regional Model for inundation analysis as described in Annex B (Hydraulic Modelling)

I.1.4 Topographic Surveys

All additional topographic surveys required for the study were carried out under a sub-contract, which was awarded to Messrs National Surveyors and Builders on 17 December 1992.

The survey work consisted of three components as follows:

(i) Checking of existing bench-marks. This component is discussed in Section I.1.2.5 above.

(ii) Khal surveys. Although extensive khal surveys were prepared for the 1990 feasibility study, the coverage of the channels from the Tripura Hills in the east was considered inadequate, and longitudinal and cross sections were taken for the Sonaichari, Ranggori Nadi, Pagli Nadi and Sonai River (see Figure I.I.2 in Appendix I.I to this Annex). In addition the longitudinal section and 9 cross sections were taken of 27 km of the Gumti River from the offtake of the Buri Nadi at Jibanpur downstream to the crossing of the Gouripur-Homna road. This survey was carried out in order to assess changes in the morphology of the Gumti River following the regulation/closure of the Buri offtake and extension of the Gumti embankments, as well as providing data for the extension of the Gumti right bank embankment under the Zone D proposals. The morphological implications are discussed in Chapter I.3 of this Annex.

(iii) Sample area topographic surveys. This component is discussed in Section I.1.2.4 above.

I.1.5 Sample Area Water Level Monitoring

I.1.5.1 Objectives and Method

Temporary gauges were established in each of the sample survey areas described in Section I.1.2.4 above, to monitor flood levels during the 1992 monsoon season, from 8 August to 15 October. Two gauges were installed in each of Areas A to C and three in Area D. The locations are indicated in Figures I.1.13 to I.1.16. The objectives of monitoring water levels were as follows:

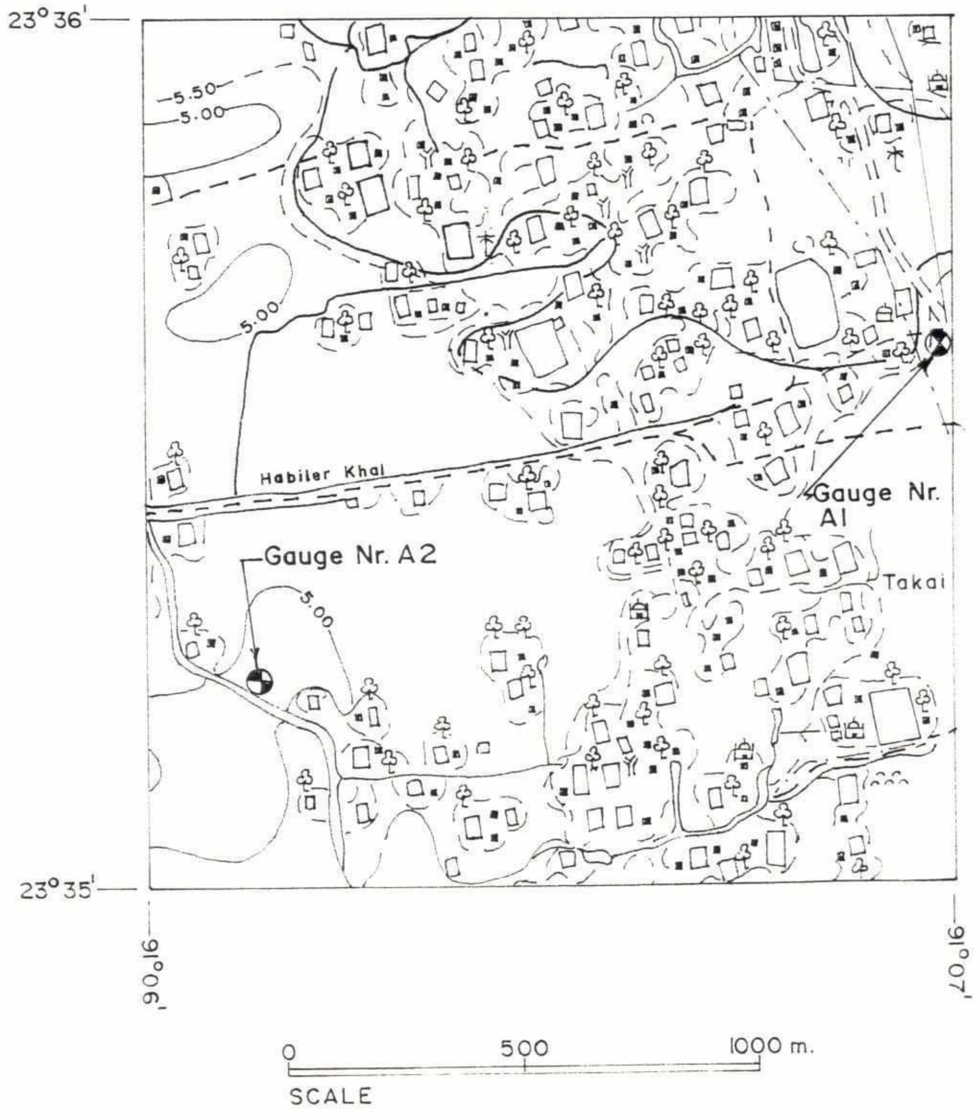
- to check actual flood depths within the sample area, and
- to test the validity of the assumption that flooding within a one minute square (and indeed in a group of one minute squares) can adequately be represented by a single water level. This assumption is implicit in the use of simulated water levels at selected model nodes for inundation analysis.

Local people were employed to take gauge readings three times a day (06.00, 12.00 and 18.00 hours), and the gauge zero elevations were subsequently determined in the course of the sample area survey work.

I.1.5.2 Observations

In the event, the 1992 monsoon season was unusually dry, and none of the gauges recorded a water depth in excess of about 0.35 m, whilst several remained above flood level for the whole period. The results for Areas C and D are presented in Figures I.1.17 and I.1.18; no significant readings were obtained for Areas A and B. Since the season was so atypical, it was not possible to draw any conclusions as to normal flood depths. It is noticeable however that gauges C1 and D1, which were set on higher ground, did not show readings, unlike C2, D2 and D3 which were on lower ground. The water levels recorded at gauges D2 and D3 move in parallel up to about 0.2 m apart. It thus appears that, at least for this shallow depth of flooding there is significant variation in actual water level across a one minute square, but there is not sufficient evidence to reach a clear conclusion. From the almost exactly parallel shape of the curves, there must be a strong suggestion that there is indeed a single water level and that there is a discrepancy in the gauge zeros, perhaps due to some

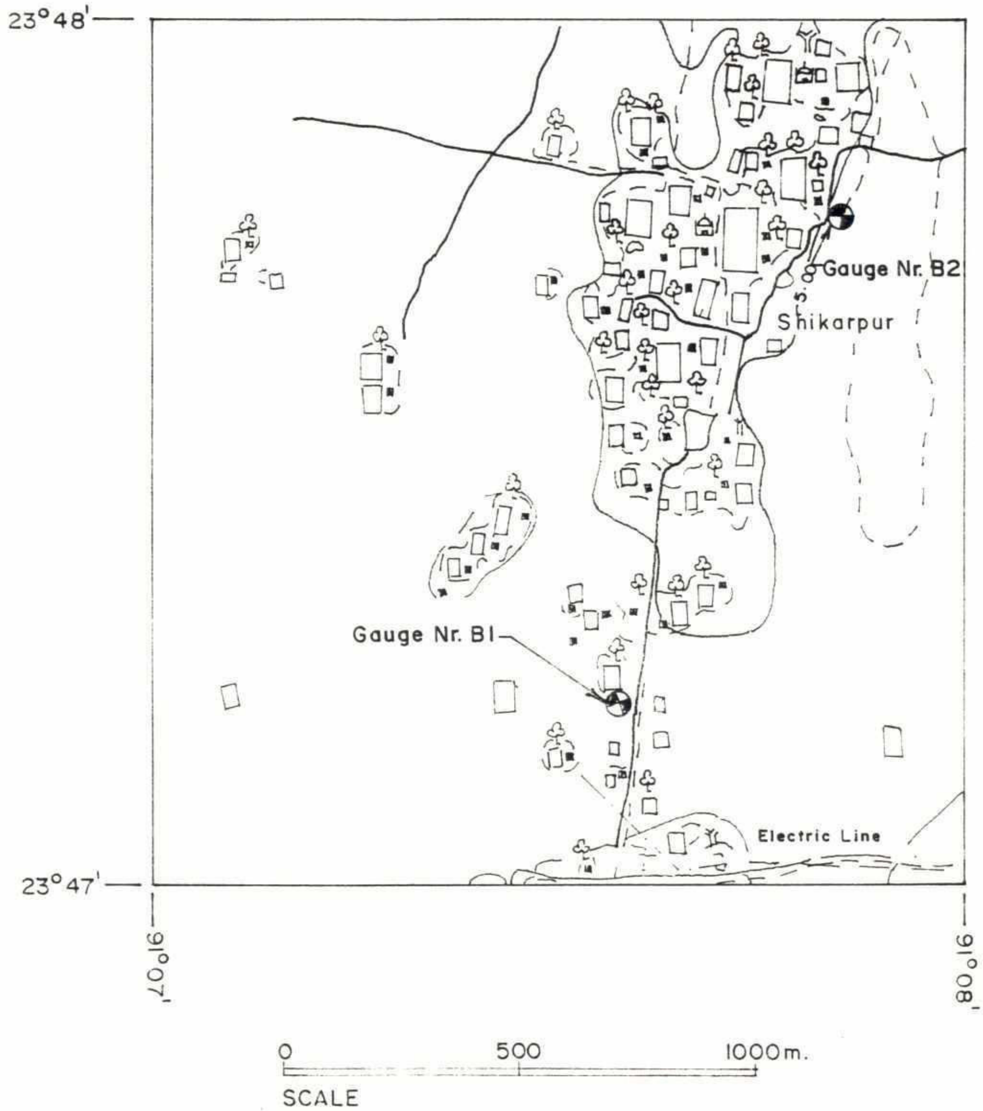
Figure I.1.13
Location of Water Level Gauges
Sample Area A



Source: - BANGLADESH WATER DEVELOPMENT MAP 1: 16000
SHEET 79 $\frac{M-2}{5}$
1989.

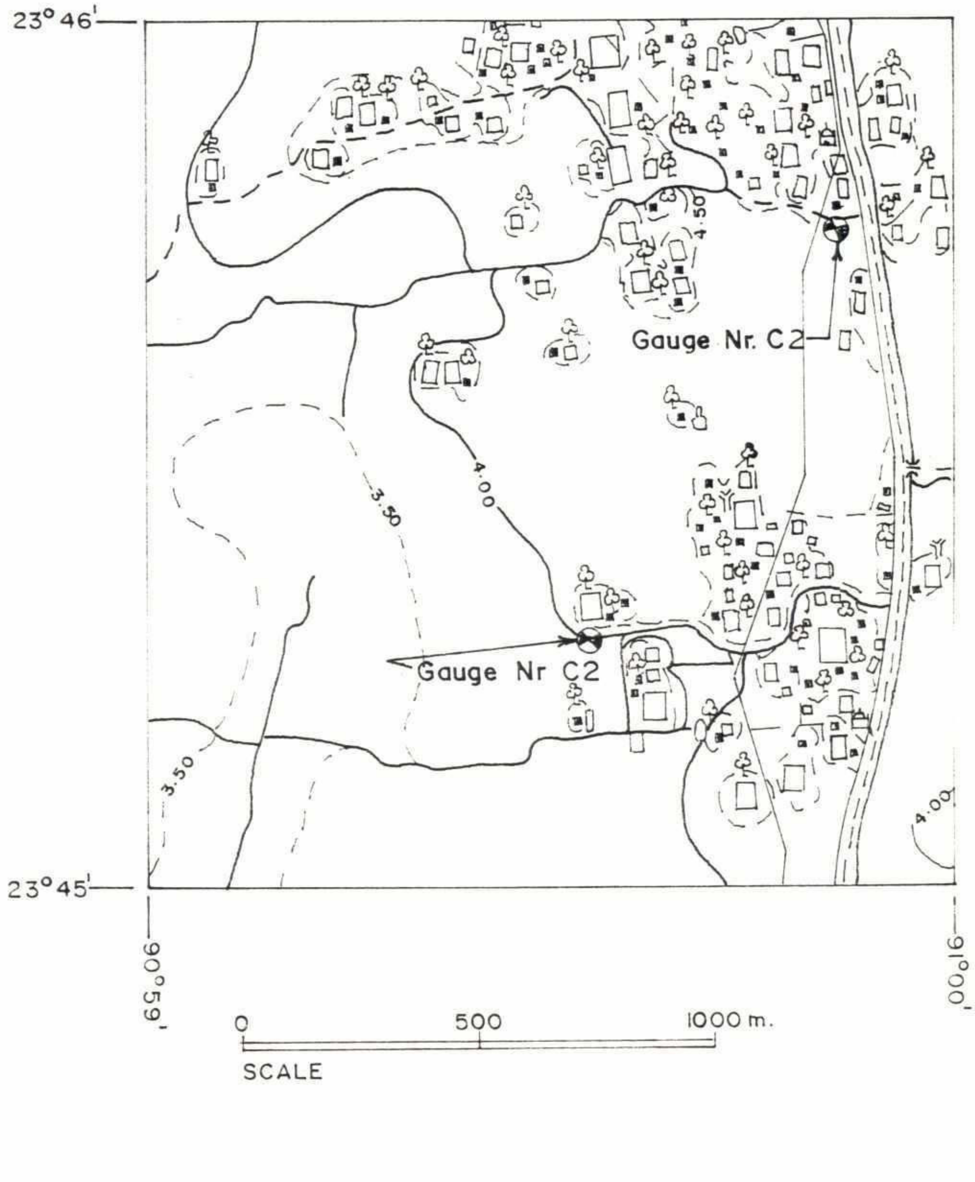
08

Figure I.1.14
Location of Water Level Gauges
Sample Area B



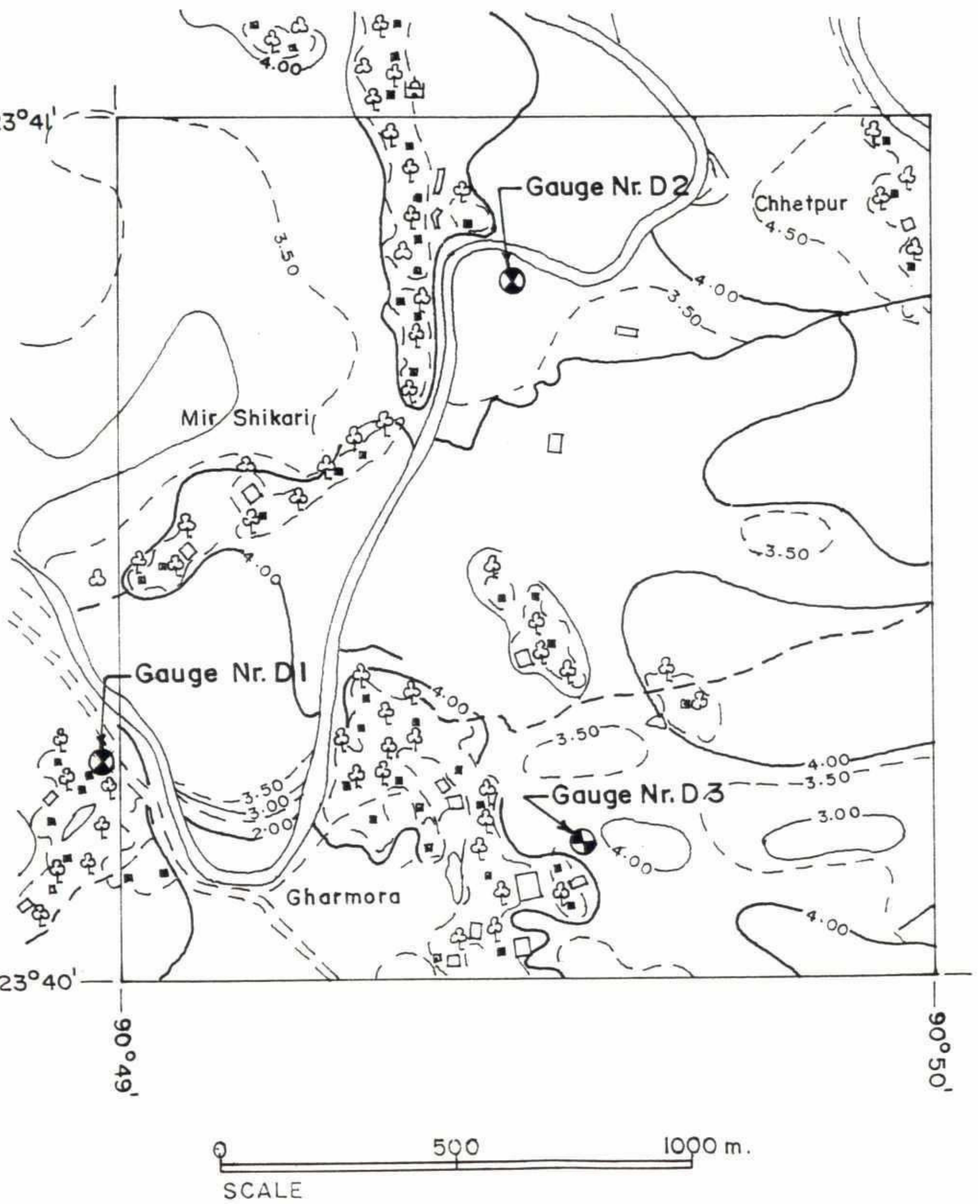
Source:- BANGLADESH WATER
DEVELOPMEMT MAP 1:16000
SHEET 79 $\frac{M-1}{6}$
1989.

Figure I.1.15
Location of Water Level Gauges
Sample Area C



Source :- BANGLADESH WATER DEVELOPMENT MAP 1:16000
SHEET 79 $\frac{1-13}{9}$
1989.

Figure I.1.16
Location of Water Level Gauges
Sample Area D



Source:—BANGLADESH WATER DEVELOPMENT MAP 1:16000 SHEET 79 $\frac{1-14}{1}$ 1989.

Figure I.1.17

Water Level Monitoring - 1992

Sample Area C

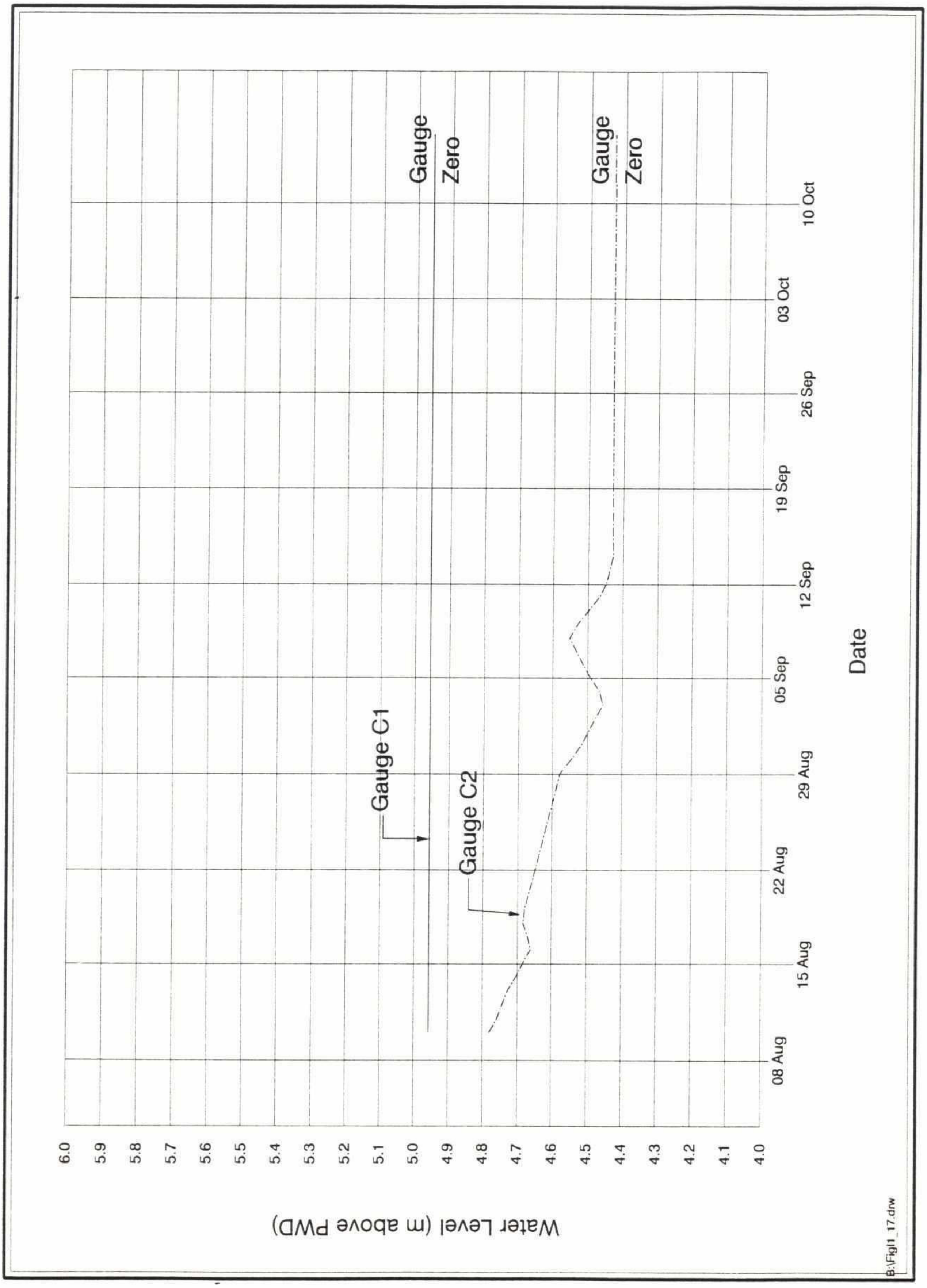
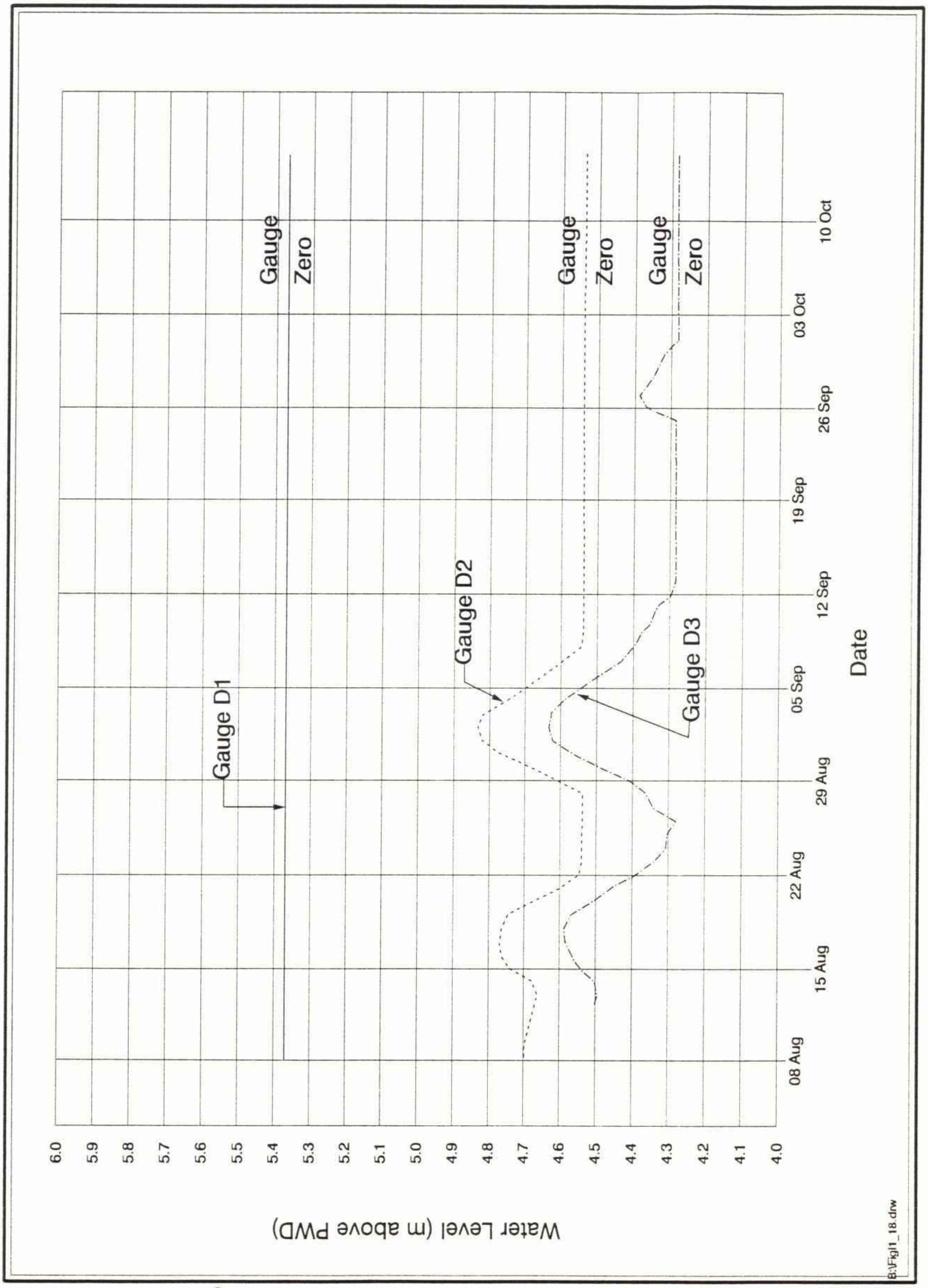


Figure I.1.18

Water level Monitoring - 1992

Sample Area D



disturbance between the time when the readings were taken and when the gauges were levelled in. As water levels rise, one would expect discrete water bodies within the depressions to combine into a more or less level sheet. As drainage takes place, some areas would lag behind others because of obstructions etc, returning to a situation of discrete water bodies with differing levels.

I.1.6 Sediment Sampling

Some suspended sediment and bed material sampling has been carried out by the SWMC with a view to its getting the morphology module of the Mike11 SERM into operation. The duration of the present study has been inadequate for the collection of significant series of suspended sediment data, and the exceptionally low flows during the 1992 monsoon season would have meant that any results would have been of little value. However, SWMC did suggest additional locations where bed material samples would be useful in estimating bed load as part of the overall sediment transport, using the morphology module. These samples were taken and the particle size analysis results are given in Appendix I.II to this Annex. In the event, the morphology module was not available for the present study, and the estimation of likely deposition rates, and hence desilting requirements for channels within the project area, has instead been based upon records of previous re-excavation, as discussed in Section I.3.2.

I.1.7 Existing Infrastructure

I.1.7.1 Roads, Bridges, Culverts and Hydraulic Structures

Data on existing road structures were collected from the local, regional and Dhaka offices of the Local Government Engineering Department (LGED) and the Roads and Highways Department (R&HD), and by field inspection. Details are presented in Appendix I.III to this annex. Very few hydraulic structures (other than road cross-drainage structures) were found. These were primarily associated with the existing submersible embankment schemes at Satdona Beel and Chandal Beel in Zone D, and are described in Chapter I.6 (Development Options).

I.1.7.2 Other Infrastructure and Buildings

Each thana within the project areas was visited by a team gathering information on public buildings etc and the vulnerability of buildings and infrastructure to floods. The reports of the team are given in Appendix I.IV to this Annex. A summary of the significant features of the reports is given below.

(i) Nabinagar

The thana contains 5 Nr colleges, 42 Nr approx. high schools and 210 Nr primary schools, as well as the usual range of thana headquarters buildings. During the 1988 flood, the entire thana headquarters area was reported to have been submerged up to 2 m deep. People were forced to take refuge on bamboo platforms. Nevertheless, during normal monsoon seasons, although flooding is extensive, the homesteads are not inundated.

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(ii) Muradnagar

The thana contains 4 Nr colleges, 32 Nr high schools and 115 Nr primary schools, as well as the usual range of thana headquarters buildings. About 70% of the buildings at the thana headquarters are properly constructed public buildings, whilst the remainder are semi-pucca public buildings or tin sheds. During the 1988 flood the entire thana headquarters area was submerged.

(iii) Kasba

This thana has a flood centre constructed after the 1974 flood. During the 1988 flood, when the Ghungur River burst, about 500 people took shelter here and others sheltered in the T Ali College, Kasba Girls High School, Shahapur High School and Shahapur Primary School.

(iv) Homna

Within the thana headquarters there is one three-storied school building and one two-storied private building. Most buildings are tin sheds, although some pucca buildings are now under construction. 90% of the thana headquarters area was submerged during the 1988 flood.

(v) Burichang

During the 1988 flood 70% of the thana headquarters was submerged, although the thana offices themselves were not affected. Construction of the Gumti right bank embankment has considerably eased the severity of flooding, but there is considerable concern locally for the many people living in lower-lying areas who would be at great risk in the event of a failure.

(vi) Daudkandi

The thana contains 5 Nr colleges, 32 Nr high schools and 208 Nr primary schools, as well as the usual range of thana headquarters buildings. The Daudkandi thana headquarters itself is outside the project area. About 50% of the buildings are of pucca construction. During the 1988 flood the headquarters area was completely submerged to an average depth of up to 0.9 m. People took refuge in Daudkandi High School, primary schools and on the first floor of Hassanpur College.

(vii) Debidwar

The Debidwar thana headquarters itself is outside the project area. During the 1988 flood only 10% of the headquarters area was flooded.

(viii) Kotwali (Comilla)

The thana headquarters itself is outside the project area.

(ix) Akhaura

The thana headquarters itself is outside the project area.

CHAPTER I.2

MINOR IRRIGATION

I.2.1 Existing Situation

All existing irrigation within the project area comes under the category of minor irrigation; that is to say that there are no schemes involving major pump stations and/or extensive gravity distribution. The CIDA funded Agriculture Sector Team (AST), in its Census of Lift Irrigation, categorises minor irrigation modes as follows:

- Low Lift Pumps (LLP)
- Deep Tubewells (DTW)
- Shallow Tubewells (STW)
- Deep Set Shallow Tubewells (DSSTW)
- Hand Tubewells (HTW)
- Traditional Methods

A discussion of the development trends of all these modes over the years, based upon AST and other data sources, is presented in Chapter C5 of Annex C (Groundwater Investigations), together with the 1991 irrigated areas by mode according to AST, tabulated by Department of Agricultural Extension (DAE) block. This section therefore concentrates on mapping the distribution of existing irrigation by mode within the project area.

A database of gross (GA) and net cultivable areas (NCA) by one minute square is available as part of the land level database discussed in Section I.1.3 of this annex. Each one minute square was associated on a map with the nearest corresponding DAE block. The ratio of NCA to GA for each block was thus estimated from that of the associated minute squares. The estimated NCA of each DAE block was then calculated from its measured GA. It was then possible from the AST data to estimate the percentage of the NCA within each block which is presently (1991) irrigated by various modes. The same percentage was then considered to apply to the one minute squares associated with each block. The results are presented for LLP, DTW, STW (including DSSTW and HTW), traditional methods and total irrigation (all modes) in Figures I.2.1, I.2.2, I.2.3, I.2.4 and I.2.5 respectively. Although some approximation is involved in this system of mapping, and anomalously high proportions of irrigation were obtained in some of the squares, it does give a useful indication of the distribution of the existing irrigation and the areas which would benefit from additional facilities. Features which become apparent are:

- the relative sparseness of irrigation in the centre of the project area, (Figure I.2.5) which the Zone C irrigation proposal seeks to address,
- the concentration of DTW in the east and especially the south-east,
- the concentration of LLP along the major rivers and surprisingly along the Salda River mid-way up the eastern boundary. In the latter case there is probably a severe risk of water shortage as the Salda flow dwindles late in the season,
- the sparsity of STW in the central areas, presumably due to the problems of gaseous aquifers, and
- the significant contribution of traditional methods over most of the area.

Figure I.2.1

Existing Low Lift Pump Irrigated Area

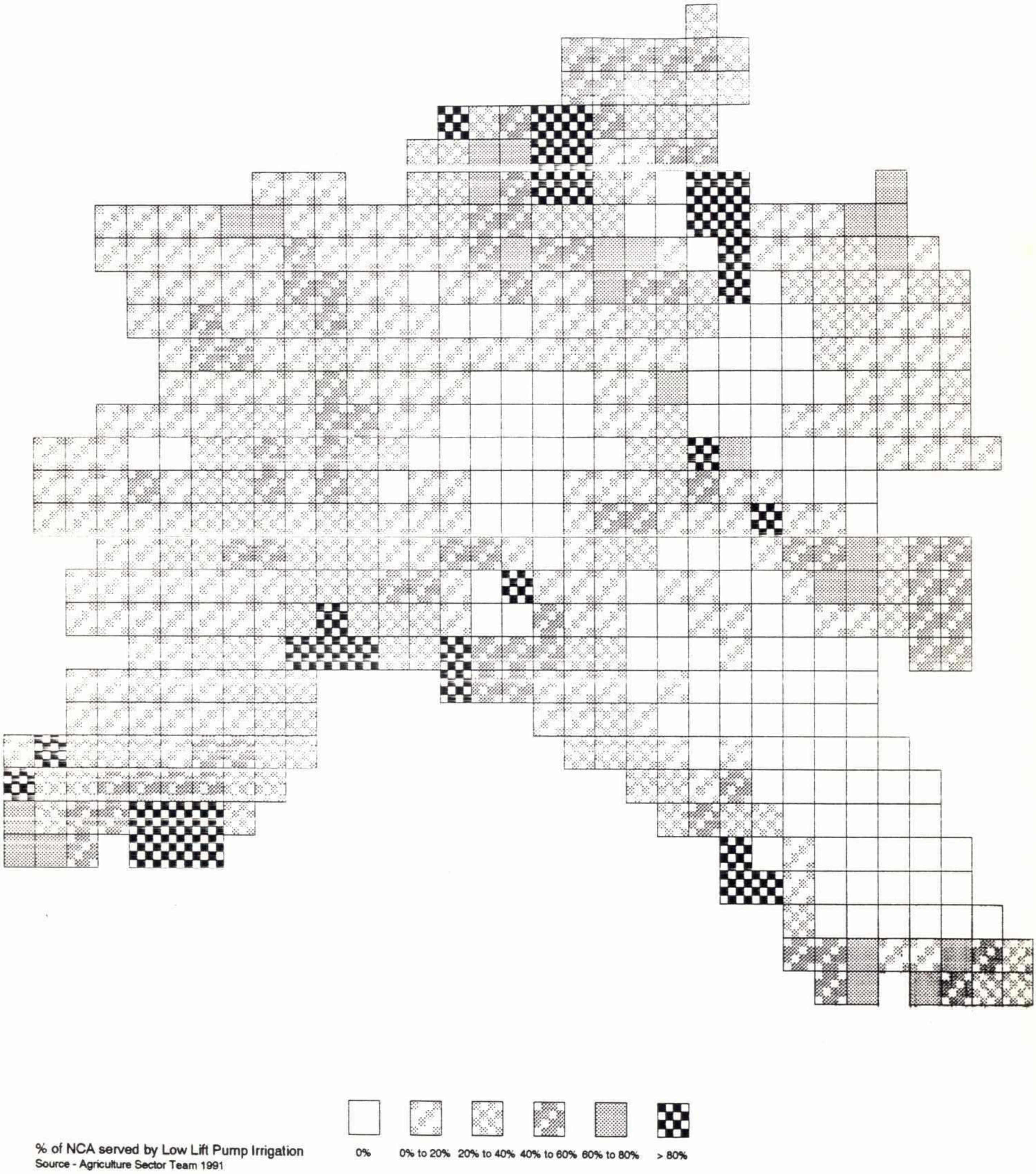

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Figure I.2.2

Existing Deep Tubewell Irrigated Area

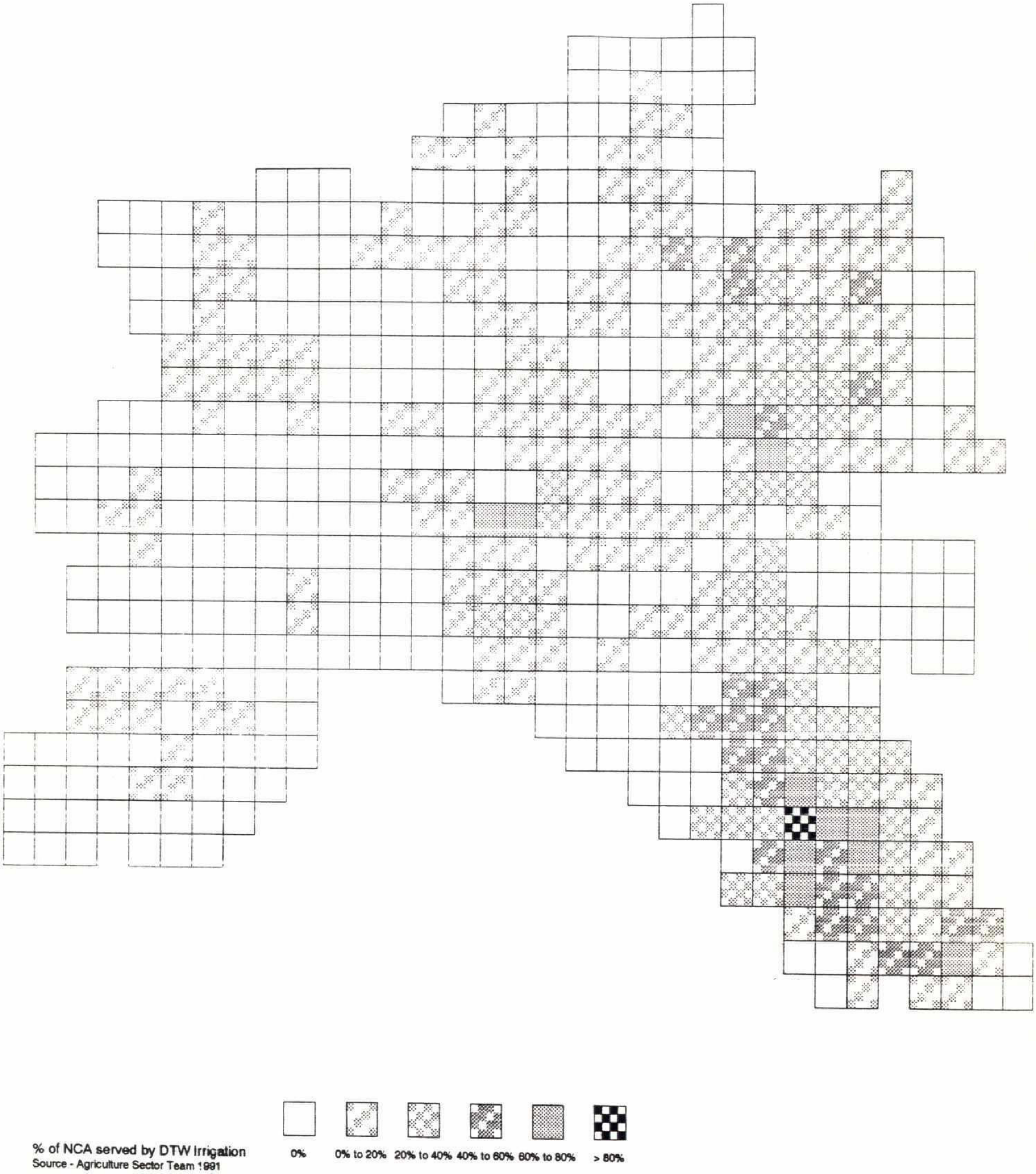
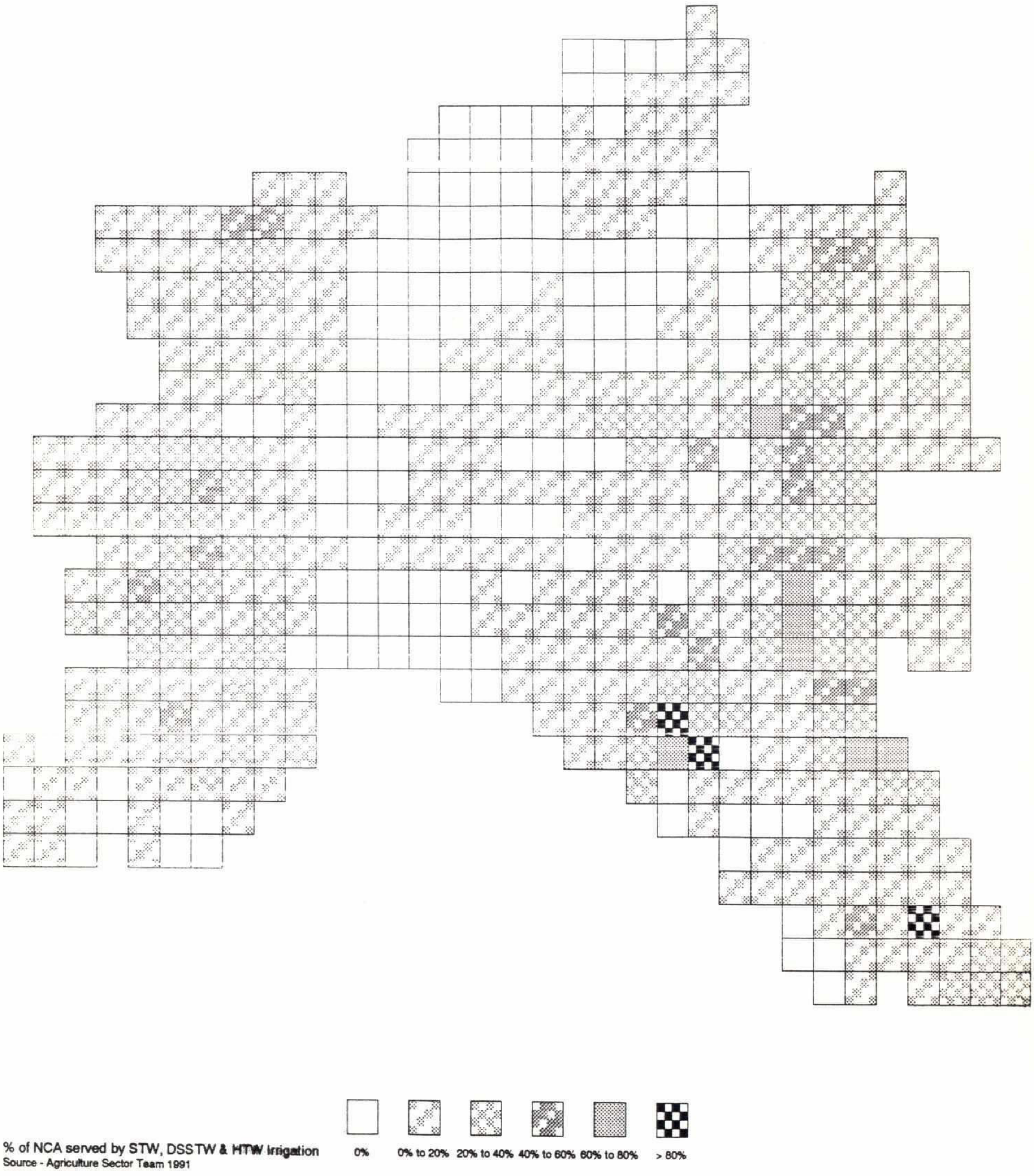


Figure I.2.3

Existing Shallow Tubewell Irrigated Area



% of NCA served by STW, DSSTW & HTW Irrigation
Source - Agriculture Sector Team 1991

Figure I.2.4

Existing Traditionally Irrigated Area

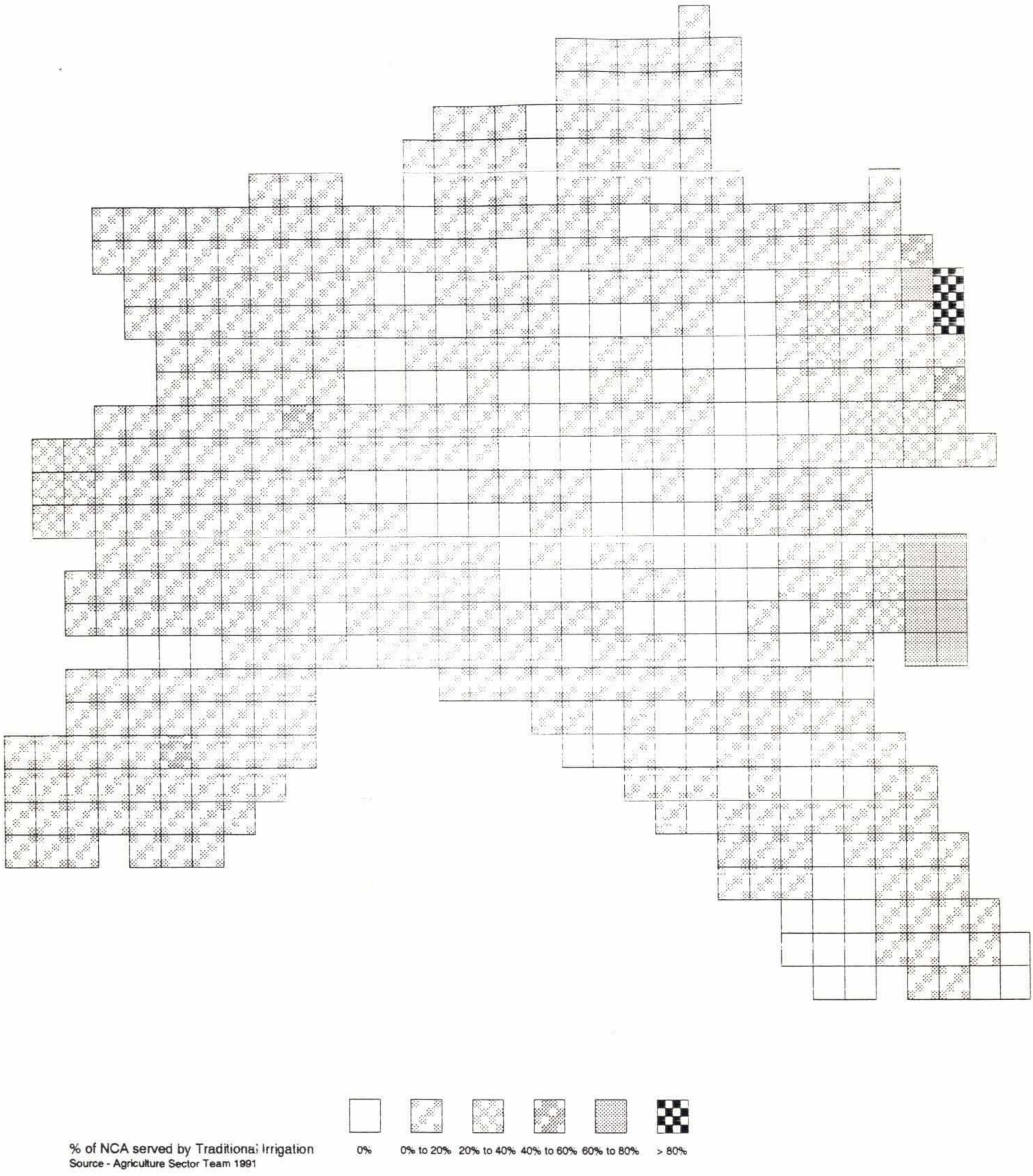


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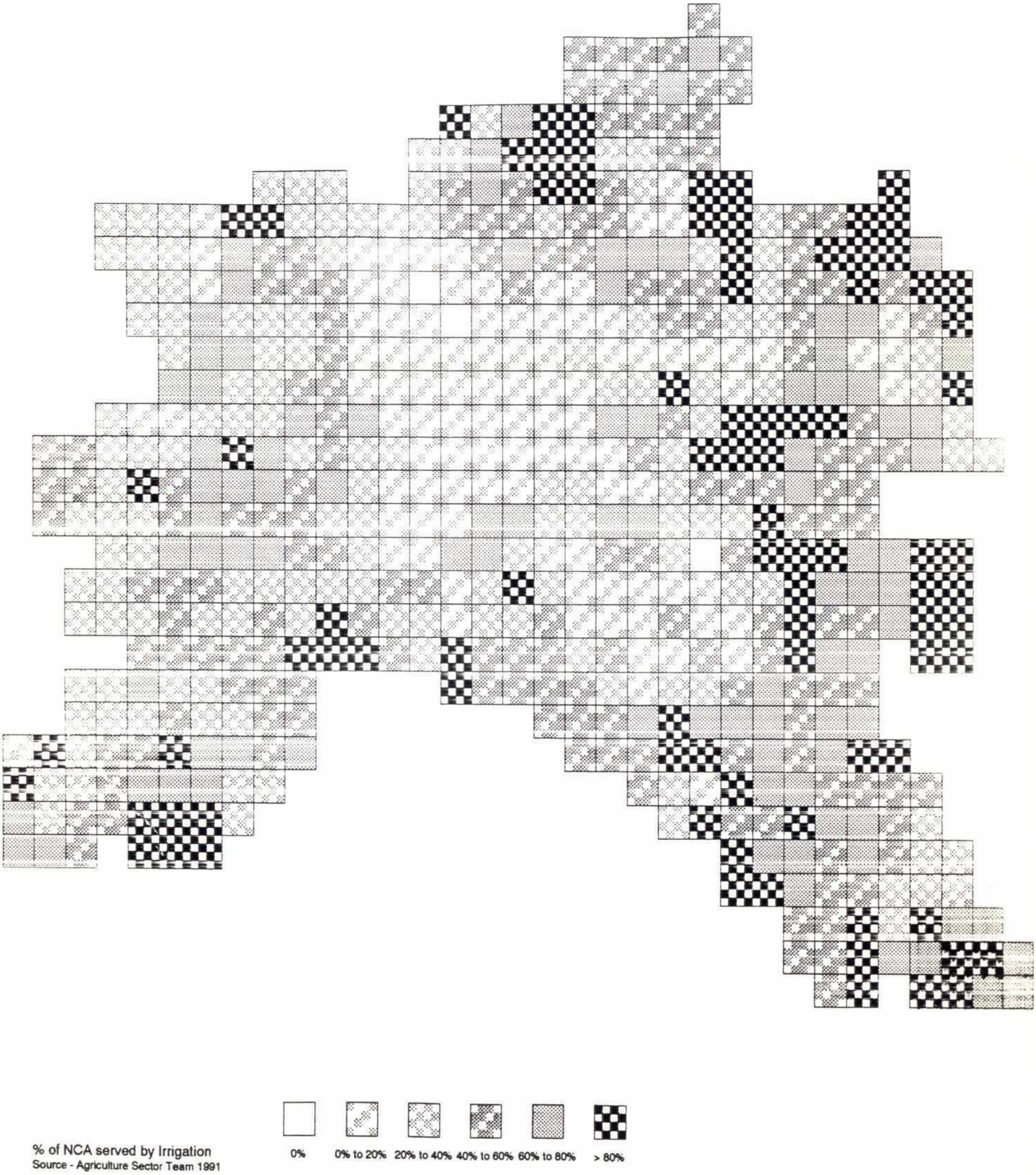
Figure I.2.5

Total Existing Irrigated Area



% of NCA served by Irrigation
Source - Agriculture Sector Team 1991

I.2.2 Irrigation Water Requirements

Irrigation water requirements have been assessed in accordance with the methodologies developed for the CROPWAT computer programme (Manual and Guidelines for CROPWAT, FAO, Rome 1991). The basic assumptions made are as follows:

(i) Irrigated boro dominates all other crops, and the water requirements have therefore been calculated for this crop alone. The crop growth stages, their lengths (rounded to whole decad periods) and the values of the crop coefficients associated with each are derived from the Deep Tubewell II Project Final Report (Supporting Volume 2.1 - Natural Resources, Mott MacDonald/ODA, 1992), and are shown in Table I.2.1. According to the same Deep Tubewell II report, boro is transplanted in Nabinagar and Muradnagar thanas between the second week of January and the third week of February. A total stagger in the crop calendar of 40 days has therefore been assumed.

(ii) Reference evapotranspiration values have been taken for Comilla, since this is the nearest climatic station collecting sufficient data for application of the modified Penman formula. The average monthly reference evapotranspiration (ET_o) for Comilla for the years 1965 to 1980, calculated in accordance with the modified Penman method (Guidelines for predicting crop water requirements, FAO Irrigation and Drainage Paper 24, Rome, revised 1977) is given in Table I.2.2. Decad values for calculating water requirements on a 10-day basis were interpolated by drawing a smooth curve.

(iii) Since the irrigation water requirements are being calculated primarily for the Zone C irrigation proposal, the rainfall station used for the calculations is Muradnagar, with records available since 1968. Although Nabinagar might have been more appropriate, records are available for this station only since 1981. The CROPWAT method derives an estimate of the 80% dependable decad rainfall by factoring the average decad rainfall by the ratio of the 80% dependable annual rainfall to the average annual rainfall.

TABLE I.2.1

Crop Growth Stages and Crop Coefficients for Boro

Growth Stage	Length (days)	Crop Coefficient (Kc)	Remarks
Nursery	30	1.2	10% of transplanted area
Land Preparation	10	-	150 mm application
Initial and Development	40	1.1	
Mid-season	40	1.05	
Late Season	30	0.8	

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TABLE I.2.2

Average Monthly Reference Evapotranspiration (ET_o, mm/day) at Comilla

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.77	4.98	6.30	7.05	6.76	5.22	5.02	4.99	4.82	4.74	4.20	3.66

Source: South East Regional Study Consultant's calculations

A range of options is available for converting the result to effective rainfall (ie allowing for that which is lost to percolation and runoff), but for the present analysis the CROPWAT Option 1 has been taken, with 80% being assumed effective, falling to 70% for monthly rainfall values in excess of 100 mm. The calculation of effective 80% dependable rainfall is presented in Table I.2.3, for the boro season (December to May).

(iv) Deep percolation rates estimated from DTW operating records are given as 5 mm/day for Comilla and 3 mm/day for Brahmanbaria in the Deep Tubewell II Project Final Report quoted above. A figure of 4.5 mm/day has been adopted for the present study.

(v) An overall transmission efficiency of 70% has been adopted in determining the water duty for the primary pump station. This is a fairly high figure because existing khals are used as the main distribution channels, and water levels will be well below ground level. Furthermore, a substantial degree of re-use is anticipated, since any surplus runoff will find its way back into the distribution system.

The calculation of the irrigation water requirement is set out in Figure I.2.6. The peak water duty for 18 hours per day pumping at the primary pump station was found to be nearly 2.3 l/s/ha, for the months of February and March.

TABLE I.2.3

Calculation of 80% Dependable Effective Rainfall at Muradnagar, Station R-366

Average Annual Rainfall - 2144 mm 80% Dependable Annual Rainfall - 1650 mm Ratio - 0.77

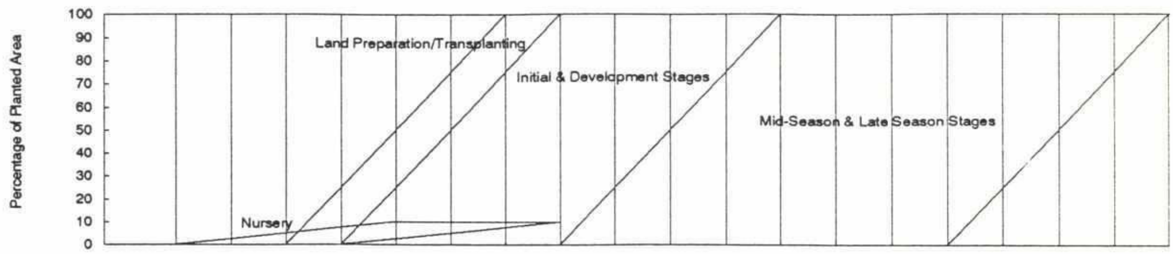
Month	December			January			February			March			April			May		
Decad Nr	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Average	9	0	3	2	0	3	6	6	7	15	19	33	38	72	70	93	135	102
80% Dep	7	0	2	2	0	2	5	5	5	12	15	25	29	55	54	72	104	78
Effective	6	0	2	1	0	2	4	4	4	9	12	20	20	39	38	50	73	55

All units in mm

Figure I.2.6

Gumti Phase II Project

Calculation of Irrigation Water Requirement



Month		December			January			February			March			April			May	
Decad (end of)	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Reference Evapotranspiration																		
ETo (Comilla) (mm)	36	37	37	37	38	38	41	51	57	61	63	65	68	72	72	71	68	64
Effective Rainfall (mm)	6	0	2	1	0	2	4	4	4	9	12	20	20	39	38	50	73	55
Nursery																		
% of area entered nursery stage	0	3	5	8	10	10	10	10	10	10	10	10	10	10	10	10	10	10
% of area left nursery stage				0	3	5	8	10	10	10	10	10	10	10	10	10	10	10
% of area at nursery stage	0	3	5	8	8	5	3	0	0	0	0	0	0	0	0	0	0	0
Crop Coefficient Kc		1.2	1.2	1.2	1.2	1.2	1.2											
Evapotranspiration ET (mm)		44	44	44	46	46	49											
Deep Percolation (mm)		45	45	45	45	45	45											
Net Irrigation Requirement (mm)																		
- over area at nursery stage		89	87	88	91	89	90											
- equivalent over whole area		2	4	7	7	4	2											
Land Preparation/Transplanting																		
% of area entered LP/T stage			0	25	50	75	100	100	100	100	100	100	100	100	100	100	100	100
% of area left LP/T stage			0	0	25	50	75	100	100	100	100	100	100	100	100	100	100	100
% of area at LP/T stage				25	25	25	25	0	0	0	0	0	0	0	0	0	0	0
Land Preparation Application (mm)				150	150	150	150											
Net Irrigation Requirement (mm)																		
- over area at LP/T stage				149	150	148	146											
- equivalent over whole area				37	38	37	37											
Initial & Development Stages																		
% of area entered I & D stage				0	25	50	75	100	100	100	100	100	100	100	100	100	100	100
% of area left I & D stage								0	25	50	75	100	100	100	100	100	100	100
% of area at I & D stage				0	25	50	75	100	75	50	25	0	0	0	0	0	0	0
Crop Coefficient Kc					1.1	1.1	1.1	1.1	1.1	1.1	1.1							
Evapotranspiration ET (mm)					42	42	45	57	63	67	69							
Deep Percolation (mm)					45	45	45	45	45	45	45							
Net Irrigation Requirement (mm)																		
- over area at I & D stage					87	85	86	98	104	103	102							
- equivalent over whole area					22	42	65	98	78	52	26							
Mid-Season Stage																		
% of area entered M-S stage								0	25	50	75	100	100	100	100	100	100	100
% of area left M-S stage												0	25	50	75	100	100	100
% of area at M-S stage								0	25	50	75	100	75	50	25	0	0	0
Crop Coefficient Kc									1.05	1.05	1.05	1.05	1.05	1.05	1.05			
Evapotranspiration ET (mm)									60	64	66	68	71	75	76			
Deep Percolation (mm)									45	45	45	45	45	45	45			
Net Irrigation Requirement (mm)																		
- over area at M-S stage									101	100	99	93	96	81	83			
- equivalent over whole area									25	50	74	93	72	41	21			
Late Season Stage																		
% of area entered L S stage												0	25	50	75	100	100	100
% of area left L S stage (ie harvested)															0	25	50	75
% of area at L S stage												0	25	50	75	75	50	25
Crop Coefficient Kc													0.8	0.8	0.8	0.8	0.8	0.8
Evapotranspiration ET (mm)													54	57	58	57	54	51
Deep Percolation (mm)													45	45	45	45	45	45
Net Irrigation Requirement (mm)																		
- over area at L S stage													79	63	65	52	26	41
- equivalent over whole area													20	32	48	39	13	10
Total Requirement over Whole Area (mm)	0	2	4	44	66	84	103	98	103	102	100	93	92	72	69	39	13	10
Overall Transmission Efficiency (%)	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Irrigation Diversion Requirement (mm)	0	3	6	63	94	120	148	139	147	145	143	133	132	103	99	56	19	15
24 hr Continuous Water Duty (l/s/ha)	0	0.03	0.07	0.72	1.09	1.38	1.70	1.61	1.70	1.67	1.65	1.54	1.52	1.19	1.14	0.64	0.21	0.17
18 hr Pumping Water Duty (l/s/ha)	0	0.04	0.09	0.96	1.45	1.84	2.27	2.15	2.27	2.23	2.20	2.05	2.03	1.59	1.52	0.85	0.28	0.22

I.2.3 Typical Command Areas

Assumed irrigation command areas for the various types of irrigation equipment at present in use are given in Table I.2.4. Additional details including the capital and operating costs associated with the pumping and distribution systems are presented in Annex J (Financial and Economic Analysis). Annex C (Groundwater Investigations) also gives details of several modified groundwater technologies, using small force mode pumps to overcome the problems of gas and underlying salinity in shallow aquifers. Cheaper versions of the existing DTW, including one having a 1 cusec (28 l/s) capacity are also proposed.

TABLE I.2.4

Capacities and Command Areas of Pumping Equipment

Description	Capacity (l/s)	Command Area (ha)
Low Lift Pump (LLP 1)	20	10
Low Lift Pump (LLP 2)	56	20.
Shallow Tubewell (STW)	8	4.5
Deep Set Shallow Tubewell (DSSTW)	8	4.5
Deep Tubewell (DTW)	60	22

CHAPTER I.3

MORPHOLOGY

I.3.1 Upper Meghna Erosion

Any development of the Gumti Phase II project area must take account of possible shifting of the existing bank line of the Upper Meghna, particularly in determining the appropriate set-back for embankments. Accordingly, the Terms of Reference require that this matter be investigated, including making any necessary adjustments to the 1990 feasibility study proposals through provision of bank protection and river training works if necessary as an alternative to increased set-back distances.

FAP 9B (Meghna Left Bank Protection) and BWDB reports relating to erosion problems along the Upper Meghna at the boundary of the project area were accordingly reviewed, and field visits undertaken along the Meghna-Titas left bank from Nabinagar to Bancharampur and the nature and extent of erosion along the bank line studied. Available aerial photographs, SPOT satellite imagery and maps from 1952 to 1990 were also studied. Subsequently a series of LANDSAT images (December 1973 - January 1993) covering part of the area also became available.

From all these sources it was observed that the Meghna is gradually shifting from a braided to a meandering form, apparently as a result of the diversion of the Brahmaputra flow through the present Jamuna channel in 1776. This shift is mainly due to the reduction of flow and the process is still continuing. Location-specific observations are given in the sections which follow.

I.3.1.1 Upper Reach - Sadiapur to Shantinagar

Referring to Figure I.3.1, which shows the different bank positions in 1952, 1984 and 1989, the following observations are made:

(i) Erosion occurs in most of the reach from Sadiapur to Shantinagar

(ii) There has been major erosion near Maniknagar, with the village market threatened. The FAP 9B Final Report estimates that land is being lost at a rate of 20 m per year.

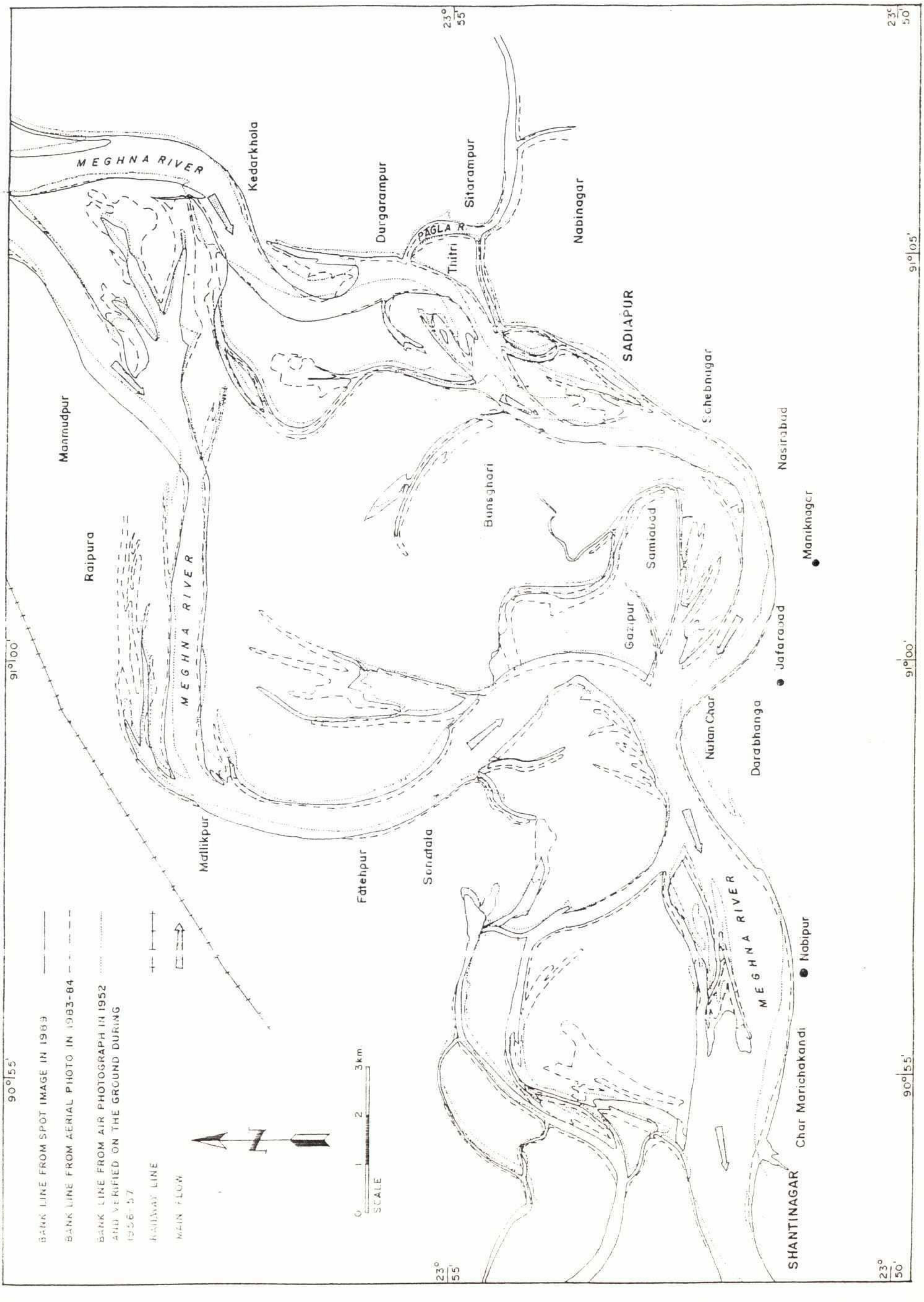
(iii) A recent field visit confirmed that at present the greatest erosion is between Maniknagar and Nasirabad village, about one kilometre upstream.

(iv) The promontory at Nutan Char near Darabhanga is in a delicate balance due to the combined effect of the two major branches of the Meghna which recombine here. The bank line upstream of the point was under erosion until 1983, but there was a tendency towards accretion by 1989. The recent field visit also confirmed this. The bank line downstream of the point as far as Nabipur was under accretion until 1983, but the 1989 bank line shows erosion compared with that of 1983. This portion is therefore in a process of oscillation, although the erosion rate is not considered serious.

Figure I.3.1

Morphological Changes in Upper Meghna

Upper Reach - Sadiapur to Shantinagar



(v) The bank line from Nabipur to Shantinagar has continuously been eroded from 1952 to 1989. Again however, the erosion is not severe.

I.3.1.2 Lower Reach - Shantinagar to Daudkandi

Referring to Figure I.3.2, which shows bank positions in 1952, 1989 and 1990, the following observations are made:

(i) Almost the entire length of the left bank downstream of Shantinagar to the south-west border of the project near Daudkandi is under accretion. The Meghna has a general tendency to move towards the west, following the major outer branches of the old braided channel.

(ii) The eastern branches of the Meghna are progressively silting up, although at a slow rate because of the low silt content in the Meghna water.

(iii) In spite of the general tendency towards siltation, in the eastern branches localised erosion and deposition is continuing at the outer and inner banks respectively on bends, but this is not considered serious.

I.3.1.3 Changes between 1973 and 1993

The recently available series of LANDSAT imagery (December 1973 - January 1993) confirms the morphological trends discussed above. Unfortunately however only the reach from Kanainagar to Daudkandi is covered, as shown in Figure I.3.3. From this figure it may be seen that the outer bends have further eroded in recent years, and the western branch is steadily increasing in width. This process may have no adverse effect on the project area, but may further aggravate the erosion problems at the Meghna bridge.

I.3.1.4 Conclusions and Implications for Project Proposals

It is concluded that there is significant erosion in the upper reach from Sadiapur to Shantinagar, particularly in the vicinity of Maniknagar and Nasirabad villages. There is only a small village and market place here, and no major infrastructure, and the cost of effective protective works is unlikely to be justified.

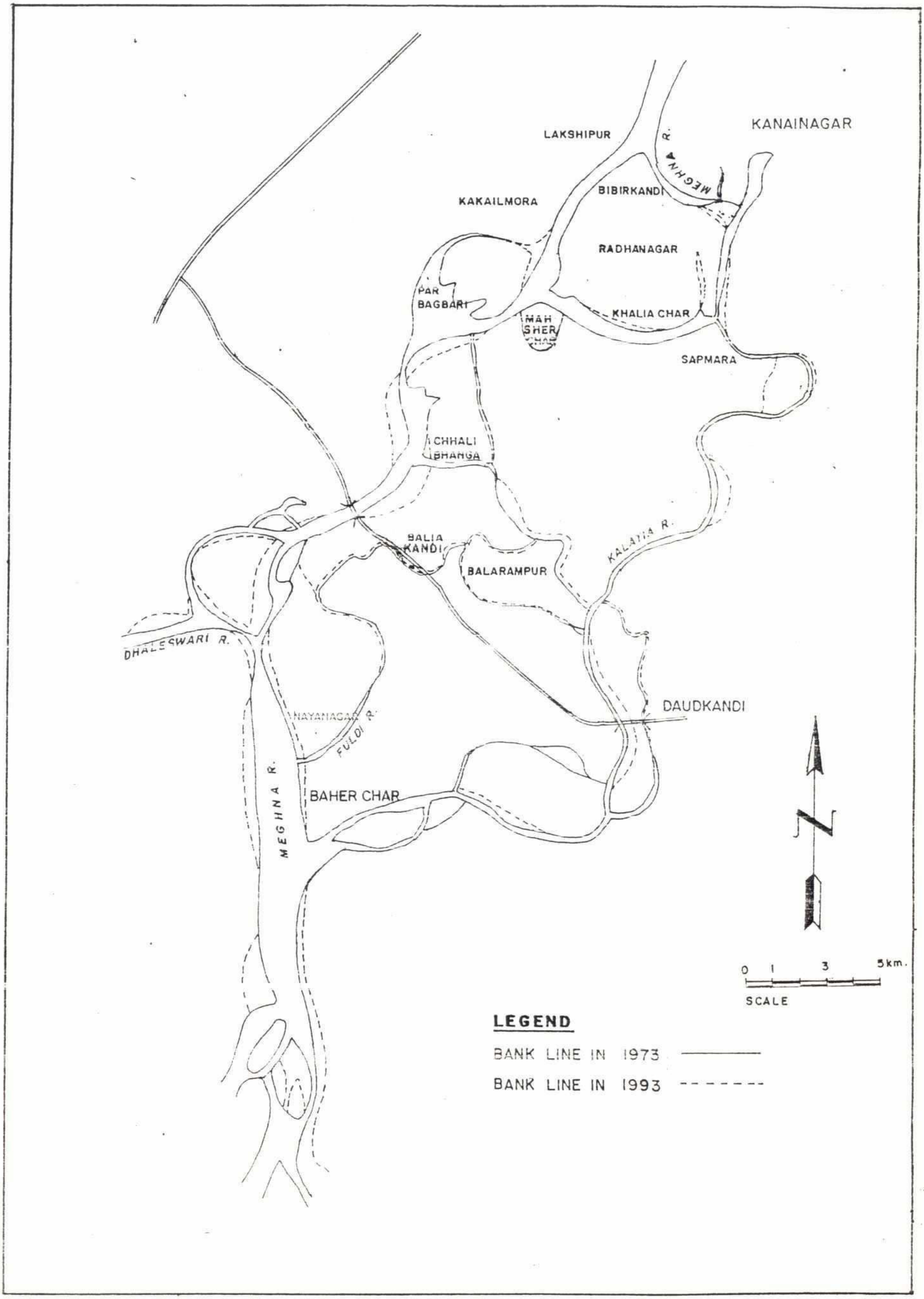
The recommended strategy is therefore to provide an adequate set back to any embankment, so that it is unlikely to be threatened within a project lifetime of, say, 30 years. An erosion rate of 20 m per year therefore suggests a set back distance of 600 m in this reach. Allowing a safety margin, the figure of 700 m proposed by FAP 9B seems entirely reasonable, and the set back of 500 m to 800 m already adopted by the 1990 feasibility study is consistent with this.

Figure I.3.2
Morphological Changes in Upper Meghna Lower Reach - Shantinagar to Daudkandi

Figure I.3.3

Morphological Changes in Upper Meghna

Kanainagar to Daudkandi



In the lower reach from Shantinagar to Daudkandi, a set back distance of 300 m has been adopted by the 1990 study, and this figure is considered adequate against erosion. However protective measures against wave action may be essential in view of the long fetch and the wind direction from the north-west during the monsoon.

The above recommendations on set back distances do of course assume that present trends continue (or are not exceeded). Major interventions in the North East Region (FAP 6), for instance, could have significant effects upon the morphology of the downstream channel, although these would be very difficult to predict. At the time of writing (May 1993), FAP 6 modelling results were not yet available.

I.3.2 Erosion and Deposition in Channels within the Project Area

Erosion and deposition on the surface of the land has already been discussed in Chapter I.1, in connection with the comparison of different topographic surveys. More important in terms of maintenance costs are the erosion and deposition which takes place within the rivers and khals in the project area.

Rivers and khals in the project area may be broadly divided into two types:

- flashy rivers and streams from the Tripura Hills in the east, and
- the flat and relatively slow-flowing rivers and khals in the west.

Notable among the flashy channels falling from the hills in the east are, from south to north, the Ghungur, Salda and Sonai Rivers. There are also many tributaries falling into these rivers. These rivers are quite steep in their upper reaches, but flatten out as they enter the flood plain in Bangladesh. Consequently, heavy sediment loads, carried from the Indian hills, are deposited in Bangladesh. Therefore the predominant morphological phenomenon within Bangladesh in these rivers is deposition rather than erosion, although there may be some localized erosion at bends.

As discussed in Section I.1.6, there are not adequate records of the volumes of sediment carried by these channels. However records are available concerning re-excavation of some of the rivers, from which some idea may be gained of the likely volume and frequency of channel re-excavation which may be required in future. The resulting estimates must however be regarded as only indicative.

The Ghungur-Salda-Buri system is the main flashy river in the area. It was first re-excavated in 1958/59 under the Annual Development Programme (ADP). Subsequently, re-excavation of the channel was again undertaken in 1975/76, under the Food for Work Programme. Local people reported that the Ghungur was also re-excavated commencing in 1984/85, taking about three years to complete. The Ghungur has silted up again significantly for about 1.5 km at its outfall. From the above information it appears that the frequency of re-excavation required in flashy rivers like the Ghungur-Salda-Buri would be of the order of about 10 years. However from the local information it appears that the lower 2 km of the Ghungur may need more frequent re-excavation, perhaps every 5 years. There is no data on the historic excavation volumes, but the excavation volume for the Ghungur-Salda-Buri system estimated under the present study is about 1.13 million cubic metres. If it is assumed that this volume of material deposits in 10 years (probably a conservative assumption) the annual deposition within the channel system is about 113 000 cubic metres.

The channels in the western part of the project area, especially in Zone D, are mainly branches and distributaries of the Meghna, which river contributes little silt. Moreover their longitudinal slopes are very flat, and consequently the channels are mostly stable and siltation is relatively slow. However the upper reaches within Zone C may undergo slightly faster siltation due to the residual silt carried from the eastern flashy channels. Sheet erosion is considered to be only a minor contributor to channel siltation within the bulk of project area, because of the very flat terrain. However, as discussed in Chapter I.1, some movement does undoubtedly take place.

The Upper Titas River is heavily silted in the loop from Brahmanbaria via Akhaura following excavation of the Anderson cut about 40 or 50 years ago, and is likely to experience further siltation in course of time. However, a minimum section is likely to be maintained for carrying the run-off from the Howrah, Bijni and other flashy rivers in the area.

I.3.3 The Gumti River

The right bank of the Gumti river facing the project area is now embanked from the Indian border as far as the village of Paniatan, some 64 km downstream, with completion of the Gumti Phase I Project in 1992. This river has a substantial catchment in the Tripura Hills of India, and is subject to violent flash flooding. The Gumti Phase I project was merely the latest in a series of works to try and contain it. Embankment protection works have been provided on the outer banks at several bends, but erosion is still serious in some reaches, which need additional protection. Figure I.3.4 shows those locations reported by the BWDB Comilla office as requiring attention, and details of revetment lengths and estimated costs are given in Table I.3.1. The cost of carrying out these works, which are strictly speaking outside the project area, has not been included in the project proposals, and they should be regarded as part of the maintenance requirements of the Gumti embankment. Nevertheless, failure of the embankment arising from their neglect would cause serious damage to the project area, whether or not the proposals arising from the present study are implemented.

Howard Humphreys and Partners (Hydrological and Morphological Studies of the Gumti, Titas and Atrai Basins, April 1990) performed a hydrodynamic and morphological model analysis of the behaviour of the embanked river. The hydrodynamic results from their report are summarised in Figure I.3.5, compared with the as-constructed levels from a recent BWDB survey. Previously the embankment was being constructed to a lower elevation, which would have been overtopped in a 1 in 20 year flood, but the design was changed during construction in response to the Howard Humphreys report, and it is now clearly adequate. Also plotted in the same figure are the 1 in 2 year and 1 in 20 year simulated 1 day duration water levels derived from a 25 year run of the South East Regional Model (SERM) under the present study. These are significantly lower than the corresponding Howard Humphreys profiles, but are not inconsistent with them, since examination of data from Comilla shows that the water level can rise by as much as 1 m during a day. The Howard Humphreys results would have been based upon a peak level of shorter duration than 1 day, and therefore reflect the flashy peak levels more closely. As discussed below, the Howard Humphreys report did not allow for the cessation of diversions into the Buri Nadi, but this would only affect the reach downstream of the closure, and this does not seem at all critical. Downstream of the end of the right embankment at Paniatan, flash floods continue to spill into the Gumti Phase II area, and a low submersible extension is recommended in the Zone D proposals under the present study. A full height extension is not justified since, in the absence of a Meghna embankment, the land on the country side will in any case be inundated when that river rises.

TABLE I.3.1

Gumti River Embankment Revetment Proposed by BWDB

Left Embankment			Right Embankment		
Serial Nr	Place	Length (m)	Serial Nr	Place	Length (m)
1	Katak Bazar	60	1	Golabari	50
2	Tikkarchar	120	2	Golabari	50
3	Durgapur	30	3	Jaluapara	60
4	Farijpur	120	4	Ratnabati	50
5	Kangsanagar	150	5	Palpara	100
6	Sagura	75	6	Palpara	60
7	Char Bakar	90	7	Simul Khara	100
8	Balibari	90	8	Simul Khara	50
9	Companiganj	60	9	Kaitara	50
10	Muradnagar	120	10	Ramnagar	50
11	Jahpur	150	11	Ramnagar	70
12	Daskandi	120	12	Mitilapur	45
13	Manikkandi	60	13	Mitilapur	25
14	Siddhesari Regulator	90	14	Gobindapur	90
			15	Monoharpur	70
			16	Monoharpur	40
			17	Khalilpur	60
			18	Ahasanpur	60
			19	Companiganj	150
			20	Muradnagar	100
Total Length of Revetment (m)		1 335			1 330
Cost @ Tk 49 000 per m length		65 415 000			65 170 000
TOTAL LENGTH OF REVETMENT (LEFT & RIGHT BANK) (m)					2 665
TOTAL COST OF REVETMENT (LEFT & RIGHT BANK) (Tk)					130 585 000

Figure I.3.4
Gumti River Embankment
Revetment Locations Proposed by BWDB

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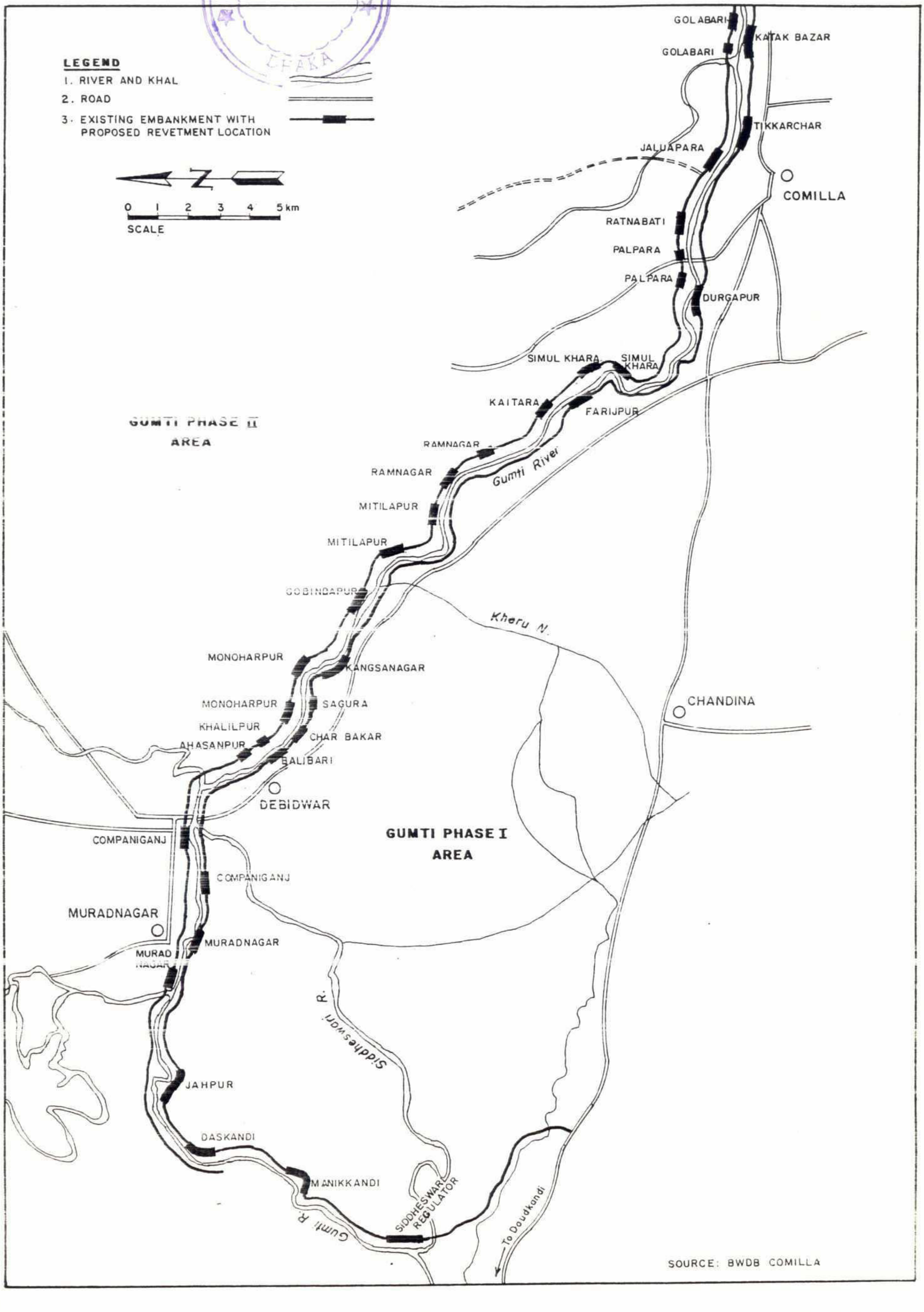
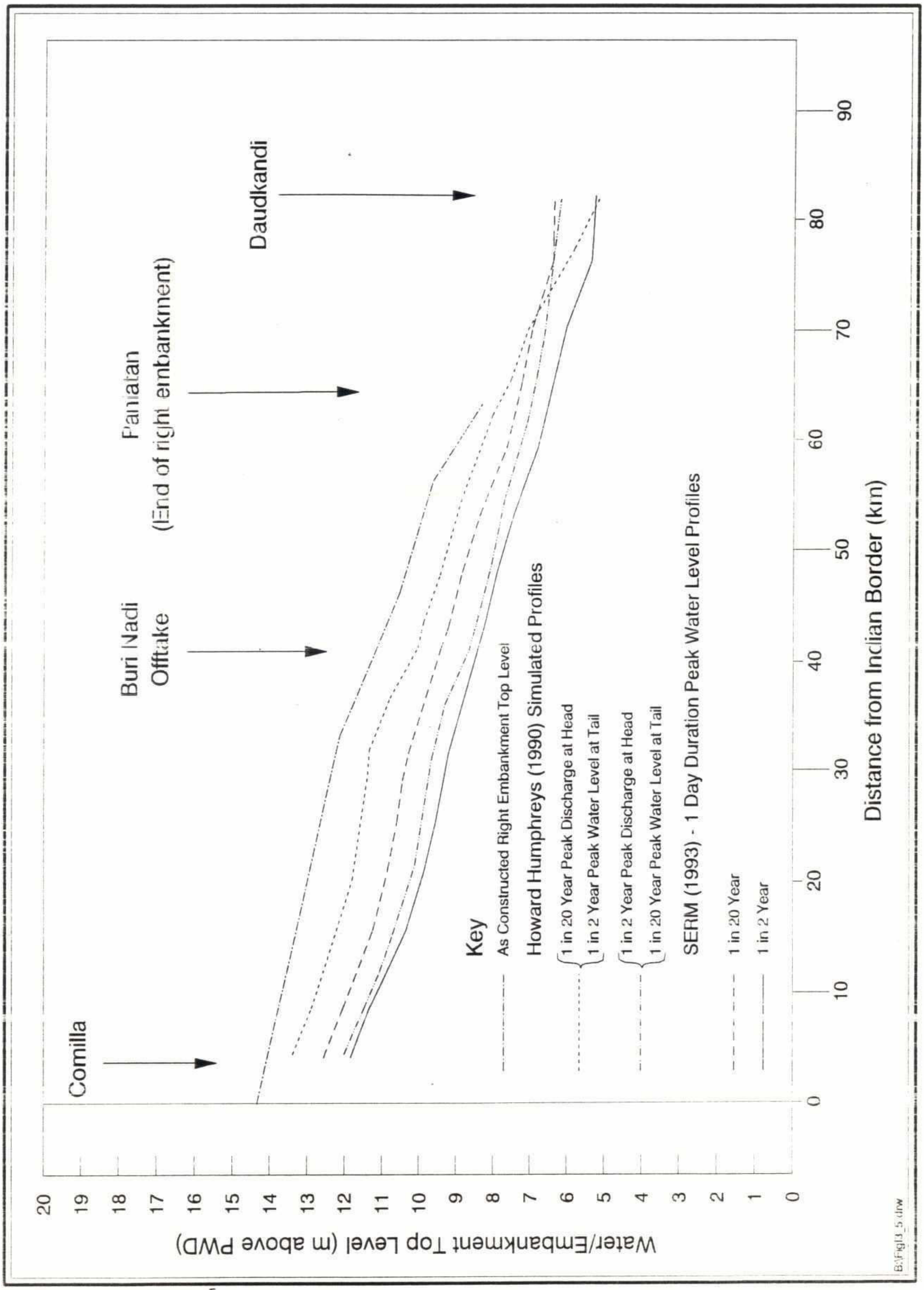


Figure I.3.5

Longitudinal Profile of the Gumti River
Simulated Water and Embankment Top Levels



Previously, up to about 30% of the discharge at Comilla used to escape into the Buri Nadi at kilometre 41 (Feasibility Report on the Gumti South Project, Annex C, NEDECO, 1984). This escape has effectively been closed as part of the Gumti Phase I works, although the closure was not allowed for in the Howard Humphreys morphological study, with about one sixth of the discharge at low flows assumed to be diverted into the Buri Nadi, rising to nearly a quarter at higher flows. Figure I.3.6 shows the bed profile downstream of the Buri Nadi offtake before the works and the predicted bed profile after implementation, as presented by Howard Humphreys. In general, little significant change in bed levels was anticipated. Also shown is the profile obtained from the 1993 surveys conducted under the present study. It now appears that the large hump in the bed downstream of the Buri Nadi offtake is being eaten away from downstream. Since it is likely that the hump was originally formed as a result of the diversion of substantial flows into the Buri Nadi, it does seem reasonable that now the diversion has ceased the hump should start to disappear. The low level in the 1993 profile at around 43 km is near Companiganj bridge and a recent loop cut, and probably very localised.

Flood plain levels are not available from the Howard Humphreys study, but Figure I.3.7 compares flood plain (and bed) levels extracted from the South East Regional Model (surveyed in 1986 approx) with those obtained from the 1993 surveys, within the embankments. There is an element of subjectivity in extracting a representative flood plain level from a cross-section, but there does appear to be a distinct rise between the two surveys, more or less mirroring the drop in bed level. The general tendency of the confined flood plains to rise can also be seen in the reaches which have been embanked for many years, where the land within the embankments can be seen both in the field and from the Water Development Maps to be distinctly higher than that outside. Localised rises in flood plain level (and bed level) can also sometimes be explained by embankment breaches.

The removal of the hump in the bed downstream of the Buri Nadi offtake would have a major positive impact upon the availability of water for irrigation within the Gumti River, since it would then be possible to draw a backflow from the Meghna River during the dry season for up to 40 or 50 km upstream. The mean February/March low water level at Daudkandi is about 1 m above PWD, so under static conditions the water depth at the Buri Nadi offtake could be nearly 2 m, although a water surface slope of 3 or 4 cm/km would reduce this to zero. It is recommended that the channel be surveyed every year or two to check whether the trend is continuing. It may be worthwhile to dredge the channel artificially in order to achieve the benefits earlier, but it is unlikely that the channel could be economically maintained at a size in excess of its natural equilibrium.

The amount of irrigation water which could be drawn depends upon the eventual dimensions of the channel, which are difficult to predict with any confidence. However, it may become possible to pump water into the western portion of the Gumti Phase I area, which suffers from a severe shortage of surface water in the dry season. The Terms of Reference make reference to considering the extension of a major pumped irrigation scheme for the Gumti Phase II area to supply Gumti Phase I, as proposed in the Supplementary Feasibility Study for the Provision of Irrigation Supplies to the Gumti Phase I Sub-Project (Bureau of Consulting Engineers/Halcrow, March 1990). Now that the provision of extensive pumped irrigation to the Gumti Phase II area has been found less attractive under the present study, the possibility of such an extension falls away. The Gumti river was previously ruled out as a source of irrigation water for the Gumti Phase I area, 'due to the considerable silt load and variable course of the lower reaches' (reference the above-mentioned report). It may now be reasonable to review this decision in the light of the current morphological changes.

Figure I.3.6

Longitudinal Profile of the Gumti River
Bed Levels from Buri Nadi Offtake to Daudkandi

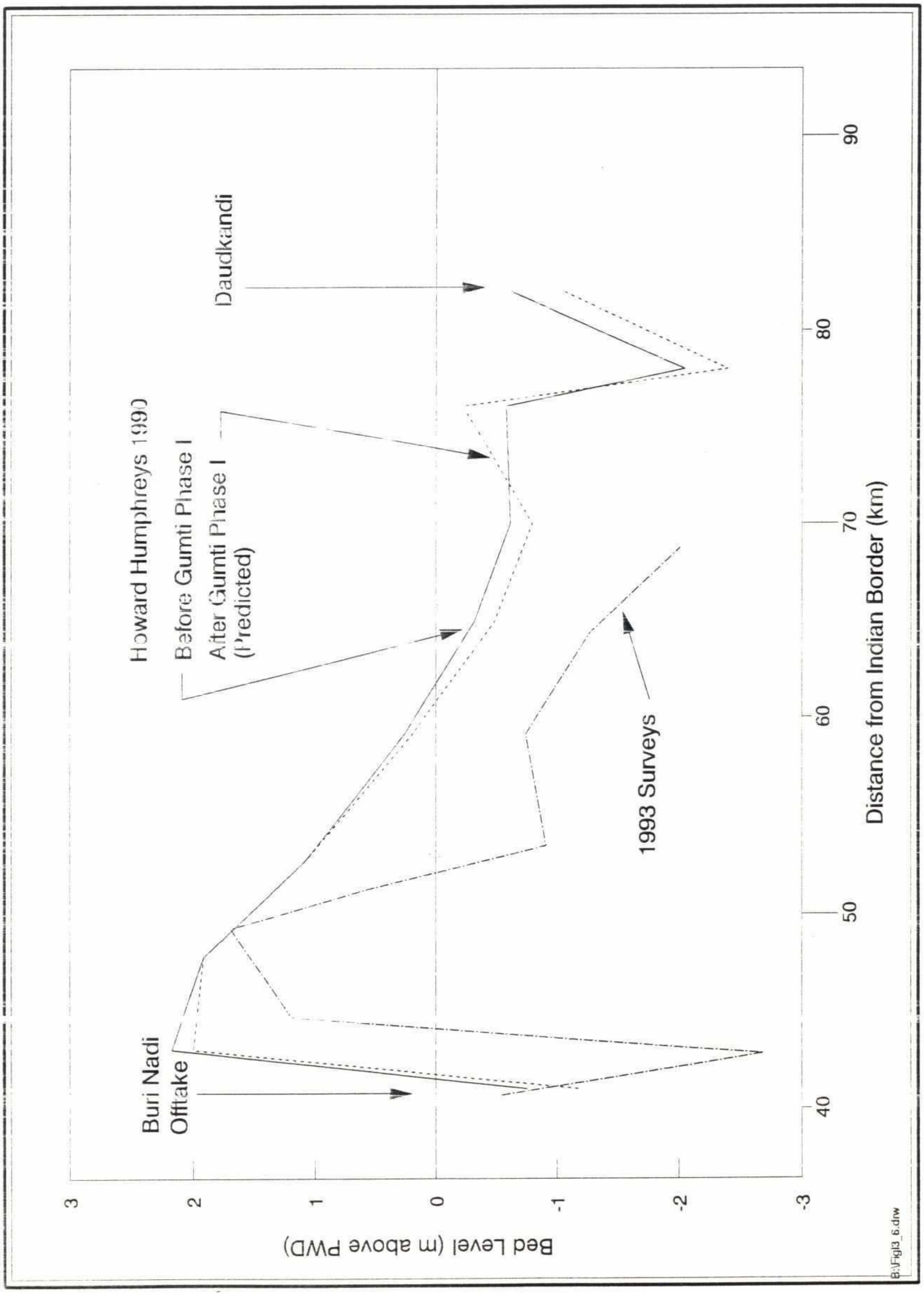
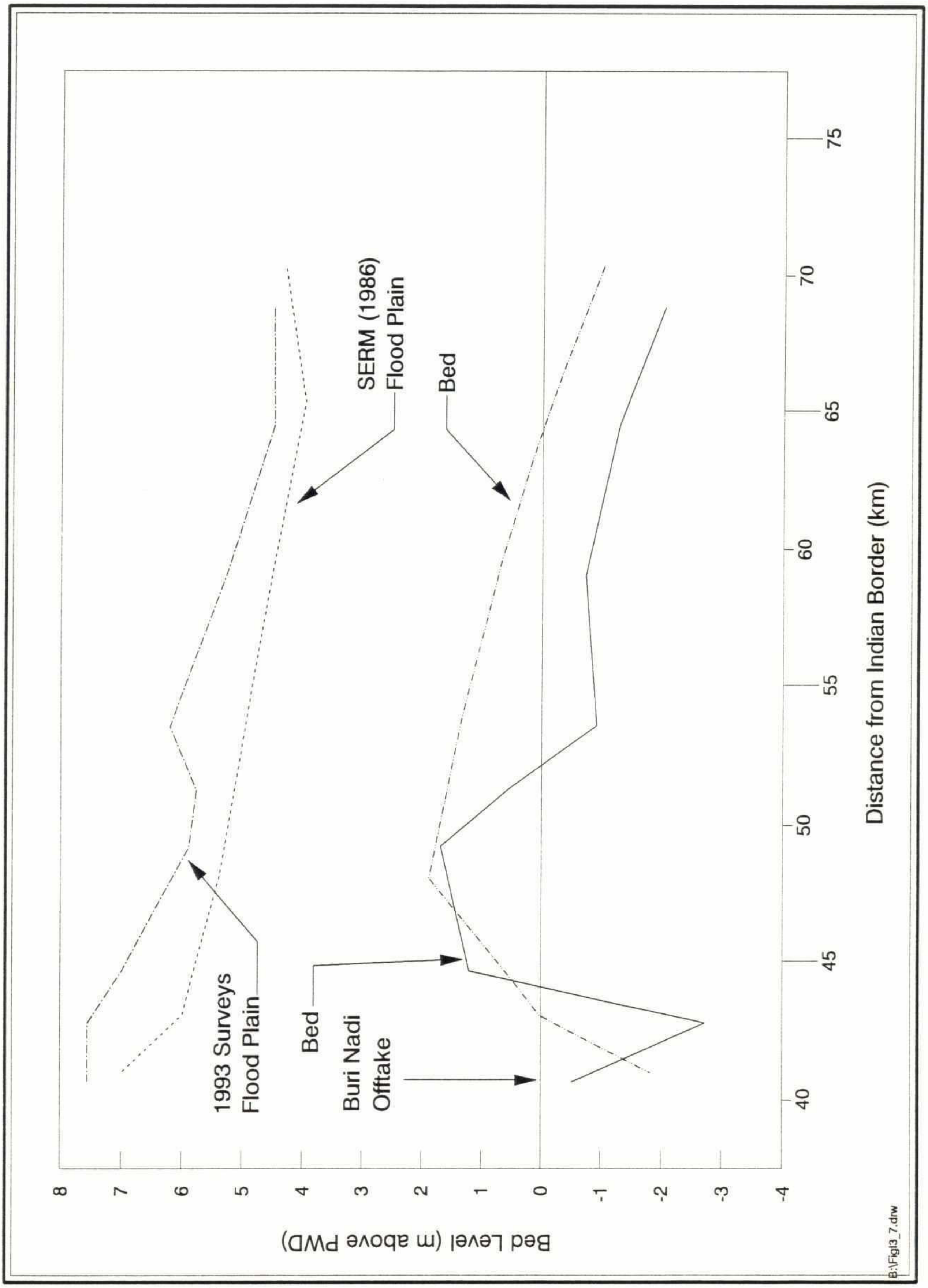


Figure I.3.7

Longitudinal Profile of the Gumti River Changes in Bed and Flood Plain Levels



CHAPTER I.4

DESIGN CRITERIA

I.4.1 Available Design Criteria

Various design criteria for water resources development have been developed over the years, based upon local and international practice as well as the latest technological developments within Bangladesh. BWDB has been the pioneer in this respect, and first developed a systematic design criteria for drainage projects in 1974, under the name 'Hydrological and Hydraulic Design Procedures for Drainage Structures'. Previously, there had been other guides lines, technical reports and manuals, but less systematic and intensive. Subsequently many consultants developed design criteria for their respective projects in the light of the BWDB Procedures, with modifications and additions to cover later technological developments and additional requirements. Among these subsequent criteria the following are important:

(i) Design Manual, FCD3 project, 1987. This is a wide-ranging and detailed work in three volumes, covering almost all the fields of water resources development, including hydrology, design of drains, hydraulic design of irrigation canals, design of embankments and roads, river training and bank protection (excluding major rivers), design of gates, selection of pumps etc. Computer programmes were developed to assist with analysis.

(ii) North West Hydraulic Consultants developed another set of criteria for the Second Small Scale Flood Control, Drainage and Irrigation Project (1990) in two volumes, dealing with Hydrological and Hydraulic Design and Structure Design of Drainage Projects respectively. These criteria are in line with standard practice in Bangladesh.

(iii) The Design Manual for Polders in South-West Bangladesh (November 1985) was developed by the Bangladesh-Netherlands joint programme under the BWDB Delta Development Project. This is another wide-ranging and detailed work, suitable both for feasibility study and detailed engineering stages. This manual is particularly important in providing guidance for dealing with coastal areas.

(iv) The Local Government Engineering Bureau (LGEB, now LGED) developed a Design Manual for Small Scale Water Resource Development Schemes (Draft Report, May 1990). This manual gave special attention to foundation and stilling basin design.

(v) The Master Plan Organisation (MPO, now WRPO) developed a number of computer models, such as the Water Balance Model and the Groundwater Model, for the assessment of water resources. MPO Technical Report Nr 2 (1986) recommended monthly evapotranspiration rates, crop coefficients, for calculation of crop water requirements and irrigation requirements within Bangladesh. Technical Report Nr 3 deals with improved irrigation water management, and suggests methods for the efficient control of irrigation distribution systems, and ideal system layouts for both major and minor projects. It also deals with various types of canal lining.

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(vi) The Surface Water Modelling Centre (SWMC) has used the Mike11 computer software package, under the guidance of the Danish Hydraulic Institute (DHI), to develop national and regional hydrological and hydrodynamic models for the planning, design and operation of water resources schemes, and river basin management. The package includes modules for modelling salinity and sediment transport/morphology, but the application of these, and particularly the latter, is still under development. These models have been recommended by FPCO for the analysis of FAP sub-projects. The Geographic Information System FAP component (FAP 19) is developing procedures for improving the visual presentation of model results, in terms of the spatial distribution of flood phases.

(vii) Other FAP studies have also developed criteria for project planning, so far mostly at the pre-feasibility level. FAP 21/22 is developing procedures for river training and bank protection, but those are still at the experimental stage. FAP 25 has modelled the effect of various confinement scenarios of the major rivers. Other engineering issues which are still under study by FAP projects are:

-	Concept of compartmentalization	(FAP 20 ongoing)
-	Controlled drainage	ditto
-	Controlled flooding	ditto
-	Fish-friendly irrigation and drainage structures	(FAP 17)

Detailed designs are not necessary or appropriate at the feasibility study stage. The objective is to establish the technical feasibility and cost of the proposals being made, leaving minor details to the detailed design stage. The feasibility level designs for the present study are generally in accordance with BWDB standards as reflected in the various design criteria referred to above, with minor modifications and additions. This chapter does not attempt to give a complete set of design criteria, but sets out the major parameters and guidelines adopted.

I.4.2 Basis for Selection of Development Options

The principal available engineering options for water resources development are FCD, FCDI and minor irrigation development. Appropriate interventions have been identified for the various parts of the project area to achieve specific agricultural objectives, in accordance with the findings of the public participation programme, and based upon an understanding of the hydrological processes involved. Although the South East Regional Model (SERM) is available for testing whether the objectives are met, and assisting in the evaluation of impacts upon the environment and fisheries, the initial identification and selection of those interventions is critical to the planning process. The various considerations involved in the selection process are discussed below. The detailed submergence constraints for various crops are presented in Annex J (Financial and Economic Evaluation).

(a) Flood control and Drainage (FCD)

(i) Partial FCD, by means of Submersible Embankments

Areas which are vulnerable to early flooding before the boro crop can be harvested in late May could benefit from protection by a submersible embankment, which goes under water later in the season. Even the B aman crop can be vulnerable to early flooding before it is established and can outgrow the rate of rise, and this could therefore also be benefitted.

(ii) Full FCD, by means of full embankments and possibly pumped drainage

T aman and HYV aman, the two principal monsoon season crops, are vulnerable to floods immediately after transplanting and at the height of the flood when they cannot tolerate complete submergence for more than two or three days. Full flood control may therefor enable these crops to be grown where previously either B aman or nothing at all grew. Even full flood control and drainage cannot provide a completely flood-free environment, unless a prohibitively large pumping capacity is provided, because internal runoff cannot generally all be drained whilst the outside river levels are high. Apart from likely fisheries and ecological impacts, there can also be some negative agricultural impacts such as a need for supplemental irrigation due to over-drainage of the higher ground, and a reduced availability of or access to surface water for irrigation in the dry season.

(b) Irrigation

In most areas there is the potential for increased irrigation without major project interventions, primarily through groundwater development but in some locations from surface water, using low lift pumps. However, if there is a risk of early flood damage to the boro crop, this can be a major disincentive to investment in irrigation. Thus, an FCD scheme may have a significant impact upon irrigation development. Elsewhere, there may be a shortage of surface water and problems of gas or salinity in exploiting groundwater, in which case the provision of additional surface water via a major pump station may be worthwhile. If this is carried out in conjunction with FCD there may then be an additional benefit in using the irrigation pumps for drainage pumping in the flood season.

I.4.3 Hydrological Analysis of FCD Projects

Three periods during the year are considered in the hydrological analysis of FCD projects:

(i) During the pre-monsoon, from March to June, main river levels are generally sufficiently low for gravity drainage of the runoff from local storms.

(ii) During the height of the monsoon, from July to September, the main rivers reach their peak and overspill their banks, completely dominating the water regime in the unprotected flood-plains and impeding the drainage of protected areas.

(iii) During the post-monsoon, from October to November, the main rivers recede, and gravity drainage is re-established.

The objectives of FCD design are:

(i) Gravity drainage (or pumped where feasible) during the pre-monsoon for protection of the standing boro crop, to facilitate broadcasting/transplanting B aman and to keep the water level as low as possible to provide maximum storage for monsoon rainfall. The drainage must be controlled to avoid over-drainage in some areas and under-drainage in others.

(ii) The exclusion of external floods, and the continuation of drainage whenever possible (pumped if available) throughout the main monsoon.

(iii) Drainage at the recession of the monsoon to facilitate harvesting and land preparation, but in a controlled manner to conserve water in channels and beels and allow time for groundwater recharge.

(iv) Controlled flooding to admit water from peripheral rivers at any time as required/available for supplemental and dry season irrigation and other uses. In the case of FCDI, pumped irrigation.

(v) Allowing access as far as possible for fish movement and navigation.

The required analysis has been carried out almost entirely by the SERM, in terms of determining discharges and water levels, as well as the benefits to agriculture. However, it has been necessary to define the dimensions of structures to be incorporated in the model for testing, as well as specifying some small structures and channels which are not separately identified in the model at all. For this reason it has been necessary to adopt a suitable value of drainage modulus to be applied to small sub-catchments within the project area. The method given in the FCD3 Design Manual (Section 1.2.2 of Volume I) was considered to be the most appropriate. After reviewing the 1990 feasibility study analysis and comparing the results with those applied on other projects in the region, it was concluded that there was no reason to alter the value of 35 mm per day used in the previous study.

I.4.4 Embankments

I.4.4.1 Full Flood Control

(a) Alignment

The following principles have been followed in fixing the alignment of embankments:

- follow the existing roads as far as possible for all types of embankments to minimise land acquisition and earthworks,
- minimum set-back distances for river embankments

Meghna - Erosive Upper Reach (Sadiapur-Shantinagar)	700 m	(see Section I.3.1.4)
Meghna - Middle/Lower Reaches (Shantinagar-Daudkandi)	300 m	ditto
Other rivers	30-100 m	(depending on the size of river)

(b) Top Level

The design flood level has been taken as the 1 in 20 year with project condition. The impacts of any upstream interventions by the North East Regional Water Management Study (FAP 6) are not yet known. Although the Flood Modelling and Management Study (FAP 25) has simulated Upper Meghna water levels for a fully embanked scenario, it is understood that this is not an option likely to be recommended by FAP 6.

Freeboard above the 1 in 20 year level has been set at 1.5 m for the Meghna and 1.0 m for other rivers. The resulting embankment top level is then checked for safety against overtopping by a 1 in 100 year high water level.

(c) Cross-Section

The final embankment cross-section will be determined by factors such as hydraulic gradient, soil stability, wave action, the need to incorporate access roads or elevated homestead areas etc, which will be fully considered during the detailed design stage. Indicative cross-section and other details for feasibility design and costing are given in Table I.4.1, including comparisons with the 1990 feasibility study recommendations.

I.4.4.2 Submersible Embankments

Two submersible embankment schemes were investigated in Zone D (in addition to the existing Satdona Beel and Chandal Beel schemes), but have not in the event been recommended for development, but the design criteria used in the investigation are given in this section.

Recommended cross-section details are as follows:

Top width	2 m	No road	
	4.27 m	With road	
Side slope	River Side	1:1.5	(for shallow depths, minimal wave attack)
	Country Side	1:2	(but check seepage line)

Spillways combined with flushing/drainage sluices (under-sluices) are provided in submersible embankments, to fill up the polder as quickly as possible after harvesting boro and/or when the B. Aman/Transplanted B. Aman is mature enough to withstand the rising flood. The polder is to be filled up before the river water overtops the embankment. The criteria applied in the analysis of submersible embankment systems are as follows:

(i) The 1 in 5 year pre-monsoon excess run-off is to be drained off with a maximum submergence of 30 cm for 2 days until 31 May, for protection of the ripe boro crop (excluding the beel/jalmahal area or the lowest 5% of the area, whichever is greater).

TABLE I.4.1

Typical Details of Full Flood Control Embankments

	Description	1990 Study	Adopted	Remarks
1	Crest width (m)			
	With metalled road	6.10	7.32	R&H Feeder Road Std.
	Without metalled road	4.27	4.27	BWDB Standard
2	Freeboard (m)			
	Meghna	1.52	1.5	BWDB Standard
	Other Rivers	0.90	1.0	BWDB Standard - 0.90 m
3	Design Flood level			
	River Side	1 in 20 year	1 in 20 year	Based on drainage criteria
	Country Side	-	1 in 5 year	
4	Side Slopes			
	River Side	1:3	1:3	wave action is critical
	Country Side	1:2	1:2	without berm
5	Intermediate Berms (m)			
	Elevation	GL + 3.04 if H>4.57 m	0.3 above Phreatic line/1.0 above 1:5 year polder WL.	1.0 above polder WL in case of resettlement of displaced persons.
	Berm width (m)	1.52	3 (minimum) 5 for resettlement	
6	Borrow pits (to be on river side)			
	Set back distance (m)	4.57	6 to cover the seepage line	
	Depth (m)	1.5	2	FCD3 Design Criteria
	Length (m)	30	30	
	Cross-bund width (m)	6	6	

(ii) The 1 in 5 year pre-monsoon excess run-off is to be drained off with a maximum submergence of 45 cm for 2 days until 30 June, for protection of the B.Aman/Transplanted B. Aman crop during establishment (excluding the beel/jalmahal area or the lowest 5% of the area, whichever is greater).

(iii) In the post monsoon, water can be drained out in time for the land to be ready for winter crops (vegetables and boro) by mid November.

(iv) The invert level of the under-sluice is placed at the beel level below which no crops are grown, or the level at which 5% of the polder is submerged, whichever is the higher (BWDB guide line).

(v) The invert level of the spillway is placed at the 1:5 year river water level at the first week of June where it is intended to protect boro, or the 1:5 year level at the end of June for protection of B aman/Transplanted B aman.

(vi) The rate of rise of the water level within the embankment is not to exceed 10 to 12 cm/day before complete submergence of the embankment, to avoid damage to growing B. Aman.

(vii) The slope between spillway and embankment top is to be 1:10 where vehicular access is required, and 1:2 elsewhere.

A computer program was developed to carry out the analysis required for the analysis of submersible embankment systems, and is described in Appendix I.V to this annex.

1.4.4.3 Embankments for Compartments

Embankment heights for compartments, where required, are based upon modelling results. Typical details are as follows:

Free Board	50 cm	:	(FAP 2)
Top width	3.6 m	:	for use as road (FAP 2)
Side slope	1:1.5	:	(FAP 2 used 1:2)

I.4.4.4 Compaction

It has been assumed that all embankment fill will be compacted mechanically to 90% of maximum dry density as determined by the Standard Proctor Test. No allowance has been made for shrinkage in design cross-sections.

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I.4.5 Channel Design

The critical discharge for drainage channel design in Bangladesh can occur either during the pre-monsoon or post-monsoon period. During the pre-monsoon period, despite the comparatively low rainfall, the required period for drainage to avoid crop damage is very short (2 or 3 days). During the monsoon most channels are submerged, with over-bank flow in addition to the normal channel flow, but drainage is generally determined by downstream water levels.

As discussed in Section I.4.3 above, major model channels have been sized by an iterative process using SERM, and minor unmodelled channels on the basis of an assumed drainage modulus. Maximum velocities etc are to be in accordance with the FCD 3 Design Manual (Volume 1, Chapter 2).

From analysis carried out by the SERS it has been observed that separate irrigation canal systems for gravity supply are not economically feasible, and involve excessive land acquisition. It has therefore been considered preferable that the same channel system be used both for irrigation and drainage. To achieve this, double lift irrigation may be necessary, with irrigation water first lifted by a primary pump from the major river into the main/branch khals and then onto the field by low lift pumps (LLP). Wherever feasible however, irrigation water is to be brought within reach of the LLP by gravity, by excavating khals leading from the main river.

The field distribution system downstream of the LLP has not been included in the feasibility designs (although allowed for in the costs of minor irrigation for economic and financial analysis). It is assumed that this part of the work will be carried out by farmers groups.

I.4.6 Structures

I.4.6.1 Regulator Structures

Conventional practice in Bangladesh is to design drainage and flushing regulators for orifice or pipe flow, to minimise the cost of the gates and structure. The high turbulence in this type of structure thought to impede or entirely prevent the passage of fish. Therefore several special types of 'fish friendly' structure have been adopted at appropriate locations as follows:

- dual opposed counterbalanced flap gate structures, of which the flaps are to be lowered only when specifically required to exclude high floods or retain irrigation water, and are otherwise to be held in the raised position,

- structures with special full height slide gates to the two outer vents, giving a free water surface when fully open for the passage of floating spawn etc, and

- bottom-hinged lifting gates, which regulate by means of weir flow as they are raised, giving a free water surface and less turbulence.

In addition, another type of bottom-hinged lifting gate structure has been adopted to allow the passage of small country boats, of width up to 3 m.

Drainage regulators may also be used for flushing and for water retention at the recession of the monsoon. Where reverse flows are a possibility, adequate stilling basins are provided on both sides. Structures have been designed in reinforced cement concrete, bearing in mind considerations of uplift pressure, scour, sliding and bearing capacity failure. Detailed checking is to be carried out at the design stage, based upon the Third Flood Control and Drainage Project (FCD 3) design procedure, with some modification for fish movement.
Every major regulator is provided with a road bridge of width 4.27 m (BWDB standard). Details of gates are given in Appendix I.VI to this Annex (Hydraulic Gates and other Electro-mechanical Plant).

I.4.6.2 Pump Stations

Pump station design details are discussed in Appendix I.VI to this Annex.

I.4.6.3 Road Bridges

The standard loads for road bridges are as follows:

Highway	-	H-20
Other	-	H-10
Cart bridge	-	5 ton

The road width over the bridge is 4.27 m (BWDB standard).

I.4.7 Flood-Proofing

I.4.7.1 General

Flood proofing is the provision of long term, non-structural or minor structural measures to mitigate the effects of floods. The objectives of flood proofing are to avoid the loss of human life and reduce the disruption of normal activities during and after a flood.

Structural flood proofing measures can include raising of floor levels of homesteads and industrial facilities above flood level; provision of refuge areas or flood shelters; ensuring water supplies and other health related facilities throughout floods; designing roads to be above peak flood level, and provision of additional bridges or culverts to improve drainage flows and also to ensure that embankments or structures are not washed away. Some non-structural measures may also be involved, including institutional measures to co-ordinate development activities related to flood control and drainage; planning controls on development, and collecting, analysing and publishing hydrological data relevant to the design and construction of infrastructure and facilities.

A flood proofing programme should aim to pool the information, resources and technology available to individuals, communities, government and non-government agencies to make individual or community actions more effective.

1.4.7.2 Flood Proofing Measures

(a) Saving Human Life and Reducing Suffering.

A flood proofing programme should identify measures to reduce the risk to human life and decrease the suffering caused by floods. Such measures may include raising of hand tubewells and house floor levels above peak water levels to ensure supply of clean drinking water and shelter throughout a flood. Protection of homesteads from floods is of particular importance to women, as their daily activities are generally centered around the homesteads.

A flood proofing programme would also include measures to protect private property and capital assets from damage or loss during floods. For individuals and families, such measures would generally be raising of floor levels of houses and protection of side slopes of homestead areas from wave action. Flood proofing measures would also include identifying homesteads that are vulnerable to flooding and determining ways to provide adequate flood free areas to store the family's capital assets.

(b) Protection of Income and Livelihood

Measures may be needed to improve the availability of employment opportunities during and after floods. These could include improvement of the yield of flood tolerant crops such as deep water aman; protection of seed and fertilizer godowns, and the identification and support of alternative employment activities that can continue throughout a flood. Flood proofing measures would also include ensuring access to and protection of commercial facilities and necessary support services so that employment activities are unaffected by flooding. A complementary approach could be to improve employment opportunities in the dry season, so that people could earn more and accumulate more reserves for use during or after a flood. The impact of flooding on economic activities needs to be assessed as an integral part of national, regional and local development planning.

(c) Agriculture

Flood proofing measures for agriculture could include:

(i) Development of farmers' skill at being able to adapt to floods with the purpose of making floods less disruptive to local economics.

(ii) Improving crop varieties using modern plant breeding techniques to make crops more resistant to floods.

(iv) Research into the development of quicker maturing varieties of boro paddy which would reduce the risk of crop loss from early monsoon flooding; higher yielding varieties of deep water aman, and aman varieties suitable for late planting and with taller seedlings which would reduce the risk of crop loss by late monsoon flooding.

(v) Crop diversification research into more intensive and less water demanding dry season crops e.g. wheat, potato, winter vegetables etc., so farmers are less dependent upon monsoon season cropping.

(d) Livestock

Flood proofing measures for livestock could include the provision of refuges to keep them and their feed dry during floods; improved availability of vaccine and veterinary attention to prevent disease and sickness after the flood, and economic support for poor families to purchase replacement livestock. An additional benefit of refuges for livestock would be that mass vaccination of the livestock could take place, thereby reducing the likelihood of disease.

(e) Fish

Fish ponds in which intensive fish culture is practiced need be protected from flood water by raising banks to prevent the ingress of predatory fish and other undesirable species, the inflow of contaminated flood water and the possible loss of stock.

(f) Rural Water Supply and Sanitation.

Rural water supplies can be flood proofed by raising the height of the discharge pipe and the operating mechanism of hand tube wells above peak flood level. Sanitation during floods can be improved by wide spread use of water sealed latrines. Covering of rubbish dumps would also reduce the amount of debris carried by flood water.

(g) Infrastructure and Public Services

During and after floods, communities within the flood affected area face disruption of public utilities and services including damage to public infrastructure. A flood proofing programme would aim to identify critical public services and infrastructures, and government agencies would be responsible for ensuring that facilities were designed and constructed to provide consistent and agreed standards of usability and accessibility to the public throughout flood events.

(i) Roads

Flood proofing measures for roads include constructing road embankments with an adequate cross-section; protecting embankment side slopes from erosion; selection of appropriate materials for embankments and pavements; ensuring compaction of embankments during construction; leaving adequate berm widths between embankments and borrow pits, and an effective maintenance programme.

(ii) Public Buildings.

Improvement of the quality and performance of public buildings by introducing uniform building codes can act as a flood proofing measure. A first requirement is that the floors of all public buildings should be raised above highest recorded flood levels.

(g) Flood Shelters

When resources are not available for flood proofing of individual houses or homesteads, an alternative measure is the provision of community flood shelters equipped with water supply (usually by hand tubewell) and sanitation facilities (water sealed pit latrines). The flood shelters can provide temporary refuge to people whose own dwellings are unable to give them protection from flood.

(h) Industry

Possible flood proofing measures for industry include raising of floor levels; locating electrical and other water - sensitive equipment on raised plinths or on upper storeys of buildings, and provision of small protective embankments around industrial premises.

(j) Markets

Markets should be located on higher ground, often on river banks, to minimise the land raising required for flood proofing.

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CHAPTER I.5

ENGINEERING COSTS

I.5.1 Basis of Costing

This chapter sets out the basis of the engineering cost estimates which were prepared for each of the development options analysed. Rates and costs have been prepared at 1992 financial prices as per FPCO Guidelines. In general, rates for the various work items have been derived from an analysis of the operations and materials etc involved, and then compared with those available from the following sources, and adjusted if appropriate:

- Schedule of Rates for Comilla O & M Circle, 1992, BWDB, Comilla.
- Schedule of Rates for Muhuri O & M Circle, 1992, BWDB, Feni.
- Schedule of Rates collected from local contractors working in BWDB projects.
- Schedule of Rates for Road & Bridge Works, 1990, RHD, Dhaka Zone.
- Schedule of Rates prepared by World Bank Resident Mission in Bangladesh, Sept. 1991.
- FAP 2 reports (1992), FAP 8A reports (1991), FAP 21/22 reports (1992)

It is anticipated that most of the work will be constructed under contracts awarded on the basis of local competitive bidding, but it is also hoped to involve landless contracting societies in the manual earthworks operations. Accordingly, the rates for these operations have been prepared with reference to information supplied by Comilla Proshika.

I.5.2 Earthworks

Earthworks constitute the major component of all the proposals, and special attention has therefore been given to deriving as realistic rates as possible for this part of the works. Various combinations of manual and mechanical methods have been investigated, in order to arrive at the most effective approach for any given circumstances. Thus, most embankment construction is based upon a combination of manual excavation and transport and mechanical compaction. Channel excavation is generally manual, but where there is perennial standing water mini-dredgers have been adopted. Full-sized dredgers as presently used in Bangladesh were also investigated, but found to be more expensive and less appropriate for the works envisaged.

Considerable attention has also been paid to the matter of spoil disposal. The system eventually adopted in almost all circumstances has been to spread the material on adjacent land, and pay the farmers compensation for the loss of a season's production. This approach is cheaper than acquiring land for spoil disposal, and is altogether more satisfactory in terms of minimising both the loss of land for agriculture and the displacement of people, and was found to be generally acceptable to the local population during the public participation process. In the case of dredgers, the spoil would be pumped as a slurry and retained within small bunds to an assumed depth of up to 20 cm. In the case of manual excavation, a lower rate for compensation has been adopted, equivalent to spreading to a thickness of 0.5 m. This is because there can be considerably more flexibility in placing the material, and the landless contracting societies should in many cases be able to build up land for markets, homesteads etc to suit the requirements of local people, without paying any compensation at all. A possible problem which may be encountered is the excavation of very sandy material, which would not be acceptable spread over agricultural land, but the proportion of this is not thought to be major.

I.5.3 Unit Rates

Unit rates were derived on the basis of the unit labour costs, materials costs and construction equipment charge rates presented in Tables I.5.1, I.5.2 and I.5.3 respectively. In each of the tables, rates and costs from various sources are compared with the value adopted for the present analysis shown in the final column. Table I.5.4 presents the build-up of the rate for each item of work from the information in the preceding tables and assumptions about production rates etc. An allowance of 5% has been made in each case for unidentified miscellaneous items. Table I.5.5 gives rates for items of electrical and mechanical equipment used in the works. A separate review of selected unit rates used in the 1990 Feasibility Study, compared with the corresponding rates derived for the present study, is presented in Table I.5.6.

Land acquisition is discussed separately in Chapter I.7 of this Annex. The financial costs of land acquisition have been taken as Tk 375 000 per hectare for agricultural land and Tk 1 617 800 per hectare for homestead areas, including replacement housing.

I.5.4 Calculation of Capital Costs

The capital costs were calculated for each intervention by applying the derived unit rates to the work quantities measured from drawings etc. In accordance with the FPCO Guidelines for Project Assessment, the following additions were made, to arrive at the total project cost:

- 15% of the total cost of work items, to cover unforeseen physical contingencies, and

- 12% of the total cost of work items plus physical contingencies to cover engineering services, made up as follows:

- survey and investigation	2%
- detailed design and preparation of tender documents	3%
- supervision of construction	5%
- administration costs	2%

The total project capital cost was then allocated between local and foreign currency costs on the basis of the assumed percentages given in Table I.5.7.

TABLE I.5.1

Daily Labour Rates

Taka per 8 hour day

TYPE OF LABOUR	BWDB Comilla 1992	BWDB Muhuri,Feni 1992	World Bank 1990	FAP8A 1991	FAP2 1992	FAP 21/22 1992	R & HD 1990	Adopted for Present Study
1 Foreman	–	–	–	225	170	190	–	225
2 Skilled labour	60	50	70	–	75	160	65	65
3 Common labour	45	40	60	80	55	70	50	50
4 Operator	60	65	–	270	85	170	–	100
5 Driver	60	65	–	150	85	220	–	125
6 Mechanic	–	100	–	210	100	–	–	125
7 Welder	–	90	–	200	85	–	–	125
8 Electrician	60	80	150	210	85	–	–	125
9 Concrete worker	–	–	–	120	75	–	–	65
10 Carpenter	70	80	130	175	110	–	110	100
11 Mason/Plasterer	70	100	130	175	110	–	110	100
12 Steel worker	75	80	–	145	110	–	–	80
13 Painter	70	85	130	140	110	–	110	80
14 Plumber	75	80	150	230	110	–	–	100
15 Pavement worker	–	–	–	130	110	–	110	80
16 Surveyor	55	70	–	260	115	–	–	170

Sources:

- Schedule of rates for Comilla O & M Circle (1992) and Muhuri O & M Circle(1992), BWDB.
- Schedule of rates for road & bridge works (R&HD, 1990)
- Schedule of rates prepared by World Bank resident mission in Bangladesh (Sept.'90).
- FAP 2 (1992), FAP 8A (1991), and average rate of FAP 21/22 (1992)

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TABLE I.5.2

Unit Rates of Principal Construction Materials

Tk (including Taxes)

Item	Unit	Comilla 1992	R&HD 1990	World Bank 1991	Soiltech 1992	Engineers 1992	FAP 21/22 1992	Muhuri, Feni 1992	FAP8A 1991	FAP2 1992	Adopted for Present Study
1. Cement, aggregates & bricks											
Portland cement	kg	4.1	4.2	4.5	5.2	4.5	4.4	4.1	5.0	5.0	4.5
Sand	cu.m	450	450	390	450	550	235	550	500	450	450
Gravel / Boulder	cu.m	1 129	1 050	850	800	900	1 800	1,275	1 200	1 050	1 000
Bricks (Including carriage)	1000 Nr	2 300	2 100	2 400	2 500	2 600	2 100	2 200	3 100	2 100	2 200
Brick chips	cu.m	960	630	–	850	880	1 000	750	1 200	750	800
2. Steel materials											
Reinforcement bar (Torsteel)	ton	–	–	–	25 000	26 000	25 000	24 000	31 000	26 000	24 000
Reinforcement bar (round)	ton	23 400	24 500	24 000	20 000	23 000	20 000	25 000	–	26 000	23 400
Structural steel	ton	22 400	–	22 000	–	32 000	–	25 000	26 000	32 000	24 000
Steel sheet pile	ton	40 000	–	–	35 000	46 000	30 000	–	31 000	40 000	40 000
3. Concrete products											
R.C.pile (250mmx250mm)	lin.m	–	–	–	–	–	–	–	–	780	570
R.C.pile (300mmx300mm)	lin.m	–	–	–	–	–	–	–	–	1 040	750
R.C.pile (400mm dia.)	lin.m	–	–	–	–	–	–	–	–	–	1 500
4. Others											
Wooden pile (d=100mm)	lin.m	75	–	–	–	–	–	–	–	200	–
Timber (class–a)	cu.m	18 000	–	23 000	21 000	25 000	24 500	17 650	25 000	25 000	20 000
Timber (class–b)	cu.m	10 500	–	14 800	14 000	15 000	–	11 475	15 000	15 000	15 000
Wood for shuttering	cu.m	–	–	–	–	–	–	8 850	–	3 600	9 000
Sand bag	Nr	10	–	–	6	7	22	7	–	7	7
Bamboo	Nr	65	–	–	100	120	90	60	–	100	100
Gasoline	litre	–	–	–	15	15	16	–	15	15	15
Diesel oil	litre	–	–	–	14	14	15	–	14.5	14.5	15

Source:

- Schedule of rates for Comilla O&M Circle (1992) and Muhuri O&M Circle, Feni (1992), BWDB.
- Schedule of rates for road & bridge works (RHD, 1990)
- Schedule of rates prepared by WB resident mission in Bangladesh (Sept. 1991)
- FAP8A report (1991), FAP2, FAP 9A, FAP 21/22 reports (1992).

TABLE I.5.3

Unit Charge Rates for Construction Equipment

Equipment	Capacity	Capital cost at site (000 Tk)	Life year	Operation of equip. (hr/yr)	Operation of equip. (day/yr)	Depreciation (Tk/hr)	Maintenance & repair (%)	Maintenance & repair (Tk/hr)	Management (%)	Management (Tk/hr)	FAP 2 Rates Foreign Currency	FAP 2 Rates Local Currency	FAP 2 Rates Total (Tk./hr.)	FAP21/22 (Tk./hr.)	Adopted for Present Study (Tk./hr.)
Cutter–suction dredger															
Dredger 18"	225m3/hr.	–	–	–	–	–	–	–	–	–	–	–	–	15 000	13 800
Dredger 12"	110m3/hr.	–	–	–	–	–	–	–	–	–	–	–	–	6 000	5 000
Mini dredger 8"	65 m3/hr.	19 000	3	5 840	300	–	–	–	–	–	–	–	–	–	2 730
Bulldozer	11 t	4 748	6	975	150	730	65	528	7	341	1 153	446	1 599	562	1 600
Bulldozer	15 t	6 045	6	975	150	930	65	672	7	434	1 467	568	2 036	750	2 000
Bulldozer	21 t	9 389	6	975	150	1 444	65	1 043	7	674	2 279	883	3 162	1 125	3 200
Backhoe/Dragline	0.35 cu.m	3 627	5	1 365	210	478	50	266	7	186	691	239	930	750	1 000
Backhoe/Dragline	0.6 cu.m	5 991	5	1 365	210	790	50	439	7	307	1 141	395	1 536	875	1 600
Dump truck	11 t	4 251	4	1 365	210	701	60	467	10	311	1 074	405	1 479	500	1 500
Ordinary truck	6 t	2 191	4	1 365	210	361	55	221	10	161	538	205	742	470	750
Compaction roller	10 t	3013	6	975	150	0	50	0	7	0	0	0	0	1 500	950
Crawler crane	30 t	10 360	7	975	150	1 366	70	1 063	7	744	2 216	956	3 173	500	3 200
Truck crane	10 t	6 084	7	1 365	210	573	35	223	7	312	751	357	1 108	–	1 100
Crawler pile driver	35 t	20 567	5	1 365	210	2 712	50	1 507	7	1 055	3 918	1 356	5 274	–	5 300
Diesel pile hammer	3.5 t	3 740	4	975	150	863	60	575	7	269	1 323	384	1 707	–	1 700
Vibration hammer	30 kw	1 643	4	975	150	379	60	253	7	118	581	169	750	–	750
Water pump	200m3/hr	–	–	–	–	–	–	–	–	–	–	–	–	–	250
Submersible pump	4 in.	69	5	1 365	210	9	110	11	5	3	18	5	23	–	25
Vibration compactor	80 kg	65	3	1 365	210	14	45	7	5	2	20	4	24	–	25
Concrete mixer	0.5 cu.m	811	5	1 365	210	107	70	83	5	30	173	46	220	250	250
Concrete vibrator	45 mm	48	3	1 365	210	11	35	4	5	2	14	3	16	–	20
Diesel generator	125 kVA	1 531	6	1 365	210	168	35	65	5	56	221	69	290	375	300
Diesel generator	30 kVA	690	6	1 365	210	76	35	29	5	25	99	31	131	250	150

Note:–

1. Rates include depreciation, operation cost, fuel cost and taxes.

2. Data on Capital cost, Operation, Maintenance and Management from FAP 2 Final Report, (1992).

TABLE I.5.4

Unit Rates for Civil Engineering Construction

No.	Work Item	Remarks	Unit	LABOUR								MATERIALS							EQUIPMENT		UNIT COST
				Foreman		Mason Carpenter etc.		Skilled Labour		Common Labour		Cement		Sand		Aggregate		Shuttering			OF ITEM
	Unit: base rate, unit rates: See Table I.5.1			Tk225/day		Tk100/day		Tk65/day		Tk50/day		Tk4.5/kg		Tk450/cum		Tk 800/cum				Operation Cost	
				Requirement per unit	Cost Tk/unit	Requirement per unit	Cost Tk/unit	Requirement per unit	Cost Tk/unit	Requirement per unit	Cost per unit	Requirement per unit kg	Cost Tk/unit	Requirement per unit cum	Cost Tk/unit	Requirement per unit cum	Cost Tk/unit			Tk/Unit	Tk
1	Clearing, grubbing & stripping incl. disposal	manual	sq.m	1/150	1.50					1/20	2.50										3.00
2	Channel excav. & spreading spoils (trans. L = 50m)	manual	cu.m	1/225	1.00					1/2	25.00	Including crop compensation for disposal by spreading 50 cm thick: Tk 2.00/cum									28.00
3	Channel excavation (transport L = 100m)	manual	cu.m	1/150	1.50					1/1.6	30.50										32.00
4	Channel excavation (transport L = 50m)	manual (transport.)/mecha.(excv.)	cu.m	1/150	1.50					1/5.5	9.50								dragline	backhoe = 37.00	17.00
5	Channel excavation (transport L = 100m)	manual (transport.)/mecha.(excv.)	cu.m	1/225	1.00					1/3.3	15.00									bulldozer = 37.00	53.00
6	Channel excavation (transport L = 200m)	manual (transport.)/mecha.(excv.)	cu.m	1/225	1.00					1/2.5	20.00									backhoe = 37.00	78.00
7	Channel excavation (transport L = 500m)	mechanical	cu.m	1/225	1.00					1/10	5.00								backhoe = 37.00,	dumptruck = 92.00	137.00
8	Channel excavation (transport L = 500m)	dredger	cu.m	1/150	1.50					1/20	2.50	Including crop compensation of land for spreading disposal 20 cm thick, tk 5.00/cum								dredger = 62.00	70.00
9	Channel excavation (transport L = 500m)	mini dredger	cu.m	1/150	1.50					1/20	2.50	Including crop compensation for disposal by spreading 20 cm thick: Tk 5.00/cum								dredger = 12.00	50.00
10	Channel excavation & formation of embankment	mechanical excv./manual comp.	cu.m	1/150	1.50					1/3	16.67								backhoe	dragline = 37.00	54.00
11	Channel excavation and formation of embankment	manual excv. /mechanical comp.	cu.m	1/150	1.50					1/5	10.00									bulldozer = 31.50	42.00
12	Construction of embkt. (excavation, compaction & shaping)	manual	cu.m	1/225	1.00					1/1.5	34.00										37.00
13	Embankment (compaction & shaping)	manual	cu.m	1/150	1.50					1/6	8.50										9.00
14	Embankment (compaction & shaping)	mechanical	cu.m	1/150	1.50					1/20	2.50									bulldozer = 22.00	25.00
15	Turfing	manual	sq.m	1/150	1.50					1/20	2.50										3.00
16	Structural excavation (transport L = 50m)	manual	cu.m	1/225	1.00			1/11	6.00	1/2	25.00										32.00
17	Structural excavation (transport L = 100m)	manual	cu.m	1/225	1.00			1/11	6.00	1/1.8	28.00										37.00
18	Structural excavation (transport L = 100m)	manual (transport.)/mecha.	cu.m	1/225	1.00					1/3.3	15.00									backhoe = 37.00	53.00
19	Backfilling of structure by local earth	manual (filling)/mechanical	cu.m	1/150	1.50			1/45	1.5	1/10	5.00									comproller = 19.00	26.00
20	Backfilling of structure by local earth	mechanical	cu.m	1/150	1.50					1/25	2.00									bulldozer = 31.50	34.00
21	Dewatering	per pump with 100 nos. well point	day																		1600.00
22	Slope protection, concrete blocks (1:3:6)	300x300x300, manual	cu.m	1/28	8.00	1/5	20.0	3.2	208.0			212	951.00	0.47	211.00	0.94	752.00	94.00	vibrator = 9.0	mixer = 111.0	2370.00
23	Structural concrete (210 kg/sq.cm)	incl. scaffold, support & form	cu.m	1/28	8.00	1/5	20.0	3.5	228.0			397	1788.00	0.42	190.00	0.84 (stone)	1218.00	165.00	vibrator = 9.0	mixer = 111.0	3716.00
24	Lean concrete (1:3:6)	manual	cu.m	1/38	6.00	1/6	16.0	3.2	208.0			212	951.00	0.47	211.00	0.94	752.00		vibrator = 9.0	mixer = 111.0	[illegible]
25	Reinforcement bar (including fabrication)	manual	ton	1.3	300.00	10	1000.0	10	650.0							rebar = 24000.00					25770.00
26	Construction of Building	Complete	Sq.m																		[illegible]

Note: Labour and material requirements derived from BWDB Schedule of Rates for Comilla O&M Circle (1992) and Muhuri O&M Circle (1992).

TABLE I.5.5

Unit Rates for Electrical and Mechanical Equipment

Item	Description	Unit	Unit rate Tk 000
1	Axial flow pump of 2.52 m^3/s @ 3.8 m capacity for P.S. Nr 1	Nr	13 657
2	Auxiliary equipment for Pump Station Nr 1	Item	5 000
3	Trash racks for Pump Station Nr 1	Item	3 500
4	HT Transformer station with switch gears for P.S. Nr 1	Nr	5 000
5	Axial flow pump of 3.65 m^3/s @ 5.1 m capacity for P.S. Nr 2	Nr	22 844
6	Auxiliary equipment for Pump Station Nr 2	Item	7 500
7	Trash racks for Pump Station Nr 2	Item	5 500
8	HT Transformer Station with Switch gears for P.S. Nr 2	Item	7 500
9	1.0 m x 1.0 m flap gate with embedded parts	Nr	15
10	1.5 m x 1.5 m flap gate with embedded parts	Nr	30
11	2.0 m x 2.0 m flap gate with embedded parts	Nr	56
12	3.0 m x 3.0 m flap gate with embedded parts and hand hoist	Nr	165
13	3.0 m x 3.5 m flap gate with embedded parts and hand hoist	Nr	183
14	1.52 m x 1.82 m slide gate with embedded parts and hand hoist	Nr	80
15	1.5 m x 3.0 m slide gate with embedded parts and hand hoist	Nr	100
16	2.5 m x 2.0 m slide gate with embedded parts and hand hoist	Nr	110
17	2.8 m x 2.5 m slide gate with embedded parts and hand hoist	Nr	140
18	3.0 m x 3.0 m slide gate with embedded parts and hand hoist	Nr	160
19	3.0 m x 2.0 m hinged gate with embedded parts and hand hoist	Nr	63
20	3.0 m x 3.5 m hinged gate with embedded parts and hand hoist	Nr	185

TABLE I.5.6

Review of Rates used in 1990 Study

	Work Item	Remarks	Unit	UNIT COST Tk 1990 Study	UNIT COST Tk Adopted for Present Study
1	Clearing, grubbing & stripping incl. disposal	manual	cu.m	8.00	
	Clearing, grubbing & stripping incl. disposal	manual	sq.m		3.00
2	Channel excav. & spreading spoils (trans. L = 50m)	manual	cu.m		28.00
3	Channel excavation (transport. L = 100m)	manual	cu.m	35.00	32.00
4	Channel excavation (transport. L = 50m)	manual (transport.)/mecha.(excv.)	cu.m	50.00	47.00
5	Channel excavation (transport. L = 100m)	manual (transport.)/mecha.(excv.)	cu.m		53.00
6	Channel excavation (transport. L = 200m)	manual (transport.)/mecha.(excv.)	cu.m		58.00
7	Channel excavation (transport. L = 500m)	mechanical	cu.m		135.00
8	Channel excavation	mini dredger	cu.m		50.00
9	Channel excavation & formation of embankment.	mechanical excv./manual	cu.m		54.00
10	Channel excavation and formation of embankment	manual excv. /mechanical	cu.m		42.00
11	Constuction of embkt. (excavation, compaction & shaping)	manual	cu.m	36.00	35.00
12	Embankment (compaction & shaping)	manual	cu.m		9.00
13	Embankment (compaction & shaping)	mechanical	cu.m	20.00	25.00
14	Turfing	manual	sq.m	1.50	3.00
15	Structural excavation (transport. L = 50m)	manual	cu.m	37.00	32.00
16	Structural excavation (transport. L = 100m)	manual	cu.m		35.00
17	Structural excavation (transport. L = 100m)	manual (transport.)/mecha.	cu.m		53.00
18	Backfilling of structure by local earth	manual (filling)/mechanical	cu.m		26.00
19	Backfilling of structure by local earth	mechanical	cu.m		34.00
20	Dewatering	per pump with 100 Nr. well point	day		3600.00
21	Slope protection, concrete blocks, (1:3:6)	300x300x300, manual	cu.m		2370.00
22	Structural concrete (210 kg/sq.cm)	incl. scaffold, support & form	cu.m	3500.00	3740.00
23	Lean concrete (1:3:6)	manual	cu.m	3062.00	2270.00
24	Reinforcement bar (including fabrication)	manual	ton	24000.00	25750.00
25	Construction of Building	Complete	Sq.m	6500.00	6500.00
26	Portland cement		kg		4.50
27	Sand		cu.m		450.00
28	Gravel / Boulder		cu.m		1000.00
29	Brick (Including carriage)		1000 Nr.		2200.00
30	Brick chips		cu.m		800.00
31	Reinforcement bar (Torsteel)		ton		24000.00
32	Reinforcement bar (round)		ton		23400.00
33	Structural steel		ton	50000.00	24000.00
34	Steel sheet pile		ton	21000.00	40000.00
35	Timber (class−a)		cu.m		20000.00
36	Timber (class−b)		cu.m		15000.00
37	Wood for shuttering		cu.m		9000.00
38	Sand bag		Nr.		7.00
39	Bamboo		Nr.		100.00
40	Gasoline		ltr.		15.00
41	Diesel oil		ltr.		14.50

f8

TABLE I.5.7

Division of Costs Between Foreign and Local Currency

Work Category	Local Currency Cost	Foreign Currency Cost
Earthworks	80%	20%
Structures (Regulators, Bridges etc)	80%	20%
Road Works	80%	20%
Building Works	80%	20%
Pump Station Civil Works	84%	16%
Pump Station Electrical & Mechanical Works	53%	47%
Vehicles	25%	75%
Land Acquisition	100%	0%

I.5.5 Operation and Maintenance (O&M) Costs

Operation and maintenance costs have been assumed in accordance with the FPCO Guidelines for Project Assessment as follows:

Embankments	6%
Khal Excavation	6%
Irrigation and Drainage Structures and Bridges	3%
Pump Stations (Civil & Electrical & Mechanical Works)	2%
Vehicles	4%

In addition to the percentage allowance for vehicles, running costs (driver, fuel, lubricants etc) of Tk 70 000 per vehicle have been allocated. Pump station electricity supply costs have been dealt with separately, and are discussed in the appropriate section in Chapter I.6 of this annex. O&M requirements generally are discussed in Chapter I.9 of this annex.

CHAPTER I.6

OPTIONS FOR DEVELOPMENT

I.6.1 Introduction

The project area has been divided into four different zones, each of which has a characteristic set of problems and hence potential development solutions. Because of these heterogeneous characteristics, it is considered important to approach the study by zone rather than to treat the area as a whole. Some of the proposed interventions would affect more than one zone, but this is easily accommodated within the analysis approach.

I.6.2 No Project Development

There are three main arguments against engineering interventions in support of agricultural development in the Gumti Phase II project area.

Firstly, the project area has one of the highest productions of floodplain fish in Bangladesh. This means that any attempt to reduce flooding in any portion of the existing floodplain will involve heavy fish losses.

Secondly, there is a heavy annual sediment load coming into the east of the area from the Tripura hills in India, resulting in a need for expensive regular desilting to maintain khal capacities.

Thirdly, despite gas and salinity constraints, it is technically feasible to provide irrigation to the entire net cultivable area from groundwater, and the total area served by tubewells is still increasing. Therefore surface water irrigation schemes which require two stages of pumping are unlikely to be economic.

However, to set against these arguments, the population density has increased significantly in the project area and additional food and employment is urgently required. People's participation meetings highlighted many specific problems in each of the zones, and also gave possible solutions.

It has therefore been concluded that despite the constraints of fisheries, sedimentation and the natural growth in "without project" irrigation, interventions in support of agricultural and other development are still desirable in the project area. However, a viable scheme has to be sympathetic to environmental considerations and address location-specific water-related problems.

I.6.3 Basic and Intermediate Flood Response and Development Planning

I.6.3.1 General

Guidance on the best way forward in determining an acceptable set of proposals for the area was taken from the public participation meetings. By listening to local people's water-related problems and discussing them together, interventions which best suited the specific needs of each area could be determined. Being location-specific rather then extensive, the proposals considered fall almost entirely within the categories of basic and intermediate flood response and development.

Strategies related to each zone were considered, and from these several interventions were proposed. The various options were analysed using the South East Regional Model (SERM) developed by the Surface Water Modelling Centre (SWMC). In the analysis the model was used to generate water levels along the khal and river system, including the floodplains, for comparison with the "without project" conditions. Initial "refining" runs were carried out using a 5 year data block. The proposals for the "with project" options were then run for a full 25 year simulation.

I.6.3.2 Zone A

(a) Background

A map of Zone A is presented in Figure I.6.1. The north-west boundary is strictly defined by the Buri Nadi, but the Comilla to Sylhet highway is a dominant feature in the drainage pattern. To the north is the flashy Salda River, whilst to the east are the Tripura Hills of India which give rise to a number of smaller flashy streams. To the south and south-west is the existing Gumti right embankment which, barring breaches, forms a watertight boundary.

The gross area of the zone is 31 976 ha and the net cultivable area (NCA) 24 506 ha. Elevations range from below 3.5 m above PWD near the Buri Nadi in the north-west to above 16.0 m against the Indian border in the south-east. It includes Brahmanpara thana and parts of Burichang, Debidwar and Comilla.

Public Participation Meetings identified the following problems within the zone:

- damage caused by flash floods originating in the Tripura Hills,
- a need for additional water for irrigation during the dry season,
- rapid falls in water levels at the end of the monsoon season causing damage to the broadcast aman crop (this was a less common problem probably related to the very dry year of 1992)

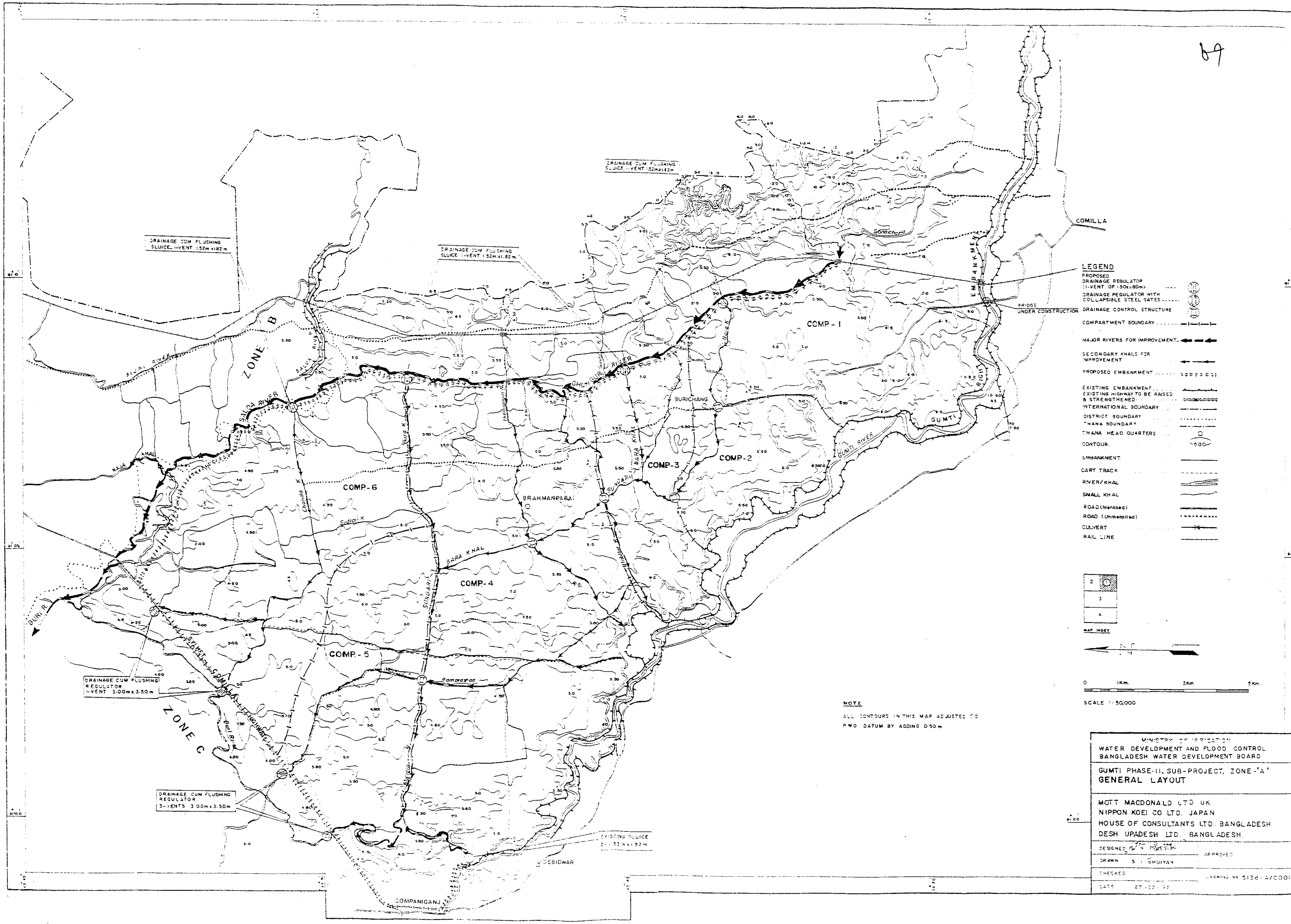
The construction of the Gumti right embankment has had a significant impact on the water regime in the zone. Although spillage from the River Gumti has been almost totally eliminated, people find it harder to get water in the dry season, and there is in any case little potential for further irrigation abstraction from the river, as discussed below.

(b) Dry Season Situation

Dry season agriculture in the zone is dominated by the cultivation of boro HYV. Wheat is another important dry season crop, planted on about 10% of the NCA.

The bulk of the boro HYV crop is irrigated. It is reported to cover over 60% of the NCA, corresponding well with the estimated irrigation coverage. The irrigation water is derived primarily from groundwater, by use of STWs (suction mode) and DTWs (force mode). DTWs are particularly prevalent in Burichang and Comilla thanas. Groundwater supplies around 80% of the irrigated area in Burichang, Comilla and Brahmanpara thanas, falling to 70% in Debidwar. The distribution of the various modes of irrigation is shown in Figures I.2.1 to I.2.5 of Chapter I.2.

Figure I.6.1


67
LEGEND
PROPOSED
DRAINAGE REGULATOR (1-VENT OF 1.50x1.80m)
DRAINAGE REGULATOR WITH COLLAPSIBLE STEEL GATES
DRAINAGE CONTROL STRUCTURE
COMPARTMENT BOUNDARY
MAJOR RIVERS FOR IMPROVEMENT
SECONDARY KHALS FOR IMPROVEMENT
PROPOSED EMBANKMENT
EXISTING EMBANKMENT
EXISTING HIGHWAY TO BE RAISED & STRENGTHENED
INTERNATIONAL BOUNDARY
DISTRICT BOUNDARY
THANA BOUNDARY
THANA HEAD QUARTERS
CONTOUR
EMBANKMENT
CART TRACK
RIVER/KHAL
SMALL KHAL
ROAD (Metalled)
ROAD (Unmetalled)
CULVERT
RAIL LINE
MAP INDEX
SCALE 1:50,000
NOTE
ALL CONTOURS IN THIS MAP ADJUSTED TO PWD DATUM BY ADDING 0.50m
MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
GUMTI PHASE-II, SUB-PROJECT, ZONE-'A'
GENERAL LAYOUT
MOTT MACDONALD LTD UK.
NIPPON KOEI CO LTD. JAPAN
HOUSE OF CONSULTANTS LTD. BANGLADESH
DESH UPADESH LTD. BANGLADESH.
DESIGNED
APPROVED
DRAWN
CHECKED
DATE
COMP-1
COMP-2
COMP-3
COMP-4
COMP-5
COMP-6
ZONE B
ZONE C
COMILLA
BURICHANG
BRAHMANPARA
DEBIDWAR
COMPANIGANJ
GUMTI RIVER
SALDA RIVER
BIJNI RIVER
BURI R.
BARA KHAL
Sundari
Chandla K
Bura K
DRAINAGE CUM FLUSHING SLUICE, 1-VENT 1.52m x 1.82m
DRAINAGE CUM FLUSHING REGULATOR 1-VENT 3.00m x 3.50m
DRAINAGE CUM FLUSHING REGULATOR 3-VENTS 3.00m x 3.50m
EXISTING SLUICE
BRIDGE UNDER CONSTRUCTION

(c) Surface Water Resources

There are reported to be 103 LLP installations delivering irrigation water from the Gumti to the northern side of the river, of which 78 units supply Zone A. A regulator has been built at the head of the Buri Nadi, designed to enable the abstraction of about 2 m^3/s from the Gumti in the dry season for irrigation. However, since the Gumti River is uncontrolled within Bangladesh and the Buri regulator has a fixed cill, the quantity of water actually diverted is dependent upon the dry season water levels in the main river. In March 1993, shortly after several fairly heavy showers, the Gumti River level was observed to be too low to pass more than a trickle through the regulator, although much of the problem seemed to be siltation of the approach channel.

There are further abstraction points on the other side of the Gumti River, supplying the area to the south. These include two offtakes and approximately 100 active LLP positions. The total abstraction of all the LLPs on both banks is about 9 m^3/s, assuming 75% of theoretical maximum utilisation. The two southern offtakes are designed to remove a total of 6 m^3/s and the Buri Nadi offtake theoretically removes a further 2 m^3/s. The current abstraction in the dry season is thus up to about 17 m^3/s.

Since 1965, 50% of the March daily flows have exceeded 15 m^3/s. For a 1 in 5 dry year (80% exceedance) the corresponding figure falls to 9 m^3/s. There has in fact been a rising trend in discharges since the construction of a dam near Tirthamukh in India, in the mid 1970's. However, it should also be noted that an irrigation network within India which will draw from the Maharani Barrage (completed in the late 1980's) will be finished shortly, and it is anticipated that the Gumti River flow will then diminish again. According to a report by the Indo-Bangladesh Joint Rivers Commission the future additional requirement of water in India amounts to some 55 m^3/s in the month of March. Therefore, as in the 1990 Feasibility Report, it has been assumed that no additional discharge will be available in the Gumti River near Comilla. A residual flow should in any case be left in the channel for environmental and navigation needs.

It is recommended that the flows are monitored closely in the coming few years, especially as the development in India will to a degree invalidate some of the analyses of the historic flow record. An additional factor which may be of importance is the degree to which the sediment transport characteristics of the river may be affected. If sediment is trapped in the upstream development works, the released flows entering Bangladesh could cause erosion to the River Gumti and a modification to the regime conditions.

The Ghungur River dry season flows are only small, relying on base flows from the streams from the Tripura Hills. Many of these streams dry up completely between February and March. Hence there is no potential for further irrigation development from the Ghungur and there are no viable storage possibilities. Such resources as do exist are already exploited through the use of LLPs.

(d) Groundwater Resources

Groundwater resources in the northern half of the zone are suitable for abstraction by both suction mode and force mode units. The area is fairly intensively irrigated in the dry season, with more than 50% coverage in some parts, most of which is groundwater-based.

The use of surface water from the Meghna or Titas Rivers for irrigation in this zone was also considered, as an alternative to groundwater development. As discussed in Chapter I.3 of this annex, there may be some prospect for drawing a backflow from the Meghna into the lower reaches of the Gumti River. The benefit in Zone A would however at best be limited to a small discharge available for pumping into the Buri Nadi at the existing offtake structure. Although the zone is linked to the Meghna/Titas by the Buri Nadi, the distance, adverse bed slopes and probable need for pumping, would rule out any transfer of irrigation water by this route, on both economic and operational grounds.

The viability of protecting the different parts of the zone from pre-monsoon flash floods and the longer duration main monsoon floods needs to be assessed separately. Protection against flash floods entails the interception of runoff from the Tripura Hills, for instance by an embankment along the left bank of the Ghungur River. Protection against monsoon flooding could also include these works, but would more importantly need embankments in the north of the zone, along the southern bank of the Buri Nadi and Salda channels. Recession of the flood is also reported to be impeded by the Comilla-Sylhet highway embankment. The public participation meetings did not generally focus upon the main monsoon flooding, which primarily affects the north-west of the zone, but rather upon the flash floods.

(g) The Zone A Scheme

The recommended intervention involves the provision of full flood control and drainage to the bulk of the zone (protected area 23 400 ha gross, 17 933 ha NCA), giving protection against both pre-monsoon flash floods and peak monsoon flooding from the main rivers. The general layout of the scheme is shown in Figure I.6.1, and at a larger scale in the separate album of drawings. The major components of the works are as follows:

- full embankment on the west bank of the Ghungur (25.4 km) and Salda (11.3 km) Rivers from the Comilla-Sylhet highway southwards to the crossing of the main railway line. South of the railway crossing the land is largely above flood level, and the railway embankment itself will in any case protect the area to its west,

- excavation of the Ghungur and Salda Rivers adjacent to their embankments,

- raising and strengthening of the existing Comilla-Sylhet national highway (under the authority of the Roads and Highways Department) from Companiganj to the crossing of the Salda River,

- excavation of the Buri River from its junction with the Salda River to about 6 km short of its outfall near Nabinagar (19 km), and

- 85 km of khal excavation for internal drainage improvement within the protected area.

Profiles of the Ghungur, Salda and Buri channels, and two of the internal channels (Chandla Khal and Sundari-Bara Khal) indicating the proposed works, are shown in Figures I.6.2, I.6.3 and I.6.4.

Figure I.6.2

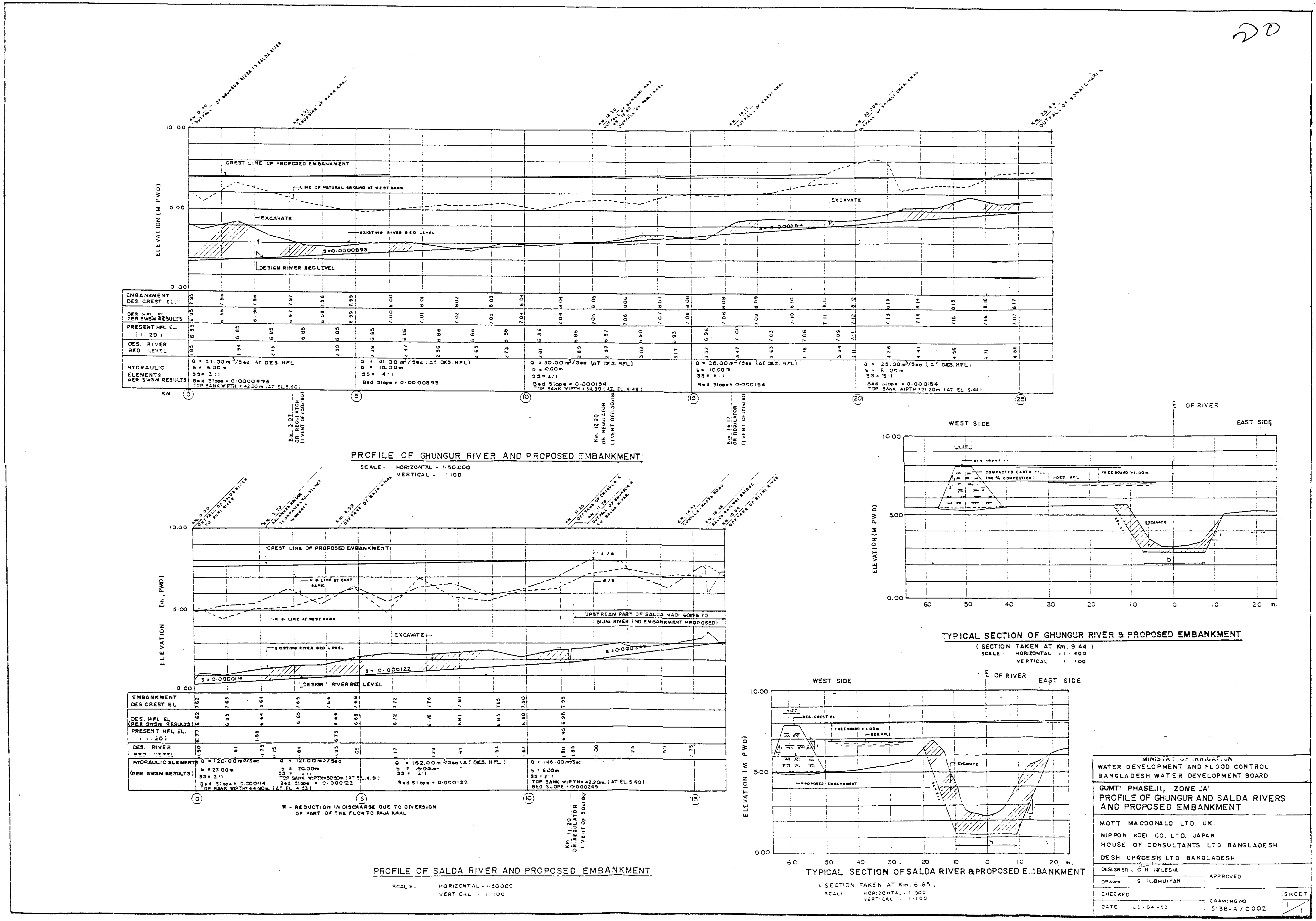

PROFILE OF GHUNGUR RIVER AND PROPOSED EMBANKMENT
SCALE - HORIZONTAL - 1:50,000
VERTICAL - 1:100
PROFILE OF SALDA RIVER AND PROPOSED EMBANKMENT
SCALE - HORIZONTAL - 1:50000
VERTICAL - 1:100
TYPICAL SECTION OF GHUNGUR RIVER & PROPOSED EMBANKMENT
(SECTION TAKEN AT Km. 9.44)
SCALE : HORIZONTAL - 1:400
VERTICAL - 1:100
TYPICAL SECTION OF SALDA RIVER & PROPOSED EMBANKMENT
(SECTION TAKEN AT Km. 6.85)
SCALE HORIZONTAL - 1:500
VERTICAL - 1:100
MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
GUMTI PHASE II, ZONE 'A'
PROFILE OF GHUNGUR AND SALDA RIVERS AND PROPOSED EMBANKMENT
MOTT MACDONALD LTD. UK.
NIPPON KOEI CO. LTD. JAPAN
HOUSE OF CONSULTANTS LTD. BANGLADESH
DESH UPADESH LTD. BANGLADESH
DESIGNED G. N. IGLESIA
DRAWN S. BHUIYAN
APPROVED
CHECKED
DATE 23-04-93
DRAWING NO 5138-A / C002
SHEET 1/1

Figure I.6.3

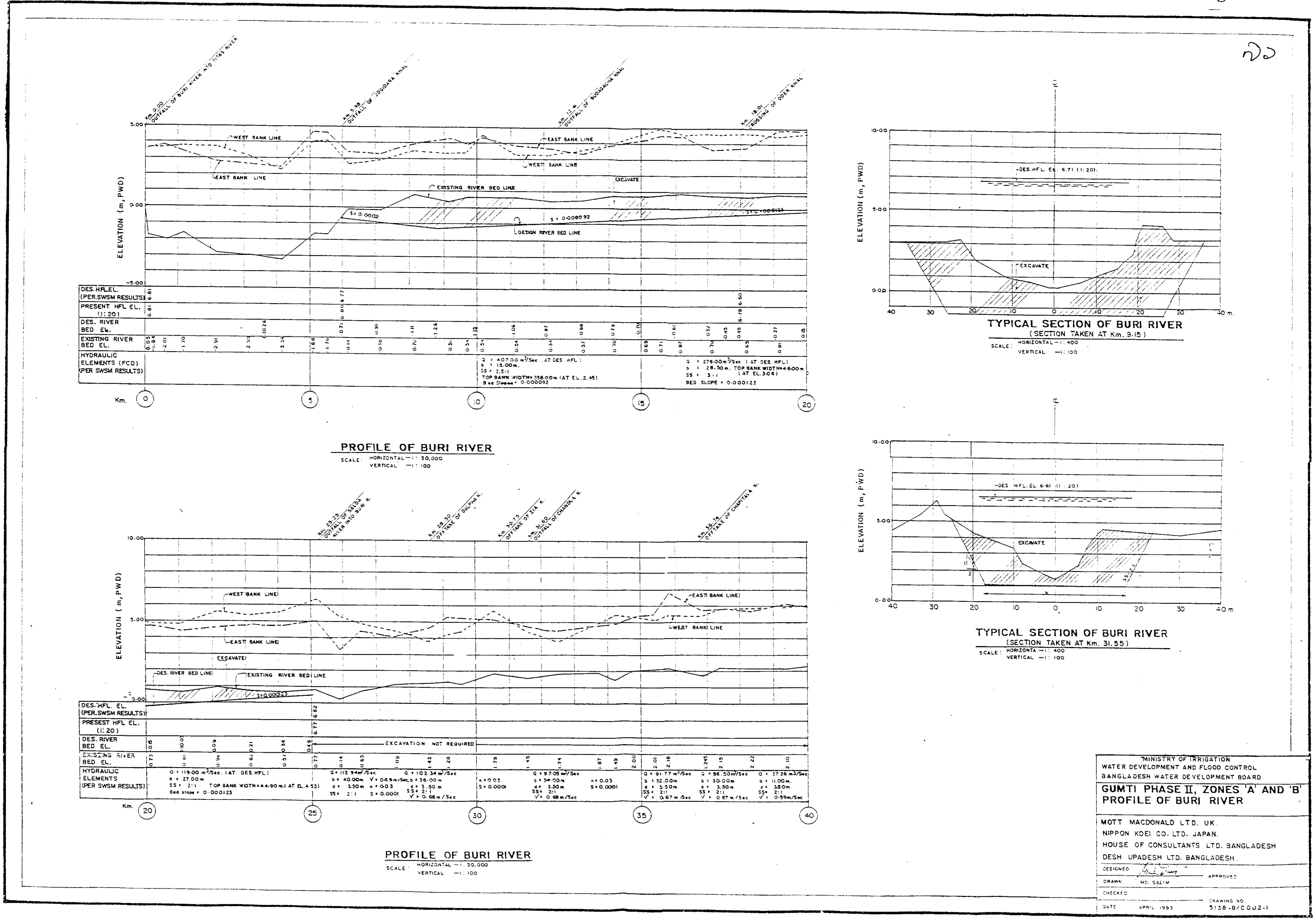
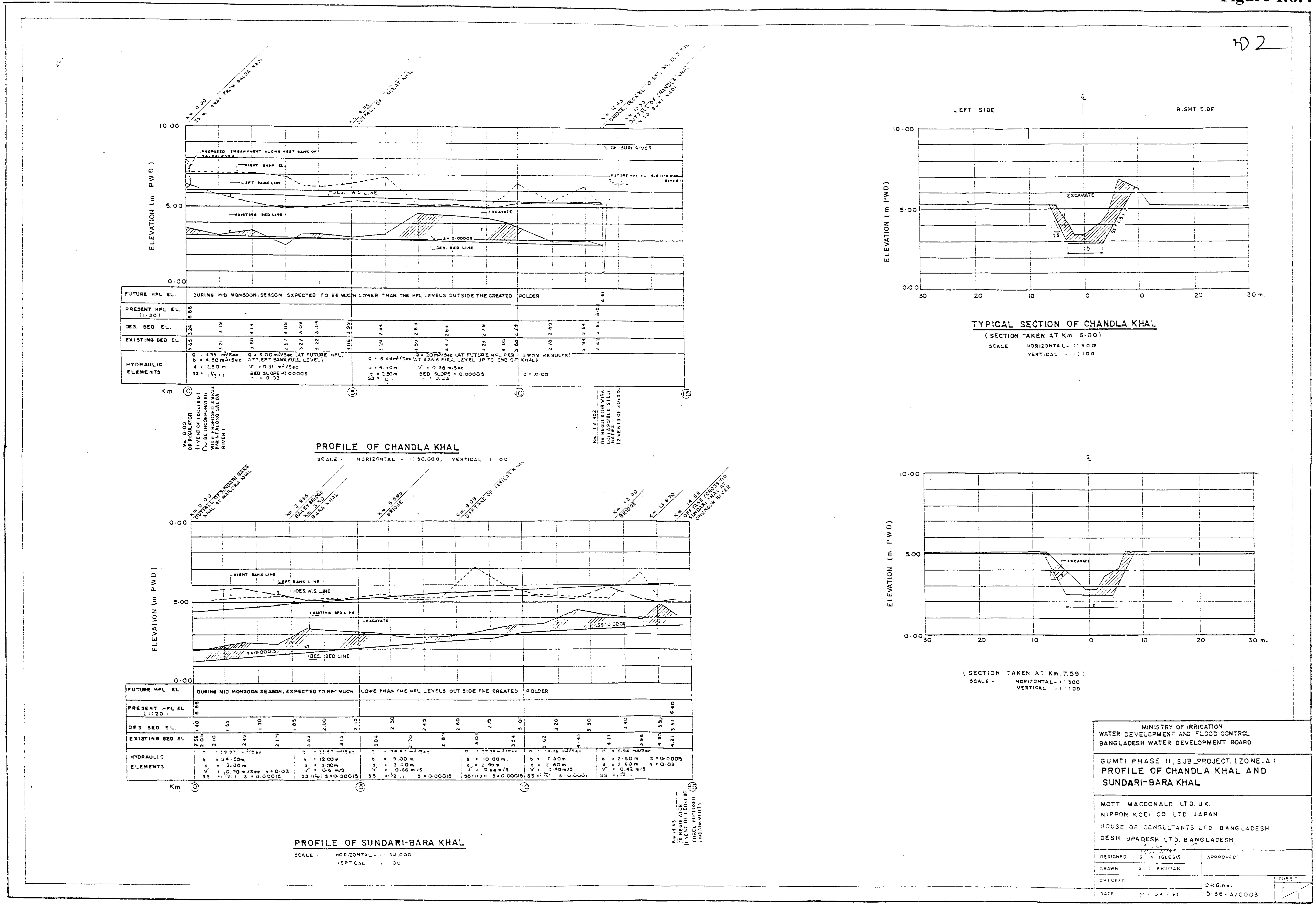

PROFILE OF BURI RIVER
SCALE: HORIZONTAL — 1 : 50,000
VERTICAL — 1 : 100
ELEVATION (m, PWD)
Km. 0.00 OUTFALL OF BURI RIVER INTO TITAS RIVER
Km. 5.98 OUTFALL OF JOGIDARA KHAL
Km. 12.41 OUTFALL OF BUDAGACHA KHAL
Km. 18.01 CROSSING OF ODER KHAL
WEST BANK LINE
EAST BANK LINE
EXISTING RIVER BED LINE
DESIGN RIVER BED LINE
EXCAVATE
DES. HFL EL. (PER SWSM RESULTS)
PRESENT HFL EL. (1:20)
DES. RIVER BED EL.
EXISTING RIVER BED EL.
HYDRAULIC ELEMENTS (FCD) (PER SWSM RESULTS)
Km. 25.25 OUTFALL OF SALDA RIVER INTO BURI R.
Km. 28.50 OFFTAKE OF DALPHA K.
Km. 30.75 OFFTAKE OF ZIA K.
Km. 31.60 OUTFALL OF CHANDLA K.
Km. 36.74 OFFTAKE OF CHAPTALA K.
EXCAVATION NOT REQUIRED
TYPICAL SECTION OF BURI RIVER
(SECTION TAKEN AT Km. 9.15)
SCALE: HORIZONTAL — 1 : 400
VERTICAL — 1 : 100
DES. HFL EL. 5.71 (1:20)
TYPICAL SECTION OF BURI RIVER
(SECTION TAKEN AT Km. 31.55)
SCALE: HORIZONTA — 1 : 400
VERTICAL — 1 : 100
DES. HFL EL. 6.61 (1: 20)
MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
GUMTI PHASE II, ZONES 'A' AND 'B'
PROFILE OF BURI RIVER
MOTT MACDONALD LTD. UK.
NIPPON KOEI CO. LTD. JAPAN.
HOUSE OF CONSULTANTS LTD. BANGLADESH
DESH UPADESH LTD. BANGLADESH.
DESIGNED
APPROVED
DRAWN MD. SALIM
CHECKED
DATE APRIL 1993
DRAWING NO 5138-B/C002-1

Figure I.6.4



PROFILE OF CHANDLA KHAL
SCALE - HORIZONTAL - 1:50,000, VERTICAL - 1:100
TYPICAL SECTION OF CHANDLA KHAL
(SECTION TAKEN AT Km. 6.00)
SCALE: HORIZONTAL - 1:300 VERTICAL - 1:100
LEFT SIDE
RIGHT SIDE
(SECTION TAKEN AT Km.7.59)
SCALE - HORIZONTAL - 1:300 VERTICAL - 1:100
PROFILE OF SUNDARI-BARA KHAL
SCALE - HORIZONTAL - 1:50,000 VERTICAL - 1:100
ELEVATION (m PWD)
FUTURE HFL EL.
PRESENT HFL EL. (1:20)
DES. BED EL.
EXISTING BED EL
HYDRAULIC ELEMENTS
DURING MID MONSOON SEASON EXPECTED TO BE MUCH LOWER THAN THE HFL LEVELS OUTSIDE THE CREATED POLDER
MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
GUMTI PHASE II, SUB_PROJECT. (ZONE.A)
PROFILE OF CHANDLA KHAL AND SUNDARI-BARA KHAL
MOTT MACDONALD LTD. U.K.
NIPPON KOEI CO LTD. JAPAN
HOUSE OF CONSULTANTS LTD. BANGLADESH
DESH UPADESH LTD. BANGLADESH
DRG.No. 5138-A/C003

A number of structures are proposed around the periphery of the protected area as follows:

- four drainage/flushing sluices through the Ghungur embankment, to enable water to be admitted to four of the major khals which presently carry overspill water westwards from the Ghungur River. Farmers within the protected area requested this provision, as in some years the aman crop has insufficient water. Each structure is provided with a single 1.82 m high by 1.52 m wide vertical slide gate on the river side, with a concrete box culvert through the embankment. Figure I.6.5 is a type drawing for these structures.

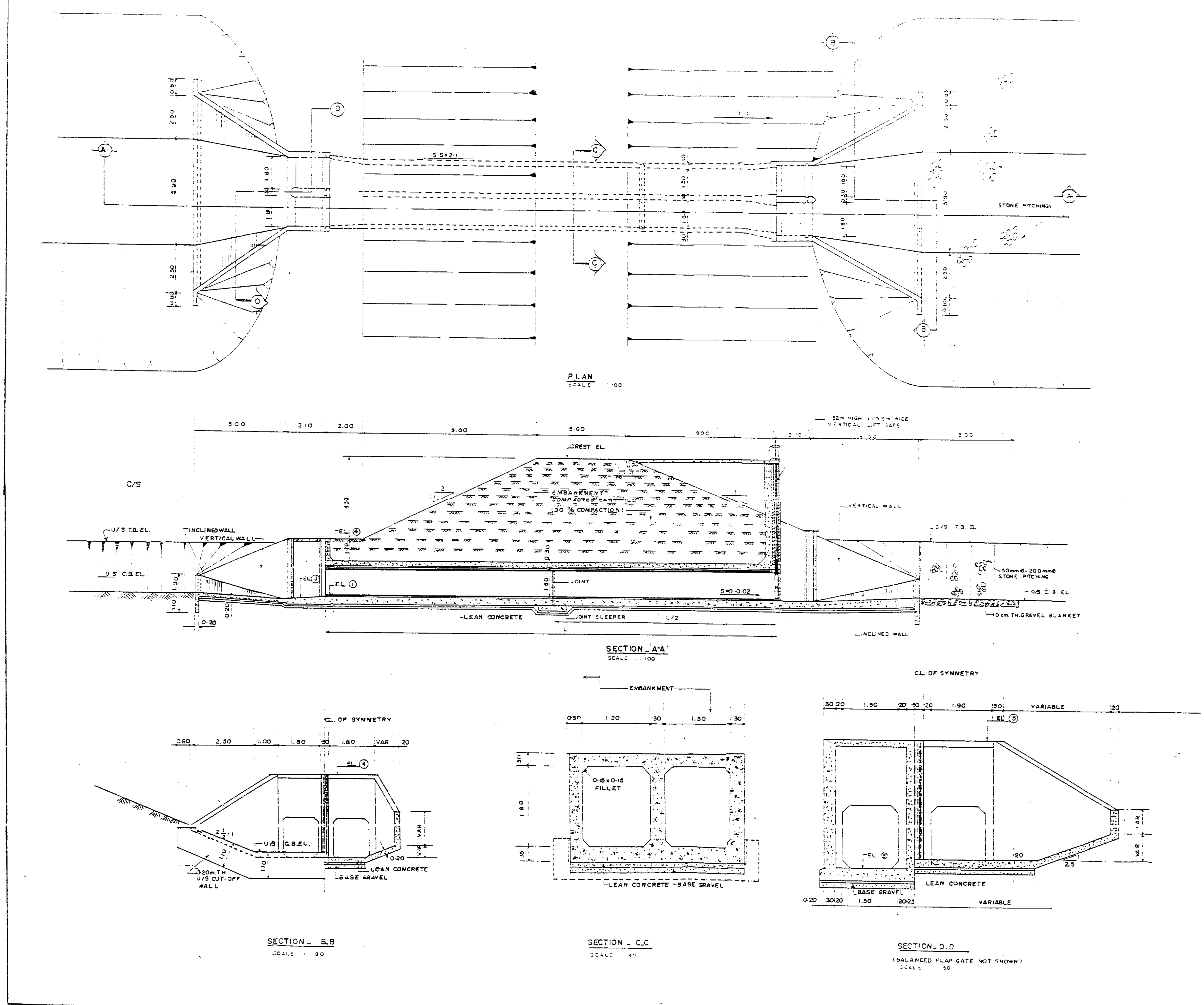
- four larger drainage/flushing regulators where four major channels cross the Comilla-Sylhet highway. Currently there are 20 cross-drainage structures on this road, between the Buri Nadi and the west bank of the Salda River, and all except four will be sealed. The new structures have been designed to be 'fish-friendly', with weir flow and a free water surface through the structure. Two of the regulators have a single 3.5 m high by 3.0 m wide bottom-hinged collapsible gate. The other two have three vents each, the outside positions fitted with 3.5 m by 3.0 m bottom-hinged gates and the central position with a 3.0 m by 3.0 m vertical slide gate. Since fish are believed to move mainly at the edges of channels, the three vent structure gives an optimal combination of the 'fish-friendly' characteristics of the bottom-hinged gates and the robustness and ease of operation of the slide gate. Various issues related to the concept of the fish-friendly gates are discussed in Section I.4.6.1 of this annex. Since these structures are adjacent to the main highway, no bridge decks are needed. They are located a little to the north-west of the highway, and tied to it by link embankments. Figure I.6.6 is a type drawing for these structures.

The whole proposal is substantially in accordance with a joint application made to the Minister, Flood Control and Water Development by seventeen Union Parishad Chairmen on 11 November 1991, for a North Debidwar, Brahmanpara and North Burichang Flood Control and Irrigation Project.

The initial model run showed that the peak water level in the unprotected area to the east of the Ghungur River rose by an additional 0.8 m approximately when the Ghungur left embankment was in place. Further runs showed that if a controlled discharge (40% of peak flow) was allowed into the protected area the additional rise could be significantly mitigated, but at the expense of much of the embankment's benefit. Provision of a second embankment on the eastern bank of the Gunghur was considered as another mitigation option, but this would interfere with the interception and evacuation of run-off from the hills, and entail additional structures which would be difficult to operate equitably, and was accordingly not investigated further.

The best mitigation appears to be given by excavation of the Salda River and Buri Nadi, and this was therefore included within the Zone A proposals, even though the downstream portion of the Buri Nadi is in fact outside the zone. With the flushing sluices along the Ghungur embankment closed, the peak (1987 and 1988) water levels then show an increase of only 30 cm in the "with project" water levels in the unprotected area. If a very severe flood did occur and villages in the unprotected area were being threatened, then opening the Ghungur embankment sluices would lower the water level by 10 cm. However, since these villages are not particularly flood-prone at the moment, it is unlikely that the additional rise will cause significant problems requiring mitigation by flood-proofing measures. In agricultural terms, about 8% of the aman crop in the unprotected area is significantly affected by the increased peak flood depth, but the model shows no additional boro damage.

Figure I.6.5



NOTES
1. ALL CONCRETE SHALL BE CLASS 'A' UNLESS OTHERWISE SPECIFIED
2. ALL DIMENSIONS, UNLESS OTHERWISE SHOWN, ARE IN METERS
3. ALL ELEVATIONS (EL) ARE IN METERS (PWD)
4. ARRANGEMENT FOR 1 VENT SIMILAR
5. ARRANGEMENT SHOWN FOR 1.82m x 1.52m GATES 1.22m x 1.52m SIMILAR

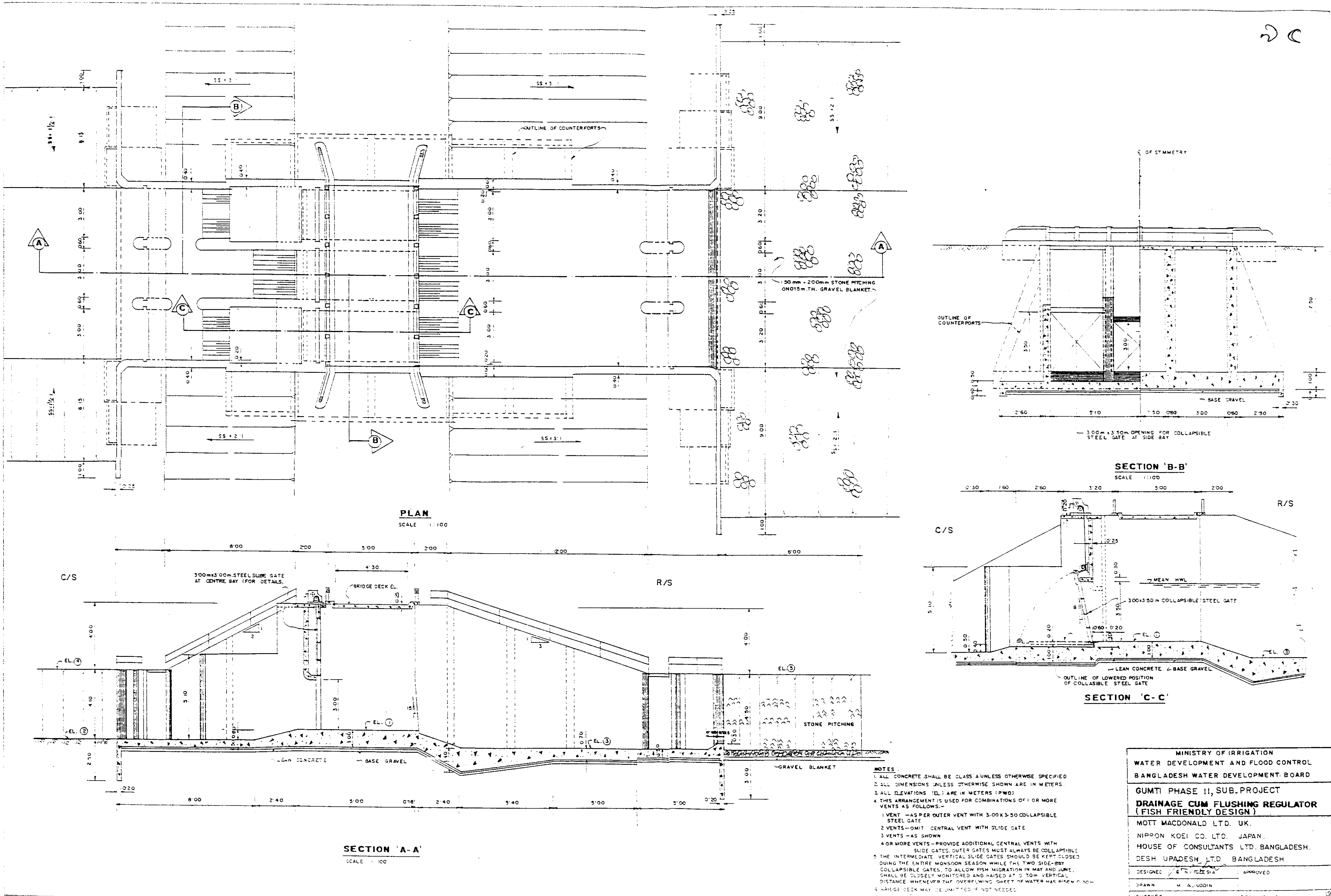
MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD

GUMTI PHASE_II SUB_PROJECT
DRAINAGE CUM FLUSHING SLUICE
(1 OR 2 VENTS)

MOTT MACDONALD LTD. UK
NIPPON KOEI CO. LTD. JAPAN
HOUSE OF CONSULTANTS LTD BANGLADESH
DESH UPADESH LTD. BANGLADESH

DESIGNED: N. ISLAM
DRAWN: S. I. BHUIYAN
CHECKED:
APPROVED:
DATE: 27.05.93
DRAWING NO: 5138-G/TS004

Figure I.6.6



NOTES :

1. ALL CONCRETE SHALL BE CLASS 'A' UNLESS OTHERWISE SPECIFIED
2. ALL DIMENSIONS UNLESS OTHERWISE SHOWN ARE IN METERS.
3. ALL ELEVATIONS (EL.) ARE IN METERS (PWD)
4. THIS ARRANGEMENT IS USED FOR COMBINATIONS OF 1 OR MORE VENTS AS FOLLOWS:-
   - 1 VENT — AS PER OUTER VENT WITH 3.00 X 3.50 COLLAPSIBLE STEEL GATE
   - 2 VENTS — OMIT CENTRAL VENT WITH SLIDE GATE
   - 3 VENTS — AS SHOWN
   - 4 OR MORE VENTS — PROVIDE ADDITIONAL CENTRAL VENTS WITH SLIDE GATES. OUTER GATES MUST ALWAYS BE COLLAPSIBLE
5. THE INTERMEDIATE VERTICAL SLIDE GATES SHOULD BE KEPT CLOSED DUING THE ENTIRE MONSOON SEASON WHILE THE TWO SIDE-BAY COLLAPSIBLE GATES, TO ALLOW FISH MIGRATION IN MAY AND JUNE, SHALL BE CLOSELY MONITORED AND RAISED AT 0.30m VERTICAL DISTANCE WHENEVER THE OVERFLWING SHEET OF WATER HAS RISEN 0.30m
6. BRIDGE DECK MAY BE OMITTED IF NOT NEEDED

MINISTRY OF IRRIGATION, WATER DEVELOPMENT AND FLOOD CONTROL	
BANGLADESH WATER DEVELOPMENT BOARD	
GUMTI PHASE II, SUB-PROJECT	
DRAINAGE CUM FLUSHING REGULATOR (FISH FRIENDLY DESIGN)	
MOTT MACDONALD LTD. UK.	
NIPPON KOEI CO. LTD. JAPAN.	
HOUSE OF CONSULTANTS LTD. BANGLADESH.	
DESH UPADESH LTD BANGLADESH	
DESIGNED	APPROVED
DRAWN M. A. UDDIN	
CHECKED	DRAWING NO 5138-C/C 014
DATE 03-04-93	SHEET 1/1

Indeed, there will be an improvement in flash flood drainage, as the channel excavation is particularly effective in the pre-monsoon season in the absence of any backwater effect from the Pagla at Nabinagar. The agricultural disbenefits are fully accounted for in the economic evaluation.

The estimated capital costs for the intervention at 1992 prices, based upon calculated quantities and the standard unit rates presented in Chapter I.5 of this Annex, are given in Table I.6.1. It has been assumed that the Buri Nadi excavation downstream of the confluence of the Salda River would be carried out by mini-dredger, and elsewhere by hand. The rates include an allowance for compensating farmers for spreading the spoil on their land where it is not required for embankment construction, and no land acquisition for disposal is anticipated. Mechanical compaction of embankment fill material has been specified. A total of about 102 ha of land acquisition has been allowed, primarily for the Ghungur left bank embankment, for which government land is not at present available. Annual O & M costs have been assumed in accordance with the standard percentages set out in Chapter I.5 of this annex, based upon the FPCO Guidelines for Project Assessment. The assumed division between local and foreign currency costs is also in accordance with standard percentages set out in Chapter I.5.

The detailed agricultural benefits are discussed in Annexes E (Agriculture) and J (Financial and Economic Analysis). However the flood control benefits of the recommended options for Zones A and B are illustrated by Figures I.6.7, I.6.8 and I.6.9 (The apparent slight benefits in Zone D should be disregarded as they arise from the limitations of the SERM in representing the proposed Gumti submersible embankment) The first two figures show the percentage of the NCA within each one minute square (1.7 km by 1.85 km) experiencing peak four day duration flood depths in a 1 in 5 wet year of greater or less than 0.9 m (ie the threshhold between flood phases F1 and F2), in the "without project" and "with project" cases respectively. The third figure shows the benefits/changes arising from the project. As well as the significant benefit within the protected area, the increased flood depth to the east of the Ghungur River is apparent. In general terms, this figure indicates the areas which can make a transition between the cultivation of B aman and T aman (local or HYV). Despite the full embanking of the protected area flooding is not completely eliminated, because internal rainfall cannot be drained off under gravity whilst external water levels are high. There is thus still a tendency for water to accumulate in the lower lying areas in the north-west.

It should be pointed out that these figures, based upon peak flood depths, do not give any indication of the reduction in flash flood damage, which in the case of Zone A is a major component of the project benefit. Flash floods in particular damage the valuable boro HYV crop, which has grown in importance following the rapid increase in STW deployment. Significant damage to this crop is reported both from the field and also from BBS statistics for Burichang and Brahmanpara thanas.

Apart from flooding considerations, attention has to be paid to the sediment being brought down from the Tripura Hills by the flashy streams, and its effect upon maintenance requirements. Quantitative estimation of the scale of deposition is difficult owing to the shortage of sediment transport data for these rivers. However, based upon recorded channel re-excavation carried out in the Ghungur, Salda and Buri Nadi, as well as the estimates of catchment sediment yield discussed in Annex B, the volume of silt which needs to be removed each year from these rivers is estimated at 113 000 m^3. The deposition in channels within the protected area will be very much less than previously, and for feasibility study purposes an overall figure of 6% of capital cost per annum for channel excavation maintenance, as recommended in the FPCO Guidelines, has been adopted as reasonable.

Figure I.6.7

Without Project 1 in 5 year Peak Flood Phasing

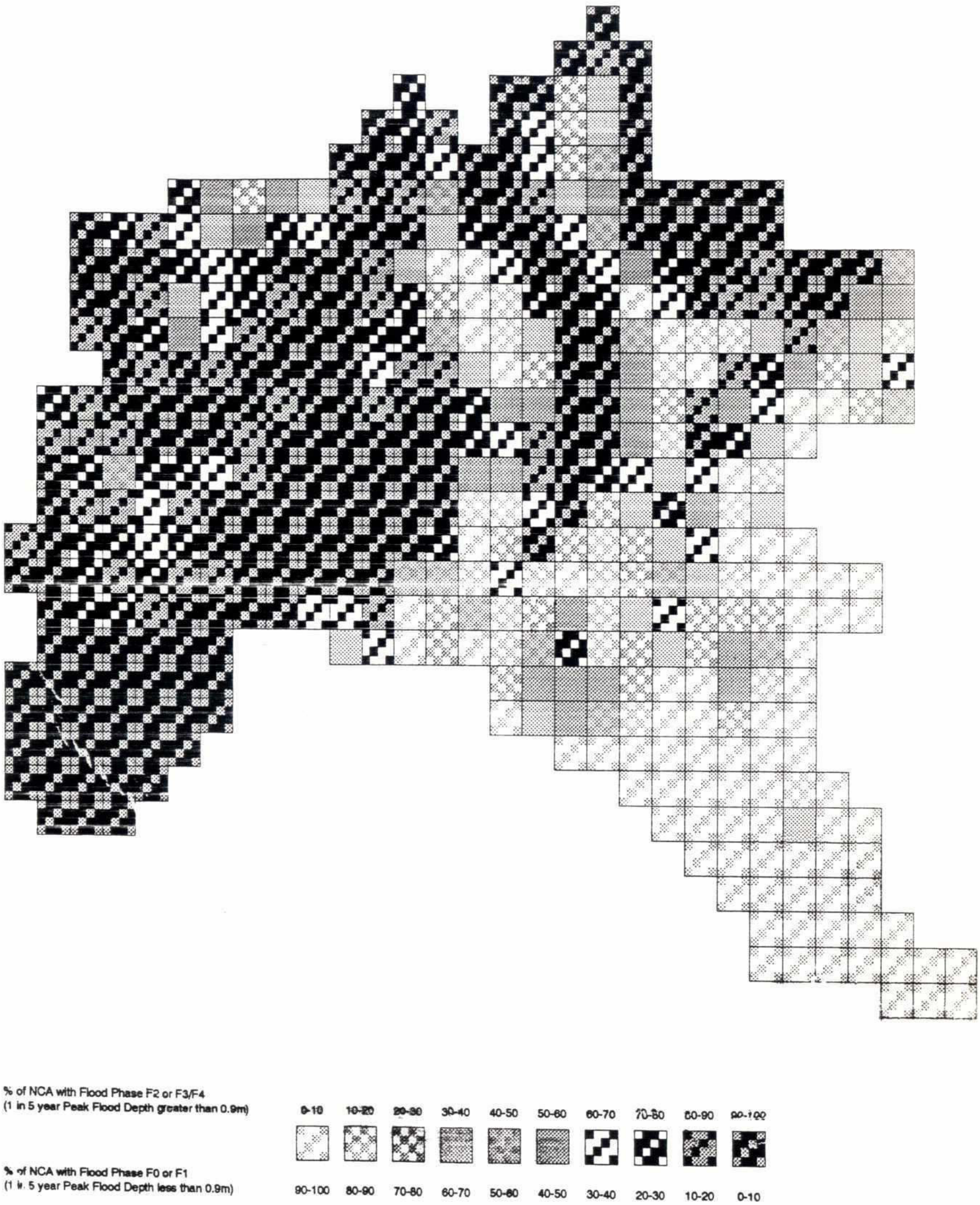
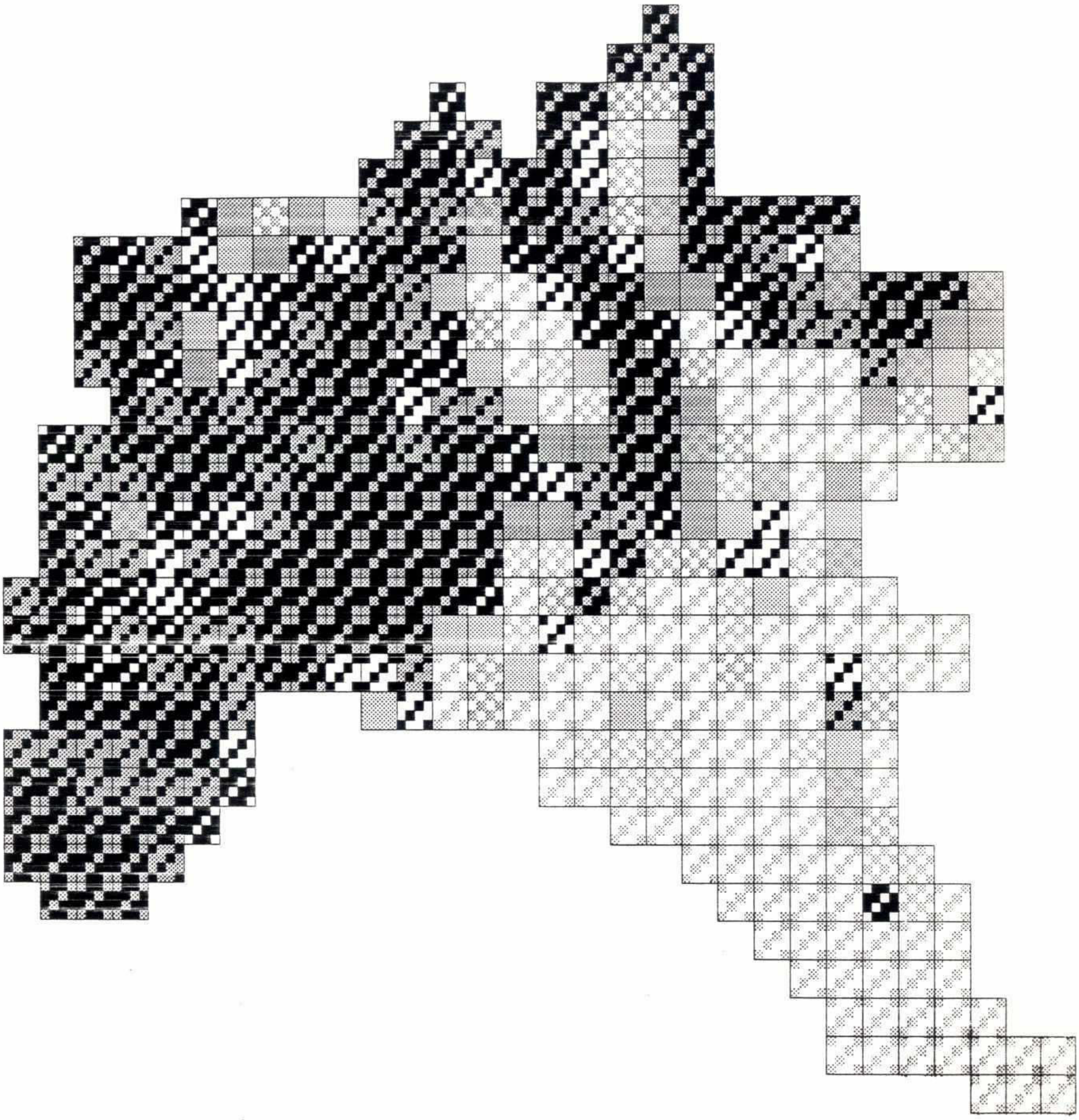


Figure I.6.8

With Project 1 in 5 year Peak Flood Phasing



% of NCA with Flood Phase F2 or F3/F4 (1 in 5 year Peak Flood Depth greater than 0.9m)	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100
% of NCA with Flood Phase F0 or F1 (1 in 5 year Peak Flood Depth less than 0.9m)	90-100	80-90	70-80	60-70	50-60	40-50	30-40	20-30	10-20	0-10

Figure I.6.9

Change in 1 in 5 year Peak Flood Phasing

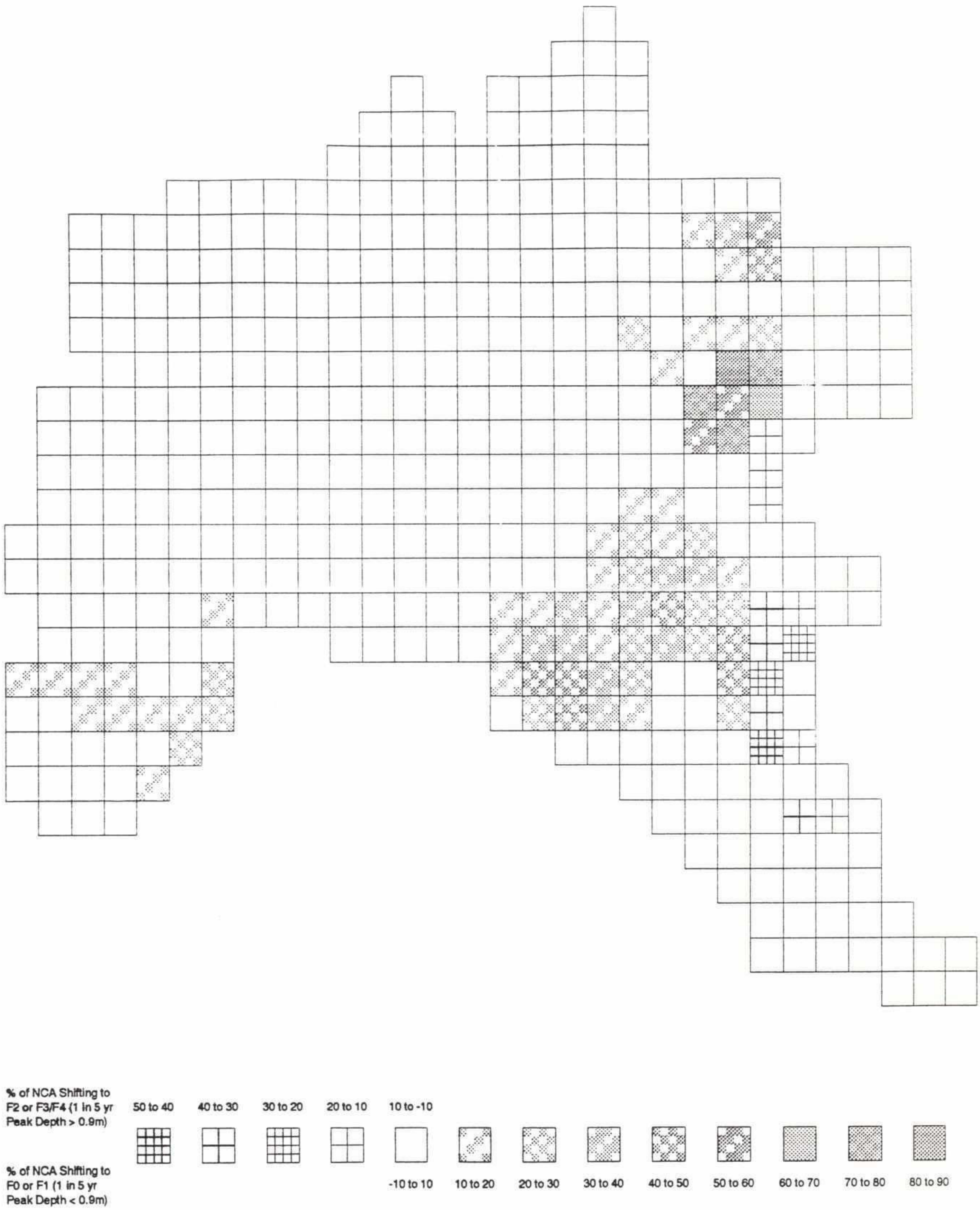


TABLE I.6.1

Capital Costs of the Zone A Scheme

	Description	Unit	Quantity	Unit Rate (Tk)	Cost (Tk 000)
1	Flood embankment				
	- Clearing, Grubbing & Stripping	sq.m	648 000	3	1 944
	- Channel Excav. and Formation of Emb. (Manual Excav./Mechanical Comp.)	cu.m	988 000	42	41 496
	- Turfing	sq.m	680 000	3	2 040
2	Channel excavation & Spreading				
	- Manual (transport 50 m)	cu.m	2 230 000	28	62 440
	- Mini-Dredger (transport 500 m)	cu.m	688 000	50	34 400
3	New regulators				
	- 1 Nr Vent 3.5m x 3.0m (fish-friendly)	Vent	2 x 1	8 500 000	17 000
	- 3 Nr Vents 3.5m x 3.0m (fish-friendly)	Vent	2 x 3	4 700 000	28 200
	- 1 Nr Vent 1.82m x 1.52m	Vent	4 x 1	2 000 000	8 000
4	Buildings	Existing facilities at Comilla			0
5	Vehicles	Nr	1	1 000 000	1 000
6	Land Acquisition				
	- Agricultural	ha	100	375 000	37 500
	- Homestead	ha	1.7	1 617 800	2 750
	Sub-Total				236 770
	Physical contingencies 15%				35 516
	Sub-Total including contingencies				272 286
	Engineering service cost 12%				32 674
	Total Project Cost				304 960
	Made up of - Local Currency				253 628
	- Foreign Currency				51 332

(h) Compartmentalisation in Zone A

Conventional FCD schemes can have the drawback of causing over-drainage in the upper reaches of the internal drainage system and under-drainage or even no drainage improvement in the lower reaches near the outfall. The over-drainage is often alleviated by providing flushing sluices to admit water from outside the protected area in the upper reaches, but in so doing the drainage problem in the lower areas is often made worse, particularly in the absence of any integrated operation procedures.

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Compartmentalisation aims to divide the protected area into small manageable drainage units or compartments, each of fairly uniform elevation, separated by low embankments. Wherever possible, the embankments follow the existing road network. The drainage of each compartment is controlled according to local requirements, by means of structures through the embankments. Additional water may also still be admitted from outside the protected area if required, via flushing sluices. Compartmentalisation has in fact been practised for many years in Bangladesh, but is currently undergoing a process of refinement and development, now that hydrodynamic models are becoming available with sufficient power to perform the required analyses.

The system has a number of benefits as follows:

- over-drainage is arrested, and surplus water is distributed more uniformly over the protected area, rather then gravitating immediately to the downstream end. The area flooded to an optimal depth for agriculture is thus increased,
- the total area flooded, albeit to a shallow depth, is increased, with benefits to fisheries and groundwater recharge,
- any breach in the peripheral embankment are initially contained by the neighbouring compartments, attenuating the effects downstream,
- farmers have more flexibility to flood their land in a controlled manner if they require, for instance for supplementary irrigation,
- migratory fish may enter the compartments if fish-friendly structures are provided, and benefit from the more stable water regime,
- maintenance of water levels in channels may extend the period during which they are navigable by small boats,
- better flushing of pollution, and
- the flushing sluices may be used during the dry season as sites for grouped LLPs or larger pumps, with the internal network of channels and structures assisting in the distribution and control of irrigation water.

The concept is particularly applicable to areas with a significant slope, and within the project area, the Zone A flood control scheme best matches this description. Within the protected area the elevation varies from about 7.0 m above PWD in the south-east to 4.5 m only 13 km away in the north-west, giving an average ground slope of 13 cm/km. This results in over-drainage in the south-eastern and a rapid accumulation of excess run-off in the north-west. There are many existing roads across the drainage path which would be suitable as compartment boundaries. Six possible compartments have been identified in Figure I.6.1, including suitable drainage control structure locations. None of these works has been included in the analysis either of the costs or the benefits of the Zone A scheme, which is viable without compartmentalisation. However, it is recommended that a decision be taken on whether or not to incorporate this concept at the detailed design stage, by which time FAP 20 (Compartmentalisation Pilot Project) should have reached its final conclusions.

I.6.3.3 Zone B

(a) Background

A map of Zone B is presented in Figure I.6.10. The northern boundary is formed by the Upper Titas and Howrah Rivers. To the west is the Salda River and the northern section of the Buri Nadi (sometimes these together with the Ghungur are referred to as the Nalia River) which separate the area from Zones A and C. To the east is the Indian border and the Tripura Hills. The zone comprises Kasba thana and parts of Nabinagar and Akhaura. Kasba thana is considered to be representative of the major western part of the zone, and Akhaura of the area to the east of the Bijni River. The gross area of the zone is 26 782 ha and the NCA 22 412 ha.

Public Participation Meetings within the zone identified the following problems:

- damage caused by flash floods originating in the Tripura Hills to the east,
- a shortage of water for irrigation during the dry season,
- flooding of the boro and aman HYV crops, and
- poor drainage (although this was primarily just outside the project area in Akhaura).

(b) Dry Season Situation

The dry season cropping pattern is predominantly based on the cultivation of boro HYV (about 70% of the NCA according to information received in four villages visited). The distribution is largely determined by the availability of irrigation, although some small areas of boro can survive on standing water and residual moisture in the low-lying land near rivers. In Akhaura, boro HYV is irrigated mainly by LLPs abstracting water from the channel network flowing into the Upper Titas River. In Kasba, over half of the irrigation is based upon groundwater, with significant increases in STW development in recent years, according to the Agriculture Sector Team Census of Lift Irrigation. The distribution of the various modes of irrigation is shown in Figures I.2.1 to I.2.5 of Chapter I.2. Pulses, oilseeds and winter vegetables are the main non-rice rabi crops, with very little wheat.

(c) Surface Water Resources

The dry season surface water resources of Zone B are found primarily in the Upper Titas and to a lesser extent the Buri, Salda, and Howrah Rivers. The dry season flows in the minor channels are meagre and could not support any major development, and are already being utilised by farmers with LLPs.

The resources of the Upper Titas are more substantial, since the water level is more or less fixed by the Upper Meghna at an average minimum level of about 1.5 m above PWD, with backflow available upstream to a point midway between the Buri and Bijni outfalls. Some backflow is also available in the Buri Nadi, but at present abstraction can reliably take place only up to about 6 km south of Nabinagar.

Figure I.6.10

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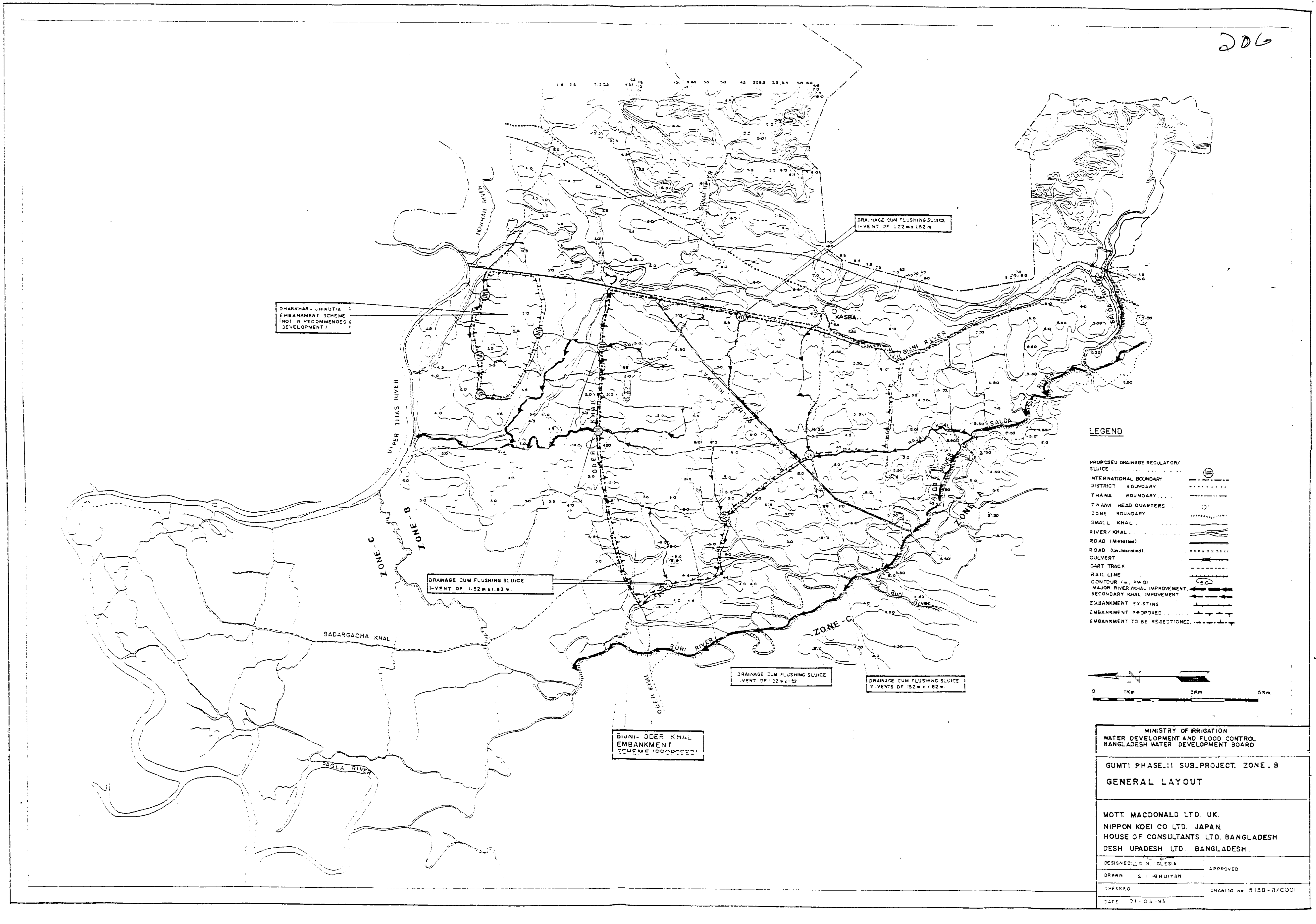


The Upper Titas resources could perhaps best be drawn upon by floating pump stations, but the type of floating pump presently being used in Bangladesh is very costly and not economically attractive. A cost effective alternative needs to be developed.

Such schemes could be supported by the National Irrigation Development Project (NMIDP).

(d) Groundwater Resources

The central part of Zone B has quite a high density of DTWs, to the north-west of Kasba and also just north of Oder Khal, located mainly on higher ground. There is also a relatively high density of STWs, although part of the area to the north of the Oder Khal suffers from gas pockets in the aquifer, which affect the operation of suction mode units. To date there has been little need for the deep setting of STWs in the area, suggesting that there are no major problems with declining water tables at the end of the dry season.

In a limited area in the south-east of the zone, immediately adjacent to the high ground of the Tripura Hills, artesian conditions are encountered, and many farmers have taken advantage of the freely available water which emerges from boreholes without pumping.

A fuller discussion of groundwater resources throughout the project area is presented in Annex C (Groundwater Investigations).

(e) Monsoon Season

Thana data for the zone show a substantial coverage of B aman of between 30% and 40% of the NCA. Significant areas of B aus are also reported, presumably in parts unsuitable for B aman. Very little T aman HYV is grown although approximately 20% of the area supports a T aman LV crop which is tolerant of slightly deeper flooding.

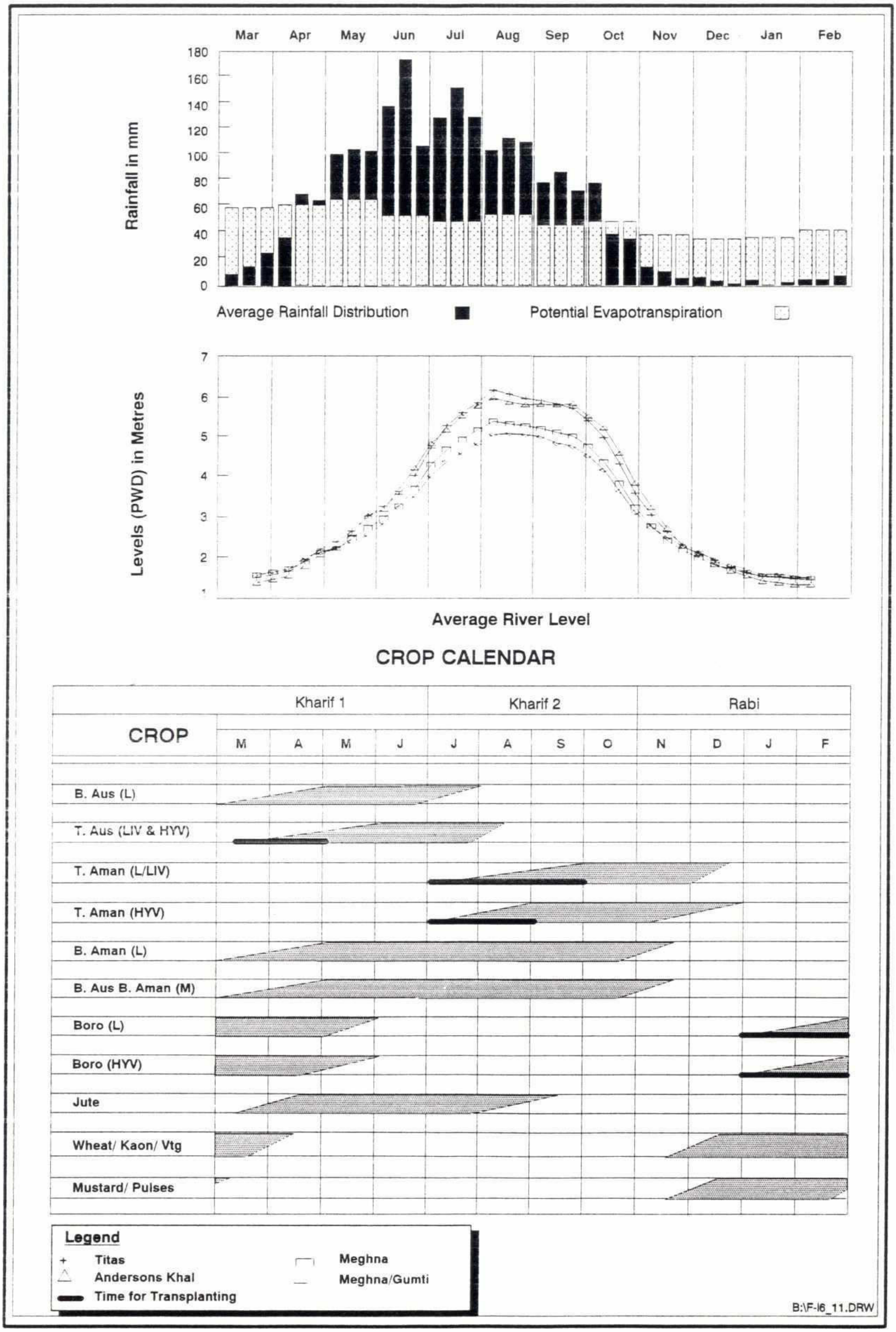
These basic monsoon crop planting characteristics are indicative of the flood regime of the zone, and are supported by Figure I.6.7. Much of the area is virtually surrounded by major river channels, and during the monsoon season, only the southern and central spine areas and the eastern foothils are free from flooding. Most of the agricultural land lies between elevations 4.7 m to 6.2 m above PWD, and monsoon season water levels are dominated by the River Meghna from about June onwards. The relationship between the average main river levels and the cropping calendar is illustrated by Figure I.6.11.

Factors such as the rate of water level rise as well as sediment content can also influence crop damage, the former being especially important. The B aman crop in particular is also liable to damage by high horizontal flow velocities.

(f) Development Possibilities

The south and west portion of the zone consists of the low-lying Salda/Buri Nadi flood plain. At the southern end it is characterised by spill channels from the Bijni River which cross in a westerly direction. No immediate flood control embankment measures are recommended in this portion of the zone, as these would tend to prevent further land accretion as well as causing unacceptable water level rises upstream. Embankments on both sides

Figure I.6.11
Relationship Between Crops, Rainfall and Floods



of the Salda River may also induce deposition between the embankments, raising the berm and bed levels, causing serious drainage congestion within the protected area. Pre-monsoon flash floods are particularly damaging, but significant improvement should result from the excavation of the Buri Nadi and Salda channels proposed in connection with the Zone A development. This excavation should also permit additional LLP irrigation from the Buri Nadi, through backflow from the Upper Titas (or Pagla) River. Raja Khal may beneficially act as a flood bypass channel to supplement the capacity of the Salda River, and excavation of this channel has therefore been included in the proposed scheme for Zone B.

The portion of the zone marked as the Bijni-Oder Khal Embankment Scheme is relatively flat, mostly lying between 5.0 m and 6.0 m above PWD. It is well served in terms of communications by the Comilla-Sylhet highway, which crosses it diagonally. It is very intensively irrigated at present, and has good potential for further groundwater development, with no apparent need at present for deep setting of STWs. There are also no constraints on DTW development, if this needs to be expanded. The proposed FCD embankment scheme should therefore prove very beneficial both in permitting a shift towards T aman (HYV or LV) during the monsoon and in encouraging further irrigation development in the dry season, secure from pre-monsoon flash flooding.

Bounded by the Upper Titas River, the Comilla-Sylhet highway and the western branch of the Bijni River is a virtual island of some 1 500 ha. It has significant STW and DTW development, whilst LLPs draw from the peripheral rivers. Monsoon season flooding is the main problem but to address this would require a long perimeter embankment. Only about 70% of the land is above the 4.5 m contour (PWD) with perhaps 20% higher than 5.0 m. There is however a ring of existing roads available, constructed to above the normal flood level, with top width varying from 2 m to 4 m. The Dharkar-Jhikutia embankment scheme was considered as indicated in Figure I.6.10, based upon upgrading these roads for full flood control, with gated structures at existing bridges to facilitate flushing and drainage. The south-eastern embankment would also need protection from wave action, according to local people. The area outside the embankment would continue to be dependent primarily upon dry season cropping, through development of groundwater and LLP irrigation facilities. Inside the embankment a shift towards T aman (HYV or LV) was anticipated, as for the proposed Bijni-Oder Khal Embankment Scheme. However, model runs showed that very little agricultural benefit was actually achieved, because the elevation is relatively low and drainage is impeded by external water levels even in the pre-monsoon season.

The remainder of the area to the north of Oder Khal has been considered as a unit for possible developments. It includes an area which is strictly part of Zone C, as shown in Figure I.6.10. Most of the area has groundwater potential, but gas problems tend to inhibit STW development. However, the introduction of force mode tubewells, as discussed in Annex C (Groundwater Investigations) could significantly extend the availability of irrigation. As discussed in Section (c) above (Surface Water Resources), there is a potential for floating pump schemes drawing from the Upper Titas River and the Buri Nadi (after the excavation included in the Zone A proposals). Some 43 km of khal excavation are proposed in the Master Plan Study on the Model Rural Development Project Phase II for Kachua, Nabinagar, Bancharampur and Debidwar Upazilas (LGEB/JICA, December 1991), aimed at extending irrigation to some 1 800 ha, apparently relying upon gravity inflow from the major rivers. Very heavy annual maintenance is however likely to be necessary to clear the silt accumulating during each monsoon season. The central part of this area is formed by a relatively higher spine sloping down to the river channels on either side. Most of the agricultural land here lies in the elevation range 4.5 m to 5.3 m above PWD. The main access track is down the central spine alongside Badargacha Khal. This khal has many channels offtaking from it on both sides. There is no real opportunity to use any existing embankments to form the basis of any flood protection works. Submersible embankments could be considered for the protection of the developing aman crop, but relatively high embankments would need to be built on lower land, along alignments where there are no existing roads which could be adopted for upgrading. Moreover, as reported by the local people and the Thana Nirbahi Officer, Nabinagar there is high wave action in the north-western periphery along the Buri-Pagla-Upper Titas Rivers which would necessitate prohibitively costly maintenance.

The catchments of the Sonai and Howrah Rivers and the lower reaches of the Bijni River, in the north-east of the zone, consist of undulating mounds and depressions, which appear from the analysis in Section I.1.2.2 to be undergoing an active process of erosion and deposition. The Howrah River carries significant base flows, which are being used by local people for irrigation. They normally construct eight earthen cross-dams to facilitate abstraction. A feasibility study for improving the Howrah River was started in 1989 but could not be continued due to shortage of funds. It is recommended that this study, which covered an area straddling the boundary of the present study, be resumed in the future. Meanwhile, it is suggested that a programme of water level, discharge and sediment sampling should be instituted. It is not considered practical to re-excavate the Bijni River to admit water for LLP irrigation, as the bed level of the Titas is too high at the Bijni outfall for a dependable flow to be admitted. The capital cost and maintenance requirement for re-excavation of both the Bijni and the Titas Rivers would make any LLP scheme much less viable than tubewell development.

The remainder of the zone, to the south of Kasba and east of the Bijni River, does not appear to present any major development opportunities. During the public participation meetings, villagers complained of poor drainage to the east of the railway line, due to inadequate cross-drainage provisions. Any works to alleviate this problem would have to be designed and constructed by Bangladesh Railways.

(g) The Zone B Scheme

The recommended development for Zone B consists primarily of the Bijni-Oder Khal Embankment Scheme, as discussed above. The layout is shown in Figure I.6.10, and at a larger scale in the separate album of drawings. The protected area is 5 000 ha gross (4 184 ha NCA). The embankment alignment has been selected to make the maximum use of existing road and other embankments as follows, working clockwise from the north-west corner:

- along the southern bank of Oder Khal, an existing embankment is being upgraded (10 km),
- the northern portion against the Bijni River follows the existing Comilla-Sylhet highway, and allowance has been made for reinforcing this by building an additional composite embankment on the eastern side up to 1 m above road level, with a drainage ditch between (1 km),
- south of the Comilla-Sylhet highway is an existing unmetalled road alongside the Bijni River, which will be upgraded to full embankment level (10 km),
- the southern portion of the road alongside the Bijni River has already been upgraded and no further work is required (3 km),
- along the southern boundary of the protected area an existing cart track is to be upgraded (3 km),

- for the southern portion along Raja Khal, a new embankment is required (2.5 km),

- for the middle portion along Raja Khal, north of the Comilla-Sylhet highway crossing, an existing spoil bank used as a cart track is to be upgraded (5 km), and

- a new embankment is required for the northern portion alongside Raja Khal (3 km).

The embankment top is to have an elevation of 1.0 m above the 1:20 year flood level.

Six drainage/flushing sluices are provided around the embankment where it crosses significant existing channels. All are fitted with vertical slide gates on the unprotected side, with a concrete box culvert through the embankment. Two have single vents of size 1.22 m high by 1.52 m wide, three have single 1.82 m by 1.52 m vents and the other has two 1.82 m by 1.52 m vents. A type design is given in Figure I.6.5.

To improve the internal drainage of the protected area, 45 km of khal excavation has been allowed for, including outfall channels to the Upper Titas River and 10 km of Oder Khal. It was found from modelling that Raja Khal may beneficially act as a flood bypass channel to supplement the capacity of the Salda River, and excavation of 12.5 km of this channel has therefore also been allowed for. The benefits are also dependent upon the excavation of the Salda and Buri Nadi channels as already included in the Zone A recommended scheme.

The estimated capital costs for the intervention at 1992 prices, based upon calculated quantities and the standard unit rates presented in Chapter I.5 of this Annex, are given in Table I.6.2. It has been assumed that all excavation will be carried out by hand. The rate includes an allowance for compensating farmers for spreading the spoil on their land where it is not required for embankment construction, and no land acquisition for disposal is anticipated. Mechanical compaction of embankment fill material has been specified. A total of about 35 ha of land acquisition has been allowed, primarily for the reaches of new embankment. Annual O & M costs have been assumed in accordance with the standard percentages set out in Chapter I.5 of this annex, based upon the FPCO Guidelines for Project Assessment. The assumed division between local and foreign currency costs is also in accordance with standard percentages set out in Chapter I.5.

The detailed agricultural benefits are discussed in Annexes E (Agriculture) and J (Financial and Economic Analysis). However the flood control benefits of the recommended options for Zones A and B are illustrated by Figures I.6.7, I.6.8 and I.6.9, as already discussed in Section I.6.3.2(g) above. The primary benefit is in enabling a shift from B aman to T aman (HYV or LV) during the monsoon, with a secondary benefit of improved security of the boro crop from flash floods. The embankments themselves will provide improved access around the area and to the Comilla-Sylhet highway. An additional benefit of the required excavation of the Buri Nadi is the additional irrigation which can take place within Zone B. An adequate depth of water for pumping cannot at present be relied upon more than about 6 km upstream of Nabinagar, but it is estimated that with the project a further 14 km of channel will hold water throughout the dry season, allowing a further 2 800 ha of LLP irrigation.

Since the recommended schemes for Zones A and B are closely related through their common need for excavation of the Buri River, they are treated as one for the purposes of economic analysis.

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TABLE I.6.2

Capital Costs of the Zone B Scheme

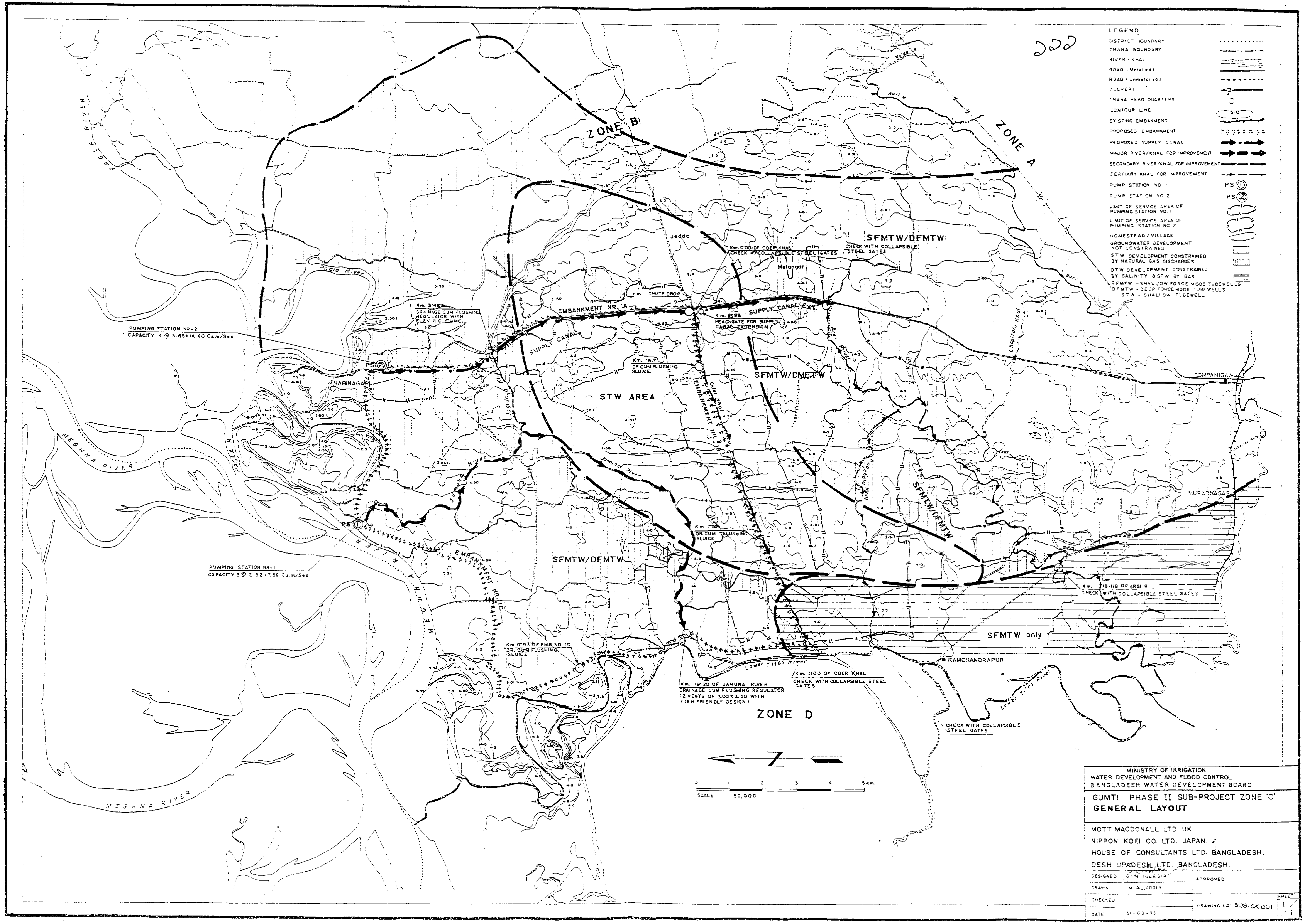
	Description	Unit	Quantity	Unit Rate (Tk)	Cost (Tk 000)
1	Flood embankment				
	- Clearing, Grubbing & Stripping	sq.m	631 300	3	1 894
	- Channel Excav. and Formation of Emb.	cu.m	713 650	42	
	(Manual Excav./Mechanical Comp.)				29 973
	- Turfing	sq.m	63 900	3	192
2	Channel excavation & Spreading				
	- Manual (transport 50 m)	cu.m	90 500	28	2 534
3	New Drainage/Flushing Sluices				
	- 2 Nr Vent 1.82m x 1.52m	Vent	1 x 2	1 700 000	3 400
	- 1 Nr Vent 1.22m x 1.52m	Vent	2 x 1	1 600 000	3 200
	- 1 Nr Vent 1.82m x 1.52m	Vent	3 x 1	2 000 000	6 000
4	Buildings	Existing facilities at Brahmanbaria			0
5	Vehicles	Nr	1	1 000 000	1 000
6	Land Acquisition				
	- Agricultural	ha	34.3	375 000	12 863
	- Homestead	ha	0.61	1 617 800	987
	Sub-Total				62 042
	Physical contingencies 15%				9 306
	Sub-Total including contingencies				71 349
	Engineering service cost 12%				8 562
	Total Project Cost				79 910
	Made up of - Local Currency				66 788
	- Foreign Currency				13 122

I.6.3.4 Zone C

(a) Background

A map of Zone C is presented in Figure I.6.12. The northern boundary is formed by the Pagla River (as the downstream portion of the Upper Titas River is called in this reach). To the east is the Buri Nadi, which separates the zone from Zones A and B. The north-eastern portion of the zone, east of the Buri Nadi and enclosed by a loop of the Pagla River, has more conveniently been shown on the map of Zone B (Figure I.6.10) and has been discussed in conjunction with that zone. To the west is Zone D, with the Lower Titas River marking most of the boundary. The zone includes parts of Nabinagar thana in the north and Muradnagar in the south, and covers a total area of 41 400 ha gross, 35 040 ha NCA.

Figure I.6.12


LEGEND
DISTRICT BOUNDARY
THANA BOUNDARY
RIVER / KHAL
ROAD (Metalled)
ROAD (Unmetalled)
CULVERT
THANA HEAD QUARTERS
CONTOUR LINE
EXISTING EMBANKMENT
PROPOSED EMBANKMENT
PROPOSED SUPPLY CANAL
MAJOR RIVER/KHAL FOR IMPROVEMENT
SECONDARY RIVER/KHAL FOR IMPROVEMENT
TERTIARY KHAL FOR IMPROVEMENT
PUMP STATION NO. 1
PUMP STATION NO. 2
LIMIT OF SERVICE AREA OF PUMPING STATION NO. 1
LIMIT OF SERVICE AREA OF PUMPING STATION NO. 2
HOMESTEAD / VILLAGE
GROUNDWATER DEVELOPMENT NOT CONSTRAINED
STW DEVELOPMENT CONSTRAINED BY NATURAL GAS DISCHARGES
DTW DEVELOPMENT CONSTRAINED BY SALINITY & STW BY GAS
SFMTW - SHALLOW FORCE MODE TUBEWELLS
DFMTW - DEEP FORCE MODE TUBEWELLS
STW - SHALLOW TUBEWELL
ZONE A
ZONE B
ZONE D
SFMTW/DFMTW
SFMTW/DMTW
STW AREA
SFMTW only
PUMPING STATION NR-2
CAPACITY 4 @ 3.65=14.60 Cu.m/Sec
PUMPING STATION NR-1
CAPACITY 3 @ 2.52=7.56 Cu.m/Sec
EMBANKMENT NR. 1A
EMBANKMENT NR. 1C
SUPPLY CANAL
SUPPLY CANAL EXT.
CHUTE DROP
Km. 3+467
DRAINAGE CUM FLUSHING REGULATOR WITH ELEV. R.C. FLUME
Km. 0+00 OF ODER KHAL
CHECK W/COLLAPSIBLE STEEL GATES
CHECK WITH COLLAPSIBLE STEEL GATES
Km. 25+95
HEAD GATE FOR SUPPLY CANAL EXTENSION
Km. 1+67
DR.CUM FLUSHING SLUICE
Km. 7+50
DR.CUM FLUSHING SLUICE
Km. 17+93 OF EMBNO. 1C
DR.CUM FLUSHING SLUICE
Km. 19+20 OF JAMUNA RIVER
DRAINAGE CUM FLUSHING REGULATOR (2 VENTS OF 3.00X3.50 WITH FISH FRIENDLY DESIGN)
Km. 11+00 OF ODER KHAL
CHECK WITH COLLAPSIBLE STEEL GATES
Km. 18+118 OF ARSI R.
CHECK WITH COLLAPSIBLE STEEL GATES
MEGHNA RIVER
PAGLA RIVER
Pagla River
Jamuna River
Lower Titas River
Jeddo
Metangar
NABINAGAR
COMPANIGANJ
MURADNAGAR
RAMCHANDRAPUR
SCALE 1:50,000
0 1 2 3 4 5 Km
MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
GUMTI PHASE II SUB-PROJECT ZONE 'C'
GENERAL LAYOUT
MOTT MACDONALL LTD. UK.
NIPPON KOEI CO. LTD. JAPAN.
HOUSE OF CONSULTANTS LTD. BANGLADESH.
DESH UPADESH LTD. BANGLADESH.
DESIGNED
APPROVED
DRAWN
CHECKED
DRAWING NO. 5138-C/C001
DATE 31-03-93

Public Participation Meetings identified the following problems within the area:

- shortage of water for irrigation during the dry season,
- damage caused to HYV crops by flooding in the pre-monsoon period, and
- poor drainage.

During the course of field surveys, local farmers reported insecurity of irrigation water supply as their main problem, and gave less emphasis to flooding, although it is apparent that the monsoon season cropping is in fact severely constrained by the flooding regime. The basic cropping pattern is irrigated boro or non-irrigated wheat in the dry season, followed by B aman and/or B aus in the monsoon season, with a fairly small area of T aman (LV).

The Nabinagar-Companiganj feeder road forms a natural divide in the pre- and post-monsoon, with the area to the west draining to the Lower Titas, and to the east to the Buri Nadi. Crossing the zone from east to west, linking the Buri Nadi and the Lower Titas, are the Jamuna River, Jogidara Khal, Oder Khal and the Arsi River. These channels have minimal dry season flows and suffer from sedimentation. During the monsoon season, however, they have an important role not only in draining the zone itself, but also in conveying towards the Meghna runoff from the Tripura Hills in the east, and even spillage short-cutting across the project area from the Upper Titas River. The monsoon season drainage direction is thus primarily from north-east to south-west.

(b) Dry Season Situation

The dry season cropping is of particular importance in this zone, since during the monsoon season only a B aman crop (if that) can be grown over much of the area. The distribution of boro is determined largely by the availability of irrigation. Thus in the north, where LLPs can draw from the channels leading from the Meghna and Pagla Rivers, significant areas are grown. BBS statistics indicate that about 40% to 45% of the NCA in Nabinagar supports a boro HYV crop. In the centre of the zone, surface water resources become very sparse and unreliable, whilst STW development is often constrained by gas problems. Thus the BBS statistics for Muradnagar indicate only 25% to 30% of the NCA supporting a boro HYV crop, and much of this would depend upon LLPs drawing directly from the Gumti River in the far south of the zone. The distribution of the various modes of irrigation is shown in Figures I.2.1 to I.2.5 of Chapter I.2.

Where irrigation is lacking, particularly on the higher land, wheat becomes an important dry season crop, covering between 10% and 16% of the NCA in Nabinagar and 15% to 20% in Muradnagar according to BBS statistics. This crop is generally grown on residual soil moisture, or with perhaps a single irrigation application if available.

The damaging effects of pre-monsoon flash floods from the east have been largely attenuated by the time they reach Zone C except within the immediate vicinity of the Buri Nadi, and main river water levels tend to dominate. Most of the agricultural land lies between 3.5 m and 5.0 m above PWD. From Figure I.6.11, taking the curve for Anderson's Khal, it may be seen that in an average year this land will not be affected by main river flooding until after mid-June, and the boro harvest is not therefore at risk. In a 1 in 5 year event the water level may be 0.5 m higher, causing some problems before the end of May, particularly in the lower-lying areas in the west of the zone. The risk may be somewhat accentuated by the fact that the boro will tend to be grown on the lowest land because of its better access to surface water, although in many cases the land adjacent to the river banks is relatively high.

(c) Surface Water Resources

The dry season surface water resources of the zone are based primarily on the Meghna and Titas/Pagla Rivers. None of the internal channels has a significant dependable flow, and once the main river level drops below the bed level of the minor channels, they quickly dry up. About 500 2 cusec LLPs operate in Nabinagar thana (Agriculture Sector Team, 1991), and most of these are assumed to draw from the Meghna and Titas/Pagla Rivers. As already noted in connection with Zone B, backflow into the Buri Nadi also enables LLPs to draw water up to about 6 km south of Nabinagar. In the south of the zone 26 LLPs were observed in the 1993 irrigation season drawing water from the Gumti River over the Gumti Right Embankment. Some of these were using the 37 purpose-built offtake positions provided on the embankment, but these are not very popular with pump operators because of the difficulty in raising the water to the inlet box high on the embankment slope, particularly in cases where the embankment is far from the water's edge.

(d) Groundwater Resources

There is a fairly complex pattern of constraints upon groundwater development within the zone, as indicated in Figure I.6.12. Most of the area suffers from gas pockets in the shallow aquifer, which interfere with the operation of suction mode tubewells (ie STWs). The south-west in addition suffers from salinity of the deeper aquifer, ruling out DTW development. Only in the central portion of the zone are there no constraints, and here the STW potential is thought to be good. Significant numbers of DTWs can also be observed along the Nabinagar-Companiganj road. It is normal for DTWs to be located on higher ground to keep their engine/electric motor systems above normal flood levels, and they also tend to be near to the main road network because of site access for the drilling rigs. Nevertheless, throughout Muradnagar and Nabinagar thanas only 20% of all irrigation is from groundwater (Agriculture Sector Team, Census of Lift Irrigation, 1991), and the growth rate is low compared with other parts of the country. A fuller discussion of groundwater resources throughout the project area is presented in Annex C (Groundwater Investigations).

Technologies are available to overcome the problems of gas, and Annex C includes a discussion on shallow force mode tubewells (SFMTW) which offer such a solution, although these are as yet unproven in Bangladesh. Also discussed is a cheaper form of DTW (known as the deep force mode tubewell - DFMTW) which would be available in a 1 cusec size as well as the more traditional 2 cusec size.

(e) Monsoon Season Situation

The zone is virtually surrounded by major river channels, which dominate the monsoon season flooding after about June. Figure I.6.7 shows that the bulk of the zone apart from the central strip is flooded to a depth in excess of 0.9 m (ie flood phase F2 or deeper) in a 1 in 5 year flood. The relationship between the average seasonal main river levels and the cropping calendar has been presented in Figure I.6.11. The spread of the four curves shown substantially represents the actual spread in water levels from the north to the south of the zone. Since most of the agricultural land lies between 3.5 m and 5.0 m above PWD, it is apparent that even in an average year depths of up to 2.0 m are fairly commonplace, whilst in a 1 in 5 year flood the water could be 0.5 m deeper.

It is apparent from the results of the surveys that many farmers do not find it worthwhile attempting even a B aman crop under these conditions, and the land lies fallow throughout the kharif II season. In many cases they grow a B aus crop which is harvested before the peak flood. T aman (LV or HYV) can be grown on only the very highest ground. The positive aspect of such deep and extensive flooding is the very rich floodplain fisheries which have resulted.

(f) Development Possibilities

In accordance with the results of the public participation programme, investigations have focused, in order of priority, upon:

- increasing and improving the reliability of the dry season irrigation water supply,
- reducing pre-monsoon flood damage to the boro crop,
- improved drainage in the post-monsoon, and
- reduction of peak flood depths.

The area has been considered in three parts for the discussion of development possibilities which follows. The area within the zone to the east of the Buri Nadi has been considered with Zone B.

(i) North of Oder Khal and West of the Nabinagar-Companiganj Road

Most of the existing irrigation in this area is in the north and west, using LLPs to pump from the Meghna and Pagla Rivers and offtaking internal channels, of which the Buri Nadi and the Jamuna and Lower Titas Rivers are the largest. The bed levels of the internal channels are generally higher than that of the River Meghna, and in many cases higher than the dry season water level. Thus, as water levels fall during the irrigation season, the lesser khals dry up entirely. The availability of water in a particular channel can also vary from year to year, according to the erosion or deposition occurring during the previous monsoon season. The bed slope of the internal channels reflects the monsoon season flow direction, from north-east to south-west (except the Buri Nadi), and the main route for the incoming backflow during the dry season is therefore from the south-west.

The use of LLPs has increased rapidly here over the last ten years, but further development must be dependent upon making more water available in the internal channel network during the dry season, and extending the coverage of that network. This can be achieved either by khal re-excavation or by pumping water from the main channels by means of a fixed primary pump station or floating pumps.

As discussed in Section (d) above (Groundwater Resources), there is thought to be the potential for all the irrigation requirements of this area to be met from groundwater. In the south-east there appear to be no constraints to STW development, whilst the problems with gas experienced elsewhere should be surmountable by use of the proposed shallow force mode tubewells (SFMTW). Nowhere are there thought to be constraints upon deep force mode tubewell (DFMTW) development, particularly if problems of deep flooding and access can be overcome. Nevertheless, bearing in mind the untried nature of the new technologies and the fact that groundwater development has been much slower here than in other parts of the country, some caution is appropriate in predicting major private sector investment in tubewells. Much depends upon the success of the imminent National Minor Irrigation Development Project (NMIDP) in promoting private sector groundwater investment in general and the new technologies in particular.

Any intervention to deal with floods, whether pre-monsoon boro damage, post-monsoon drainage or peak flood depths, is likely to involve embankment works. Although khal excavation (preferably associated with dry season irrigation improvements as discussed above) may marginally improve the first two, all three are primarily dominated by Meghna water levels. The level of pre-monsoon flood damage appears insufficient to justify alone the provision of submersible embankments, and full height embankments therefore seem to be the only effective option. It makes sense to combine full flood control with a pumped irrigation scheme, so that the benefits of each may be multiplied by:

- making use of the irrigation pumps to enhance monsoon season drainage. This will be even more effective if the pumps serving the proposed irrigation scheme south of Oder Khal (see below) are also used for drainage of the northern area, and

- the increased security of the boro crop encouraging even more LLP development.

A full FCDI intervention has therefore been devised for this portion of the zone, and forms part of the Zone C scheme described in Section (g) below. A major disbenefit of this intervention is its impact upon the rich floodplain fisheries of the area, and allowance is made for this in the economic analysis. At local level meetings a significant number of people were concerned about the negative effects of such a scheme, both upon fisheries and navigation. The viability of the irrigation component depends upon the assumptions made about future groundwater development; if this shows a significant upturn then pumping of surface water for irrigation could not be justified. The FCD component would probably then also become non-viable without the possibility of pumped drainage.

(ii) South of Oder Khal and West of the Nabinagar-Companiganj Road

This area is crossed from north-east to south-west by Oder Khal, and the Arsi River with its tributaries, Zia Khal and Chapitala Khal. It was found in the course of modelling that these channels have three roles:

- local drainage,

- the conveyance to the Meghna of Buri Nadi overspill, when this channel cannot cope with the floods from the Tripura Hills, and

- the conveyance during the height of the monsoon of spillage from the Upper Titas/Pagla Rivers, which finds a preferential route by entering the Buri Nadi and flowing across the Gumti Phase II area.

These channels are thus of great importance to the whole project area. The peak simulated discharge within Oder Khal was found to be as high as 125 m^3/s.

Initially, an FCD scheme was tested for this part of the zone, similar to that proposed to the north of Oder Khal. However, it became apparent that even though Oder Khal was left open between the two schemes, the closure of the other channels and the loss of flood plain area would cause significant water level rises in the Buri Nadi/Salda/Ghungur River system, leading to major disbenefits in much of the eastern part of the project area. The scheme was therefore not considered further.

Surface water availability is similar to that north of Oder Khal. In the west of the area, LLPs are able to draw on backflow from the Meghna entering the various branches of the Lower Titas River, but this supply dwindles as the main river level falls. In the extreme south, LLPs are able to draw from the Gumti River, but completion of the Gumti Right Embankment, cutting off the water supply from offtaking khals, means that this opportunity is now limited to a fairly narrow riverine strip. Before completion of the embankment, however, the vicinity was exposed to very damaging flash floods, which meant that although easier to irrigate, the boro was frequently destroyed.

Groundwater potential is also similar, with the added complication of salinity of the deep aquifer in the west. Even here however, it is considered that the proposed shallow force mode tubewells (SFMTW) are capable of meeting the irrigation demand, but also as in the north, the uptake of the new technologies is uncertain.

A pumped irrigation scheme for this southern area has therefore been devised, and forms the second part of the Zone C scheme described in Section (g) below. Water is drawn from the Pagla/Upper Titas River near Nabinagar, and the pumps are therefore available to increase the monsoon season drainage pumping capacity for the proposed northern FCDI area.

(iii) Between the Nabinagar-Companiganj Road and the Buri Nadi

Flooding in this part of the zone is dominated by the Buri Nadi. Although most of the land adjacent to the Buri is high enough for the boro not to be threatened by main river levels in May, there is a danger that flash floods from the Salda and Ghungur Rivers may briefly inundate the crop, causing it to lodge and covering it with silt. The most effective way of dealing with this problem is by excavation of the rivers concerned, as already proposed under the Zone A scheme. Fully embanking the Buri Nadi is not recommended, as it would:

- raise upstream water levels,
- prevent further land accretion,
- entail a substantial embankment set-back, within which floods would be worsened, and
- seal an important route for fish migration into the project area.

As already discussed in connection with Zones A and B, LLPs can at present draw a reliable supply from the Buri Nadi to about 6 km upstream of Nabinagar, and the proposed excavation works should increase this by a further 14 km, but a major pump station could not be supported. Part of the area would also benefit from the Zone C pumped irrigation proposals. For all except the northern portion, STWs are constrained by gas in the shallow aquifer and, as elsewhere in Zone C, full exploitation of groundwater depends upon successful development and promotion of the SFMTW and DFMTW technologies.

(g) The Zone C Scheme

The layout of the proposed scheme for Zone C is given in Figure I.16.12, and at a larger scale in the separate album of drawings. It consists of two parts; an FCDI scheme in an area to the north of Oder Khal and a pumped irrigation scheme serving an area to the south of Oder Khal.

(i) The Northern FCDI Area

An area of 10 460 ha gross, 8 852 ha NCA is to be given full flood control by upgrading of existing embankments and constructing new as follows:

- embankment 1A in the east follows the existing Nabinagar-Companiganj road (9.9 km). The road already has in excess of 1.5 m freeboard against a 1 in 20 year flood and no additional filling is required. The supply canal for the southern irrigation scheme runs immediately adjacent to this embankment. Details are given Figure I.6.13,

- embankment 1B in the south follows the right (north) bank of Oder Khal (11 km). Over some of the length there is an existing embankment, which is to be improved. The design crest level is 1.0 m above the 1 in 20 year flood level. Details are given in Figure I.6.14, and

- embankment 1C in the west and north (25.5 km) follows the alignment of existing roads wherever possible, but a substantial length of new embankment is required. The route followed is well back from the Meghna River except at the site of pump station Nr 1, to take advantage of high ground and existing roads as well as avoiding the risk of main river bank erosion. The first 7 km from Nabinagar has a design crest level 1.5 m above the 1 in 20 year flood level, but as the embankment moves away from the main river bank further south, the freeboard reduces to 1.0 m. Details are given in Figure I.6.15.

Oder Khal is to be left unregulated, and is to be excavated as shown in Figure I.6.14. This excavation, together with that of the Arsi River and Roachala Khal, crossing the southern portion of the zone, is necessary to mitigate the adverse effects of the embankments on other parts of the project area. These three channels also serve for irrigation distribution under the proposals for the southern area described in Section (ii) below.

Regulators are provided through the embankments as follows:

- where Jogidara Khal crosses embankment 1A, a drainage/flushing regulator enables water to be drained from or admitted to the protected area. This structure has been designed to be 'fish-friendly', with weir flow and a free water surface through the structure, by fitting the two vents with 3.5 m high by 3.0 m wide bottom-hinged collapsible gates. This structure also incorporates a concrete flume to carry the supply canal for the southern irrigation area

Figure I.6.13

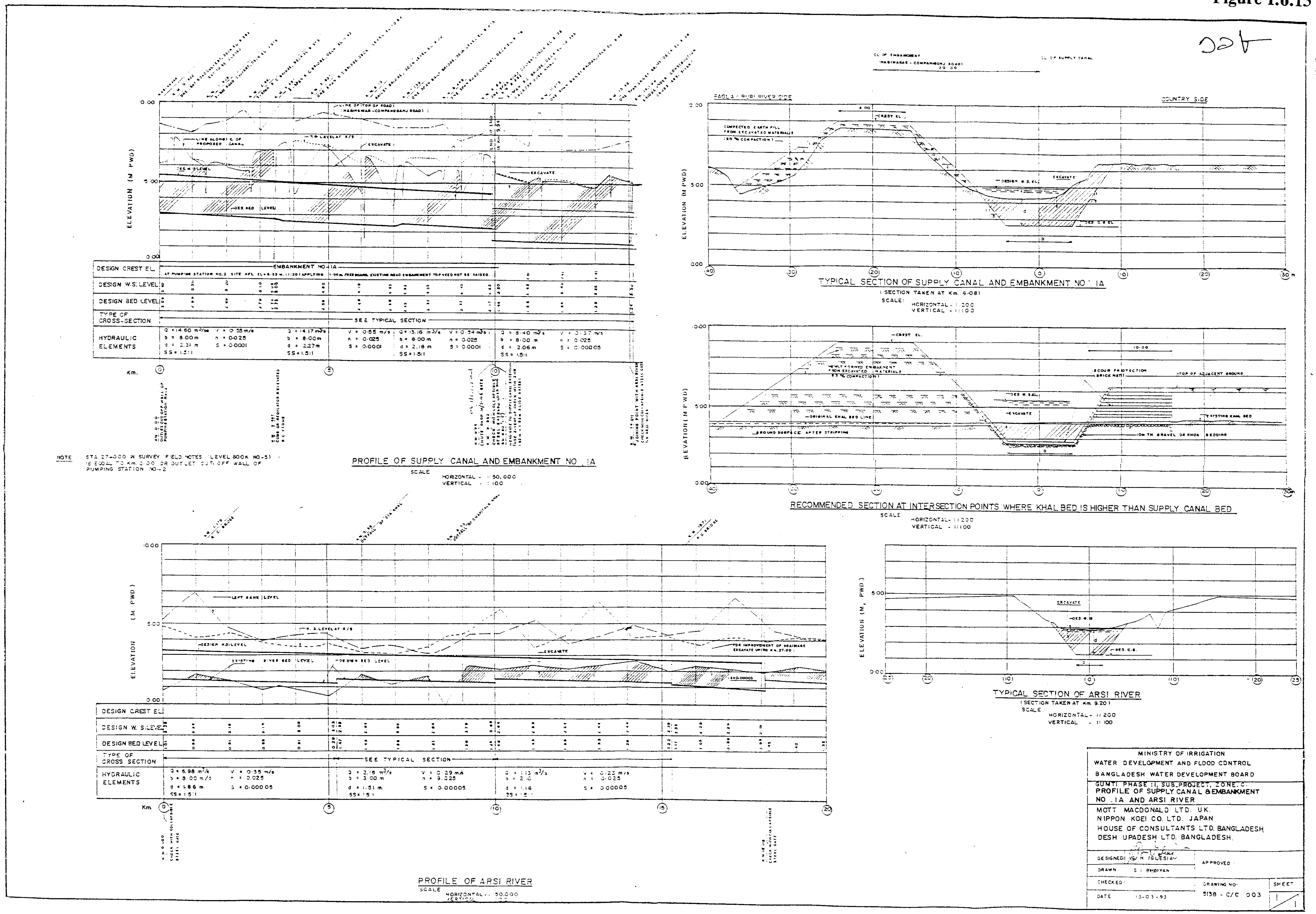

PROFILE OF SUPPLY CANAL AND EMBANKMENT NO. 1A
SCALE HORIZONTAL - 1:50,000 VERTICAL - 1:100
NOTE STA 27+000 IN SURVEY FIELD NOTES (LEVEL BOOK NO-5) IS EQUAL TO Km 0.00 OR OUTLET CUT-OFF WALL OF PUMPING STATION NO-2
DESIGN CREST EL.
DESIGN W.S. LEVEL
DESIGN BED LEVEL
TYPE OF CROSS-SECTION
HYDRAULIC ELEMENTS
SEE TYPICAL SECTION
EMBANKMENT NO-1A
ELEVATION (M PWD)
TYPICAL SECTION OF SUPPLY CANAL AND EMBANKMENT NO. 1A
(SECTION TAKEN AT Km. 6-08)
SCALE: HORIZONTAL - 1:200 VERTICAL - 1:100
COUNTRY SIDE
RECOMMENDED SECTION AT INTERSECTION POINTS WHERE KHAL BED IS HIGHER THAN SUPPLY CANAL BED
SCALE HORIZONTAL - 1:200 VERTICAL - 1:100
PROFILE OF ARSI RIVER
SCALE HORIZONTAL - 1:50,000
TYPICAL SECTION OF ARSI RIVER
(SECTION TAKEN AT Km. 9.20)
SCALE HORIZONTAL - 1:200 VERTICAL - 1:100
EXCAVATE
MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
GUMTI PHASE II, SUB-PROJECT, ZONE-C.
PROFILE OF SUPPLY CANAL & EMBANKMENT NO. 1A AND ARSI RIVER
MOTT MACDONALD LTD. UK.
NIPPON KOEI CO. LTD. JAPAN
HOUSE OF CONSULTANTS LTD. BANGLADESH
DESH UPADESH LTD. BANGLADESH.
DESIGNED
DRAWN S. I. BHUIYAN
CHECKED
DATE 13-03-93
APPROVED
DRAWING NO. 5138 - C/C 003
SHEET 1

Figure I.6.14

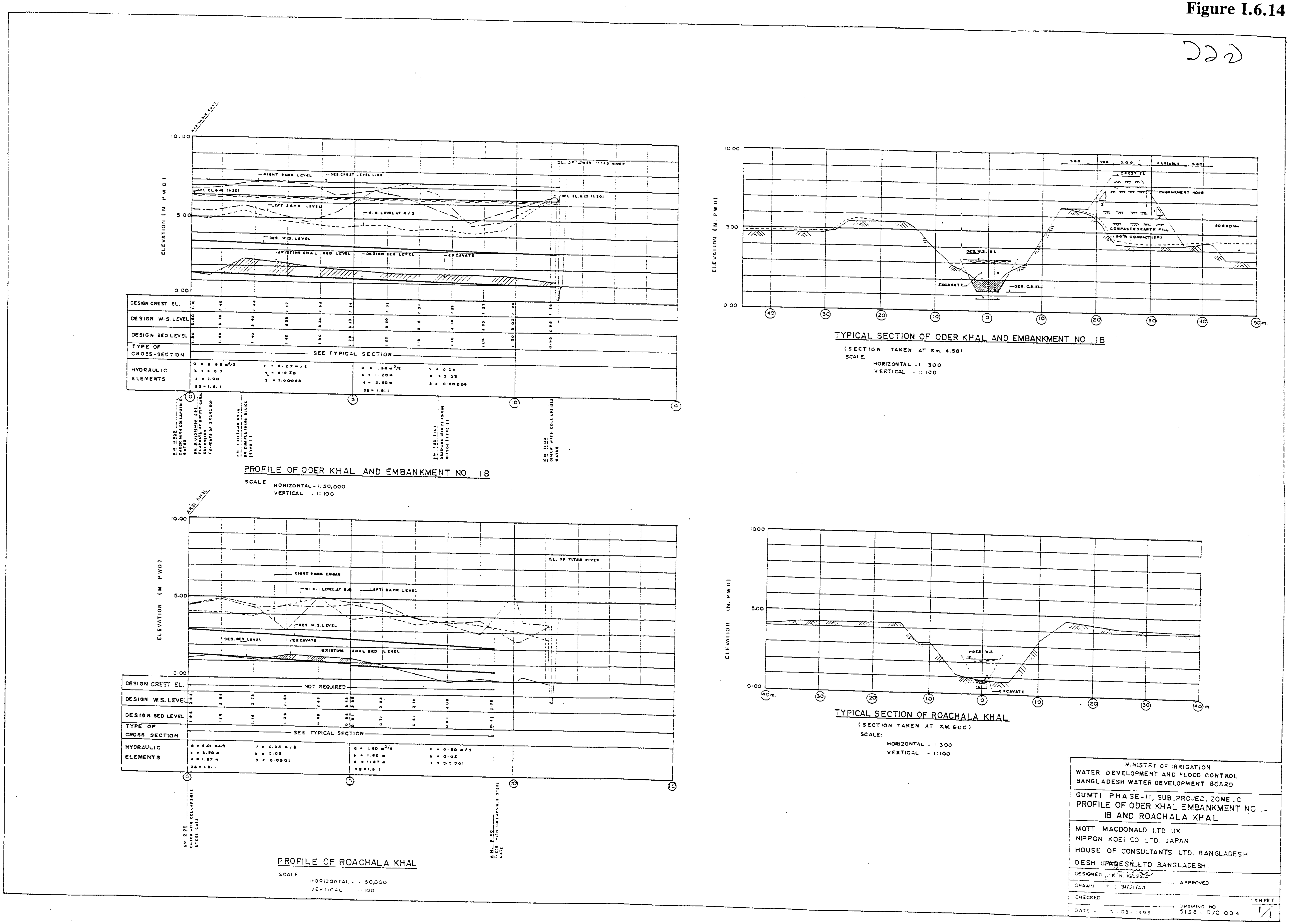
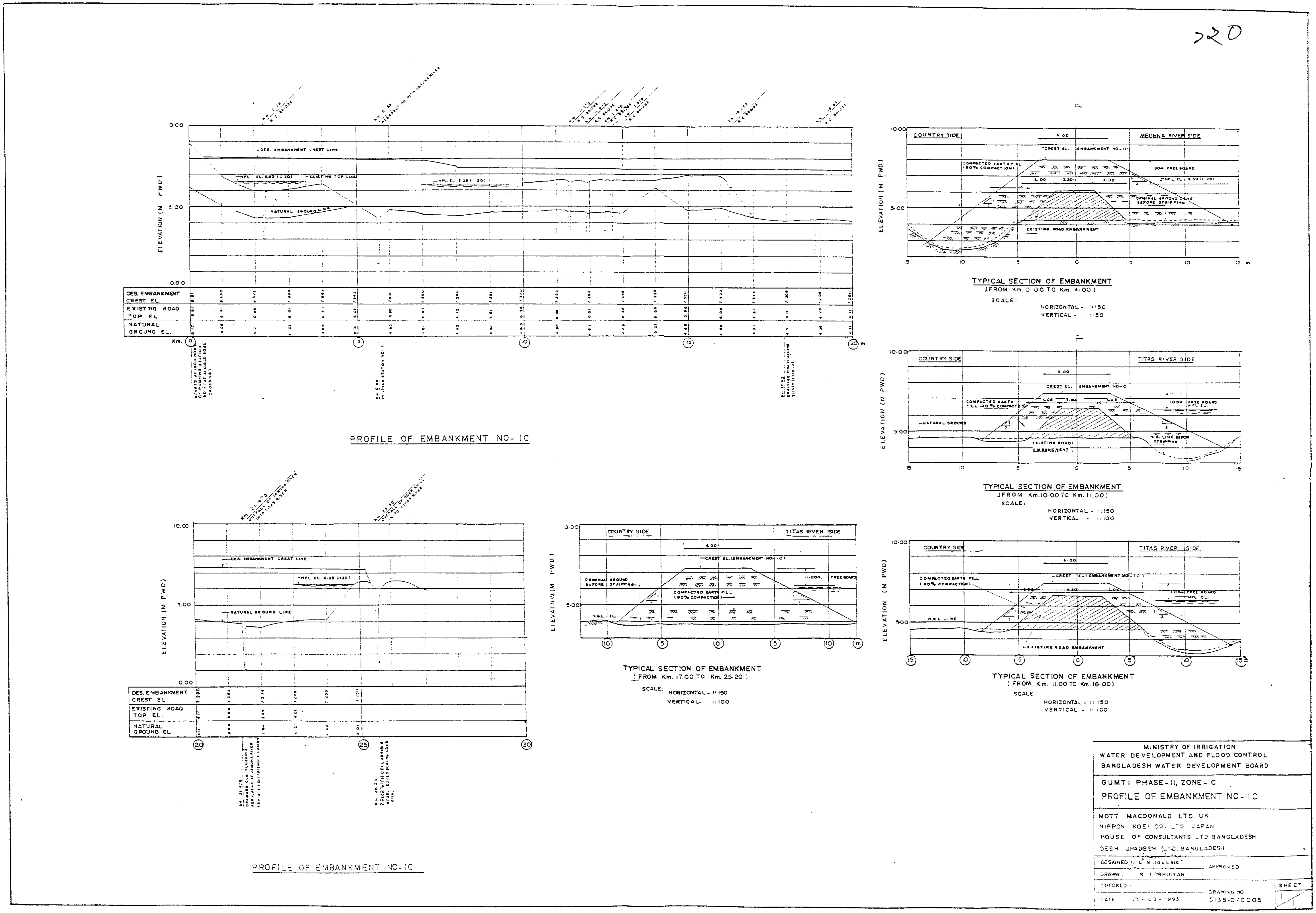

PROFILE OF ODER KHAL AND EMBANKMENT NO 1B
SCALE HORIZONTAL - 1:50,000
VERTICAL - 1:100
ELEVATION (M. PWD)
RIGHT BANK LEVEL
DES. CREST LEVEL LINE
LEFT BANK LEVEL
W.S. LEVEL AT 8/5
DES. W.S. LEVEL
EXISTING KHAL BED LEVEL
DESIGN BED LEVEL
EXCAVATE
DESIGN CREST EL.
DESIGN W.S. LEVEL
DESIGN BED LEVEL
TYPE OF CROSS-SECTION
SEE TYPICAL SECTION
HYDRAULIC ELEMENTS
TYPICAL SECTION OF ODER KHAL AND EMBANKMENT NO 1B
(SECTION TAKEN AT Km. 4.38)
SCALE
HORIZONTAL - 1:300
VERTICAL - 1:100
CREST EL.
EMBANKMENT HOLE
COMPACTED EARTH FILL
(80% COMPACTION)
BORROW
DES. W.S. EL.
DES. C.B. EL.
EXCAVATE
VARIABLE
PROFILE OF ROACHALA KHAL
SCALE HORIZONTAL - 1:50,000
VERTICAL - 1:100
RIGHT BANK EMBAN
LEFT BANK LEVEL
DES. W.S. LEVEL
DES. BED LEVEL
EXCAVATE
EXISTING KHAL BED LEVEL
CL. OF TITAS RIVER
NOT REQUIRED
SEE TYPICAL SECTION
CHECK WITH COLLAPSIBLE STEEL GATE
TYPICAL SECTION OF ROACHALA KHAL
(SECTION TAKEN AT KM. 6.00)
SCALE:
HORIZONTAL - 1:300
VERTICAL - 1:100
DES. W.S.
MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD.
GUMTI PHASE-II, SUB.PROJEC. ZONE .C
PROFILE OF ODER KHAL EMBANKMENT NO.-
1B AND ROACHALA KHAL
MOTT MACDONALD LTD. UK.
NIPPON KOEI CO. LTD. JAPAN
HOUSE OF CONSULTANTS LTD. BANGLADESH
DESH UPADESH LTD. BANGLADESH.
DESIGNED
DRAWN
CHECKED
APPROVED
DATE 15-03-1993
DRAWING NO 5138-C/C 004
SHEET 1/1

Figure I.6.15

220



across the khal, without any interconnection. The structure is located just to the west of the Companiganj-Nabinagar road, and is connected to it by a link embankment. Although the main road is so close it is separated from the protected area by the supply canal, so a bridge deck is provided across the structure,

- another similar 'fish-friendly' drainage/flushing regulator (but without the flume) is provided where the Jamuna River leaves the flood protected area (19.2 km on the Jamuna River, 21.48 km on embankment 1C). Various issues related to the concept of fish-friendly structures are discussed in Section I.4.6.1 of this annex, and

- three drainage/flushing sluices are provided, two through embankment 1B (Oder Khal north embankment) on the alignment of existing khals, at 1.61 km and 7.55 km, and the third at 17.93 km on embankment 1C (the northern and western embankment). These all have a single vent with a 1.82 m high by 1.52 m wide vertical slide gate at the unprotected end of a box culvert through the embankment. A type design was presented in Figure I.6.5.

Irrigation water is supplied from pump station Nr 1, 4 km west of Nabinagar, feeding into the Jamuna River (19.2 km) and thence also into Jogidara Khal (3.3 km), both of which are to be excavated as shown in Figure I.6.16. A double lift irrigation system has been adopted, with LLPs drawing from these channels. It is assumed that a strip of up to 1 km wide on each side of the channel can be served in this way. This system is preferred to a full gravity distribution system because:

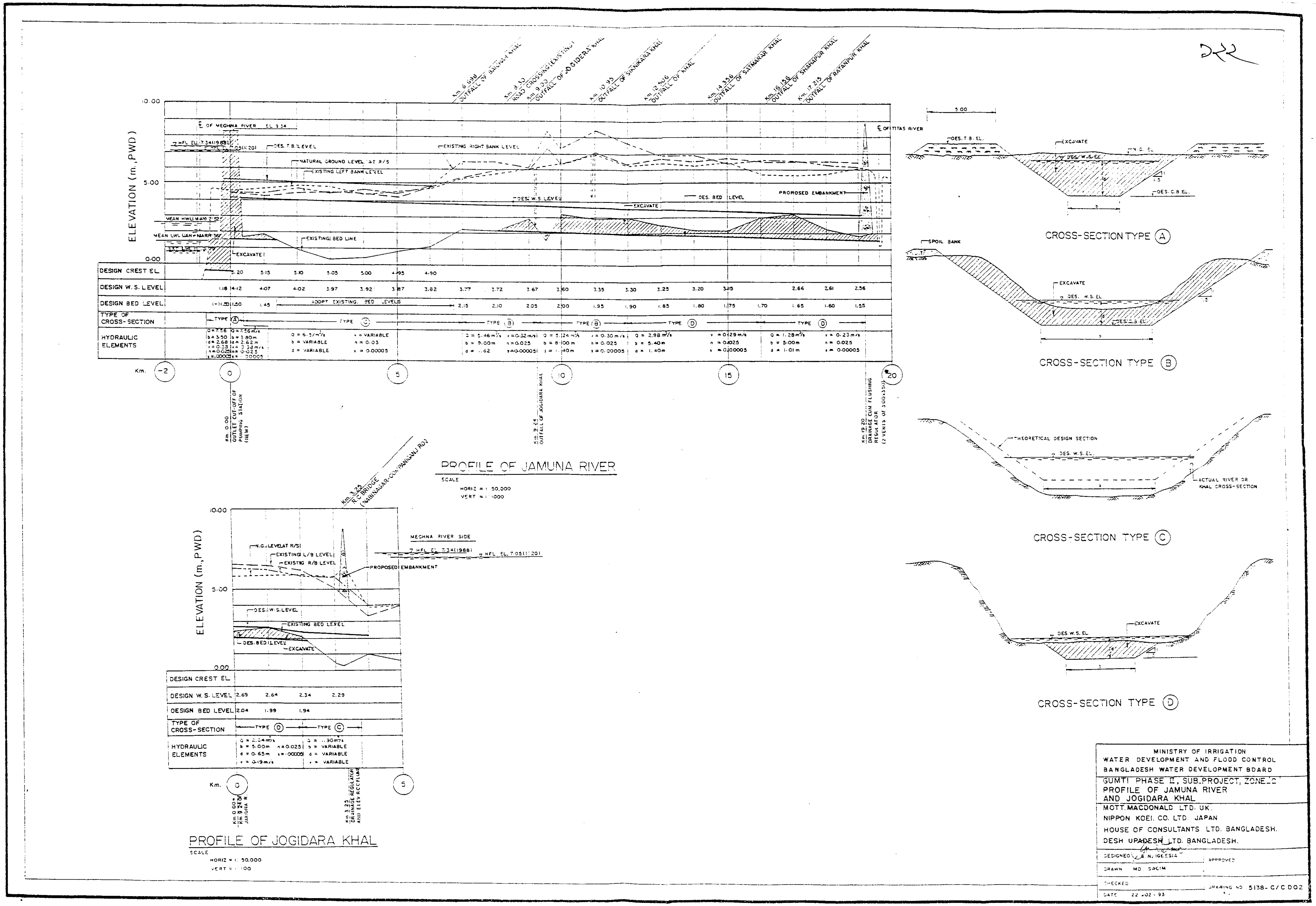
- although total pumping costs may be theoretically higher, the farmers automatically make a significant contribution in paying the LLP costs. This in itself is likely also to lead to more economical water use,

- gravity systems, with water levels above ground level, are liable to high seepage losses as well as damage/breaches through unauthorised offtakes, and

- in the double lift system the channels can serve both for irrigation distribution and drainage, whilst in the gravity system completely independent networks are required, with the elevated canals needing particularly wide reservations, resulting in greatly increased capital costs and land acquisition.

After allowing for the non-irrigable area (homesteads, high lands etc) the net irrigated area served has been estimated at 3 320 ha. A large proportion of the area will therefore continue to be dependent upon groundwater. The incremental irrigated area, after deduction of existing irrigation within the command area, is estimated at approximately 2 700 ha net. Since most of the existing irrigation relies upon surface water (LLP or traditional methods), which will now have to be pumped, the pump station capacity is based upon the total net irrigated area. Assuming a peak gross water duty in February of 2.27 l/s/ha for 18 hours per day pumping (see Section I.2.2 of this Annex), a pump station of capacity of 7.56 m^3/s has been provided, configured as 3 Nr units of 2.52 m^3/s. The full supply water level at delivery is 4.12 m above PWD, whilst the inlet water level varies between 0.79 m and 2.52 m. Details of the pump station are given in Figure I.6.17. The actual sizing of the units is subject to review, and in particular it is desirable from the point of view of maintenance that the units should be compatible with those in pump station Nr 2 discussed below.

Figure I.6.16



PROFILE OF JAMUNA RIVER
SCALE
HORIZ = 1 : 50,000
VERT = 1 : 1000
PROFILE OF JOGIDARA KHAL
SCALE
HORIZ = 1 : 50,000
VERT = 1 : 100
ELEVATION (m.,PWD)
DESIGN CREST EL.
DESIGN W.S. LEVEL
DESIGN BED LEVEL
TYPE OF CROSS-SECTION
HYDRAULIC ELEMENTS
Km.
Km. 0.00 OUTLET CUT-OFF OF PUMPING STATION (NEW)
Km. 9.24 OUTFALL OF JOGIDARA KHAL
Km. 19.20 DRAINAGE CUM FLUSHING REGULATOR (2 VENTS OF 3.00x3.50)
Km. 6.698 OUTFALL OF BAIGADA KHAL
Km. 8.50 ROAD CROSSING (EXISTING)
Km. 9.00 OUTFALL OF JOGIDARA KHAL
Km. 10.95 OUTFALL OF SIKNIKARA KHAL
Km. 12.506 OUTFALL OF KHAL
Km. 14.356 OUTFALL OF SATMARAR KHAL
Km. 16.156 OUTFALL OF SHAHAPUR KHAL
Km. 17.215 OUTFALL OF RATANPUR KHAL
℄ OF MEGHNA RIVER EL. 3.34
℄ OF TITAS RIVER
NATURAL GROUND LEVEL AT R/S
EXISTING LEFT BANK LEVEL
EXISTING RIGHT BANK LEVEL
EXISTING BED LINE
DES. W.S. LEVEL
DES. BED LEVEL
PROPOSED EMBANKMENT
EXCAVATE
ADOPT EXISTING BED LEVELS
Km. 3.25 R.C. BRIDGE (NABINAGAR-COMPANIGANJ RD)
MEGHNA RIVER SIDE
Km. 3.25 DRAINAGE REGULATOR AND ELEV RCC FLUME
N.G. LEVEL AT R/S
EXISTING L/B LEVEL
EXISTING R/B LEVEL
EXISTING BED LEVEL
CROSS-SECTION TYPE (A)
CROSS-SECTION TYPE (B)
CROSS-SECTION TYPE (C)
CROSS-SECTION TYPE (D)
SPOIL BANK
THEORETICAL DESIGN SECTION
ACTUAL RIVER OR KHAL CROSS-SECTION
MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
GUMTI PHASE II, SUB.PROJECT, ZONE-C
PROFILE OF JAMUNA RIVER
AND JOGIDARA KHAL
MOTT MACDONALD LTD. UK.
NIPPON KOEI CO. LTD. JAPAN
HOUSE OF CONSULTANTS LTD. BANGLADESH.
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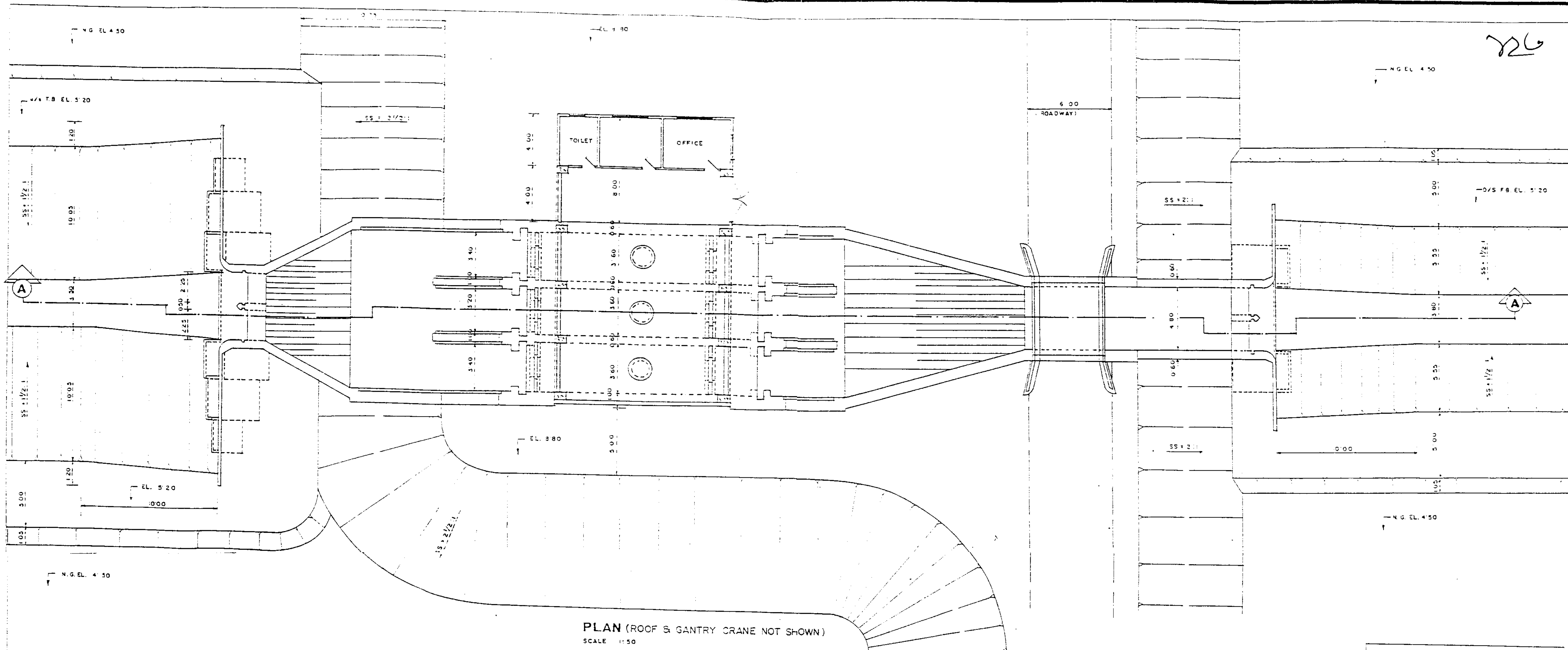
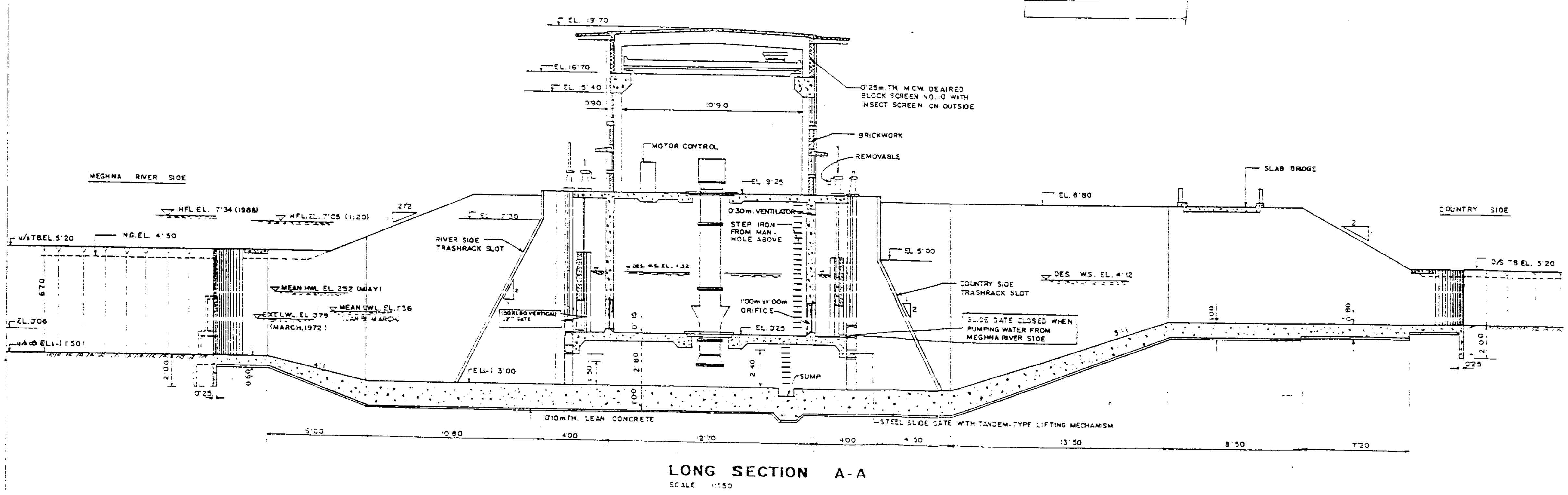
DRAWN MD. SACIM
CHECKED
APPROVED
DATE 22-02-93
DRAWING NO. 5138-C/C D02

Figure I.6.17





CANAL HYDRAULIC ELEMENTS		
	RIVER SIDE	COUNTRY SIDE
Q (m3/Sec)	7.55	7.56
V (m/Sec)	0.376	0.38
b (m)	3.50	3.80
d (m)	2.68	2.62
A (m2)	20.15	20.25
P (m)	13.16	13.25
R (m)	1.53	1.53
n	0.025	0.025
S	0.00005	0.00005
SS	1½	1½

NOTES

1. ALL CONCRETE SHALL BE CLASS 'A' UNLESS OTHERWISE SPECIFIED.
2. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE SHOWN
3. ALL ELEVATIONS ARE IN METERS (PWD)

MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD

GUMTI PHASE II, ZONE 'C'
PUMPING STATION NO I
PLAN AND LONG SECTION

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DRAWN	M. AMIUDDIN	
CHECKED		DRAWING NO
DATE	14-02-1993	5138-C/C 006-2

Both pump station Nrs 1 and 2 are reversible, and the full 22 m^3/s capacity is available for pumping drainage water from the northern FCDI area. In this way the percentage of F0 land within the protected area can be increased from 7% to 73%, permitting a huge increase in the cultivation of T aman. The effect upon the floodplain fisheries in the area would however be devastating.

(ii) The Southern Pumped Irrigation Area

Irrigation, without flood control, is provided to an area south of Oder Khal by pump station Nr 2, feeding into a supply canal (9.9 km) crossing the northern FCDI area adjacent to the Nabinagar-Companiganj road and dropping into Oder Khal (Figure I.6.14). An extension of the supply canal (4.2 km) continues beside the road, feeeding into the Arsi River (18.1 km) and its branch, Roachala Khal (9.4 km), both of which are to be excavated as shown in Figures I.6.13 and I.6.14. The supply canal and extension are formed by remodelling the roadside borrow pit, as also shown in Figure I.6.13.

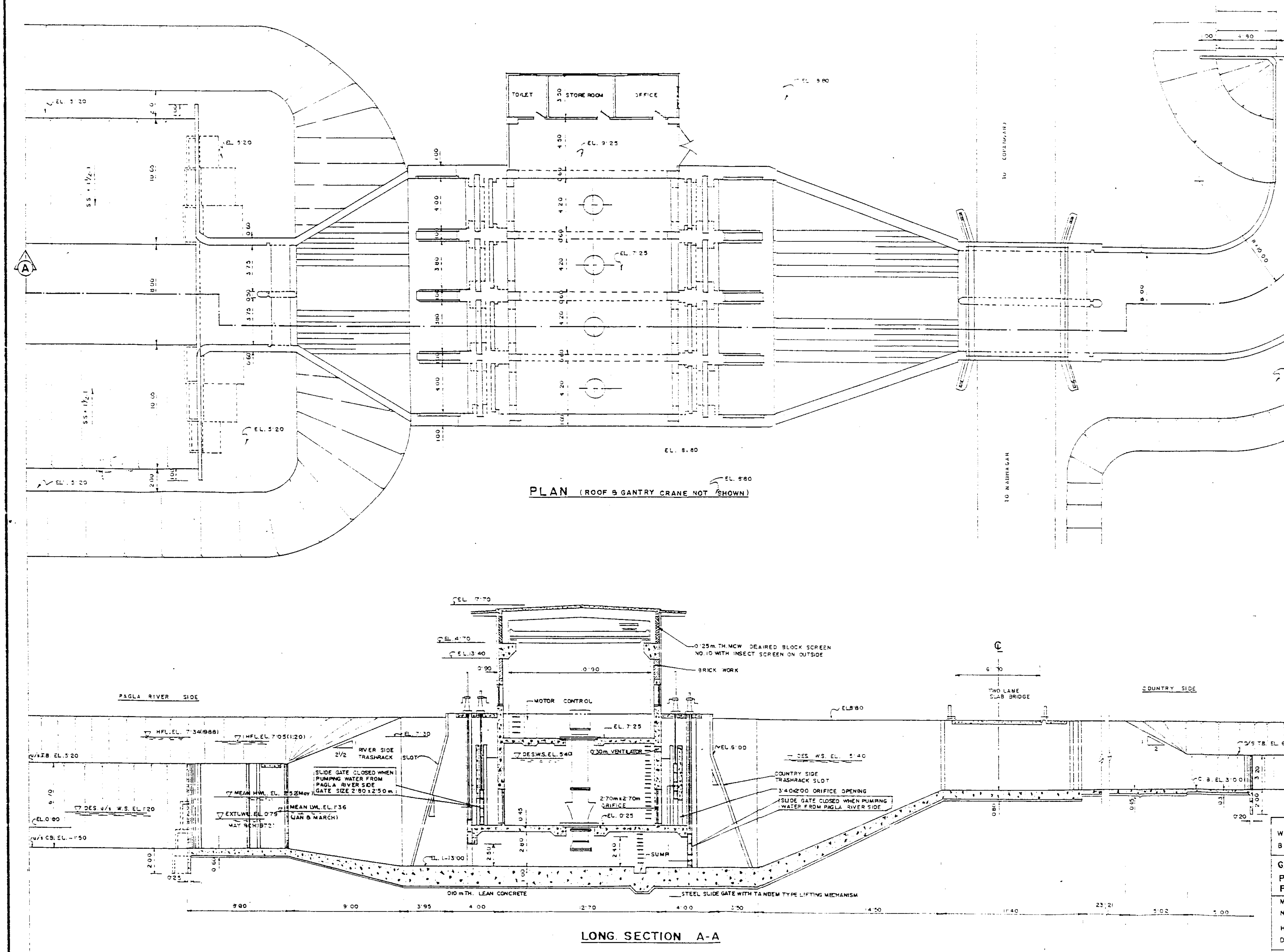
A double lift irrigation system has been adopted as for the northern area. After allowing for the non-irrigable area (homesteads, high lands etc) the net irrigated area served has been estimated at 6 300 ha, of which about 1 300 ha are within the northern FCDI area, and 1 000 ha are east of the Nabinagar-Companiganj road. Again, significant areas will not be served by the scheme and will continue to be dependent upon groundwater. The incremental irrigated area, after deduction of existing irrigation within the command area, is estimated at approximately 5 100 ha net. As for pump station Nr 1, the capacity is however based upon the total net irrigated area. Assuming the same peak gross water duty in February of 2.27 l/s/ha for 18 hours per day pumping, a pump station of capacity of 14.62 m^3/s has been provided, configured as 4 Nr units of 3.65 m^3/s. The full supply water level at delivery is 5.4 m above PWD, whilst the inlet water level varies between 0.79 m and 2.52 m. Details of the pump station are given in Figure I.6.18. The actual sizing of the units is subject to review, as discussed above in connection with pump station Nr 1. As already noted, the pumps are reversible, to provide monsoon season drainage pumping in the northern FCDI area in conjunction with pump station Nr 1.

Regulators are provided on the supply canal and distribution channels as follows:

- at 9.94 km on the supply canal, where it crosses the north bank embankment of Oder Khal on leaving the flood-protected area, a combined regulator and chute drop down into Oder Khal itself is provided. The structure has two vents fitted with 1.82 m high by 1.52 m wide vertical slide gates on the unprotected side. It is similar to the type design given in Figure I.6.5, except the barrel through the embankment is shorter, and a chute drop with stilling basin is added at the downstream end.

- the division of flow between Oder Khal and the supply canal extension is regulated by two check structures. At 0 km on Oder Khal is a two-vented structure fitted with 2.0 m high by 3.0 m wide bottom-hinged collapsible navigation gates. These are designed specifically to permit the passage of small country boats into the upper reaches of Oder Khal when water levels permit, and they would generally be kept in the open or lowered position outside the pumped irrigation season. No road bridge is provided, since there is an existing bridge over Oder Khal. A type design is given in Figure I.6.19. Various issues related to the concept of bottom-hinged gates are discussed in Section I.4.6.1 of this annex. At 9.99 km, at the head of the supply canal extension, is a simple two-vented check structure fitted with 1.82 m high by 1.52 m wide vertical slide gates.

Figure I.6.18



CANAL HYDRAULIC ELEMENTS	RIVER SIDE	COUNTRY SIDE
Q (m^3/Sec)	14·52	14·62
V (m/Sec)	0·48	0·55
b (m)	8·00	8·00
d (m)	2·79	2·31
A (m^2)	3·996	2·484
P (m)	18·059	16·2329
R (m)	1·882	1·622
n	0·025	0·025
S	0·00005	0·0001
SS	1½	1½

NOTES

1. ALL CONCRETE SHALL BE CLASS 'A' UNLESS OTHERWISE SPECIFIED.
2. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE SHOWN.
3. ALL ELEVATIONS ARE IN METERS (PWD)

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WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD

GUMTI PHASE II, SUB-PROJECT, ZONE-C
PUMPING STATION NO-2
PLAN AND LONG. SECTION.

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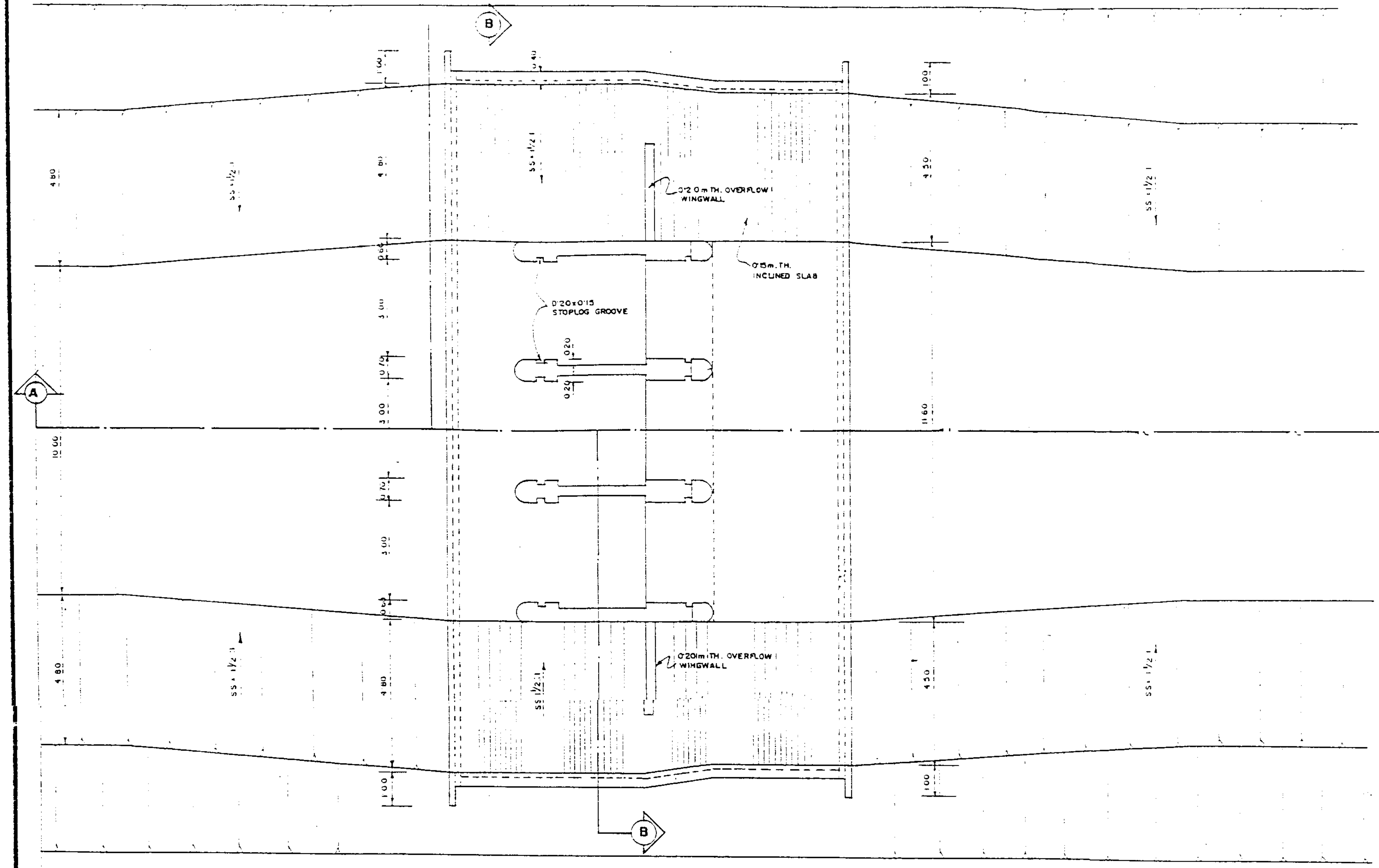
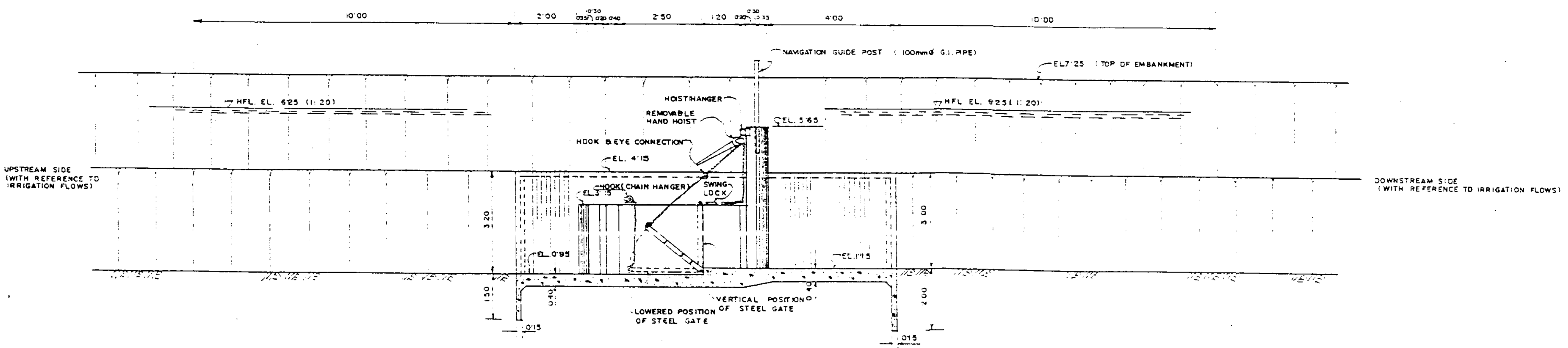
CHECKED		DRAWING NO.
DATE	20-03-93	5138-C/C 008
SHEET		1

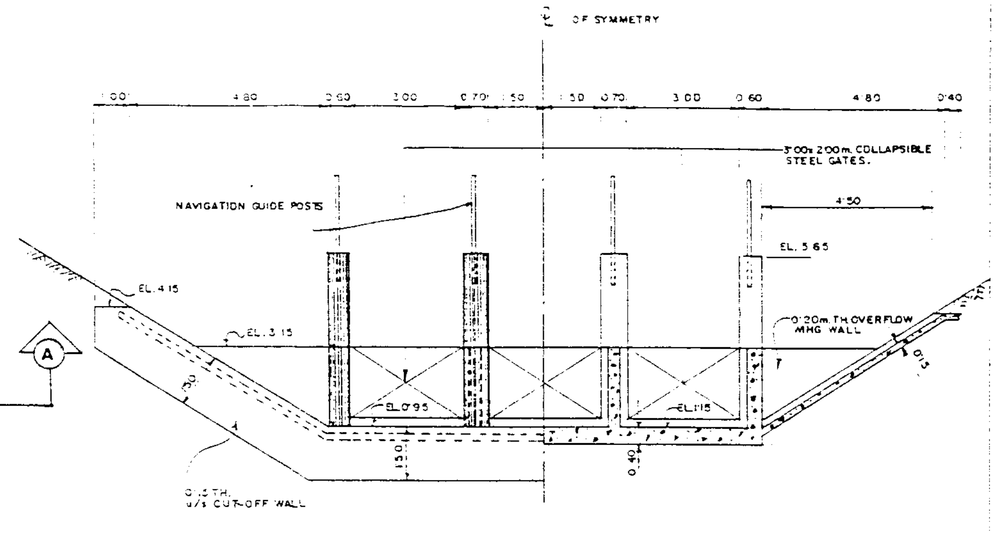
Figure I.6.19



PLAN (COLLAPSIBLE STEEL GATES NOT SHOWN)
SCALE 1:80



SECTION "A-A"
SCALE 1:80



SECTION "B-B"
SCALE 1:100

NOTES

1. ALL CONCRETE SHALL BE CLASS A UNLESS OTHERWISE SPECIFIED
2. ALL DIMENSION, UNLESS OTHERWISE SHOWN, ARE IN METERS
3. ALL ELEVATIONS (EL) ARE IN METERS (PWD)
4. ARRANGEMENT FOR 2 VENTS SIMILAR

MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD

GUMTI PHASE II, SUB-PROJECT.
CHECK WITH COLLAPSIBLE NAVIGATION GATES (2 or 3 Nr. 3m x 2m VENTS)

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DRAWN	M. UDDIN		
CHECKED		DRAWING NO	
DATE	23-03-93	5138- C/C 013	SHEET 1/1

- within the Arsi Nadi, at its junction with the supply canal extension, is another two-vented check structure fitted with 2.0 m high by 3.0 m wide bottom-hinged collapsible navigation gates, identical to that on Oder Khal above, and

- three further check structures identical to those at the head of Oder Khal and the Arsi River are provided at the downstream ends of Oder Khal, Roachala Khal and the Arsi River, to retain water within the irrigation area during the dry season, without impeding the passage of small country boats at other seasons.

Since the two parts of the Zone C scheme are interdependent, they have been considered as a single intervention. The estimated capital costs at 1992 prices, based upon calculated quantities and the standard unit rates presented in Chapter I.5 of this Annex, are given in Table I.6.3. It has been assumed that all excavation will be carried out by hand. The rate includes an allowance for compensating farmers for spreading the spoil on their land where it is not required for embankment construction, and no land acquisition for disposal is anticipated. Mechanical compaction of embankment fill material has been specified. A total of about 46 ha of land acquisition has been allowed for, primarily for the reaches of new embankment and the pump stations. Annual pumping costs have been estimated at Tk 3 432 470 for pump station Nr 1 and Tk 8 519 630 for pump station Nr 2. As well as meeting the irrigation requirement, these pumping costs include an allowance for 70 days drainage pumping at 22.18 m^3/s for 18 hours per day, assuming that the average year's rainfall (less evaporation) falling in the months of May to September all has to be pumped. The Bangladesh Power Development Board has confirmed during discussions that both generating capacity and distribution systems are adequate to meet the needs of these pump stations. Annual O & M costs have otherwise been assumed in accordance with the standard percentages set out in Chapter I.5 of this annex, based upon the FPCO Guidelines for Project Assessment. The assumed division between local and foreign currency costs is also in accordance with standard percentages set out in Chapter I.5.

The detailed agricultural benefits are discussed in Annexes E (Agriculture) and J (Financial and Economic Analysis). The primary benefits within the northern FCDI area is in enabling a major shift from B aman to T aman (HYV or LV) during the monsoon, and providing dependable irrigation facilities for 4 620 ha of boro, within an environment secure from the effects of early flooding. The embankments themselves will provide improved access around the area. To set against these benefits are huge capture fisheries losses, as estimated in Annex F (Fisheries). Within the remainder of the area the benefit consists of the provision of some 5 000 ha of dependable irrigation facilities, with no change in flooding conditions.

As already discussed, this scheme can only be regarded as viable if the shallow force mode tubewell (SFMTW) and deep force mode tubewell (DFMTW) technologies can be made attractive to the private sector. There is also a policy issue to be resolved, as to whether it is desirable to disrupt the existing rich floodplain fisheries of the area in favour of more intensive agricultural production, even if the scheme is economically viable, particularly as the demand for flood control among the local people did not appear very strong.

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TABLE I.6.3

Capital Costs of the Zone C Scheme

	Description	Unit	Quantity	Unit Rate (Tk)	Cost (Tk 000)
1	Flood embankment				
	- Clearing Grubbing & Stripping	sq.m	593 890	3	1 782
	- Channel Excav. and Formation of Emb. (Manual Excav./Mechanical Comp.)	cu.m	1 219 943	42	51 238
	- Turfing	sq.m	807 500	3	2 423
2	Channel excavation & Spreading				
	- Manual excavation (transport 50m)	cu.m	914 967	28	25 619
3	New regulators				
	- 2 Nr Vent 3.5m x 3.0m fish-friendly/flume	Vent	1 x 2	7 000 000	14 000
	- 2 Nr Vent 2.0m x 3.0m check/navigation	Vent	5 x 2	600 000	6 000
	- 2 Nr Vent 1.82m x 1.52m check/head gate	Vent	1 x 2	550 000	1 100
	- 2 Nr Vent 3.5m x 3.0m fish-friendly	Vent	1 x 2	6 600 000	13 200
	- 1 Nr Vent 1.82m x 1.52m	Vent	3 x 1	2 000 000	6 000
	- 2 Nr Vent 1.82m x 1.52m chute drop	Vent	1 x 2	2 000 000	4 000
4	Pump Stations				
	- Nr 1 (Q = 3 @ 2.52 = 7.56 cu.m/sec)				
	- Civil Works	sum		39 441 630	39 442
	- Electrical & Mechanical Works	sum		41 271 600	41 272
	- Nr 2 (Q = 4 @ 3.655 = 14.62 cu.m/sec)				
	- Civil Works	sum		58 235 000	58 235
	- Electrical & Mechanical Works	sum		91 637 671	91 638
5	Buildings	sq.m	900	6 000	5 400
6	Vehicles	Nr	4	1 000 000	4 000
7	Land Acquisition				
	- Agricultural	ha	43.5	375 000	16 313
	- Homestead	ha	2.33	1 617 800	3 769
	Sub-Total				385 429
	Physical contingencies 15%				57 814
	Sub-Total including contingencies				443 243
	Engineering service cost 12%				53 189
	Total Project Cost				496 432
	Made up of - Local Currency				358 297
	- Foreign Currency				138 135

I.6.3.5 Zone D

(a) Background

A map of Zone D is presented in Figure I.6.20. The north and west boundary is defined by the Upper Meghna River and the south by the Gumti River, whilst to the east is the Lower Titas River separating the zone from Zone C.

The gross area of the zone is 40 696 ha and the net cultivable area (NCA) 36 080 ha. Elevations range from about 2.5 m above PWD in the south-west to 5.5 m on the Meghna bank in the north. The zone comprises part of Bancharampur thana in the north, Homna thana in the centre and part of Daudkandi in the south.

The Public Participation Meetings identified the following problems within the zone:

- shortage of water for irrigation during the dry season,
- poor drainage, and
- early flood damage to the boro crop in low-lying areas such as Satdona Beel, and along the right bank of the Gumti where there is no embankment.

The problems are in fact very similar to those in the western part of Zone C.

During the course of field surveys, local people including farmers reported insecurity of irrigation water supply as their main problem, and gave less emphasis to flooding, although it is apparent that the monsoon season cropping is in fact severely constrained by the flooding regime. The basic cropping pattern is irrigated boro or non-irrigated wheat in the dry season, followed by B aman and/or B aus in the monsoon season, with a negligible area of T aman.

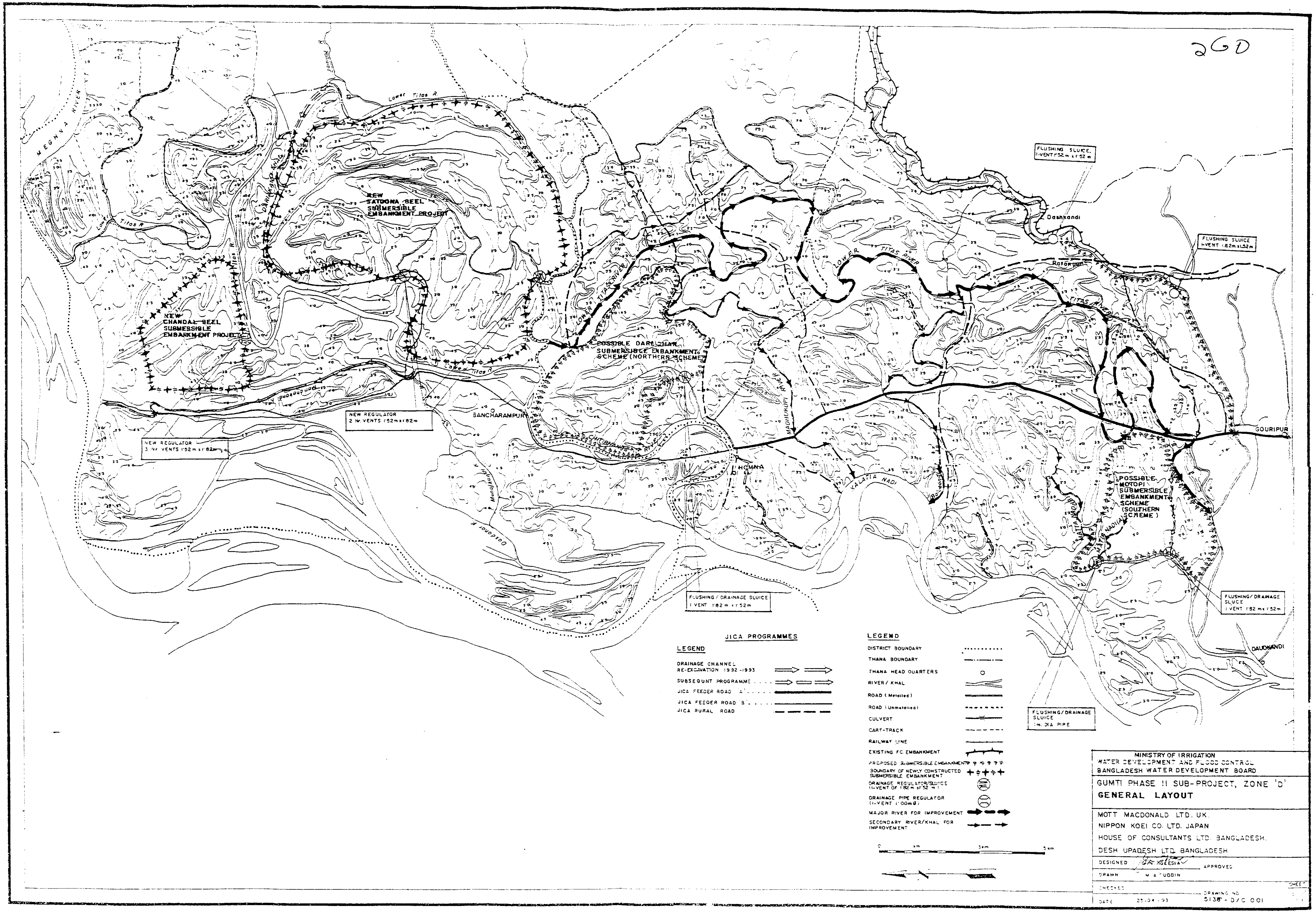
(b) Dry Season Situation

Dry season cropping consists either of irrigated boro, or wheat relying on rain or residual moisture. The boro HYV coverage is surprisingly low (about 50% from farmer surveys) considering the availability of water in the complex channel network and the groundwater resources which could be developed.

The distribution of the various modes of irrigation is shown in Figures I.2.1 to I.2.5 of Chapter I.2 of this Annex. The intensity of LLP irrigation is highest in the south, apparently drawing from the Gumti River and offtaking channels. STW coverage is less significant than surface water irrigation, although more widespread than in Zone C, whilst deep tubewells are very sparse.

The effects of pre-monsoon flash floods from the east have largely been attenuated by the time they reach Zone D. Problems do however occur in the south of the zone when, as in 1993, early Gumti floods spill from the channel downstream of the end of the newly constructed right embankment near Ratanpur, and damage the boro crop in the strip of low-lying land between the Gumti River and the Gouripur-Homna road, also dumping sand in the fields and khals. Throughout most of the zone, main river water levels tend to dominate, although there

Figure I.6.20


2GD
MEGHNA RIVER
Lower Titas R.
NEW SATDONA BEEL SUBMERSIBLE EMBANKMENT PROJECT
NEW CHANDAL BEEL SUBMERSIBLE EMBANKMENT PROJECT
POSSIBLE DARI-CHAR SUBMERSIBLE EMBANKMENT SCHEME (NORTHERN SCHEME)
POSSIBLE MOTOPI SUBMERSIBLE EMBANKMENT SCHEME (SOUTHERN SCHEME)
LOWER TITAS RIVER
TITAS RIVER
MADHUKUPI RIVER
KALATIA NADI
NADIA NADI
BANCHARAMPUR
HOMNA
GOURIPUR
Dashkandi
DAUDKANDI
Dosdonar K.
NEW REGULATOR 3 Nr. VENTS 1·52m x 1·82m
NEW REGULATOR 2 Nr. VENTS 1·52m x 1·82m
FLUSHING SLUICE 1-VENT 1·52m x 1·52m
FLUSHING SLUICE 1-VENT 1·82m x 1·52m
FLUSHING / DRAINAGE SLUICE 1 VENT 1·82m x 1·52m
FLUSHING/DRAINAGE SLUICE 1 VENT 1·82m x 1·52m
FLUSHING/DRAINAGE SLUICE 1m. DIA PIPE
JICA PROGRAMMES
LEGEND
DRAINAGE CHANNEL RE-EXCAVATION 1992-1993
SUBSEQUNT PROGRAMME
JICA FEEDER ROAD 'A'
JICA FEEDER ROAD 'B'
JICA RURAL ROAD
LEGEND
DISTRICT BOUNDARY
THANA BOUNDARY
THANA HEAD QUARTERS
RIVER/KHAL
ROAD (Metalled)
ROAD (Unmetalled)
CULVERT
CART-TRACK
RAILWAY LINE
EXISTING FC EMBANKMENT
PROPOSED SUBMERSIBLE EMBANKMENT
BOUNDARY OF NEWLY CONSTRUCTED SUBMERSIBLE EMBANKMENT
DRAINAGE REGULATOR/SLUICE (1-VENT OF 1·82m x 1·52m)
DRAINAGE PIPE REGULATOR (1-VENT 1·00mØ)
MAJOR RIVER FOR IMPROVEMENT
SECONDARY RIVER/KHAL FOR IMPROVEMENT
0
1km
3km
5km
MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
GUMTI PHASE II SUB-PROJECT, ZONE 'D'
GENERAL LAYOUT
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M. A. UDDIN
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SHEET
DRAWING NO.
5138 - D/C 001
DATE
25-04-93

are several depressions where local drainage congestion may cause problems. From Figure I.6.11, taking the curve for Meghna/Gumti, it may be seen that in an average year land of elevation just under 3.0 m above PWD may be flooded by the end of May and the boro harvest put at risk. In a 1 in 5 year event the water level may be 0.5 m higher, causing problems over quite a significant area. The risk may also be accentuated by the fact that the boro will tend to be grown on the lowest land because of its better access to surface water, although in many cases the land adjacent to the river banks is relatively high. Particular problems were reported in the Satdona Beel area. Farmers in some low-lying areas reported that they planted their boro early so that it could be harvested in April, before the main river rose.

(c) Surface Water Resources

The dry season surface water resources of the area are based primarily on the Meghna River, as none of the internal channels apart from the Gumti River in the south has a significant baseflow. Meghna backflow can be drawn into the Lower Titas and the other small meandering rivers, but once the main river level drops below the bed level of the minor channels, they quickly dry up. The tide does help a little in bringing in water, but the normal tidal range is only of the order of 0.3 m. The highest intensity of LLP irrigation within the zone is found in the south, where channels leading from the unembanked Gumti River provide ample opportunity for drawing water.

(d) Groundwater Resources

STW potential is considered to be good throughout the zone, apart from small areas in the south, where gas pockets in the aquifer mean that the shallow force mode tubewell (SFMTW) would be the recommended mode, perhaps supplemented by deep force mode tubewells (DFMTW) although deep aquifer salinity is also a constraint in places. Bancharampur and Homna thanas are reported to have similar numbers of operating STWs (Agriculture Sector Team, Census of Lift Irrigation, 1991) although conditions are more favourable for development in Bancharampur. The growth in STW development in the area over recent years has been very slight compared to other parts of the country, and some caution is necessary in predicting future growth. A fuller discussion of groundwater resources throughout the project area is presented in Annex C (Groundwater Investigations).

(e) Monsoon Season Situation

Monsoon season water levels in the zone are entirely dominated by the River Meghna. The extent of flooding is clearly illustrated by Figure I.6.7, which shows only a small proportion of the zone flooded to a peak depth of less than 0.9 m, ruling out T aman HYV or LV over most of the area. B aman LV is the dominant monsoon season crop, although B Aus is also common, but these both conflict with boro in the cropping calendar. Thus, as suggested by the farmers' survey, it would appear that no crop at all is grown during the kharif season in many areas. Figure I.6.11 illustrates the relationship between peak flood depth and the cropping calendar. Taking the curve for the Meghna/Gumti, even in an average year, peak flood depths in excess of 2 m may be expected on land at below 3 m above PWD. In a 1 in 5 year flood the depth could be 0.5 m more.

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(f) Proposed and New Developments by Others

(i) Proposals by Japan International Cooperation Agency (JICA)

Two separate studies have been carried out by JICA affecting Zone D:

- The Model Rural Development Project Plan for Homna and Daudkandi Upazila, Comilla District (Final Report November 1989), and
- The Master Plan Study on the Model Rural Development Project Phase II for Kachua, Nabinagar, Bancharampur and Debidwar upazilas (Final Report December 1991).

JICA has proposed a number of works within the zone relating to water resources and agricultural development, including:

- khal re-excavation for LLP irrigation development,
- khal re-excavation for improved drainage,
- provision of floating pump stations for irrigation (where khal re-excavation is not effective),
- feeder road improvements, and
- rural road improvements.

The locations of the proposed works are included in Figure I.6.20.

The khals proposed for re-excavation are relatively small and it is envisaged that their depth would be increased by a standard 1.0 m. The programme also includes for the provision of LLPs.

The improvement of the feeder and rural roads in the area is an important development since communications in the monsoon season is very problematic. The upgraded feeder road from Gouripur to Bancharampur and beyond is substantially complete to Homna.

(ii) Satdona and Chandal Beel Submersible Embankment Projects

These two schemes, indicated on Figure I.6.20, are still under implementation. The Satdona Beel scheme covers 5 153 ha gross (3 350 ha NCA), whilst the smaller Chandal Beel scheme covers 813 ha gross (615 ha NCA). Relatively little peripheral embankment work has been undertaken as the rim of the beel was considered sufficiently high in most locations to protect the boro crop. The main component of the works is therefore the regulator structures.

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Although it is apparent, as discussed in Section (b) above, that the two beel areas used to be subject to early flood damage to the boro HYV crop, the schemes as presently envisaged could have a serious detrimental affect on migratory fish. This is because the gates are not 'fish-friendly' and will in any case be closed during the critical pre-monsoon period, when fish move between river and beel. Fishermen in the area have already complained of significantly reduced catches in Satdona and Chandal Beels. This matter is discussed further in Annex H (Environment).

(g) Development Possibilities

As already discussed, the zone is highly flood prone during the monsoon season, and agricultural practices and other activities have to a large extent been tailored to suit this environment. Floodplain fisheries are extremely important, and any intervention which might disturb the aquatic regime must be considered very carefully. Interviews with local inhabitants strongly indicated that major flood control embankments were not favoured, and these have therefore not been considered further under basic and intermediate flood response.

The main development thrust in the zone should be:

- improving the potential for dry season irrigation, and
- protecting the boro HYV crop against early flooding.

(i) Irrigation

To supplement the groundwater potential discussed in Section (d) above, further khal excavation may be carried out, to enable more Meghna water to be drawn into the zone for abstraction by LLP. This is the most effective intervention for the Gumti Phase II area, with almost no negative effects. Fisheries will incur no loss of floodplain, and will achieve gains in khal volumes. Drainage should also be improved, although peak water levels will not be affected. Re-excavation of the Lower Titas River, Madhukupi Nadi, Matia Nadi and the Batakandi River constitutes one of the Zone D schemes recommended in Section (h) below.

(ii) Protection against Early Flooding

The most serious early flood risk is associated with the Gumti River in the south of the zone. Extension of the Gumti right embankment as a submersible embankment has been recommended as a component of the Zone D schemes in Section (h) below. It would protect the land between the Gumti River downstream of Ratanpur and the Gouripur-Homna road from Gumti flash flood damage.

There are two further low lying areas in addition to the Satdona and Chandal Beel projects where submersible embankments could be beneficial in protecting the boro crop from early flooding, at Dari Char to the north-east of Homna and at Motopi to the north-west of Gouripur (See Figure I.6.20). Many of the negative effects upon fisheries observed in connection with the two existing schemes would also apply, although the permanent beel area within the protected area is not so great. Farmers here generally manage to avoid damage by planting early, so as to harvest the boro crop in April, but they could not cope with a slight increase in water levels due, for instance, to future interventions in the North East Region. The two schemes have therefore been included as possible mitigation interventions, if the need arises, in Section (h) below.

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(h) The Zone D Schemes

(i) Khal Re-excavation

Details of the proposed re-excavation of the Lower Titas River (45 km), Madhukupi Nadi (15 km), Matia Nadi reaches A (2 km) and B (5.7 km), and the Batakandi River (11 km) are presented in Figures I.6.21, I.6.22 and I.6.23. The channel locations are shown in Figure I.6.20, and at a larger scale in the separate album of drawings. The design cross-sections have been sized according to irrigation rather than drainage requirements, based upon an assumed Meghna 1 in 5 year dry season low water level of 0.8 m above PWD. In the case of the Lower Titas, the southern half is assumed to carry flows northwards from the Gumti River, whilst the northern half flows southwards from near Bancharampur. The reach between Bancharampur and the main river near Homna does not require excavation as it is a major navigation route maintained by BIWTA.

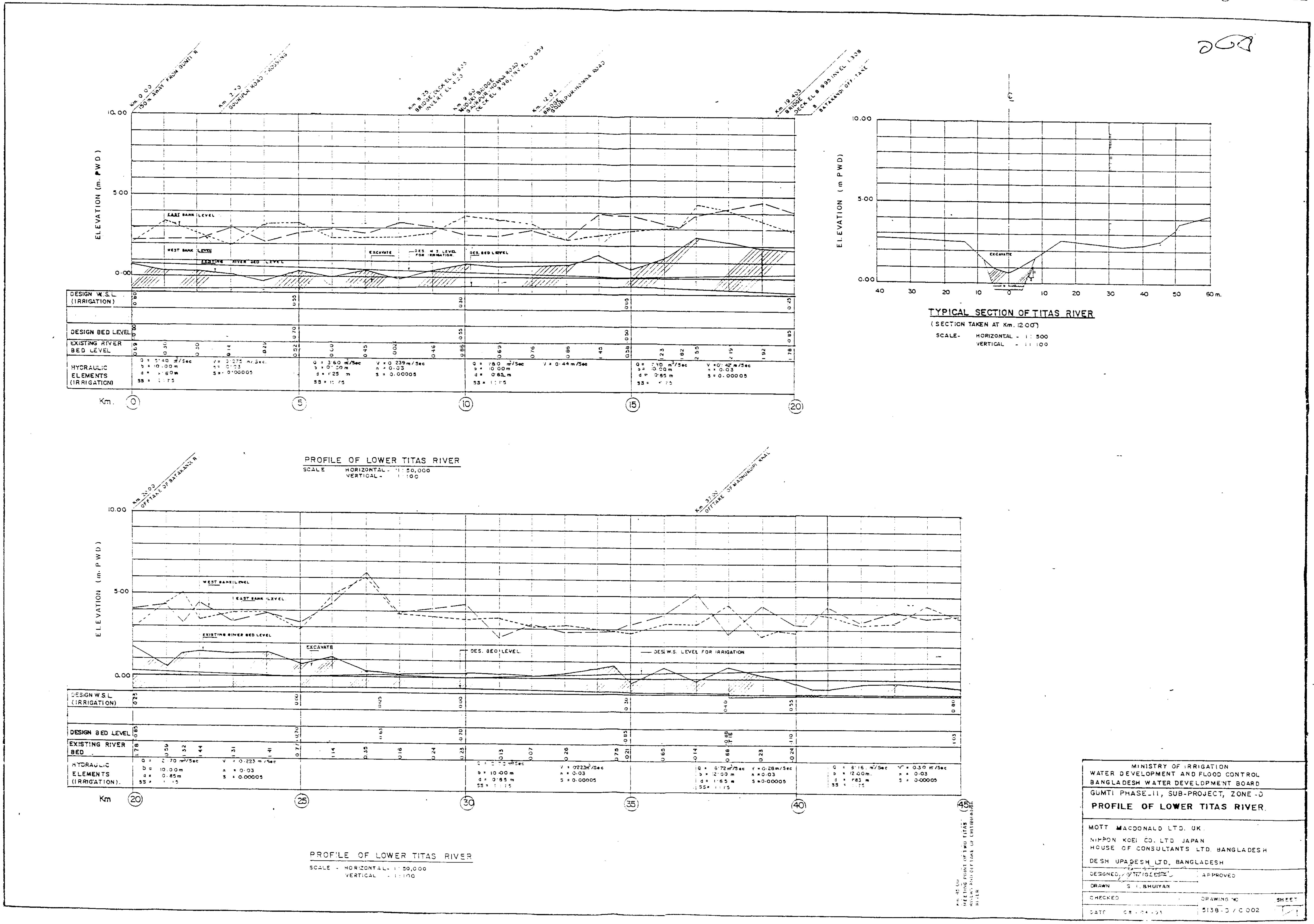
The estimated capital costs at 1992 prices, based upon calculated quantities and the standard unit rates presented in Chapter I.5 of this Annex, are included in Table I.6.4. It has been assumed that 50% of the excavation will be carried out by hand, and 50% by mini-dredger. The rate includes an allowance for compensating farmers for spreading the spoil on their land where it is not required for embankment construction, and no land acquisition for disposal is anticipated. Annual O & M costs have been assumed in accordance with the standard percentages set out in Chapter I.5 of this annex, based upon the FPCO Guidelines for Project Assessment. The allowance of 6% of capital cost per annum for the maintenance of khal excavation is considered to be ample in this zone, since the sediment load of the Upper Meghna is relatively low. The assumed division between local and foreign currency costs is also in accordance with standard percentages set out in Chapter I.5.

The detailed agricultural benefits are discussed in Annexes E (Agriculture) and J (Financial and Economic Analysis). At present, about 4 000 ha are estimated to be irrigable by LLP during a 1 in 5 dry year. This area is expected to increase to 14 000 ha after re-excavation. Farmers generally appear willing to invest in LLPs even when the reliability of the supply is less than 4 years out of 5. The present and with project irrigated areas are therefore likely to be greater than the above estimates, with a greater element of risk involved. The proposed works are complementary to the JICA re-excavation programme, which is aimed at the smaller channels, and should increase its effectiveness.

(ii) Extension of the Gumti Right Bank Embankment

A low submersible embankment has been proposed, extending from the end of the existing Gumti right embankment to the Gouripur-Homna road crossing (10.75 km). A submersible embankment has been selected since protection against peak floods would not be effective in the absence of a Meghna embankment. The embankment is designed to become submerged in June, under the influence of the main river flood. The design crest level at the upstream end near Ratanpur is 5.7 m above PWD and at the Gouripur road crossing 4.7 m, giving an average height of between 1.2 m and 1.7 m.

Figure I.6.21


PROFILE OF LOWER TITAS RIVER
SCALE HORIZONTAL - 1:50,000
VERTICAL - 1:100
ELEVATION (m. PWD)
DESIGN W.S.L. (IRRIGATION)
DESIGN BED LEVEL
EXISTING RIVER BED LEVEL
HYDRAULIC ELEMENTS (IRRIGATION)
Km
EAST BANK LEVEL
WEST BANK LEVEL
EXISTING RIVER BED LEVEL
EXCAVATE
DES. BED LEVEL
DES. W.S. LEVEL FOR IRRIGATION
TYPICAL SECTION OF TITAS RIVER
(SECTION TAKEN AT Km. 12.00)
SCALE- HORIZONTAL - 1:500
VERTICAL - 1:100
MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
GUMTI PHASE-II, SUB-PROJECT, ZONE-D
PROFILE OF LOWER TITAS RIVER
MOTT MACDONALD LTD. UK
NIPPON KOEI CO. LTD. JAPAN
HOUSE OF CONSULTANTS LTD. BANGLADESH
DESH UPADESH LTD. BANGLADESH
DESIGNED
APPROVED
DRAWN S. I. BHUIYAN
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DRAWING NO
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DATE
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Figure I.6.22

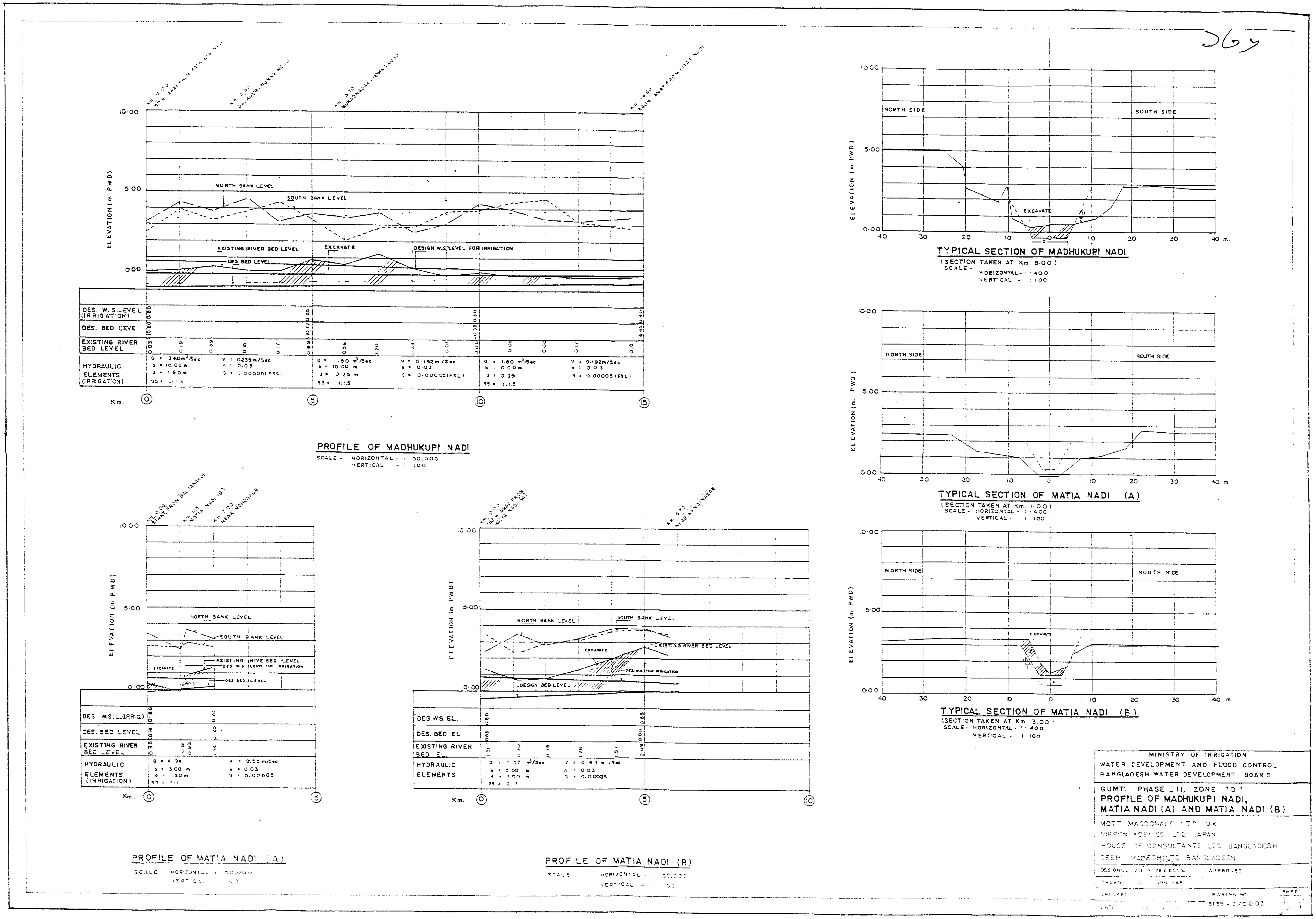
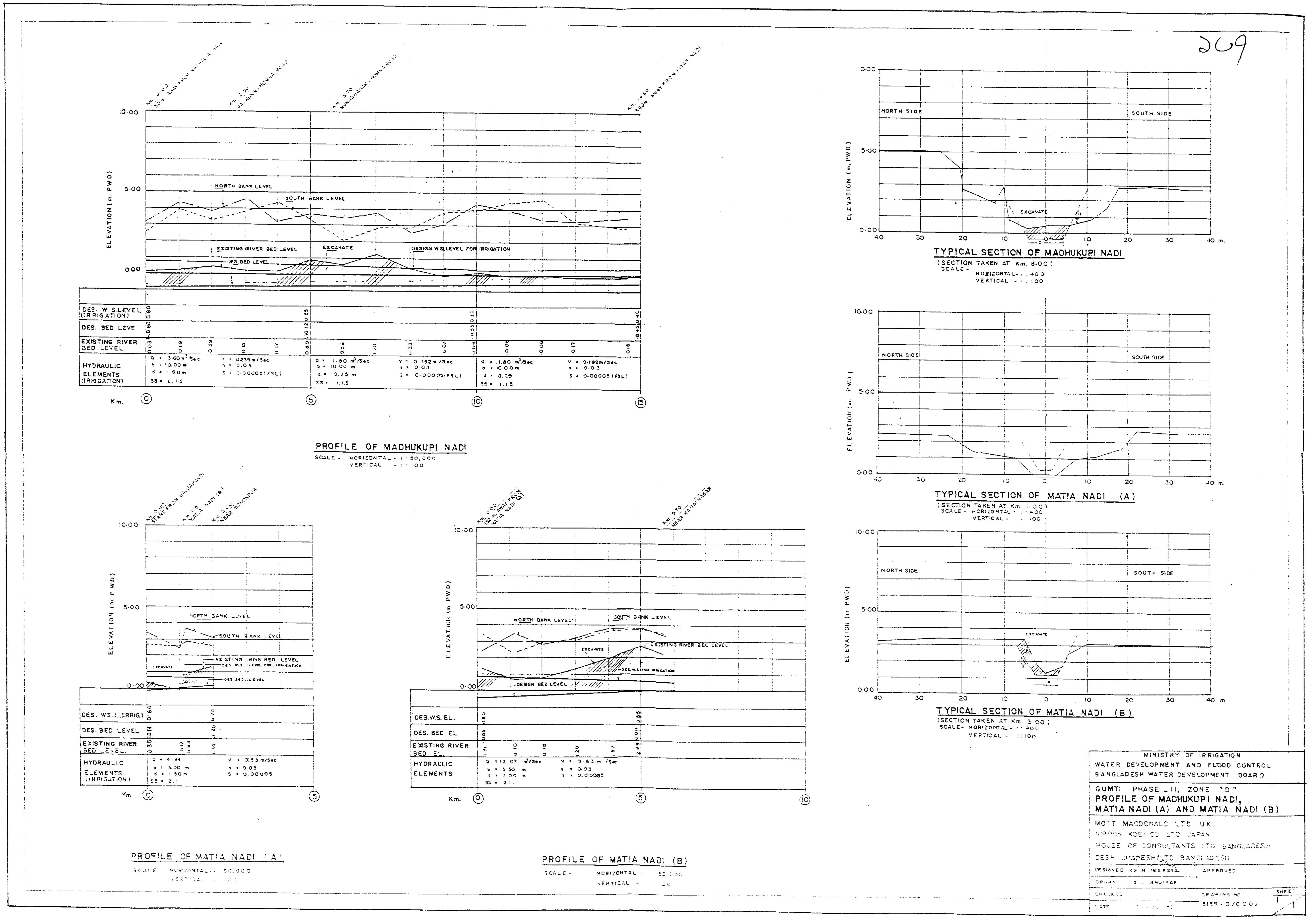

PROFILE OF MADHUKUPI NADI
SCALE - HORIZONTAL - 1:50,000
VERTICAL - 1:100
ELEVATION (m. PWD)
NORTH BANK LEVEL
SOUTH BANK LEVEL
EXISTING RIVER BEDLEVEL
DES. BED LEVEL
EXCAVATE
DESIGN W.S.LEVEL FOR IRRIGATION
DES. W.S.LEVEL (IRRIGATION)
DES. BED LEVE
EXISTING RIVER BED LEVEL
HYDRAULIC ELEMENTS (IRRIGATION)
Km.
PROFILE OF MATIA NADI (A)
DES. W.S.L.(IRRIG)
DES. BED LEVEL
EXISTING RIVER BED LEVEL
HYDRAULIC ELEMENTS (IRRIGATION)
PROFILE OF MATIA NADI (B)
DES.W.S.EL.
DES. BED EL
EXISTING RIVER BED EL.
HYDRAULIC ELEMENTS
DESIGN BED LEVEL
EXISTING RIVER BED LEVEL
TYPICAL SECTION OF MADHUKUPI NADI
(SECTION TAKEN AT Km. 8.00)
SCALE - HORIZONTAL - 1:400
VERTICAL - 1:100
NORTH SIDE
SOUTH SIDE
TYPICAL SECTION OF MATIA NADI (A)
(SECTION TAKEN AT Km. 1.00)
TYPICAL SECTION OF MATIA NADI (B)
(SECTION TAKEN AT Km. 3.00)
MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
GUMTI PHASE - II, ZONE "D"
PROFILE OF MADHUKUPI NADI,
MATIA NADI (A) AND MATIA NADI (B)
MOTT MACDONALD LTD UK
HOUSE OF CONSULTANTS LTD BANGLADESH
APPROVED

Figure I.6.22



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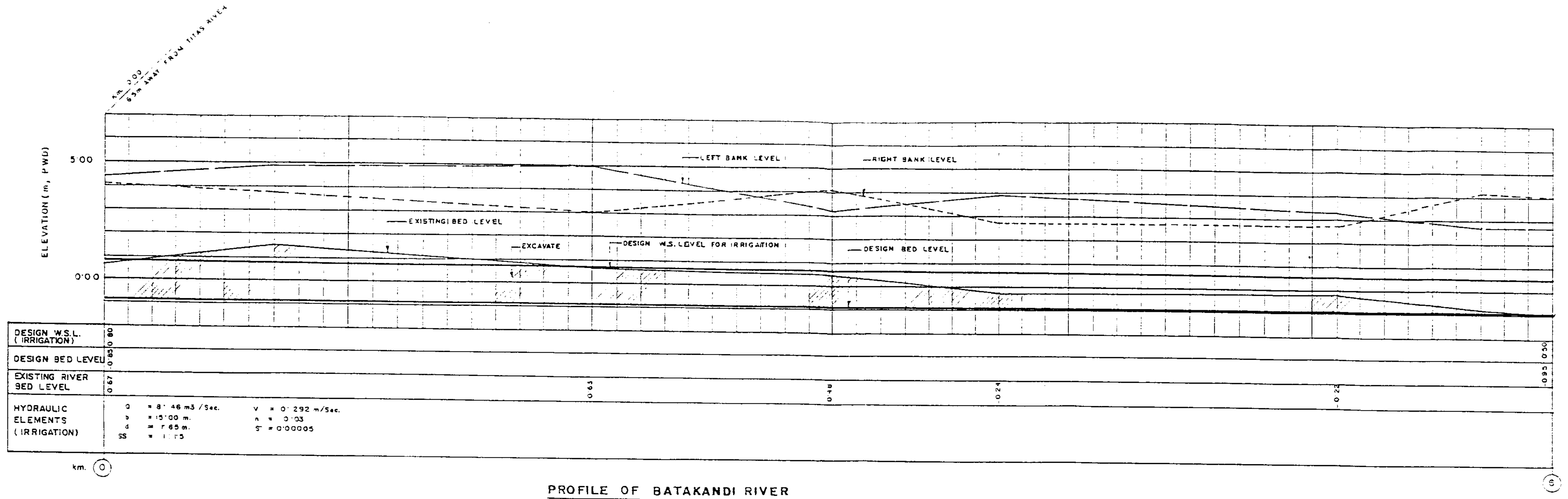
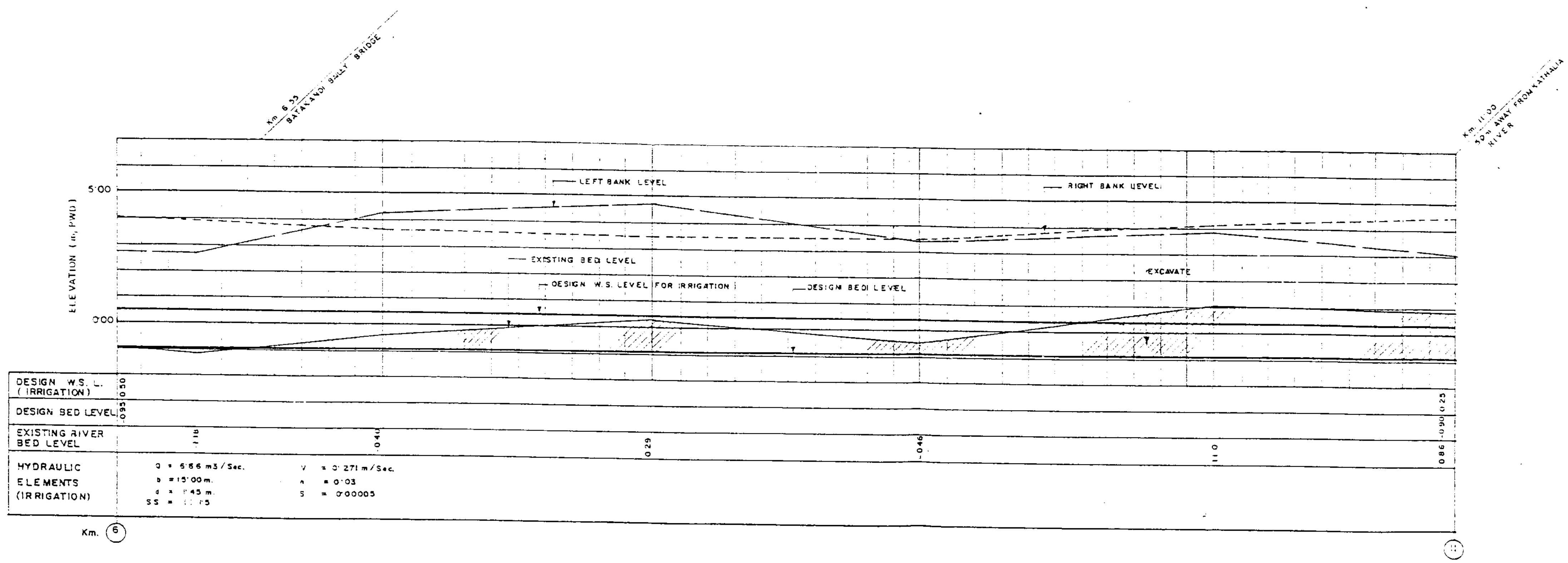


PROFILE OF BATAKANDI RIVER

SCALE – HORIZONTAL – 1 : 10000
VERTICAL – 1 : 100



PROFILE OF BATAKANDI RIVER

SCALE – HORIZONTAL – 1 : 10000
VERTICAL – 1 : 100

MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD

GUMTI PHASE II, SUB-PROJECT, ZONE - D

PROFILE OF BATAKANDI RIVER.

MOTT MACDONALD LTD UK
NIPPON KOEI CO LTD JAPAN
HOUSE OF CONSULTANTS LTD BANGLADESH
DESH UPADESH LTD BANGLADESH

DESIGNED S.S.S. ABEDIN	APPROVED
DRAWN M.A. UDDIN	
CHECKED	DRAWING NO
DATE	

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TABLE I.6.4

Capital Costs of the Zone D Schemes

	Description	Unit	Quantity	Unit Rate (Tk)	Cost (Tk 000)
1	Submersible embankment (Gumti R. Bank)				
	- Clearing, Grubbing & Stripping	sq.m	83 471	3	250
	- Channel Excav. and Formation of Emb. (Manual Excav./Mechanical Comp.)	cu.m	75 447	42	3 169
	- Turfing	sq.m	88 707	3	266
2	Channel excavation & Spreading				
	- Manual excavation (transport 50 m)	cu.m	677 000	28	18 956
	- Mini-Dredger (transport 500 m)	cu.m	677 000	50	33 850
3	Drainage/flushing sluices (Gumti R. Bank) - 1 Nr Vent 1.82m X 1.52m	Vent	2 x 1	2 000 000	4 000
4	Irrigation Inlet Structure (Gumti Right Emb.) - 6 inch dia PVC Pipe with Dist. Box	Nr	15	50 000	750
5	Buildings	Existing facilities at Comilla			0
6	Vehicles	Nr	1	1 000 000	1 000
7	Land Acquisition				
	- Agricultural	ha	8.35	375 000	3 131
	- Homestead	ha	0	1 617 800	0
	Sub-Total				65 373
	Physical contingencies 15%				9 806
	Sub-Total including contingencies				75 178
	Engineering service cost				9 021
	Total Project Cost				84 200
	Made up of - Local Currency				67 458
	- Foreign Currency				16 742

For the first 1.6 km upstream of Gouripur an existing road is to be improved to serve as the embankment, whilst for the remainder of the length a new embankment is to be constructed, set back about 30 m from the river bank. Top width is to be 4.27 m, and side slopes 1 in 1.5 on the river side and 1 in 2 on the country side. Two flushing sluices, each having a single 1.82 m high by 1.52 m wide slide gate, are provided at the locations shown in Figure I.6.20, to facilitate the continuation of LLP irrigation in the protected area. A type design for these structures is given in Figure I.6.5.

Extension of the embankment from Gouripur to the River Meghna was originally considered, and was favoured by public opinion, but this would have to include a large structure at the Lower Titas outfall to the River Gumti, which would be very expensive and problematic to operate. The SERM is not able accurately to predict any negative effects the proposed extension may have upon the area further downstream from Gouripur. This area is already affected by flash floods, but it is anticipated that the excavation of the Lower Titas River and the Matia Nadi should substantially mitigate any adverse impact. This matter should be reviewed at the detailed design stage.

The estimated capital costs at 1992 prices, based upon calculated quantities and the standard unit rates presented in Chapter I.5 of this Annex, are included in Table I.6.4. It has been assumed that all excavation will be carried out by hand. Mechanical compaction of embankment fill material has been specified. A total of about 8 ha of land acquisition has been allowed for. Annual O & M costs have been assumed in accordance with the standard percentages set out in Chapter I.5 of this annex, based upon the FPCO Guidelines for Project Assessment.

The detailed agricultural benefits are discussed in Annexes E (Agriculture) and J (Financial and Economic Analysis), and are based primarily upon reductions in flood damage to the boro crop. In addition to giving protection against inundation by flash floods, the embankment will also prevent the associated deposition of sand, thereby reducing land damage and the maintenance requirements of the Lower Titas re-excavation. On the debit side, the rate at which the ground level rises through accretion will also reduce.

(iii) Submersible Embankment Schemes

Two potential submersible embankment schemes were identified, as indicated on Figure I.6.20.

The northern (Dari Char) scheme is largely encircled by road developments proposed under the JICA rural improvement programme referred to in Section (f)(i) above, meaning that a new embankment is required only along the bank of the Chitibhanga River plus a short stretch linking to the highland in the south-west corner (6.3 km). The protected area is 1 560 ha gross. A drainage sluice with a single 1.82 m high by 1.52 m wide slide gate would control inflow and outflow. Approximately 7 km of minor khal would also require resectioning.

The southern (Motopi) scheme includes the Matia Nadi (reach A) and one of the khals proposed for excavation by JICA. The northern, eastern and southern boundaries are largely defined by homesteads and high land, so the total length of embankment required is only about 8.7 km. The protected area is 1 060 ha gross. Inflow and outflow would be controlled by a drainage sluice with a single 1.82 m high by 1.52 m wide slide gate at the western end of the JICA khal and a 1m diameter gated pipe sluice on Matia Nadi (reach A). The eastern end of the JICA khal would be closed, but this should not have any significant negative impact on drainage or navigation, since the Gumti River provides an alternative path.

An important feature of both schemes, in which they differ from most other submersible embankments constructed in Bangladesh, is the provision of lowered spillway sections in the embankments, which will automatically overtop when the water outside rises above a certain level. By selection of an appropriate crest length and elevation, it can be ensured that the water level inside will always have equalised with that outside before the embankment itself is submerged. One of the major problems with existing schemes is the damage done when water spills into the protected area across the embankment because the inlet structures either have insufficient capacity or else have been opened too late to equalise water levels before overtopping. The spillway sections would be provided with herringbone brick paving on the crest with a brick gabion mattress spillway down the inner slope.

The effects of both schemes are analysed in detail in Appendix I.V to this annex, using the results of a computer programme developed specifically for this purpose. The drainage sluice capacity for the southern scheme as described above is somewhat in excess of that used in the analysis, but this will have only a beneficial effect.

It was concluded that it was not practical to include a fish gate in the design, because any viable fish gate would let an unacceptable amount of water into the protected area before the boro crop could be harvested. The submersible embankment schemes are therefore considered to incur heavy fish losses (50%) because of lack of access to fish and spawn in the months of April and May. This degree of loss is consistent with that reported for the existing Satdona beel scheme.

A further disadvantage of the concept is that when water is allowed into the protected area, the rate of rise of water level is much higher (10 cm per day) than the normal Meghna level rise (5 cm per day). This means that if B aman is to grow, a faster growing but inferior yielding variety will be required.

In order properly to assess the benefit of the schemes, the Agriculturalist visited the two areas in question. The farmers stated that they did not generally incur damage to their boro crop, as they tended to plant very early. The crop could therefore be harvested early, prior to natural flooding. The farmers also stated that they did not bother with the B aman crop as it was incompatible with the boro crop and the flood water was too deep for it.

It is concluded that at present it is not cost effective to provide submersible embankment schemes in Zone D. This situation could however change. The North East Regional Study (FAP 6) is presently considering interventions which could affect the timing of Meghna floods in the Gumti project area. Unfortunately, the FAP 6 "with project" modelling results are not yet ready, so the downstream effect is not yet known. If the time of flood is brought forward, then the boro crops in the lowest lying areas will suffer damage. In this case, the submersible embankment schemes should be taken up in mitigation of the FAP 6 interventions, as part of the cost of those interventions. The estimated cost of the two schemes as analysed is Tk 5.4 million for the northern and Tk 7.7 million for the southern.

Since under present conditions the schemes are clearly not viable, and any changes in the Upper Meghna hydrograph arising from FAP 6 proposals are not yet known, it is not meaningful at this stage to attempt a full economic analysis. They have however been carried forward to the Main Report as possible schemes which may warrant further attention should circumstances so require.

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I.6.4 Full Flood Control and Drainage (FCD)

Figure I.6.24 shows the Full Flood Control and Drainage system. The Consultants for the 1990 report went into considerable detail when considering the engineering aspects of the scheme. As such, it has not been considered worthwhile to attempt to fine tune the proposal, so the scheme analysed, using our methodology, is substantially the same scheme as proposed in the 1990 Report. The only revision which has been made is the provision of slope protection to the peripheral embankment where it is subject to wave attack. It was reported during field visits that embankments fronting the Pagla/Upper Titas River near Nabinagar are highly vulnerable to wave erosion because of the very long wind fetch across the flood plain during the peak monsoon. Parts of the embankment fronting the Upper Meghna at the western boundary of the project area would be similarly vulnerable. Allowance has therefore been made for a provisional quantity of 50 000 square metres of 300 mm concrete cube protection laid on a 100 mm bed of broken brick with a geotextile filter beneath.

The scheme consists of a main perimeter embankment, the Salda/Buri Nadi double embankment, the Ghungur and Bijni left embankments and 12 nr drainage regulators. Most of the regulators are arranged to act as flushing sluices to admit irrigation water during the dry season. There will also be a flushing sluice in the extreme north-east of the project area.

The area is divided into the following 3 main polders:

- The south and west block of 103 019 ha, gross
- The north-east block of 24 082 ha, gross
- The Bijni block of 10 529 ha, gross

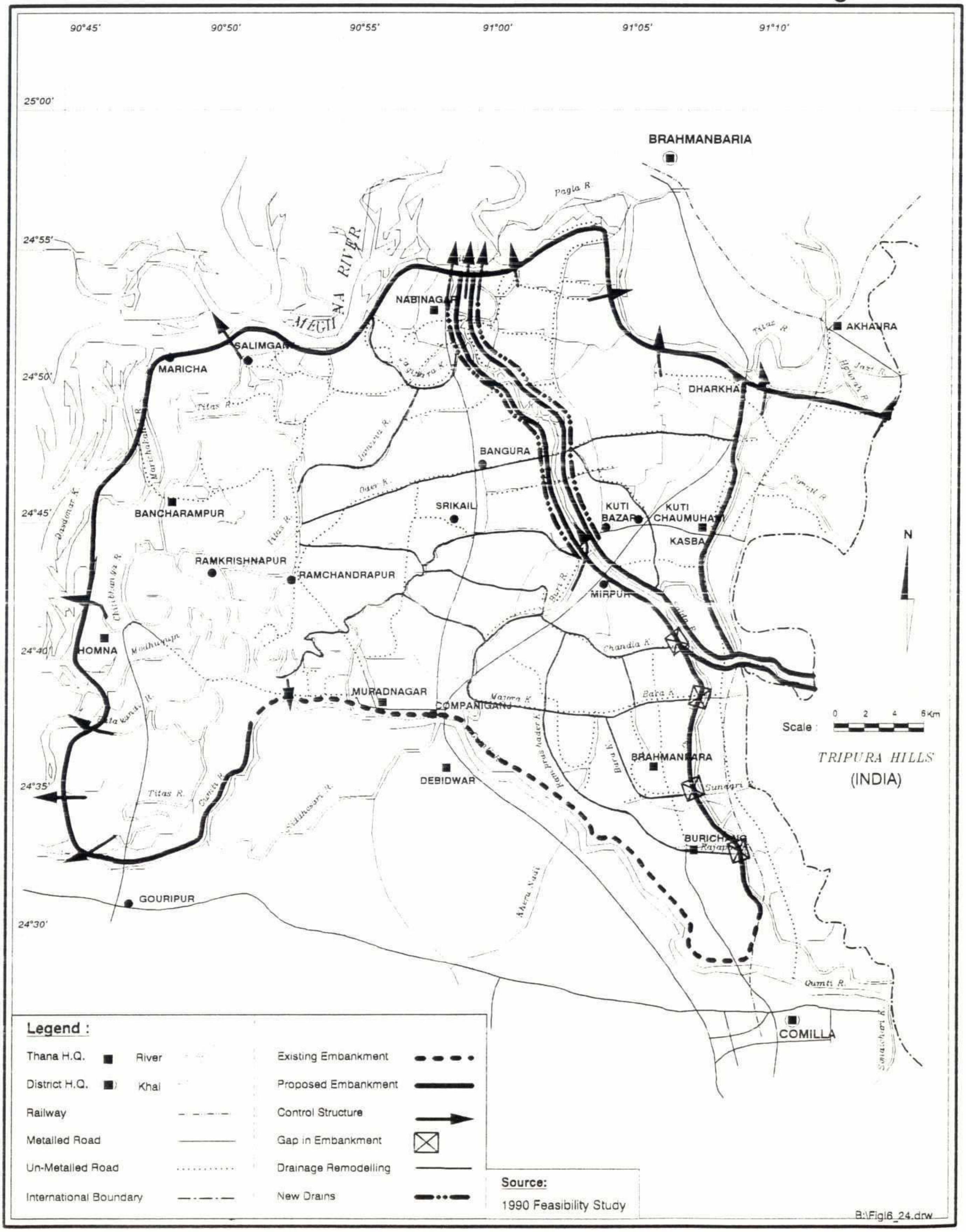
The major flows into the area, from the Indian border, have been routed to the relevant drainage regulators by way of enlarged drainage channels. Since the enclosure of the Buri-Salda channel has disrupted the normal drainage pattern in the Buri area, two side drains from Kuti to the Nabinagar regulators are included in this alternative.

The South and West Block

Approximately 13 300 ha of Indian territory drains into the area. The drainage water from this area is collected by the Ghungur River. Four gaps in the Ghungur left embankment discharge the water into the Chandla Khal, Bara Khal, Sundari Nadi and the Ramprashader khal. These khals will be enlarged to carry the drainage water. In addition, parts of the Buri Nadi, Arsi Nadi and Zia khal will also be enlarged to the point where they discharge into the Lower Titas River. From these points, the pre and post monsoon flows will be discharged through the regulator and lock at Homna and regulators at Mirpur, Lalpur, Batakandi and on the Matia River.

The Northern part of the block will drain to Homna or Muktarampur via the Titas and Chitibhanga Rivers or to Nabinagar West regulator via the Jamuna and Jogidara Rivers.

Figure I.6.24
Full Flood Control and Drainage Scheme



The North Buri Block

Small drainage regulators are provided at Shibnagar, Nar Ghat and Chandai Ghat, but the major part of the drainage will be by way of the large Nabinagar East regulator. The only channel excavated to help drain this area will be the east side drain of the Buri Nadi.

The Bijni Block

This block is part of a drainage catchment of nearly 30 000 ha, 18 000 of which are in India. A major drainage regulator is therefore required at the mouth of the Bijni River, where it crosses the main embankment and close to the river's confluence with the Titas.

Irrigation

The source of irrigation in the FCD case will be from tubewells or surface water admitted by flushing sluices. In addition, a very limited amount of water may be stored by closing the regulator at Nabinagar on the Buri Nadi. This stored water may be used by farmers near the embankments with LLP's pumping over the embankment.

As discussed in Chapter 2 and Annex C, the empoldering of the area will not have a major effect on groundwater. Assuming adoption of force mode tubewells, groundwater will be able to supply the area not covered by LLPs. The area covered by LLPs is assumed to be the same for "with project" and "without project" conditions. From our surveys and AST data, this amounts to 22 500 ha.

Transport

The relatively high water levels inside the polder during the monsoon mean that there is little point in road construction in the western half of the area. However, the existing Gouripur to Homna road will be usable and it is proposed to link this road to the main embankment at the Homna regulator with a metalled road. A short metalled road will link the launch ghat on the Titas with Nabinagar town.

There is no intention to provide more roads, although the remaining lengths of the main embankment, the Salda-Buri embankments and the Ghungur and Bijni left embankments will be wide enough to carry light traffic.

Because of the widening of the drainage channels, it will be necessary to provide new bridges on the Companiganj to Nabinagar road at the crossings of the Chapitala khal, the Zia khal and the Arsi Nadi. Access bridges will also be provided along the bank of the southern arm of the Buri Nadi where it crosses the Majora khal, Chandla khal and Chapitala khal.

Since no road works are envisaged within the western area, it is important to maintain the existing waterway links. The 1990 Report water traffic surveys showed that the majority of the inward and outward boat traffic was on the Chitibhanga River near Homna. In consequence, it was decided to include a double navigation lock with the regulator at Homna.

Costs

The capital costs of the proposed scheme according to the 1990 report, compared with those used in the present analysis, based upon the standard unit rates presented in Chapter I.5 of this Annex, are presented in Table I.6.5. Annual O & M costs for the purposes of economic analysis have been assumed in accordance with the standard percentages set out in Chapter I.5 of this annex, based upon the FPCO Guidelines for Project Assessment.

TABLE I.6.5

Summary of Capital Costs for FCD Option

Item Nr	Description	Capital Cost (Million Taka) 1990 Feasibility Study	Capital Cost (Million Taka) Present Study (1992 Prices)
1	Land Acquisition	1 197	1 943
2	Civil Works		
	(a) Embankments	1 095	1 160
	(b) Drains	672	746
	(c) Structures	511	547
3	Roads		
	(a) New Roads	5	6
	(b) Embankment Paving	97	108
	(c) Bridges	29	31
4	Buildings	150	171
5	Vehicles	44	50
6	Additional Slope Protection	-	50
	Sub-Total	3 800	4 812
	Physical Contingencies 15%	-	722
	Total including Contingencies	-	5 534
	Engineering Service Cost 12%	-	664
	Total Project Cost		6 198
	Made up of -	Local Currency	5 424
	-	Foreign Currency	774

The assumed division between local and foreign currency costs is also in accordance with standard percentages set out in Chapter I.5.

Benefits

The detailed agricultural benefits are discussed in Annexes E (Agriculture) and J (Financial and Economic Analysis). However Figure I.6.25 shows the with project flood phasing, for comparison with the without project situation in Figure I.6.7, whilst Figure I.6.26 shows the change as a result of the proposals.

I.6.5 Full Flood Control, Drainage and Irrigation (FCDI)

Figure I.6.27 illustrates the proposed FCDI scheme. Again, the scheme is substantially unaltered from the FCDI Alternative A proposed in the 1990 Report, apart from the provision of embankment slope protection as discussed in Section I.6.4 above.

Flood Control

The flood control works consist of the main perimeter embankment, the Salda/Buri double embankment, the Ghungur and Bijni River left embankments and 9 drainage regulators and flushing sluices.

Drainage

The area is divided into the same three main polders as the FCD option. The south and west area is further divided by the embankments on both banks of the southern section of the Buri Nadi.

The south and west block is enclosed by the Indian border to the east, the River Gumti to the south, the Meghna to the west, the Titas to the north and the Buri/Salda channel to the north-east. The drainage of this area, and the 13 300 ha in India, is collected in the Ghungur River. The Ghungur will normally drain through check structures on the Chandla khal, Bara khal, Sundari Nadi and Ramprashader khal. These four channels will be enlarged, as will the Majora Nadi which will convey the flow, with the Chandla khal, to the Buri Nadi. Parts of the Buri Nadi channel will be enlarged to transfer these inflows to the Chapitala khal and Zia khal.

The Chapitala, Zia, Arsi, Roachala khals will also be re-excavated to convey the flow to the Lower Titas and Chitibhanga Rivers, eventually to be drained via the Homna pump station on the Chitibhanga. The northern part of the area will drain either to Homna or Nabinagar West pumping station, via the western side drain, parallel to Buri Nadi, or Jogidara khal.

The south-west corner is to be drained via the Matia khal and a reversible pump station at Mohanpur.

In addition to the three pump stations at Mohanpur, Homna and Nabinagar West, there are three drainage regulators at the junction of the Lower Titas and Gumti Rivers, the Batakandi River and at Muktarampur on the Lower Titas to the north. While these regulators may assist local drainage during the pre-monsoon period, it is not expected that they will have much effect on the overall water level in the polder.

Figure I.6.25
1990 Study FCD Proposals - 1 in 5 year Peak Flood Phasing

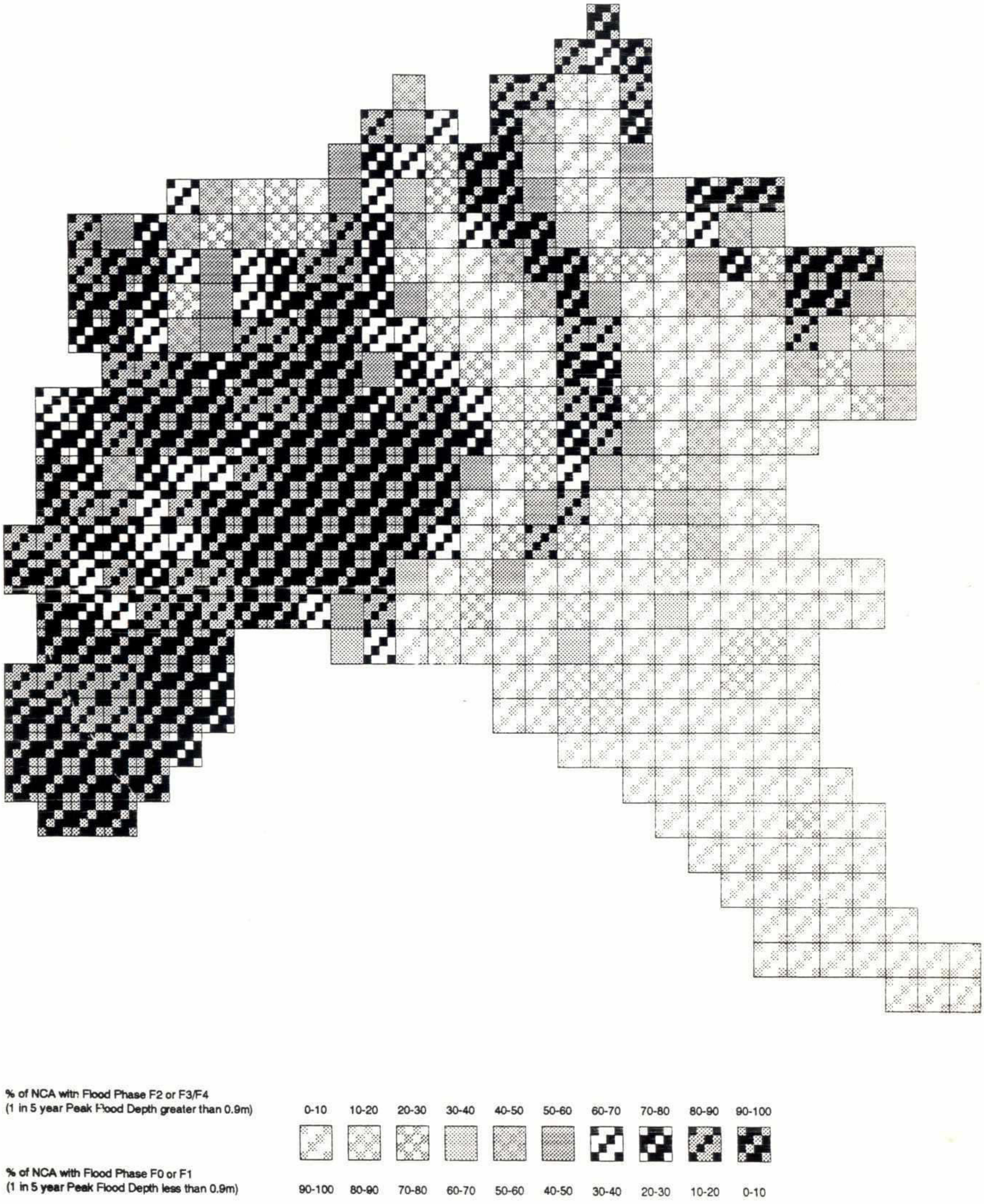


Figure I.6.26
1990 Study FCD Proposals - Change in 1 in 5 year Peak Flood Phasing

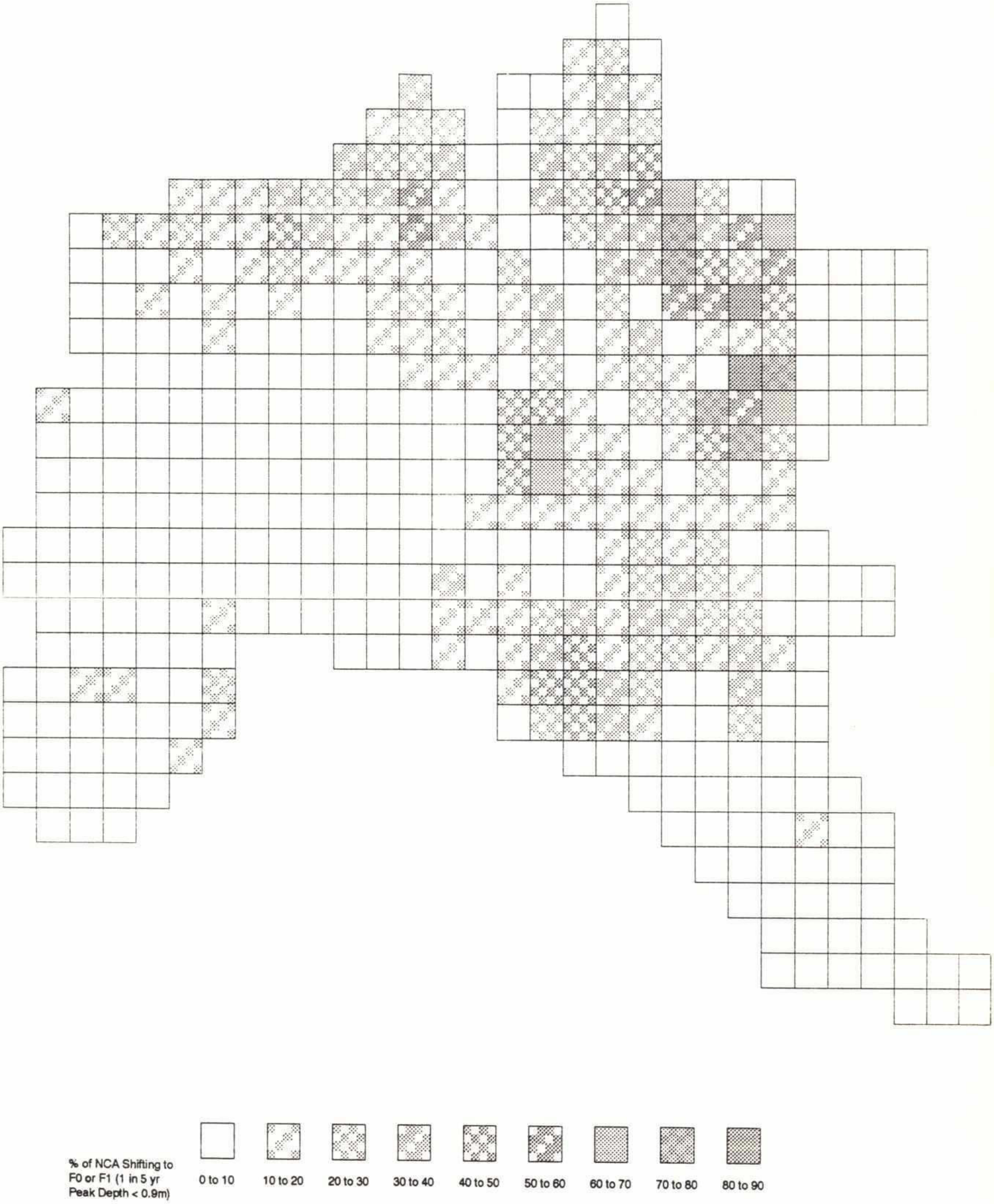
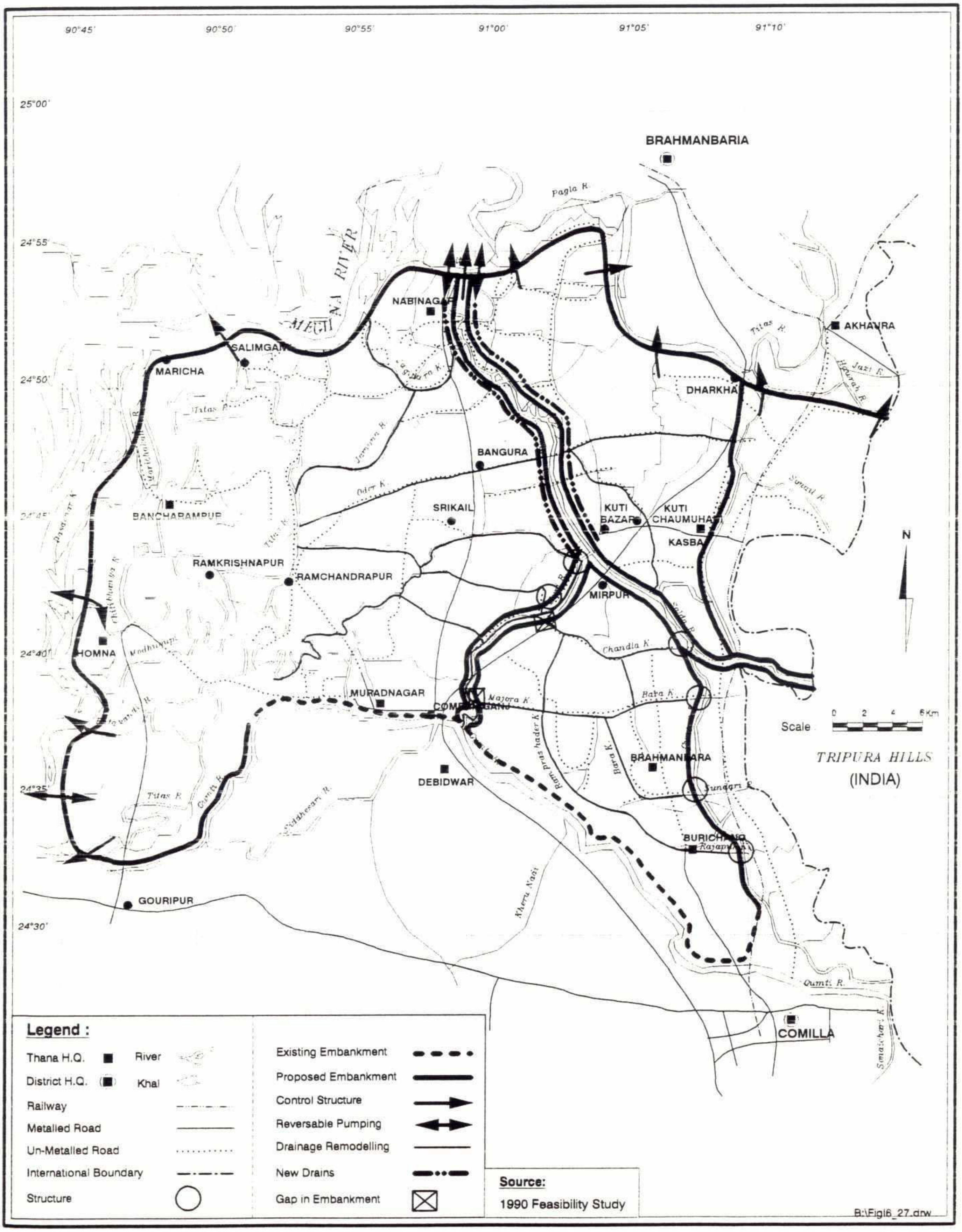


Figure I.6.27

Full Flood Control, Drainage and Irrigation Scheme



The North Buri Nadi block is enclosed by the perimeter embankment to the north, the Bijni left embankment to the east and the Salda/Buri Nadi right embankment to the south and west. The major khal network in the area will be enlarged and improved and will drain north-west to the Nabinagar East pump station.

The Bijni block is bounded by the perimeter embankment to the north, the Indian border to the east and the Bijni left embankment to the south and west.

The block is drained north into the Titas, involving a large regulator in the perimeter embankment where the Bijni River crosses the embankment alignment. Excavation to the Bijni River is also proposed.

Irrigation

Irrigation supplies are provided by a combination of four main pumping stations and tubewells. Three options for the capacities of the major pump stations were studied, according to different assumptions about the area which was served by tubewells. The three options are given in Table I.6.6.

TABLE I.6.6

Main Pump Station Capacities

	Option 1 Capacity (m^3/s)	Option 2 Capacity (m^3/s)	Option 3 Capacity (m^3/s)
Nabinagar East	18.75	12.5	18.75
Nabinagar West	31.25	25	25
Homna	50	50	37.5
Mohanpur (S of Homna)	4.5	4.5	3.8
Total Capacity	104.5	92.0	85.05

The 1990 Report hydraulic model assumed the capacities corresponding to Option 2, and in order to compare like with like, this report has assumed the same capacities. The axial flow pumps are assumed to be powered by electricity and in all cases are reversible.

The Mohanpur pump station supplies the area in the south-west corner of the project area. The Homna pump station pumps from the Meghna into the Chitibhanga River and thence into the network of khals and beels of the Lower Titas River. This irrigation network includes a system of relift pumps.

The Nabinagar East and West pump stations pump water into the embanked Buri Nadi channel. The combined irrigation flows of both the east and west pumping stations at Nabinagar are distributed by this channel and the relift pumping stations at Bijni and Ghungur. There are therefore six combined irrigation outlets/aqueducts (aqueducts) on the Buri Nadi, which transfer irrigation water to the drainage system over the low level drains which run parallel to the Buri Nadi. A large irrigation structure at Kuti controls flows into the southern arm of the Buri Nadi, while a similar outlet controls the flow into the Rajar khal.

On the Ghungur, in addition to the four large drainage control structures, which will also control irrigation flows, there are five small irrigation offtakes to supply local areas adjacent to the embankment. Three similar structures distribute irrigation water to the North Buri Nadi block from the Bijni.

The main pump stations are designed to operate for 24 hours a day during peak demand. However, it is assumed that the relift pumps and LLPs will only pump for 16 hours a day. In consequence, water will be stored in the lower Titas and the Buri Nadi. This will have minimal effect on the Lower Titas but will generate water level increases of between 0.3 and 0.4 m in the Buri/Salda channel, which is confined. This will not threaten overtopping but will make operation more complicated.

In addition to the four main pumping stations, there are five relift pump stations. Their locations and capacities, for the option 2 case, are as follows:

Arsi PS - 4 m^3/s capacity, situated on the Arsi Nadi commanding the area drained by the Arsi Nadi, Zia khal and Chapitala khal.

Oder Khal PS - 4 m^3/s capacity, situated on the Oder Khal commanding the area drained by the Oder khal.

Jamuna PS - 12 m^3/s capacity, situated on the Jamuna River commanding the area drained by the Jamuna and Jogidara khal.

Bijni PS - 12 m^3/s capacity, situated on the right bank of the Salda River commanding the Bijni and North Buri Nadi blocks.

Ghungur PS - 9 m^3/s capacity, situated on the left bank of the Salda, opposite the Bijni PS, commanding the areas either side of the Ghungur River.

In addition to the pump stations and their associated structures, there are many other irrigation structures controlling the flows and levels of irrigation water supplies, such as irrigation offtakes, inlets and check structures. These, as well as other details of the scheme are discussed in the 1990 Report.

All these pumping stations and control structures are intended to supply water to the existing of khals within the area. Water will then be relifted to the fields by LLPs, owned and operated by the farmers.

Costs

The capital costs of the proposed scheme according to the 1990 report, compared with those used in the present analysis, based upon the standard unit rates presented in Chapter I.5 of this Annex, are presented in Table I.6.5. Annual O & M costs for the purposes of economic analysis have been assumed in accordance with the standard percentages set out in Chapter I.5 of this annex, based upon the FPCO Guidelines for Project Assessment. The assumed division between local and foreign currency costs is also in accordance with standard percentages set out in Chapter I.5.

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Benefits

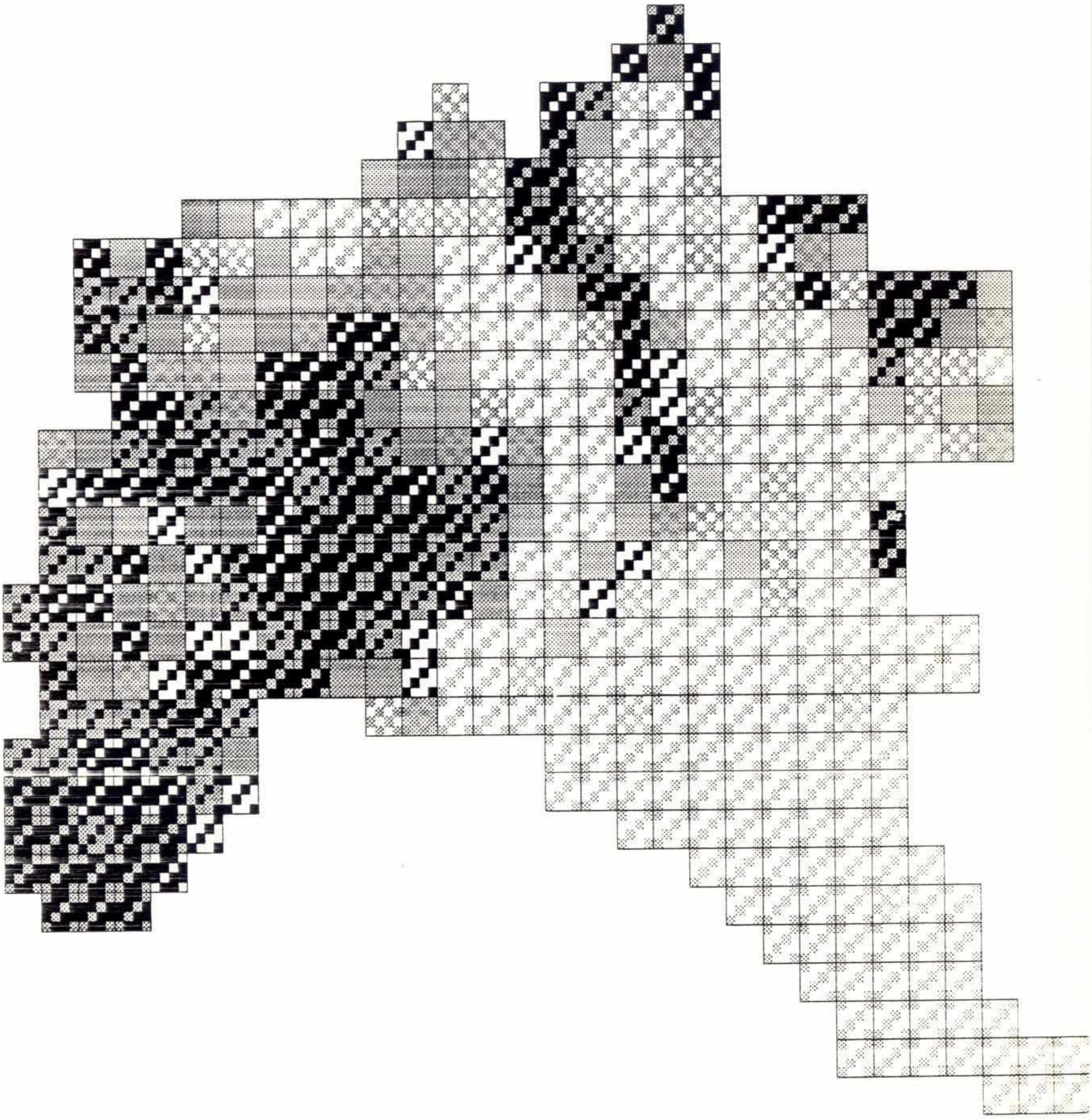
The detailed agricultural benefits are discussed in Annexes E (Agriculture) and J (Financial and Economic Analysis). However Figure I.6.28 shows the with project flood phasing for comparison with the without project situation in Figure I.6.7, whilst Figure I.6.29 shows the change as a result of the proposals.

TABLE I.6.7

Summary of Capital Costs for FCDI Option

Item Nr	Description	Capital Cost (Million Taka) 1990 Feasibility Study	Present Study(1992 Prices)
1	Land Acquisition	1 335	2 167
2	FCD Works		
	(a) Embankments	1 095	1 160
	(b) Drains	803	891
	(c) Structures	280	300
3	Irrigation Works		
	(a) Pump Stations (Civil Works)	585	651
	(b) Pump Stations (Electr. & Mech.)	507	620
	(c) Structures	258	277
4	Roads		
	(a) New Roads	67	71
	(b) Embankment Paving	149	165
	(c) Bridges	51	55
5	Buildings	150	171
6	Vehicles	44	50
3	Additional Slope Protection	-	50
	Sub-Total	5 324	6 628
	Physical Contingencies 15%	-	994
	Total including Contingencies	-	7 622
	Engineering Service Cost 12%	-	915
	Total Project Cost	-	8 537
	Made up of -	Local Currency	7 170
	-	Foreign Currency	1 367

Figure I.6.28
1990 Study FCDI Proposals - 1 in 5 year Peak Flood Phasing



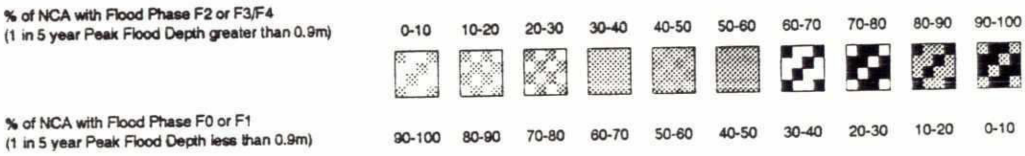
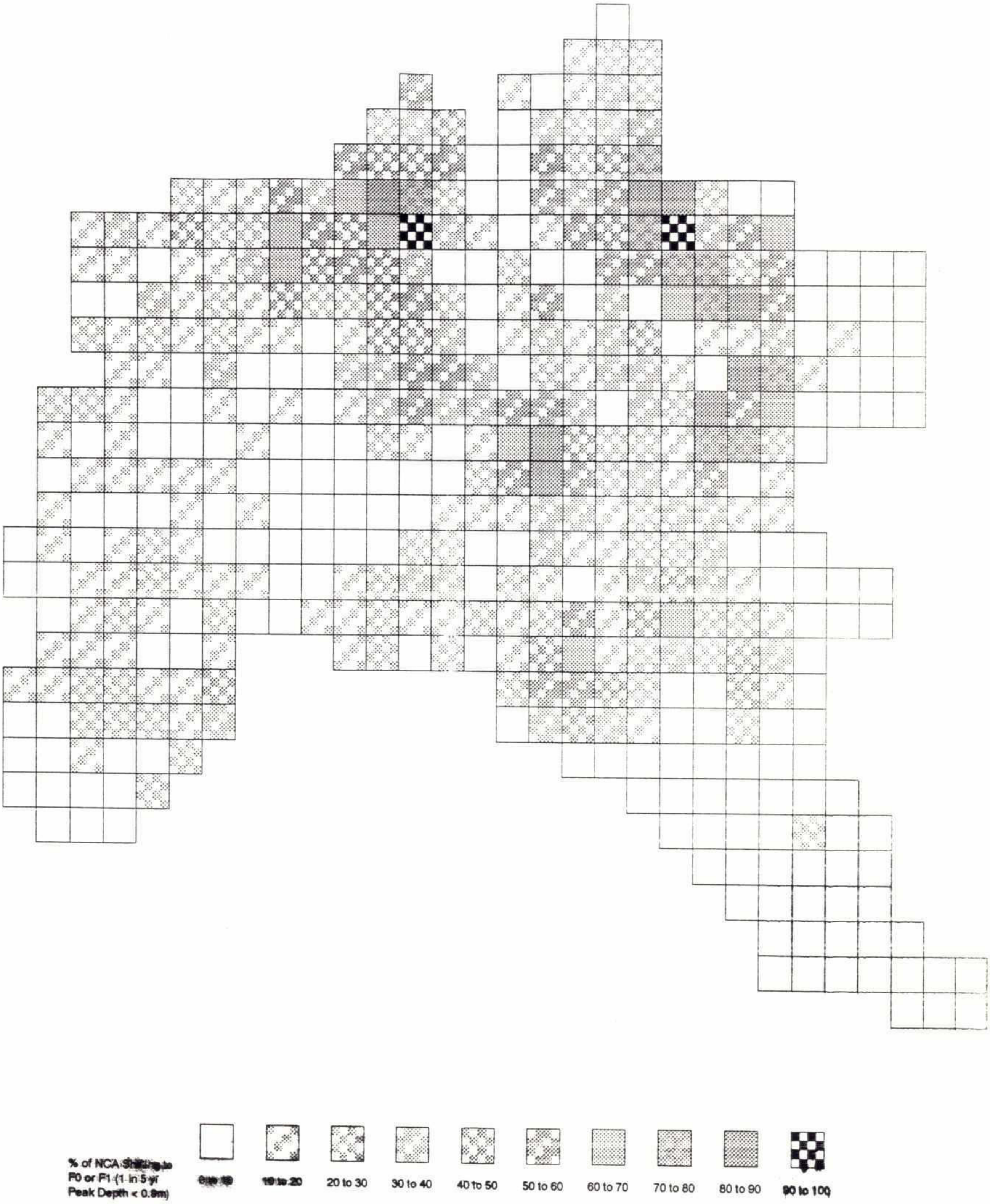


Figure I.6.29
1990 Study FCDI Proposals - Change in 1 in 5 year Peak Flood Phasing



CHAPTER I.7

LAND ACQUISITION AND RESETTLEMENT REQUIREMENTS

I.7.1 General

Land acquisition and resettlement is a sensitive issue in a densely populated country like Bangladesh. According to an analysis by WRPO, agricultural land is likely to decrease by about 50% by 2000 AD. The issue is made even more sensitive because compensation payments are often received only after a long delay, and are inadequate for the purchase of comparable replacement land. The reasons for the inadequacy of the payments can include the following:

- land values for compensation purposes are assessed on the basis of recorded land sales. However, the declared price in any transaction is often less than the sum actually paid, in order to minimise or evade stamp duty,

- land prices often rise with the advent of a project, so that even if the compensation set accurately reflects historic market values, it is not applicable post-project. Delays in effecting payment exacerbate this problem, and

- illegal levies may be extorted from those entitled to compensation.

Where projects have been implemented without the participation and support of local people the compulsory acquisition of land is a particular source of discontent, especially as such projects are unlikely to meet their objectives, and there may be no net benefit (or even a disbenefit) to the community as a whole.

To try and resolve some of these issues the Flood Action Plan includes a Land Acquisition and Resettlement Study (FAP 15). This chapter discusses some of the findings of FAP 15 in the context of the project area.

I.7.2 Land Acquisition

The following general principles apply in the planning of any works which may involve land acquisition:

(i) Land acquisition should be minimised as far as possible. Thus, embankment designs should be compact and follow existing roads etc as far as possible (but see (vi) and (vii) below), whilst channels should be deeper rather than wider, subject to the requirements of stability.

(ii) Fill material should preferably be obtained by removal of a uniform thin layer from agricultural land, which can then return to production, rather than by acquiring land for borrow pits. A royalty will be payable to the farmers, at least to compensate for lost production. Topsoil stripping and replacement may also be required in some circumstances.

(iii) New embankments should be planned for multiple use, for instance as roads.

(iv) Existing channels should be adopted and improved wherever possible, rather than excavating new. In this respect double lift irrigation, which uses existing khals for both irrigation distribution and drainage, is preferable to gravity systems which require independent networks of canals and drains.

(v) The acquisition of land for the dumping of spoil should be avoided. Instead, excavated material should be regarded as an asset, which can be used to raise lower lying land or for raising homestead/village areas above flood level. This approach requires the detailed involvement of the local people, both in planning and implementation. Even if no beneficial use of the material may be found, it can generally be spread over agricultural land in return for compensation for the loss of a season's cropping.

(vi) Where resettlement of displaced families is required, an additional berm of 5m width may be provided on the country side of the flood control embankment. This will increase the embankment stability, and the country side slope may therefore be increased from 1 in 2 to 1 in 1.5, in partial compensation for the additional land taken.

(vii) The land acquired for an embankment may include an additional width of 1.7 m on each side for tree-planting, protective works and to enable future bank raising without further land acquisition.

(viii) Where borrow pits cannot be avoided, the possibility of multiple use for drainage etc or fisheries should be investigated. In such cases, the borrow pit may be on the country side with a set back distance of 6 m from the embankment toe, and a depth of about 2 m. The side slope should be 1 in 1.5 on the country side and 1 in 1 on the river side.

(ix) A clay core may be used to decrease the base width of an embankment if suitable clay can be obtained economically.

(x) Embankment set back distances should be minimised as far as possible, to maximise the protected area. Nevertheless, an inadequate set back distance can cause higher water levels, increased bank erosion and a higher risk of failure. River training and or bank protection may be worthwhile in some circumstances. If it is unavoidable that some homesteads are left within the floodplain of an embanked channel, the families concerned should either be compensated to enable them to move, or else provided with flood proofing measures appropriate to their increased risk.

Items (vi) and (vii) above are illustrated by Figure I.7.1, reproduced from the FAP 15 Final Report.

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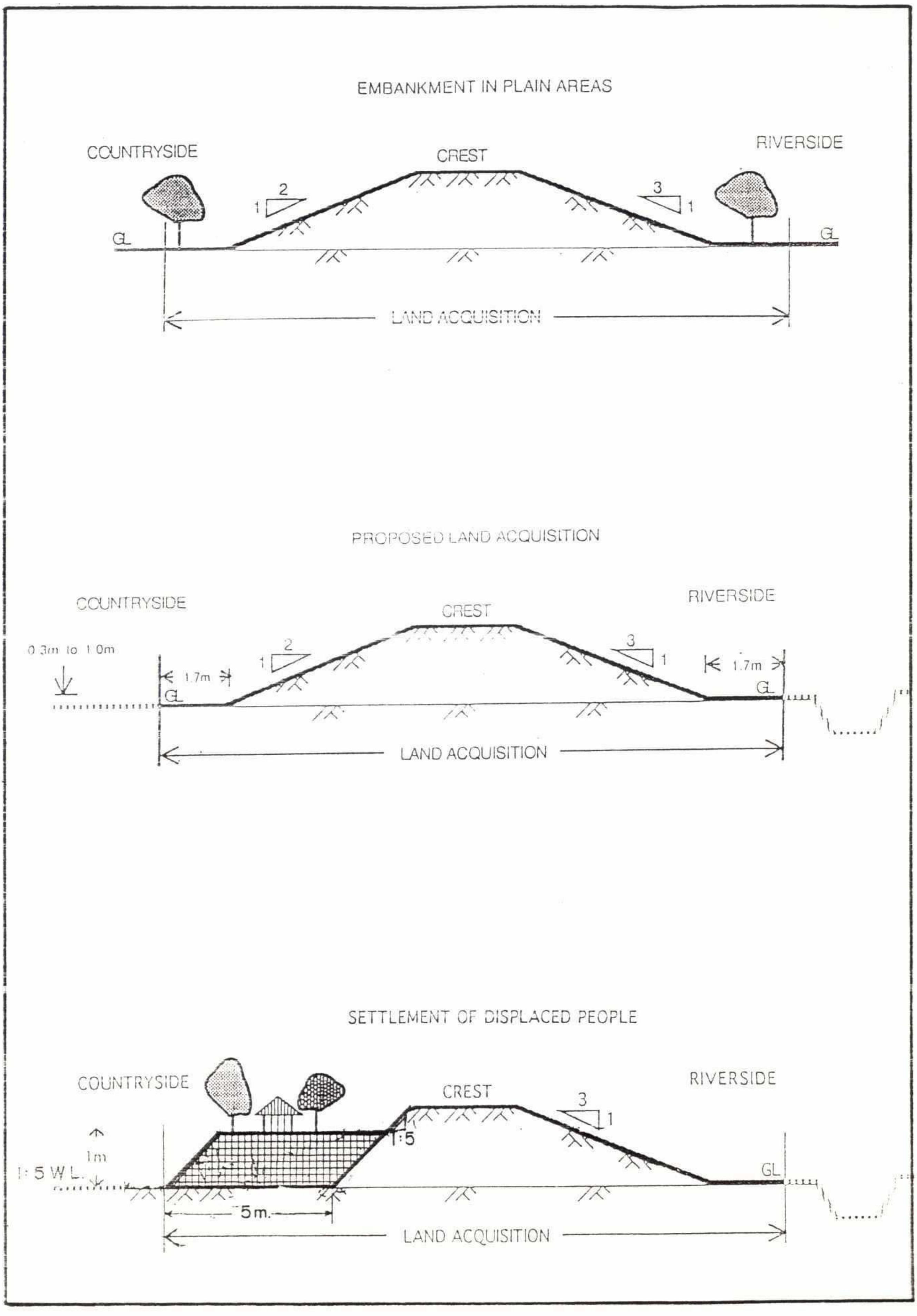
Figure I.7.1
Land Acquisition for Embankments



I.7.3 Resettlement

When homes are lost through the acquisition of land for projects, compensation is usually monetary, with the families themselves being responsible for finding replacement land on the open market and rebuilding their houses. Some of the problems associated with monetary compensation, discussed in Section I.7.1 above, may be alleviated if the project includes a component for physically resettling the displaced families on land specifically allocated for the purpose. This approach would be appropriate if embankments with country side berms are planned as in Section I.7.2(vi) above, or in cases where the project will be disposing of spoil by raising up 'new' land previously unsuitable for homesteads. It is in any case desirable that, where substantial numbers of people are affected and the supply of land available for sale is inadequate and prices are liable to be forced up, specific arrangements should be made for resettlement, for instance by the acquisition of land from large landholders or the allocation of government khas land.

In addition to compensation for the loss of physical assets, by resettlement and/or payments, it may also be necessary to give displaced people further assistance to rehabilitate them socially and economically in their new environment, to re-establish themselves in business etc.

I.7.4 Land Acquisition Requirements for the Basic and Intermediate Flood Response Proposals

(a) Zone - A

Land acquisition is required for the entire length of the Ghungur-Salda embankment, as shown in Figure I.6.2. No land acquisition is required for the proposed modifications to the Comilla-Sylhet highway, since these will be confined to the road borrow pit area. A small area of land will need to be acquired for structures, and perhaps for channel excavation, although most of this will be within the existing top width. No land is required for offices and buildings, since the existing BWDB facilities at Comilla town are considered adequate.

(b) Zone - B

Land acquisition will be required, at least for those reaches of embankment not based upon existing roads. In some cases where there is an existing road, the present reservation width may not be wide enough for the proposed upgrading. A small area of land will need to be acquired for structures, and perhaps for channel excavation, although much of this will be within the existing top width. No land is required for offices and buildings, since the existing BWDB facilities at Brahmanbaria are considered adequate.

(c) Zone - C

No land acquisition for the embankment and supply channel along the Nabinagar-Muradnagar road is proposed, since the existing road borrow pit area is available. Land will however be required for upgrading/construction of the other embankments, as well as for the excavation of Oder Khal. No land acquisition is anticipated for re-excavation of the other channels, although small areas may be required at structures. At Nabinagar, construction of the two proposed pump stations, together with offices (Executive Engineer and Sub-Divisional Engineer), workshop, godown and staff houses will require land acquisition.

(d) Zone - D

The only land acquisition anticipated for the proposals in this zone would be in respect of the submersible embankments and associated structures. No land acquisition would be necessary for khal excavation.

I.7.5 Unit Rates for Land Acquisition

Land has been split into two categories for the purpose of estimating land acquisition costs; agricultural land and homesteads. Most of the land to be acquired is agricultural, but in a few locations it has not been possible to avoid villages. Estimated land acquisition costs for the two categories, based upon the recommendations of FAP 15, have been derived as follows:

Agriculture land

From local enquiry, the market price of land was found to be of the order of Tk 250 000 per hectare. An allowance of 50% was added to this for dislocation, making a total of Tk 375 000 per hectare.

Homestead land

The rate for homestead land was based upon that for agricultural land, plus a rebuilding allowance of Tk 12 000 per household. Assuming just over 100 homesteads per hectare gave a total rate of Tk 1 617 800 per hectare.

CHAPTER I.8

NAVIGATION, ROAD TRANSPORT AND POWER SUPPLY

I.8.1 River Transport

Month long sample surveys were performed during March/April and September/October 1988 under the 1990 Feasibility Study, to ascertain the water borne traffic entering and leaving the project area. The results are reproduced in Table I.8.1, and the survey locations are indicated in Figure I.8.1. Traffic surveys were not carried out at the outfall of the Lower Titas on the Gumti River because the route was observed to be little used, or at its offtake from the Meghna at Salimganj, because a newly-built road bridge has severely restricted headroom.

TABLE I.8.1

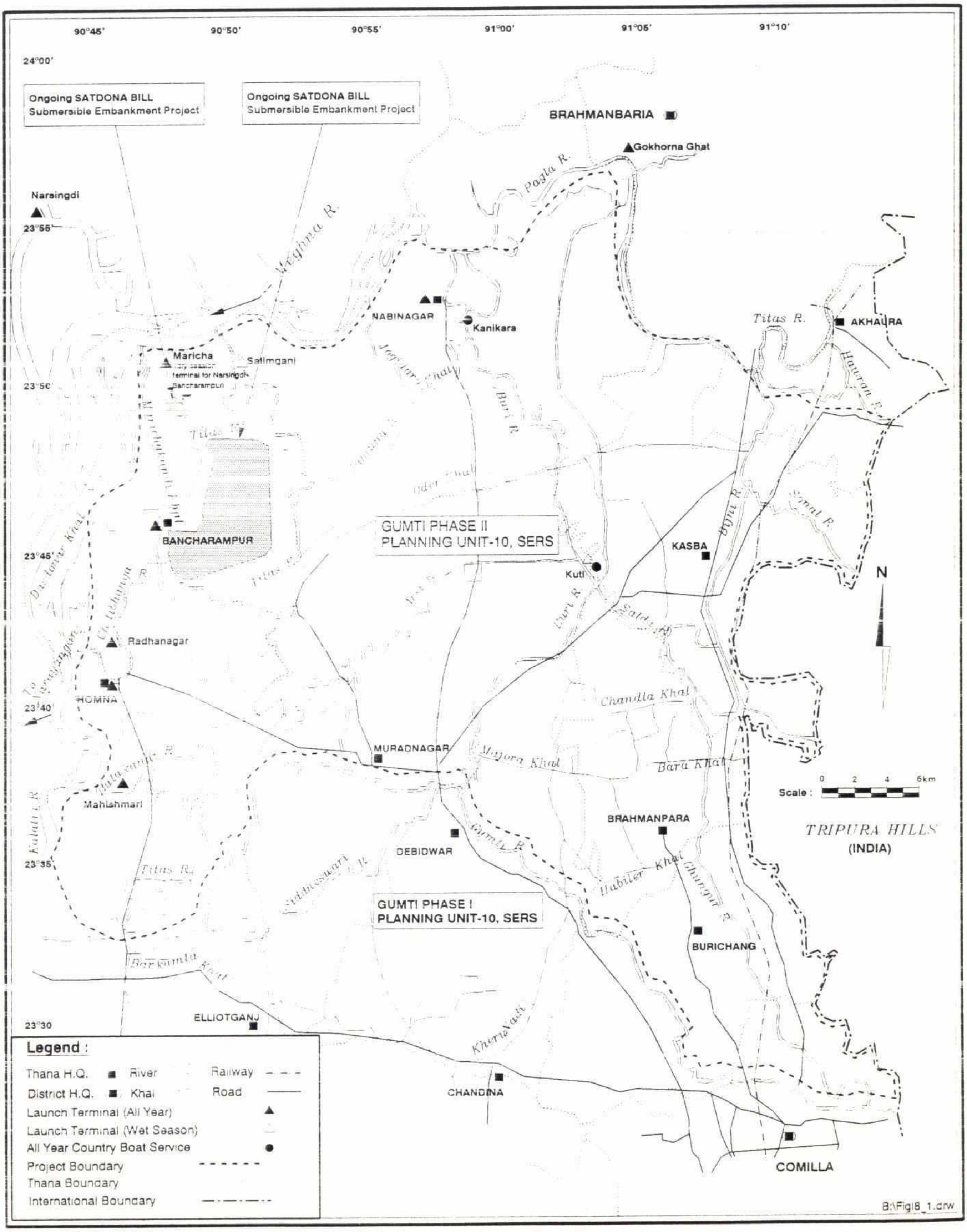
1990 Feasibility Study Water Traffic Survey Results

PERIOD		MARCH to APRIL			SEPTEMBER to OCTOBER			
STATION		MAHISHMARI BATAKANDI	RADHANAGAR HOMNA	KANIKARA BURI NADI	KANIKARA BURI NADI	MAHISHMARI BATAKANDI	SALIMGANJ TITAS	HOMNA
1	Nr of Vessels per day each way	14	25	52	34	12	53	26
2	Nr of service launches per day each way	3	13	0	0	3	35	12
3	Nr of Goyna * per day each way	0	8	0	0	0	0	12
4	Nr of Passengers each way per day	236	1742	663	815	120	779	1516
5	Nr of Passengers on peak days per day each way	373	1849	800	880	212	965	1755
6	Goods in Tonnes per day each way	38.6	98.7	81.2	55.3	5.6	32.8	105.9
7	Max Draft	2.44 m	1.52 m	2.44 m	3.05 m	2.13 m	1.20 m	1.52 m
8	Largest size (beam) of Vessel	5.18 m (beam)	6.09 m (beam)	4.27 m (beam)	4.57 m (beam)	4.87 m (beam)	4.87 m (beam)	6.09 m (beam)
9	Nr of largest size plying per day each way **	3	13	-	-	3	-	12

* A Goyna is a kind of country vessel that carries passengers over long distances. It is generally powered by a small diesel engine with a locally-made propeller fitted to the shaft.

** The BIWT Masterplan specifies representative vessels as follows:
Passenger launch carrying 250 passengers or less - L <= 29.44 m, B <= 6.5 m, D <= 1.22 m.
Cargo launch carrying 150 tons and less - L <= 27.00 m, B <= 6.7 m, D <= 2.25 m.

Figure I.8.1
Existing Navigation



Reconnaissance trips under the present study confirmed the general pattern of navigation given in the 1990 Study. However, the 1990 Study does not adequately convey the importance of Nabinagar as a navigation centre. The town has a bustling river front, with general cargoes of earthenware items etc and large rafts of bamboo, as well as the launch terminal for services along the Pagla/Titas River. The Nabinagar waterfront appears to be cut off from the Pagla by the Buri regulator complex under the 1990 Study FCD and FCDI proposals, with no provision for a lock. Even with a lock the traffic would probably be inhibited. It is considered that the closure ought to be moved upstream to the outfall of the Buri Nadi into the old loop of the Pagla, just north of Kanikara.

Even at this location a small lock is desirable to admit country boats. Kanikara itself appears to be a major base for country boats, even by comparison with Nabinagar. There are 150 engine boats based within the Buri Nadi according to information collected in the field. It is understood that some of these ply upstream as far as Kuti, even in the dry season. Although transhipment across the regulator might be an alternative to provision of a lock, it is likely that once unloaded, road transport would be used for forwarding goods to their final destination.

The 1990 study quotes the following comparative statement of economic transport costs from the Bangladesh Inland Water Transport Masterplan:

Road	Cost/ton =	68.3 +	1.202 x Distance (km)
Railway	Cost/ton =	184.0 +	0.827 x Distance (km)
Waterway (self-propelled)	Cost/ton =	323.3 +	0.262 x Distance (km)
Waterway (tug with 2 barges)	Cost/ton =	309.7 +	0.273 x Distance (km)

Self propelled waterway transport thus seems competitive with road only for distances in excess of 270 km. Reference to the Masterplan Final Report (August 1989) however reveals that these comparisons assume that the basic road or rail links are already in existence, whilst the costs of transport by waterway include for an average of 20 km road feeder transport, 1.5 transhipments in addition to that associated with the road transport, 2 days transit storage costs and an allowance of Tk 135 per ton for time loss, pilferage etc. The Masterplan also suggests that the overall average cost of transport by motorised country boat of draught less than 1.2 m is about 2.4 times that of for the larger self-propelled vessels. The economic costs of "point to point" transport by country boat without road delivery, transhipment, transit storage or pilferage etc allowance is then estimated at:

Country Boat	Cost/ton =	121.2 +	0.629 x Distance (km)

Thus, in cases where the whole journey can be made by country boat, waterway transport becomes competitive with road transport for distances of less than about 100 km.

From Table I.8.1, the average cargo (excluding service launches and goyna, assumed to carry passengers only) ranged in weight from 0.62 to 3.5 tonnes, apart from Radhanagar and Homna where average loads of 25 tonnes in March/April and 53 tonnes in September/October were carried respectively. Average loads are thus generally quite small, and the economic cost of "point to point" country boat transport given above is almost certainly applicable, given the high density of channels within the northern and western parts of the study area which permit many deliveries to be made directly to their final destination, especially in the monsoon season. The existing road network is nothing like as extensive as the channel system, and the costs of providing such a network would certainly swing the economic balance back in favour of the country boat, even for distances substantially less than 100 km.

Although from Table I.8.1 it appears that the weight of cargo carried during the monsoon season is less than during the dry season (except for that carried by the larger vessels at Radhanagar/Homna), it is likely that the survey missed much of the traffic because of the unrestricted access by country boats during the monsoon to most of the western part of the area. Under these circumstances it does not appear desirable for road transport entirely to replace navigation, particularly in the case of heavy cargoes (eg construction materials and grain), which cause severe wear and tear on roads, bridges and vehicles.

I.8.2 Road Transport

(a) General

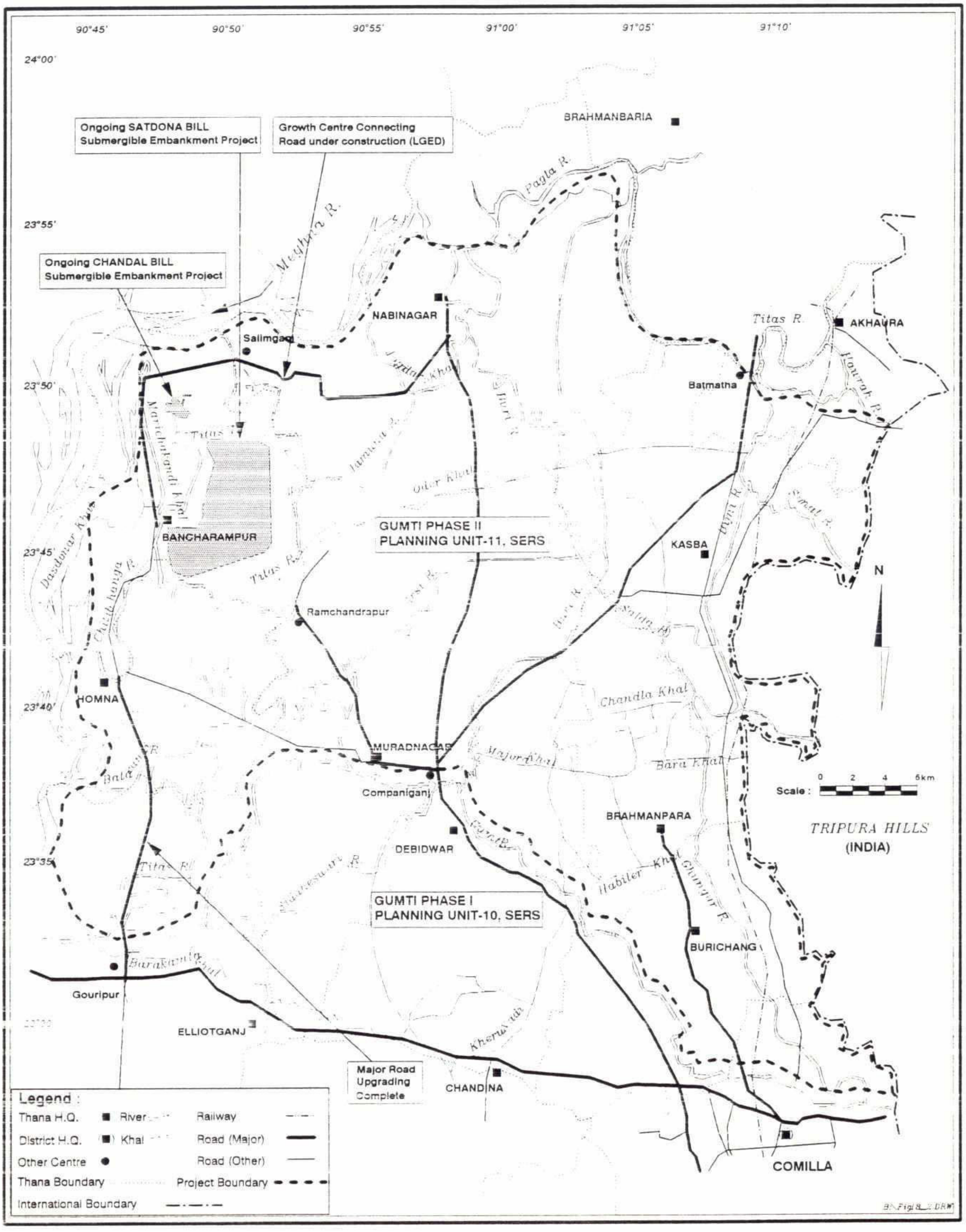
The major road connections within the project area are shown in Figure I.8.2. The major routes under the responsibility of the Roads and Highways Department (RHD) are:

- Comilla-Brahmanbaria-Sylhet (Companiganj to Batmatha within the project area)
- Kuti-Kasba
- Companiganj-Nabinagar
- Companiganj-Muradnagar-Ramchandrapur
- Comilla-Burichang-Brahmanpara
- Gouripur-Homna

(b) Present Situation and Planned Developments

Since the 1990 Feasibility Study field work and data collection, significant road developments have been undertaken by the Roads and Highways Department (R&HD) and the Local Government Engineering Department (LGED), the latter particularly under the auspices of the Japan International Cooperation Agency (JICA) funded Model Rural Development Projects for Kachua, Nabinagar, Bancharampur and Debidwar thanas, and for Homna and Daudkandi thanas. The Gouripur-Homna R&HD road said in the 1990 Study to have three gaps to be bridged is undergoing major upgrading which is now substantially complete. The Nabinagar-Salimganj-Bancharampur-Homna road, said to be of lesser importance, is also currently being upgraded/constructed as a growth centre connecting road by LGED. Both roads will be above peak flood

Figure I.8.2
Major Roads



levels, and they therefore have major significance not only for communications but also as flood embankments. They could be used to protect the bulk of the western part of the project area from Meghna flooding, and might be much preferable to a new dedicated embankment a little closer to the river. It is also understood (from the Thana Nirbahi Officer, Nabinagar) that an R&HD road is now being planned to link Nabinagar eastwards to the Comilla-Sylhet road, which would more or less complete the closure of the project area.

Maps as listed in Appendix I.I to this Annex have been acquired from R&HD and LGED in Dhaka and several of the thana parishad offices (minor and growth centre connecting roads) setting out the present situation and future plans. Details of road structures are presented in Appendix I.III to this Annex.

(c) Traffic Surveys and Analysis

Under the 1990 Feasibility Study, a week-long traffic survey was carried out during February 1988 on the three major routes diverging into the project area from Companiganj. The results are presented in Table I.8.2. The movement of commodities on the main road to Brahmanbaria and Sylhet, especially that of general merchandise, was found to be very much in excess of that on the roads to Nabinagar and to Ramchandrapur. It was accordingly deduced that the areas to the west of the Companiganj-Brahmanbaria road are "neither industrially advanced nor produce enough goods to be exported by the land route" when compared with the areas to the east, and this was attributed to their flood-proneness. The deduction is probably correct, although a truer picture of the distribution of economic activity would have been obtained if the traffic passing straight through the project area had been accounted for by means of a further observation point where the road leaves the project area at Batmatha.

(d) Flooding of Roads

The 1990 Feasibility Study reports that the Comilla-Sylhet road goes under water "every year" south-west of the Salda River and between Oder Khal and the Titas River, whilst during 1988 about 6 km of the road was submerged by up to 0.7 m for about one month. During the same year the Gouripur-Homna-Bancharampur road was submerged over its whole length, together with major portions of the Companiganj-Nabinagar and Companiganj-Muradnagar-Ramchandrapur roads. On occasions when the Gumti Right Embankment has breached, the whole of the Comilla-Burichang-Brahmanpara road has been submerged. Even the major roads cannot therefore be guaranteed as passable in all seasons. The obviation of the need to raise the major roads above flood level has been cited as one of the benefits of the 1990 Study FCD proposals. Another parallel benefit is the reduction in headroom problems beneath existing and proposed road bridges. The fact that many of the roads do become submerged has been taken account of in those proposals under the present study which aim to use existing roads as flood embankments, and allowance has been made for raising them where necessary. However, it is unlikely to be economically viable to raise roads *per se* within the project area above the highest recorded flood levels. One of the major problems with maintenance of roads, or any other type of embankment, particularly in the deeply flooded areas north and east of Nabinagar, is reported to be wave damage. Substantial wave heights are generated across the wide expanse of the flooded Titas/Pagla River, and most roads in this area have very rapidly been damaged.

TABLE I.8.2

Results of 1990 Feasibility Study Road Traffic Survey

ROAD	COMILLA - BRAHMANBARIA	COMPANIGANJ - NABINAGAR	COMPANIGANJ - MURADNAGAR - RAMCHANDRAPUR
Number of buses each way	80	34	3
Number of Passengers	4 647	1 813	1 158
Trucks:	205	10	16
Commodities carried			
a) Rice incoming	30 Tonnes	3.7 Tonnes	9.9 Tonnes
Rice outgoing	42 Tonnes	17.5 Tonnes	16.7 Tonnes
b) Jute incoming	52.7 Tonnes	0.72 Tonnes	2.9 Tonnes
Jute outgoing	0	0	4.3 Tonnes
c) Potato incoming	23.7 Tonnes	0.14 Tonnes	4.3 Tonnes
Potato outgoing	97.4 Tonnes	0.15 Tonnes	5.0 Tonnes
d) General incoming	694 Tonnes	5.85 Tonnes	14.0 Tonnes
General outgoing	720 Tonnes	21.0 Tonnes	19.7 Tonnes

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(e) Development Proposals

The 1990 Feasibility Study did not recommend the development of a comprehensive communication system within the area as part of its proposals, and roads are only included where they are necessary for the construction, operation and maintenance of the water control and agricultural development infrastructure. However, one of the cited benefits of the proposals is the provision of a 76 km road link from Homna to Batmatha around the peripheral embankment. This benefit is being made somewhat redundant by the developments outlined in Section (b) above. The present study has maintained the policy of only including roads which are directly associated with the main development proposals; indeed, wherever possible existing roads have been improved for use as embankments, to minimise land acquisition and construction costs. Since the basic and intermediate flood response proposals developed in Chapter I.6 will have less of an impact upon navigation than the full FCD/FCDI proposals, a major shift from waterborne to land transport is not anticipated.

I.8.3 Power Supply

Maps of the existing distribution system and developments under way for Bangladesh as a whole (33 kV to 230 kV) and Comilla and Brahmanbaria districts (11 kV to 132 kV) were obtained (see Appendix I.I to this Annex). Meetings were held with officials of the Bangladesh Power Development Board, and assurances obtained that adequate generating and distribution capacity is available for the basic and intermediate flood response proposals for Zone C, discussed in Chapter I.6. It is also understood that power supply connections are now available within the project area through the Rural Electrification Programme, and this should give added impetus to the development of electrical powered irrigation pumping.

CHAPTER I.9

IMPLEMENTATION

I.9.1 Institutional Issues

I.9.1.1 General

As far as possible the aim should be to implement and manage the project through existing institutions and to strengthen and develop them as needed. Therefore it is expected that government agencies, such as BWDB, LGED, DAE and BRDB as well as the local government structure will be involved as they are at present engaged in flood prevention work.

In addition, there will be a need to include within the management structure NGOs and others who can play a leading role in establishing and supporting continued public participation. The most prominent NGO in the project area is Comilla Proshika Centre for Development. Project staff have liaised extensively with Comilla Proshika, as discussed in Annex G.

A separate FAP study (FAP 26) is underway to recommend institutional reform for water resources development projects. There are other programmes such as SSFCDI, EIP, SRP working on O&M. National Water Plan Phase II dealt with exercises to recommend responsibility of various GOB Agencies for different types and sizes of projects. FAP 13 and many other agencies identified that public participation is very important for the successful implementation of a project. In this connection it was recommended that the public should be involved right from planning and design to implementation of a project. Recommendations were to involve the NGOs and the landless people in the project management.

Traditionally, great emphasis has been put on project committees to obtain the necessary interaction between different departments and institutions. By the time Gumti Phase II recommendations come to be implemented, useful experience will be available from FAP 20 on planning, implementation and management for projects of this type. Meanwhile, it is suggested that, where required, there should be a much smaller form of committee called the Project Coordination Committee (PCC).

The following institutions may be involved at different stages of development and at different levels in the project:

GOB	:	BWDB, LGED, DAE, IWTA, DOF, R&H, Forest Department
Local Government	:	Thana officials
Public representatives	:	Local MPs, Union Council Chairmen NGO's and landless people.

In order to secure efficient running of all stages of a project, direct participation of the beneficiaries is essential. They should be involved at all phases of development starting from planning and design. Accordingly, during the present feasibility study, the public, their representatives and the Thana officials were duly consulted before formulation of different options for development. The BWDB, as the major GOB agency with the required technical skills and experience, is involved for the over all responsibility and monitoring of the project.

I.9.1.2 Pre-Design Stage

The future work programme covering environmental aspects is covered in Section 12.6.3 of the Main Report. These works should be started at the outset and should carry on alongside the design of the schemes. The BWDB should be responsible for letting the contracts to Consultants.

The works detailed in Section 12.6.3 include land acquisition requirements. It is proposed that the cadastral land area surveys in the line of embankment construction should be carried out at the same time as the topographic surveys. The cadastral maps can then be handed to the land registration office for land ownership identification. Once the design is complete, then the full land requirement will be known and compensation paid. NGOs could be involved in land acquisition, which should be undertaken by the Land Acquisition Officer. The Land Acquisition Officer normally works under the Deputy Commissioner, but in this case will be under the Project Authority. Compensation given for the land to be acquired should be fair and the valuation of land should be done at current market prices. Compensation for land in village areas included an enhanced rate for land acquisition as well as 12,000 taka per family to meet reconstruction cost.

Geotechnical surveys should also be carried out at the same time as the topographical and cadastral surveys. These too will be contracts let by the BWDB. Further details of requirements are given in Appendix I.VII to this annex.

I.9.1.3 Design Stage

The contract for scheme design will be let by BWDB. The Consultants should be ready to start work as soon as the results of the first surveys are ready.

Additional computer modelling will be required for optimisation at the design stage. It is therefore likely that the Surface Water Modelling Centre will be required to assist.

I.9.1.4 Implementation Stage

During the implementation phase there may be two levels of management. The project level committee (PCC) involving the local MPs, BWDB officials, district and thana officials and NGO's. A local professional (eg a teacher or a doctor) may also be invited. It should be noted that the MPs have been included as the GOB are presently considering a proposal that MPs should lead Thana development activities.

The PCC have the full responsibility of the project management. As recommended by FAP 15, the committee could be chaired by a local MP, with the Executive Engineer, BWDB as Secretary. The Committee should monitor the over all progress of works and solve various bottlenecks towards the implementation of the project. Day to day works and other technical and financial responsibilities will remain with the Executive Engineer, BWDB as per the present practice. He will be the executive officer for the project. Representation of groups who could be adversely affected by the project or who are underprivileged (eg landless, fishermen or women) may be represented by NGOs.

Other GOB officials representing DAE, DOF, other Thana level officials will also take part in monitoring the work, being members of the implementation committee. They may also be involved in the following in-depth activities:

(a) TNOs, NGOs and public representatives may be involved in forming local beneficiaries committees and motivating the people about the project, its benefit and nature of participation at different levels.

(b) BRDB may be involved in co-operative development and to arrange credit facilities.

(c) DAE will be involved mostly in the extension works in changing the cropping pattern and application of fertilizer and manure.

(d) The DOF may assess the impact of the project to fisheries and suggest improvements in mitigating those by different alternative measures.

(e) The Forest Department will be responsible for growth of tree plantation and selection of species for forestry on the embankments.

All the GOB officials and local representatives should be trained in their respective fields at the time of implementation so that they know about the project, its different components of development and the benefits well ahead of starting the O&M.

Major works and their implementation responsibilities are given below:

- Pump houses and hydraulic structures are to be constructed by contractor under the technical and administrative control of the executive engineer, BWDB.

- Drainage channel excavation, earthworks in embankments and turfing may be done manually as far as possible through LCS groups administered by NGOs or BRDB, but the quality and quantity would be controlled by the BWDB.

- Compaction of embankments and under-water excavation should be done mechanically by contractors under the supervision of the BWDB.

- Tree plantation is to be organized by the Forest Department in consultation with the BWDB and R&H. NGOs and LCS could be involved.

- The BWDB/ Consultant design team will develop O&M manuals for the different infrastructure of the project.

I.9.1.5 Operation and Maintenance Stage

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The following major activities are involved during the O&M stage :

- Regular operation and maintenance of the infrastructure.
- Review of the operation manuals of the infrastructures especially pump stations and regulators.
- Collection of hydrological, socio-economic and fisheries data, analysis of the data collected and reviewed to monitor the correct operation of the project and to identify any changes or improvements needed.
- Extension and credit facilities.
- Training programmes.

The first two of the above being technical requirements should remain with the BWDB. The data collection should be carried out by the BWDB, BBS statistical officers and DOF.

The existing Design Directorate for the region should be involved in the ongoing review of design, for example if khals are under or over-sized. In case of different projects under the Directorate, a separate team headed by an experienced executive engineer should carry out the work. Adequate training for the executive engineer and his staff in this connection is important.

Maintenance of infrastructure includes:

- Pump Houses,
- Regulators,
- Embankments and
- Drainage/irrigation channels.

Maintenance of pump houses, buildings and regulators is a technical task which should be the responsibility of the BWDB. The Electro-mechanical works should be under the control of a Mechanical S.D.E. while the civil works may be looked after by the civil S.D.E.s, all under the control of the Comilla O & M circle.

Maintenance of embankments and drainage channels are of two types:

- regular maintenance and
- major/emergency maintenance

Work relating to regular maintenance may be given to the affected people, especially the landless. There are various recommendations about maintenance of the embankments and drainage channels in FAP 13, FAP 15 and others. The procedures adopted by the SRP is a good system which appears to be working well. Major and emergency maintenance works should be carried out by BWDB officials as per the present practice.

Units of farmers who are to pay for maintenance of the works, discussed in Section I.9.4, should ensure adequate control of funds and quality of works, but through the award of maintenance contracts similar to those used by SRP.

The Project Coordination Committee (PCC) will continue during the O&M stage with full responsibility for mediation in any matter concerning O & M between staff, beneficiaries and other groups.

The Executive Engineer, O&M, BWDB will remain the executive officer of the project. Representatives from DAE, DOF and other thana officials will remain responsible for their relevant fields.

For operation of all the regulators, a local committee for each of the structures could be formed. The committee may be formed involving the chairman of a Union Council, NGOs, beneficiaries, BWDB Section Officer. The U.C. Chairman may be the chairman of the committee and the Section Officer, BWDB, the Secretary. The committee will work in consultation with the Executive Engineer and as per the operation manual. The committee will be accountable to the PCC.

Specific details of O&M requirements are discussed later in this chapter.

I.9.2 Implementation Schedule

I.9.2.1 Schemes Recommended for Immediate Implementation

Six possible schemes have been identified for implementation. Three of these schemes are recommended for immediate implementation. Their implementation schedule is given in Figure I.9.1.

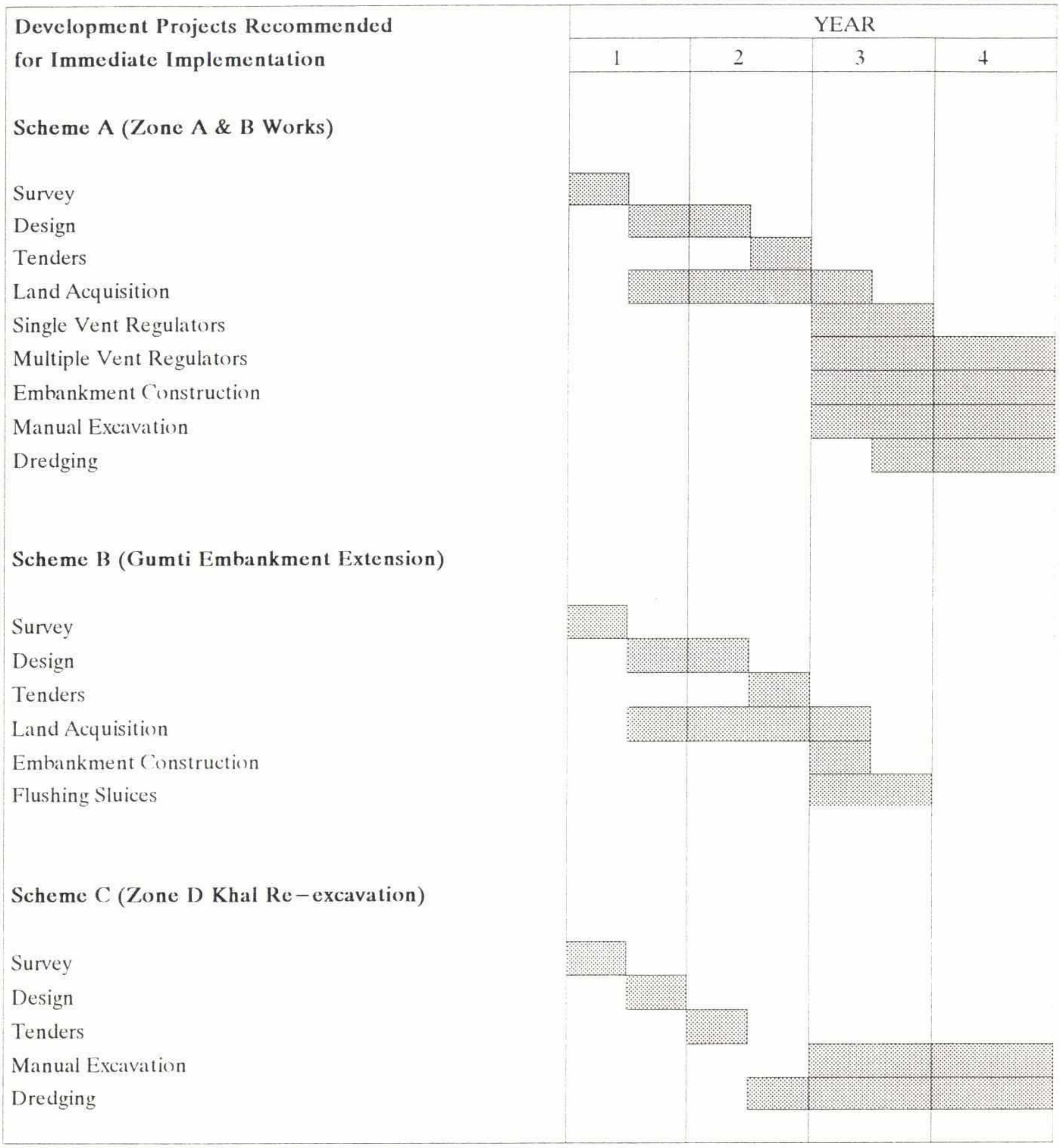
The beginning of each year is assumed to occur at the start of the dry season. The dry season is the only time when activities such as survey, foundation of structures and manual excavation may take place.

The design of Scheme A, which comprises the whole of the Zone A and B proposals described in Chapter I.6 of this annex, should include further model studies in order to optimise the excavation in the Salda and Buri Nadi Rivers along with the effects on the area to the east of the Gunghur River. In addition the design should address the possible use of compartmentalisation in the Zone A protected area, to further optimise water distribution.

The design of Scheme B, which involves the extension of the existing Gumti right bank embankment in Zone D as a submersible embankment, should also include a detailed sub model of the area, which will be able to accurately predict the effects of the proposed works, including those on the areas downstream.

It should be noted that JICA, with LGED and BRDB, are already carrying out khal excavation and supply of LLPs in the Homna and Daudkandi areas. Although the khals this project has selected do not include those planned for excavation by JICA, it is quite possible that JICA may wish to take up Scheme C (khal excavation for irrigation improvement within Zone D) under it's present project, or an extension to it.

Figure I.9.1
Implementation Schedule



I.9.2.2 Schemes which May be Implemented at a Later Date

The remaining three schemes are not recommended for immediate implementation. This is because their viability is dependant on other factors, which can only be determined at a later date. Their implementation schedule is given in Figure I.9.2.

Scheme D includes the irrigation schemes and embanked area in Zone C as described in Chapter I.6 of this annex. The economic analysis has shown this scheme is not viable if force mode tubewell technology is taken up. This is logical, as the economic cost of two stage pumping with conveyance canals will be more than irrigation from force mode tubewells.

The National Minor Irrigation Project (NMIDP), which started in May, 1993, will address the viability of force mode tubewells. Efforts should be made immediately to ensure that pilot projects should take place in Zone C of the project area. The scheme should then only start if and when NMIDP has concluded that force mode tubewells will not be taken up by farmers in the area. A further condition will be that the Government of Bangladesh has assessed the environmental situation and have decided that the area should be given to agricultural production as opposed to fish production.

Scheme E includes the two small submersible embankment schemes in Zone D. Under present conditions, farmers do not suffer damage to their boro crops as they plant very early. However, if FAP 6 interventions upstream of the Gumti project area extend the duration of the flood hydrograph, then farmers may face damage to their boro crops. It is therefore recommended to wait for the FAP 6 "With Project" computer model outputs. If there is a detrimental effect, Scheme E should be considered by FAP 6 as partial mitigation measures.

I.9.2.3 The 1990 Report Schemes

The 1990 Report assumed that their proposed schemes would be constructed in 2 phases of 4 years each. However, in order to maximise the benefits, the full FCD and FCDI schemes were assumed to be constructed in a single phase of 5 years.

I.9.3 Project Costs

The costs for the viable Schemes A, B, C and D are summarised in Tables I.9.1 to I.9.5. The revised costs for the 1990 Report FCD and FCDI schemes amount to approximately 6 198 million and 8 537 million Taka respectively. These costs are taken at 1992 prices.

The cost estimates used in the economic analysis have been reduced to 1991 level, as directed in the FPCO Guidelines.

The rates for the most important sections of construction, e.g. earthwork and dredging, were independently analysed, as discussed in Chapter I.5 of this annex. Dredging was assumed to be carried out by "mini dredgers", capable of shifting 65 m^3/hour.

Figure I.9.2
Implementation Schedule

Development Projects Not Recommended for Immediate Implementation	YEAR 1		2		3		4		5	
Scheme D (Zone C Works) (Year 1 starts if force mode tubewell technology is NOT taken up)										
Survey	X		X							
Design		X	X	X						
Tenders				X	X					
Land Acquisition		X	X	X	X					
Regulators							X	X	X	X
Pump Stations					X	X	X	X	X	X
Embankment Construction					X	X	X	X		
Excavation					X	X	X	X		
Dredging					X	X	X	X		
Buildings					X	X				
Scheme E										
Zone D South Submersible (Year 1 starts if FAP 6 interventions alter the flood timing, causing damage to the boro crop)										
Survey	X									
Design		X	X							
Tenders				X						
Land Acquisition		X	X	X	X					
Regulator					X	X				
Spillway					X	X				
Embankment Construction					X	X				
Zone D North Submersible (Year 1 starts if FAP 6 interventions alter the flood timing, causing damage to the boro crop)										
Survey	X									
Design		X	X							
Tenders				X						
Land Acquisition		X	X	X	X					
Regulator					X	X				
Spillway					X	X				
Embankment Construction					X	X				

TABLE I.9.1

Costs for Scheme A (Interventions 1A and 1B)

Zone A Capital Costs
Zone Area - 31 976 ha gross, 24 506 ha NCA
Protected Area - 23 400 ha gross, 17 933 ha NCA

Description	Unit	Quantity	Unit Rate (Tk)	Cost (Tk ,000)
1. Flood embankment				
- Clearing, Grubbing & Stripping	sq.m	648,000	3	1,944
- Channel Excav. and Formation of Emb. (Manual Excav./Mechanical Comp.)	cu.m	988,000	42	41,496
- Turfing	sq.m	680,000	3	2,040
2. Channel excavation & Spreading				
- Manual (transport 50 m)	cu.m	2,230,000	28	62,440
- Mini-Dredger (transport 500 m)	cu.m	688,000	50	34,400
3. New regulators				
1 - Vent 3.5m X 3.0m fish-friendly	Vent	2*1	8,500,000	17,000
3 - Vent 3.5m X 3.0m fish-friendly	Vent	2*3	4,700,000	28,200
1 - Vent 1.82m X 1.52m	Vent	4*1	2,000,000	8,000
4. Buildings	Existing facilities at Comilla			
5. Vehicles	Nr	1	1,000,000	1,000
6. Land Acquisition				
- Agricultural	ha	100	375,000	37,500
- Homestead	ha	1.7	1,617,800	2,750
Sub-Total				236,770
Physical contingencies 15%				35,516
Sub-Total including contingencies				272,286
Engineering service cost 12%				32,674
Total Project Cost				304,960

TABLE I.9.2

Costs for Scheme A (Intervention 2)

Zone B Capital Costs
Zone Area - 26 782 ha gross, 22 412 ha NCA
Protected Area - 5 000 ha gross, 4 184 ha NCA

	Description	Unit	Quantity	Unit Rate (Tk)	Cost (Tk ,000)
1.	Flood embankment				
	- Clearing Grubbing & Stripping	sq.m	631,300	3	1,894
	- Channel Excav. and Formation of Emb. (Manual Excav./Mechanical Comp.)	cu.m	713,650	42	29,973
	- Turfing	sq.m	63,900	3	192
2.	Channel excavation & Spreading				
	- Manual (transport 50 m)	cu.m	90,500	28	2,534
3.	New Drainage/Flushing Sluices				
	2 - Vent 1.82m X 1.52m	Vent	1*2	1,700,000	3,400
	1 - Vent 1.22m X 1.52m	Vent	2*1	1,600,000	3,200
	1 - Vent 1.82m X 1.52m	Vent	3*1	2,000,000	6,000
4.	Buildings	Existing facilities at Brahmanbaria			
5.	Vehicles	Nr	1	1,000,000	1,000
6.	Land Acquisition				
	- Agricultural	ha	34.3	375,000	12,863
	- Homestead	ha	0.61	1,617,800	987
	Sub-Total				62,042
	Physical contingencies 15%				9,306
	Sub-Total including contingencies				71,349
	Engineering service cost 12%				8,562
	Total Cost for Intervention 2				79,910
	Total Cost for Interventions 1A and 1B (from Table 13.1)				304,960
	Overall Cost for Scheme A				**384,870**

TABLE I.9.3

Costs for Scheme B (Intervention 3)

	Description	Unit	Quantity	Unit Rate (Tk)	Cost (Tk 000)
1.	Submersible embankment (Gumti R. Bank)				
	- Clearing Grubbing & Stripping	sq.m	83,471	3	250
	- Channel Excav. and Formation of Emb. (Manual Excav./Mechanical Comp.)	cu.m	75,447	42	3,169
	- Turfing	sq.m	88,707	3	266
2.	Drainage/flushing sluices (Gumti R. Bank)				
	1 - Vent 1.82m X 1.52m	Vent	2*1	2,000,000	4,000
3.	Irrigation Inlet Structure (Gumti Right Emb.)				
	6 inch dia PVC Pipe with Dist. Box	Nr	15	50,000	750
4.	Buildings : Existing facilities	Nr	0	6,000	0
5.	Vehicles	Sum		500,000	500
6.	Land Acquisition				
	- Agricultural	ha	8.35	375,000	3,131
	- Homestead	ha	0	1,617,800	0
	Sub-Total				12,067
	Physical contingencies 15%				1,810
	Sub-Total including contingencies				13,877
	Engineering service cost				1,665
	Total Project Cost				**15,542**

TABLE I.9.4

Costs for Scheme C (Intervention 6)

	Description	Unit	Quantity	Unit Rate (Tk)	Cost (Tk 000)
1.	Channel excavation & Spreading				
	- Manual excavation (transport 50 m)	cu.m	677,000	28	18,956
	- Mini-Dredger (transport 500 m)	cu.m	677,000	50	33,850
2.	Buildings : Existing facilities	Nr	0	6,000	0
3.	Vehicles	Sum		500,000	500
	Sub-Total				53,306
	Physical contingencies 15%				7,996
	Sub-Total including contingencies				61,302
	Engineering service cost				7,356
	Total Project Cost				**68,658**

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TABLE I.9.5

Costs for Scheme D (Intervention 4)

Zone C Area - 41 400 ha gross, 35 040 ha NCA
FCDI Area - 10 459 ha gross, 8 852 ha NCA
Add. Irrig. Area - 11 887 ha gross, 9820 ha NCA

	Description	Unit	Quantity	Unit Rate (Tk)	Cost (Tk ,000)
1.	Flood embankment				
	- Clearing Grubbing & Stripping	sq.m	593,890	3	1,782
	- Channel Excav. and Formation of Emb. (Manual Excav./Mechanical Comp.)	cu.m	1,219,943	42	51,238
	- Turfing	sq.m	807,500	3	2,423
2.	Channel excavation & Spreading				
	- Manual excavation (transport 50m)	cu.m	914,967	28	25,619
3.	New regulators				
	2 - Vent 3.5m X 3.0m fish-friendly + flume	Vent	1*2	7,000,000	14,000
	2 - Vent 2.0m X 3.0m check/navigation	Vent	5*2	600,000	6,000
	2 - Vent 1.82m X 1.52m check/head gate	Vent	1*2	550,000	1,100
	2 - Vent 3.5m X 3.0m fish-friendly	Vent	1*2	6,600,000	13,200
	1 - Vent 1.82m X 1.52m	Vent	3*1	2,000,000	6,000
	2 - Vent 1.82m X 1.52m chute drop	Vent	1*2	2,000,000	4,000
4.	Pump Stations				
	Nr 1 (Q = 3 @ 2.52 = 7.56 cu.m/sec)				
	Civil Works	sum		39,441,630	39,442
	Electrical & Mechanical Works	sum		41,271,600	41,272
	Nr 2 (Q = 4 @ 3.655 = 14.62 cu.m/sec)				
	Civil Works	sum		58,235,000	58,235
	Electrical & Mechanical Works	sum		91,637,671	91,638
5.	Buildings	sq.m	900	6,000	5,400
6.	Vehicles	Nr	4	1,000,000	4,000
7.	Land Acquisition				
	- Agricultural	ha	43.50	375,000	16,313
	- Homestead	ha	2.33	1,617,800	3,769
	Sub-Total				385,429
	Physical contingencies 15%				57,814
	Sub-Total including contingencies				443,243
	Engineering service cost 12%				53,189
	Total Project Cost				**496,432**

I.9.4 Cost Recovery

The issue of cost recovery is extremely complex for the proposed developments. In Zone A, the major benefit of the embankment is flood protection, however, not all of Zone A will benefit. Also, the excavation works on the Salda and Buri Rivers are required for Zones A, B and part of C as well as the benefit of the LLP operators who will take irrigation water directly from it.

If Scheme D is taken up, the farmers in the protected area to the north will benefit not only from primary pump station water for their LLPs but also for pumped drainage, during the monsoon season. There will also be areas within the embankment perimeter which cannot be supplied by surface water but who will benefit from the pumped drainage and flood control.

In Zone D the situation will be simpler, as all the beneficiaries of the khal re-excavation will be in the same proximity as the required works, and will therefore identify with it.

The many attempts to impose water rates since 1963 when the first Water Rate Ordinance was enacted have met with difficulties. This has been due to the following reasons:

- no correlation between payments made by water users and the service they received
- water users were not properly consulted on the requirement and purpose of cost recovery
- water users were not encouraged to participate in project planning or cost assessment and collection activities of water rates
- inadequate project performance and service levels of O & M.

Amendments and new rules were therefore produced in 1990, which encouraged participation in assessment and collection activities. The payment of water rates is based on the level of O & M service received by the users.

The BWDB Systems Rehabilitation Project (SRP) is presently studying the aspect of cost recovery. They are in the late stages of a pilot project and the final report is expected to be submitted to the BWDB in the near future.

At present, the main considerations for successful cost recovery presented by SRP are as follows:

- Elicit participation at all levels of the project, so the target beneficiaries are convinced of the rationale and objectives of the project. It is crucial that beneficiaries are convinced that payment is justified and the rates are reasonable.
- The framework for beneficiary participation should be linked with O & M costs.

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- Beneficiaries should be organised to assure participation and representation. The project area should be divided into units, in the case of the LLP schemes, covering about 20 LLPs. A representative committee will be formed in each unit. Through this unit, the water users will voice their concerns to the PCC on which they could be represented by an NGO or through directly elected representatives concerning:

  - Review of the O & M budget and recommendation of the rate to be paid
  - Review of progress of water rate and identification of bottlenecks

The above procedure is mainly related to Water User Committees, for cost recovery of irrigation water. However, the key issue of including farmers into the process of O & M is just as relevant for flood protection and drainage schemes. At present, SRP pilot projects have been successful in recovering part of the costs for O & M. However, it is hoped in the near future that full O & M costs can be recovered and following this, parts of the capital costs.

Apart from the incremental approach adopted by SRP, the only practical methodology for cost recovery would be taxation. This tax could raised by one or more of the following:

- tax on farmer's inputs
- land drainage rates
- fuel tax

The most rational basis would be the application of a land drainage rate. However, there are difficulties regarding farmers who own land over which there is little or no change in depth of flooding.

This issue can only be addressed by the Government of Bangladesh on a national scale, however, the taxation could be carried out at a more local level, eg thana.

I.9.5 Specific O&M Requirements

Preparation of O&M manuals will be taken up during the design stage. A general outline for O&M of different infrastructure for the proposed projects are discussed below. O&M costs are discussed in Chapters I.5 and I.6 of this annex.

I.9.5.1 Zone A

Embankments

The new embankments along the Ghungur and Salda may need more intensive care during the initial few years until the embankments are stabilized. No major erosion by wave action or current is anticipated. Normal turfing for protection is recommended. Improved varieties of grasses and other vegetation like dhancha and napier grass, which have additional benefits such as fuel and cattle feed should be used in consultation with the Forest Department. Trees may be grown on the berm and slopes, if they do not have any adverse effect on the stability of the embankment. Landless people should carry out this work wherever possible, under the supervision of the BWDB.

The modified reach of the R&H Highway, to the north-west of the scheme boundary, should also be maintained in similar way, in consultation with the R&H Department. The R&H Department should share part of the responsibility for maintenance.

Ghungur and Salda Rivers

Annual silt deposition in the Ghungur, especially at its outfall, and in the upper Salda may be significant. As reported by local people, silt clearance after four to five years may be required. This should, if possible, be done under Food For Works Programme. Annual maintenance in other reaches of the rivers should be normal and can be carried out by LCS under the supervision of the BWDB. However, maintenance in the lower Salda/Buri may need dredging as this work will be mostly underwater. This should be done by the BWDB directly as BIWTA are only responsible for dredging of Class 1 navigation routes.

Internal Drainage Channels

Normal maintenance of these channels will be required. This should be done by the fishermen to whom the channels may be leased by reaches. Special O&M should be carried out by the BWDB.

Regulators along Ghungur (4 nos)

These regulators are provided for controlled flooding within the polder and for flood by-pass during the catastrophic floods. A committee for each of the structures should be formed representing people of the area both inside and outside the embankment. GOB and BWDB officials at the local level will also be involved. A qualified person from the village nearest to the structure will be selected by the committee to operate the structure. Normal maintenance will be done by the BWDB but financed by the beneficiaries.

Regulators Along the R&H Highway

There are 4 drainage regulators equipped with fish friendly gates. The gates are expected to remain open until June and will have free flow (weir flow). As the water level rises, the gates will be lifted so that the depth of flow over the gate will be adequate for fish movement. As with the Ghungur regulators,the structures will be operated by the local committee and maintained by the BWDB.

I.9.5.2 Zone B

O&M for embankments and structures are similar to those in Zone A.

I.9.5.3 Zone C

Interventions in Zone C involves major pump stations for irrigation/ drainage, embankments, irrigation/ drainage channels, buildings and structures.

Pump Houses, Buildings

These will be maintained and operated by the BWDB. An S.D.E. (Mechanical) will be in-charge of the pump house and the related warehouse. He will look after the operation and maintenance of the electromechanical parts of the pump houses. The SDE (Mechanical) will also look after the maintenance of the gates of all other regulators. Operation of the pump houses should be done as per the instruction of the project committee through the executive engineer.

Structures and Embankments

Similar to Zone A.

I.9.5.4 Zone D

Major work in Zone D are the irrigation/ drainage channels, flushing regulators and the submersible embankment along the right bank of the Gumti. O&M for the drainage channels and structures may be similar to those of Zone A in that the channels may need dredging. However, the rate of siltation in the area is much lower than near to the Indian border. Maintenance dredging will be the responsibility of the BWDB.

Submersible Embankments

Contrary to the other embankments, the submersible embankment along the Gumti will need special care, because it will be submerged every year. Therefore the responsibility for O&M should be with the BWDB. However, A committee should be formed at local level to carry out the day to day operation and maintenance. Petty works like earth filling and turfing should be done by LCS groups, formed by NGOs but under the supervision of the BWDB.

APPENDIX I.I

MAPS, AERIAL PHOTOGRAPHY, SATELLITE IMAGERY AND TOPOGRAPHIC DATA

TABLE I.I.1

Topographic Mapping

Area Covered	Scale	Type	Producer/Sponsor	Year	Source	Remarks
Nation	1:50 000	Topographic	SOB	1961	Surveys, 1956-57 /aerial photos	
Nation	1:40 000	Irrigation map (5 ft contours)	SOB	1958	Surveys, 1956-57 /aerial photos, 1950	
Nation	1:15 840	1 ft Contours	BWDB/SOB	1968	Surveys, 1967-68 /aerial photos, 1963	See Figure I.I.1
Nation	1:125 000	Soil Associations	MPO	1990	SRDI	Draft
Nation	1:125 000	Planning	MPO	1990	MPO	Draft
Gumti II/FCD3	1:16 000	Contours 0.5 m	FINNMAP/BWDB	1989	Survey/aerial photos, 1987	See Figure I.I.1
Gumti II/FCD3	1:16 000	Present Land use map	FINNMAP/BWDB	1989	Survey/aerial photos, 1987	
Gumti II/FCD3	1:16 000	Winter Land use map	FINNMAP/BWDB	1989	Survey/aerial photos, 1987	
Gumti II/FCD3	1:16 000	Land Type map	FINNMAP/BWDB	1989	Survey/aerial photos, 1987	
Gumti II/FCD3	1:16 000	Land Type/Soil Moisture map	FINNMAP/BWDB	1989	Survey/aerial photos, 1987	

Figure I.1.1

Index to Water Development Maps

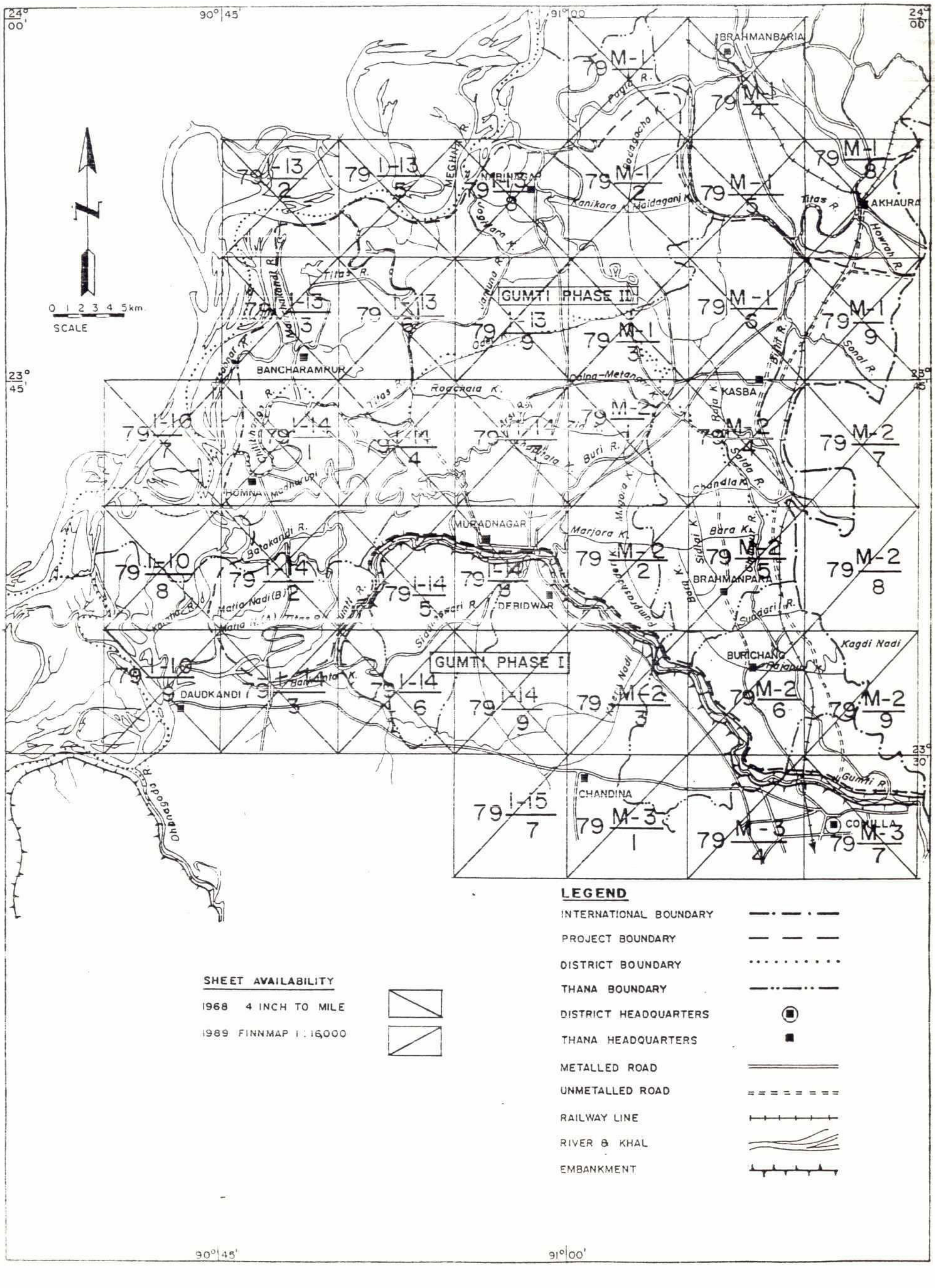

TABLE I.1.2

Aerial Photography and Satellite Imagery

Area Covered	Scale	Type	Producer/Sponsor	Year	Source	Remarks
PHOTOGRAPHY						
Nation	1:50 000	Black & White Prints	SPARRSO/SOB	1983 & 1984	French Nat. Geog. Instit.	
Gumti II/FCD III	1:16 000	Infra-red colour Prints	FINNMAP/BWDB	1987	----	North from Gumti River to Meghna. No flights within 8 km of Indian border.
Gumti II/FCD III	1:16 000	B&W Controlled Photo Mosaics	FINNMAP/BWDB	1987	1:50 000 Air photos, 1987	Covers Gumti I & II except two sheets
Gumti II/FCD III	1:4 000	B&W Controlled Photo Mosaics	FINNMAP/BWDB	1987	1:12 000 Air photos, 1987	50% coverage, of which half received from BWDB
SATELLITE IMAGERY						
Nation	1:50 000	Multi-spectral SPOT imagery	FPCO	Jan/Feb 1989	France/FPCO	20 m x 20 m resolution
Western Edge of Project Area	1:50 000	Multi-spectral SPOT Imagery	FPCO	Mar. and Nov. 1990	France/FPCO	20 m x 20 m resolution
SE Region (Part)	1:250 000	Landsat MSS Image Print		5 Dec 1973	FAP 19	80 m x 80 m resolution 1976/79/84 & 90 also requested.

Note: SOB - Survey of Bof Bangladesh, SPARRSO - Space Research and Remote Sensing Organisation

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TABLE I.1.3

Infrastructure Development and Agricultural Extension Maps

Sl.Nr.	Description	Scale	Type	Producer\Sponsor	Date	Source
A.	**Major Roads (R & H Dept)**					
1	Gouripur-Homna	Not to Scale	Strip Index of culverts/bridges	R & H	1987	R & H. Comilla
2	Companiganj-Muradnagar-Ramchandrapur-Bancharampur	Not to Scale	Strip Index of culverts/bridges	R & H	1987	R & H. Comilla
3	Comilla-Burichang-Brahmanpara-Mirpur	Not to Scale	Strip Index of culverts/bridges	R & H	1992	R & H. Comilla
4	Companiganj-Nabinagar	Not to Scale	Strip Index of culverts/bridges	R & H	1992	R & H. Comilla
5	Mainamati-Companiganj-Brahmanbaria-Sarail-Madhabpur	Not to Scale	Strip Index of culverts/bridges	R & H	1987	R & H. Comilla
6	Comilla Division	1:253 440	Road Map (Two Sheets)	R & H	-	R & H. Comilla
7	Chittagong/CHT Zone	1:506 880	Road Map	R & H	06.04.87	R & H. Dhaka
B.	**RESP Maps**					
1	Brahmanbaria Zila	1:000 040	G C C R	LGED	30.04.92	LGED
2	Comilla Zila	1:000 000	G C C R	LGED	02.11.92	LGED
C.	**Thana Road maps (LGED)**					
1	Nabinagar Thana	1:63 360	Thana roads	Thana Parishad	1992	LGED
2	Homna Thana	1:100 000	Thana roads	Thana Parishad	1992	Thana Parishad
3	Debidwar Thana	-	Thana roads	Thana Parishad	1991	Thana Parishad
4	Kasba Thana	1:63 360	Thana roads	Thana Parishad	1992	Thana Parishad
5	Muradnagar Thana	1:63 360	Thana roads	Thana Parishad	1990	Thana Parishad
6	Comilla Sadar Thana	1:20 000	Thana roads	Thana Parishad	-	Thana Parishad
7	Burichang Thana	1:63 360	Thana feeder roads	Thana Parishad	15.11.92	Thana Engineer
D.	**Transmission line Maps**					
1	Brahmanbaria Zila	1:253 440	132, 33 & 11 kV	PDB	-	PDB
2	Comilla Zila	1:253 440	132, 33 & 11 kV	PDB	-	PDB
3	Bangladesh	1:1 013 760	230, 132 & 33 kV	PDB	30.06.90	PDB
E.	**Agricultural Extension Block Boundary**					
1	Daudkandi Thana	-	AEB	Thana Parishad	-	Thana Parishad
2	Debidwar Thana	-	AEB	Thana Parishad	-	Thana Parishad
3	Homna Thana	-	AEB	Thana Parishad	1992	Thana Parishad
4	Comilla Sadar Thana	-	AEB	Thana Parishad	1992	Thana Parishad
5	Brahmanpara Thana	-	AEB	Thana Parishad	-	Thana Parishad
6	Bancharampur Thana	1:79 200	AEB	Thana Parishad	-	Thana Parishad
7	Nabinagar Thana	1:126 720	AEB	Thana Parishad	-	Thana Parishad
8	Akhaura		AEB	Thana Parishad	-	Thana Parishad
9	Burichang		AEB	Thana Parishad	-	Thana Parishad
10	Kasba		AEB	Thana Parishad	-	Thana Parishad
11	Muradnagar		AEB	Thana Parishad	-	Thana Parishad

Note: GCCR - Growth Centre Connecting Road, RESP - Rural Employment Sector Project.

TABLE I.I.4

Results of Bench-mark Checking

Gauge Nr./ BM Nr.	Gauge Name/BM Location	Old BM Elevation (m PWD)	New BM Elevation (m PWD)	Difference (m)	Current Gauge Zero Elevation (m PWD)	Remarks
G - 102	BATAKANDI	6.752	6.690	-0.062	0.326	
G - 104	FAKIRHAT	9.003	9.032	+0.029	-	Gauge missing
G - 105	HARINMANGAL	7.398	7.322	-0.076	-	Gauge missing
G - 109	KALAMURA	12.308	12.410	+0.102	0.547	Double checked against 2nd BM
G - 110	SALIMGANJ	6.909	6.851	-0.058	0.550	
G - 112	BATMATHA	13.815	13.931	+0.116	0.924	Double checked against 2nd BM
G - 121	GOPALNAGAR	11.098	11.034	-0.064	-	Gauge missing
G - 122	SUBIL	7.632	7.710	+0.078	-	Gauge missing
G - 130	SALDA RAILWAY BRIDGE	9.710	10.218	+0.508	3.469	Double checked against same BM
S - 109	BIBIR BAZAR	11.354	11.394	+0.040	6.989	
S - 110	COMILLA	10.848	10.904	+0.056	7.008	
S - 113	KANGSANAGAR	8.585	8.620	+0.035	3.021	
S - 114A	JIBANPUR (GUMTI)	8.530	8.475	-0.055	1.386	
S - 114B	JIBANPUR (BURI)	8.530	8.475	-0.055	-	
S - 115	DAUDKANDI	6.105	6.159	+0.054	- ?	Gauge missing
S - 123	GANGASAGAR RLY.	7.866	8.253	+0.387	3.604	Double checked against 2nd BM
S - 296	BRIDGE	11.116	10.894	-0.222	(-)0.210	Double checked against 2nd BM
S - 298	AKHAURA	6.372	6.274	-0.098	(-)0.553	
B - 36(a)	NABINAGAR	7.944	7.856	-0.088	-	BM only
B - 45	MIRPUR	6.283	6.331	+0.048	-	BM only
-	GOURIPUR	-	9.323	-	2.810	
	CHAPITALA	-	6.370	-	-	Gauge missing
FM BM 4101	PIPRAKANDI HASANPUR COLLEGE	-	6363	-	-	BM only

Note: For locations see Figure I.I.2.

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Figure I.I.2

Location of Bench-Marks and Cross-Sections

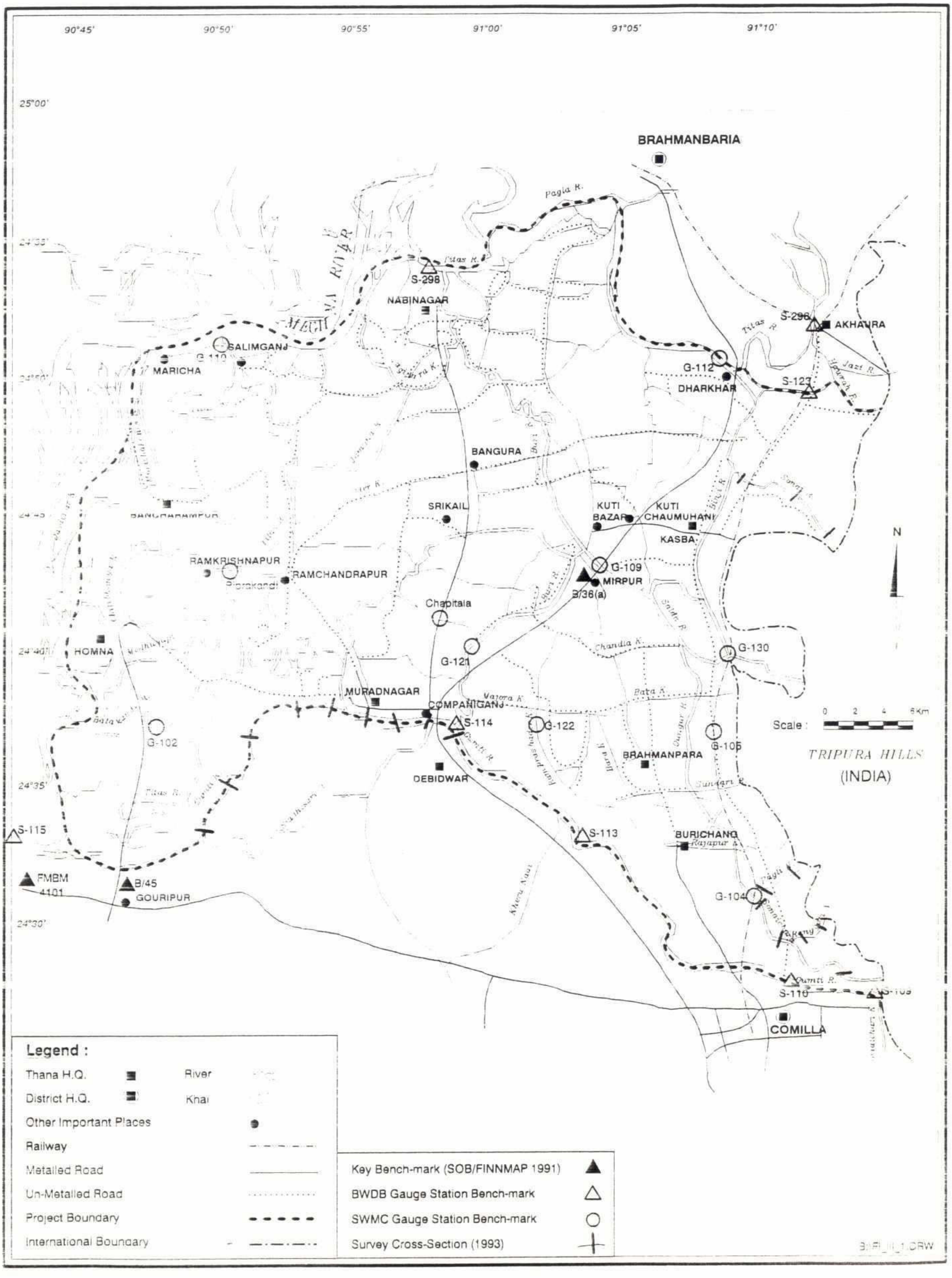

TABLE I.I.5

Channel Longitudinal Sections and Cross-sections from the 1990 Feasibility Study

Channel Name	Length (km)	No of X-Sections	No of Drawing Sheets: Long Sections	No of Drawing Sheets: X - Sections
Sundari Bara Khal	18.590	26	1	3
Chandla Khal	12.530	21	1	3
Arsi Nadi	51.150	55	1	10
Chittibhanga River	32.800	46	2	14
Ghungur River	25.440	31	2	4
Salda River	21.850	27	1	5
Gumti River from Daskandi to Daudkandi	20.600	30	1	7
Titas River	76.800	82	4	16
Buri Nadi	50.550	60	3	15
Madhu Kupi Nadi	13.600	15	1	3
Magora Khal	7.615	12	1	2
Matia Nadi (A & B)	7.700	11	1	1
Bijni River	26.590	32	1	4
Bodagacha Khal	12.850	13	1	2
Oder Khal	29.700	36	2	6
Jogidara Khal	6.700	8	1	1
Kagdi Nadi	6.400	9	1	1
Sonaichari Nadi *	5.000	7	1	1
Rajapur Khal	2.950	7	1	1
Dalpa Metangor	8.000	8	1	2
Nasimpur Khal *	6.800	8	1	1
Sidali Khal	6.000	12	1	2
Batakandi Nadi	11.000	12	1	2
Chapitala Khal	8.700	10	1	2
Zia Khal	9.933	12	1	1
Jamuna River	19.300	34	2	6
Rajapur Khal	8.000			
Ramprashader Khal	13.600	44	2	5
Majora Khal	4.800			
Maidaganj - Waruk Khal	5.850	7	1	1
Bara Khal	10.810	17	1	2
Chittibhanga - Arsi Nadi *	2.420	2	1	incl in LS
Waruk - Kasikara Khal	5.700	6	1	incl in LS
Roachala Khal	11.200	13	1	3
Raja Khal	16.675	23	1	4
Chittibhanga - Titas river	0.850	2	1	incl in LS

* Exact location/identity of channel unclear

TABLE I.1.6

Channel Cross-sections Available in the South East Regional Model

Channel Name		Nr of Cross-Sections
SWMC Terminology	Table I.1.5 Terminology	
Bara Khal	Bara Khal	6
Bijni River	Bijni River	8
Buri Nadi	Buri Nadi	5
Chandla Khal	Chandla Khal	4
Chapitala Khal	Chapitala Khal	8
GN 1	N/A	4
GN 12	Bara Khal/Sidali Khal/N/A	5
GN 13	Bara Khal	2
GN 2	Chittibhanga River	4
GN 3	Madhu Kupi Nadi	4
GN 4	Titas River	5
GN 5	Jamuna River/Titas River	12
GN 9	Arsi Nadi	3
Gumti River	Gumti River	20
Howra River	N/A	2
Jogidhara Khal	Jogidara Khal	4
Nalia River	Gunghur/Salda/Buri Nadi	24
Oder Khal	Oder Khal	5
Pagli River	N/A	3
Ramprashader Khal	Ramprashader Khal	3
Salda River	Salda River	3
Lower Titas River	Titas/Chittibhanga/Batakandi Nadi	20
Upper Titas River	Titas River	17

APPENDIX I.II

SEDIMENT DATA

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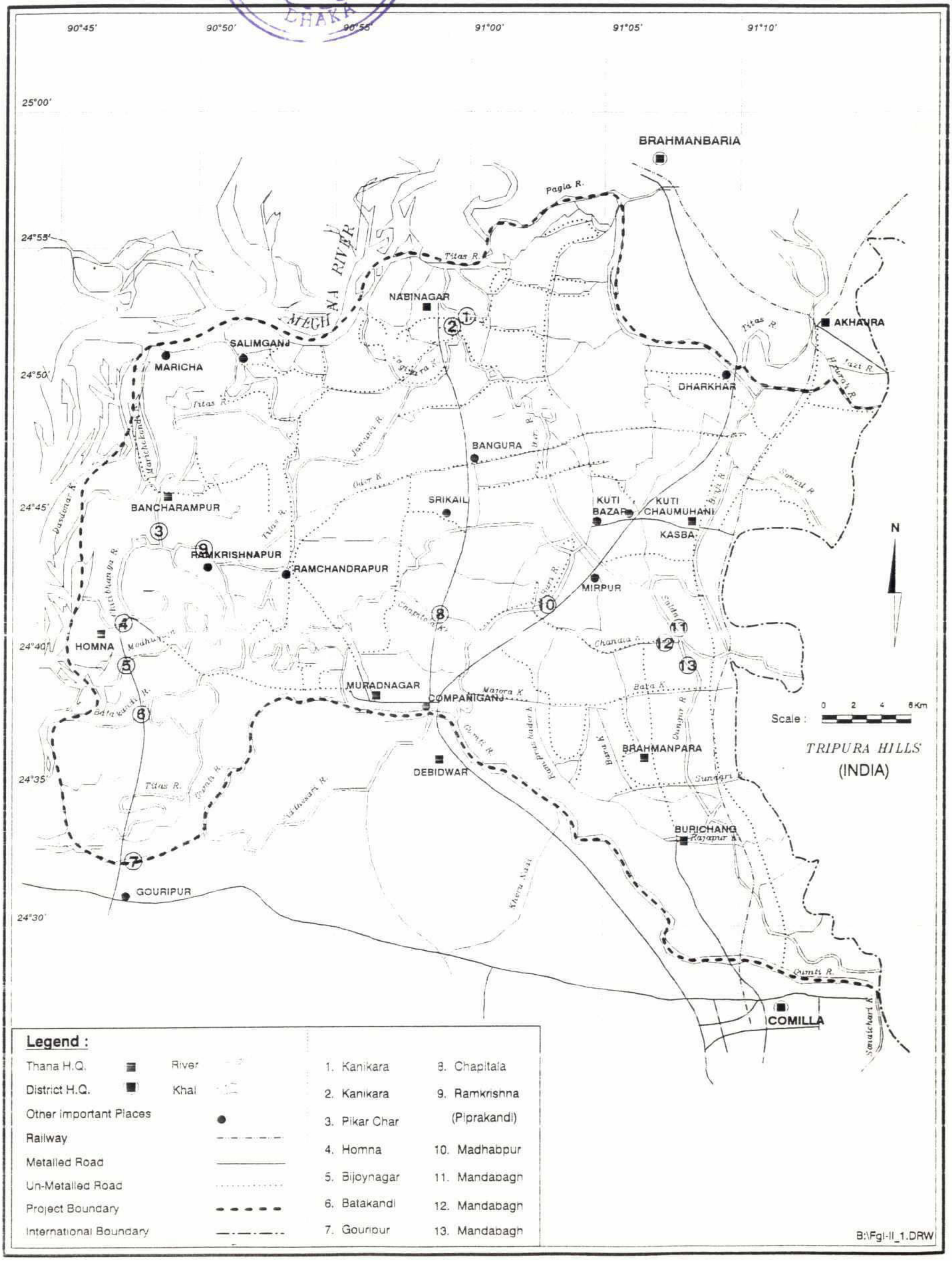
Figure I.II.1
Channel Bed Material Sample Locations



Determination of Grain Size with Settling Tube

River:	① TITAS UPPER(CEN)	Date of collection:	19/01/93	Salinity (ppt):	1
Station:	KANIKARA	Time of collection:	11:10	Initial Temperature (C):	26
Vertical No.:		Depth of sampling from surface:		Final Temperature (C):	26
Bed/Suspended:	BED	Depth of water (m):		Factor	0.0127
Density:		Volume of Sample (l):	21.686	Multiplying Fraction value (%):	93.04
Water (kg/m3)	997	Dry weight d >= d=0.063mm (g):	0.3981		
Sediment (kg/m3)	2650	Sieve analysis is -------------------->	REQUIRED	FILE NAM	TITA-6

Comments:

Analysed by: BASET

Time			Time	h	h/t	Volume	Bottle	FILT E		Tare	Gross	Net	C	(h/t) ^ 0.5	d	%
Day	hr	min	min	(cm)	(cm/min)	(ml)	No.	No.		(g)	(g)	(g)	(mg/l)	(cm/min) ^ 0.5	(mm)	finer
1	8	30	0	109.9		69.5	1	S-	12	0.0663	0.1302	0.0639	919			98.04
1	8	31	1	107.3	107.30	63	2	S-	13	0.0661	0.1215	0.0554	879	10.38	0.132	93.77
1	8	33	3	105.9	35.30	67	3	S-	14	0.0690	0.1222	0.0532	794	5.94	0.075	84.67
1	8	37	7	104.1	14.87	64	4	S-	15	0.0681	0.1125	0.0444	694	3.86	0.049	73.93
1	8	45	15	102.2	6.81	62	5	S-	16	0.0673	0.1056	0.0383	618	2.61	0.033	65.87
1	9	0	30	100.2	3.34	62	6	S-	17	0.0685	0.1003	0.0318	513	1.83	0.023	54.69
1	9	30	60	98.3	1.64	65	7	S-	18	0.0705	0.0982	0.0277	426	1.28	0.016	45.41
1	10	30	120	96.2	0.80	67	8	S-	19	0.0716	0.0949	0.0233	348	0.90	0.011	37.08
1	12	30	240	94.3	0.39	65	9	S-	20	0.0714	0.0879	0.0165	254	0.63	0.008	27.07
1	16	30	480	91.1	0.19	63	10	S-	21	0.0704	0.0826	0.0122	194	0.44	0.006	20.63
2	8	30	1440	90.0	0.06	63	11	S-	22	0.0709	0.0789	0.0080	127	0.25	0.003	13.51
3	0	0	0	0.0	0.00							0.0000	0	0.00	0.000	0.00

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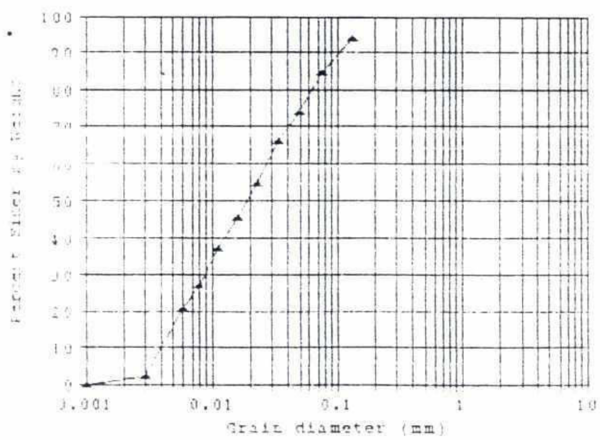
F. ı. ꞮI. 3

Particle Size Distribution

River: ① TITAS UPPER(CE Date of collection: 19/10/93
Station: KANIKARA Time of collection: 11:10
Vertical No.: 0 Depth of sampling:
Bed/Suspended: BED FILE NAME: TITA-6
Perc. of total sample:

d (mm)	Material < d (% by weight)
0.000	98.04
0.132	93.77
0.075	84.67
0.049	73.98
0.033	65.87
0.023	54.69
0.016	45.44
0.011	37.08
0.008	27.07
0.006	20.65
0.003	2.10
0.000	0

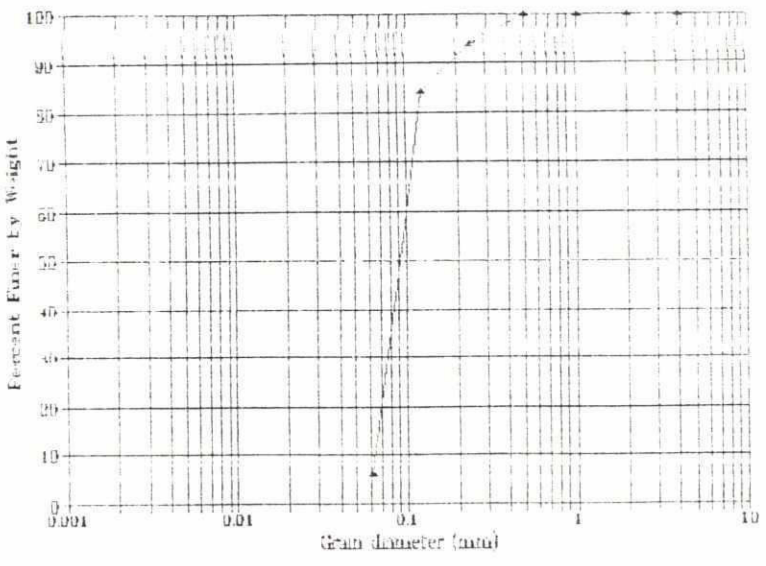


D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.010	0.019	0.032	4.296

Sieve Analysis of Bed Material

Wet/Dry: ①	Dry	Total Weight (g):	
River:	TITAS UPPER(CEN)	Before sieving	0.3981
Station:	KANIKARA	After sieving	0.3760
Date of collection:	19/01/99	Loss	0.0221
Settling Analysis:	NOT REQUIRED	FILE NAME:	TITA-6A

Sieve Size, d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000		0.0000	100.0000
0.2500	0.0225	5.9840	94.0160
0.1250	0.0377	10.0266	83.9894
0.0625	0.2931	77.9521	6.0372
Pan	0.0227	6.0372	0.0000

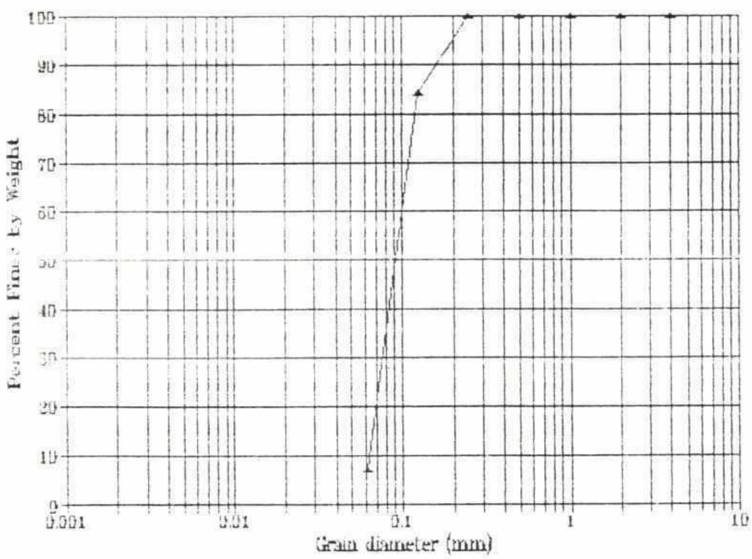


D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.0810	0.0920	0.1060	1.3658

Sieve Analysis of Bed Material

Wet/Dry:	(2) Dry	Total Weight (g):	
River:	BURI	Before sieving	0.1683
Station:	KANIKARA U/S	After sieving	0.1472
Date of collection:	19/01/93	Loss	0.0211
Settling Analysis :	NOT REQUIRED	FILE NAME:	BURI-4A

Sieve Size, d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000		0.0000	100.0000
0.2500		0.0000	100.0000
0.1250	0.0233	15.8288	84.1712
0.0625	0.1134	77.0380	7.1332
Pan	0.0105	7.1332	0.0000

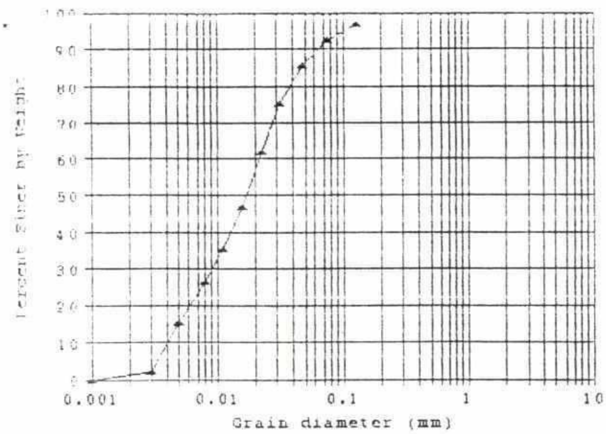


D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.0800	0.0920	0.1050	1.3558

Particle Size Distribution

River: (2) BURI — Date of collection: 19/01/93
Station: KANIKARA U/S — Time of collection: 11:10
Vertical No.: 0 — Depth of sampling: 0
Bed/Suspended: BED — FILE NAME: BURI-4
Perc. of total sample:

d (mm)	Material < d (% by weight)
0.000	99.16
0.130	96.96
0.074	92.31
0.048	85.44
0.032	75.35
0.023	61.80
0.016	46.73
0.011	35.27
0.008	26.46
0.005	15.22
0.003	2.10
0.000	0



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.011	0.017	0.025	3.024

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Determination of Grain Size with Settling Tube

River:	② BURI	Date of collection:	19/01/93	Salinity (ppt):	0
Station:	KANIKARA U/s	Time of collection:	11:10	Initial Temperature (C):	26
Vertical No.:		Depth of sampling from surface:	0	Final Temperature (C):	26
Bed/Suspended:	BED	Depth of water (m):	0	Factor	0.0127
Density:		Volume of Sample (l):	20.95	Multiplying Fraction value (%):	99.16
Water (kg/m3)	997	Dry weight d >= d=0.063mm (g):	0.1683		
Sediment (kg/m3)	2650	Sieve analysis is ----------------	REQUIRED	FILE NAM	BURI-4
Comments:				Analysed by:	BASET

Time Day	Time hr	Time min	Time min	h (cm)	h/t (cm/min)	Volume (ml)	Bottle No.	Filer No.	Tare (g)	Gross (g)	Net (g)	C (mg/l)	(h/t)^0.5 (cm/min)^0.5	d (mm)	% finer
1	9	5	0	106.0		56	1	K-34	0.0748	0.1280	0.0532	950			99.16
1	9	6	1	104.0	104.00	67.5	2	K-35	0.0746	0.1373	0.0627	929	10.20	0.130	96.96
1	9	8	3	102.1	34.03	64	3	K-36	0.0748	0.1314	0.0566	884	5.83	0.074	92.31
1	9	12	7	100.4	14.34	54	4	K-37	0.0743	0.1185	0.0442	819	3.79	0.048	85.44
1	9	20	15	98.2	6.55	73	5	K-38	0.0748	0.1275	0.0527	722	2.56	0.032	75.35
1	9	35	30	96.2	3.21	76	6	K-39	0.0740	0.1190	0.0450	592	1.79	0.023	61.80
1	10	5	60	94.2	1.57	86	7	K-40	0.0723	0.1108	0.0385	448	1.25	0.016	46.73
1	11	5	120	92.4	0.77	72.5	8	K-41	0.0668	0.0913	0.0245	338	0.88	0.011	35.27
1	13	5	240	90.4	0.33	86	9	K-42	0.0680	0.0898	0.0218	253	0.61	0.008	26.46
1	17	5	480	88.6	0.18	77.5	10	K-43	0.0681	0.0794	0.0113	146	0.43	0.005	15.22
[illegible]	9	5	1440	86.5	0.06	87	11	K-44	0.0681	0.0757	0.0076	87	0.25	0.003	9.12
3	[illegible]	0	0	0.0	0.00						0.0000	0	0.00	0.000	0.00

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Determination of Grain Size with Settling Tube

River:	(2) BURI	Date of collection:	19/01/93	Salinity (ppt):	0
Station:	KANIKARA U/s	Time of collection:	11:10	Initial Temperature (C):	26
Vertical No.:		Depth of sampling from surface:	0	Final Temperature (C):	26
Bed/Suspended:	BED	Depth of water (m):	0	Factor	0.0127
Density:		Volume of Sample (l):	22.196	Multiplying Fracion value (%):	99.49
Water (kg/m3)	997	Dry weight d >= d=0.063mm (g):	0.1262		
Sediment (kg/m3)	2650	Sieve analysis is -------------------->	REQUIRED	FILE NAM	BURI-3

Comments:

Analysed by: BASET

Time			Time	h	h/t	Volume	Bottle	Filter	Tare	Gross	Net	C	(h/t)^0.5	d	%
Day	hr	min	min	(cm)	(cm/min)	(ml)	No.	No.	(g)	(g)	(g)	(mg/l)	(cm/min)^0.5	(mm)	finer
1	9	5	0	107.3		60	1	K-23	0.0710	0.1376	0.0666	1110			99.49
1	9	6	1	105.0	105.00	67	2	K-24	0.0693	0.1378	0.0685	1022	10.25	0.130	91.64
1	9	8	3	103.0	34.33	63	3	K-25	0.0681	0.1294	0.0613	973	5.86	0.074	87.21
1	9	12	7	101.3	14.47	63	4	K-26	0.0685	0.1248	0.0563	894	3.80	0.048	80.10
1	9	20	15	99.1	6.61	59	5	K-27	0.0695	0.1163	0.0468	793	2.57	0.033	71.10
1	9	35	30	97.2	3.24	56	6	K-28	0.0694	0.1066	0.0372	664	1.80	0.023	59.54
1	10	5	60	95.0	1.58	69	7	K-29	0.0740	0.1091	0.0351	509	1.26	0.016	45.59
1	11	5	120	93.3	0.78	66	8	K-30	0.0701	0.0967	0.0266	403	0.88	0.011	36.12
1	13	5	240	91.2	0.38	61	9	K-31	0.0691	0.0886	0.0195	320	0.62	0.008	28.65
1	17	5	480	89.2	0.19	61	10	K-32	0.0707	0.0838	0.0131	215	0.43	0.005	19.25
	9	5	1440	87.0	0.06	67	11	K-33	0.0728	0.0829	0.0101	151	0.25	0.003	13.51
	0	0	0	0.0	0.00						0.0000	0	0.00	0.000	0.00

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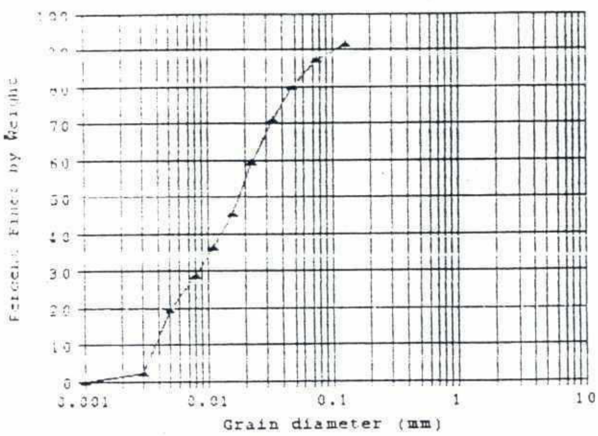
Particle Size Distribution

River:	(2) BURI	Date of collection:	19/01/93
Station:	KANIKARA U/S	Time of collection:	11:10
Vertical No.:	0	Depth of sampling:	0
Bed/Suspended:	BED	FILE NAME:	BURI-3
Perc. of total sample:			

d (mm)	Material < d (% by weight)
0.000	99.49
0.130	91.64
0.074	87.21
0.048	80.10
0.033	71.10
0.023	59.54
0.016	45.59
0.011	36.12
0.008	28.65
0.005	19.25
0.003	2.10
0.000	0

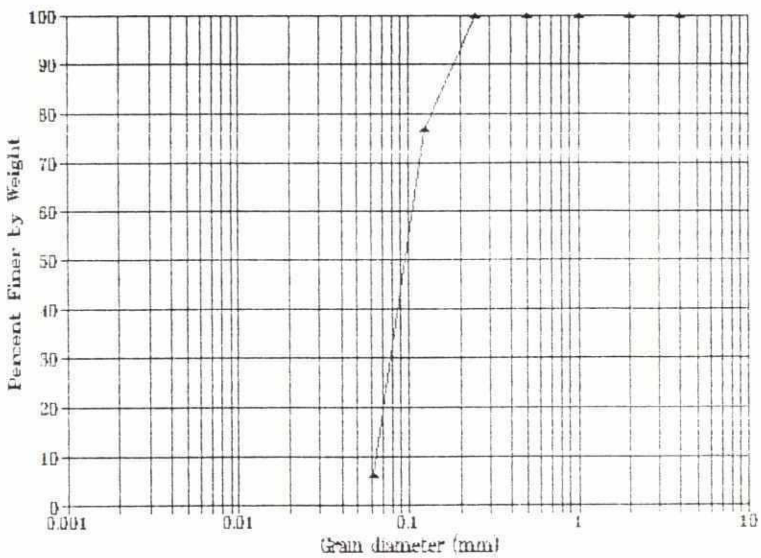


D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.010	0.018	0.027	3.944

Sieve Analysis of Bed Material

Wet/Dry:	(2) Dry	Total Weight (g):		
River:	BURI	Before sieving		0.1216
Station	KANIKARA U/S	After sieving		0.1163
Date of collection:	19/01/93	Loss		0.0053
Settling Analysis :	REQUIRED	FILE NAME:	BURI-3A	

Sieve Size, d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000		0.0000	100.0000
0.2500		0.0000	100.0000
0.1250	0.0272	23.3878	76.6122
0.0625	0.0820	70.5073	6.1049
Pan	0.0071	6.1049	0.0000



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.0830	0.0960	0.1120	1.5082

Determination of Grain Size with Settling Tube

River:	(2) BURI	Date of collection:	19/01/93	Salinity (ppt):	0
Station:	KANIKARA	Time of collection:	11:10	Initial Temperature (C):	26
Vertical No.:		Depth of sampling from surface:	0	Final Temperature (C):	26
Bed/Suspended:	BED	Depth of water (m):	0	Factor	0.0127
Density:		Volume of Sample (l):	21.532	Multiplying Fraction value (%):	97.83
Water (kg/m3)	997	Dry weight d >= d=0.063mm (g):	0.4332		
Sediment (kg/m3)	2650	Sieve analysis is ---------------- ------>	REQUIRED	FILE NAM BURI-2	

Comments:

Analysed by: BASET

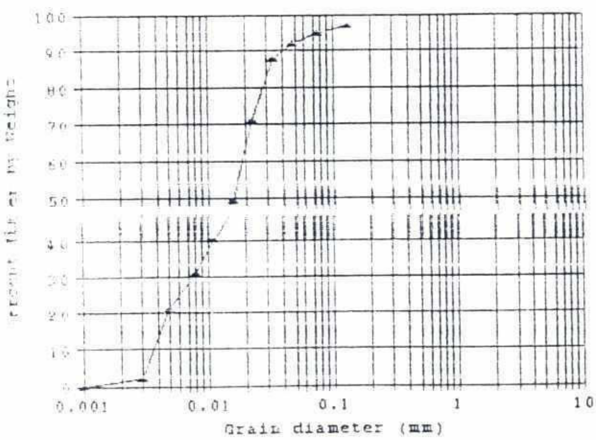
	Time		Time	h	h/t	Volume	Bottle	Filter	Tare	Gross	Net	C	(h/t)^0.5	d	%
Day	hr	min	min	(cm)	(cm/min)	(ml)	No.	No.	(g)	(g)	(g)	(mg/l)	(cm/min)^0.5	(mm)	finer
1	9	0	0	108.0		68	1	K-12	0.0703	0.1340	0.0632	929			97.88
1	9	1	1	106.0	10600	70	2	K-13	0.0710	0.1354	0.0644	920	10.30	0.131	96.89
1	9	3	3	103.7	3457	66	3	K-14	0.0714	0.1308	0.0594	900	5.88	0.075	94.78
1	9	7	7	101.3	1447	75	4	K-15	0.0743	0.1397	0.0654	372	3.80	0.048	91.83
1	9	15	15	99.4	663	70	5	K-16	0.0736	0.1319	0.0583	333	2.57	0.033	87.70
1	9	30	30	97.2	324	77	6	K-17	0.0750	0.1269	0.0519	674	1.80	0.023	70.99
1	10	0	60	95.2	159	79	7	K-18	0.0771	0.1142	0.0371	470	1.26	0.016	49.46
1	11	0	120	92.7	077	79	8	K-19	0.0759	0.1062	0.0303	384	0.88	0.011	40.39
1	13	0	240	90.9	038	80	9	K-20	0.0722	0.0958	0.0236	295	0.62	0.008	31.07
1	17	0	480	38.8	019	84.5	10	K-21	0.0734	0.0905	0.0171	202	0.43	0.005	21.31
2	9	0	1440	36.5	006	78	11	K-22	0.0749	0.0858	0.0109	140	0.25	0.003	14.72
3	0	0	0	0.0	000						0.0000	0	0.00	0.000	0.00

2D B

Particle Size Distribution

River:	(2) BURI	Date of collection:	19/01/93
Station:	KANIKARA	Time of collection:	11:10
Vertical No.:	0	Depth of sampling:	0
Bed/Suspended:	BED	FILE NAME:	BURI-2
Perc. of total sample:			

d (mm)	Material < d (% by weight)
0.000	97.88
0.131	96.89
0.075	94.78
0.048	91.83
0.033	87.70
0.023	70.99
0.016	49.46
0.011	40.39
0.008	31.07
0.005	21.31
0.003	2.10
0.000	0

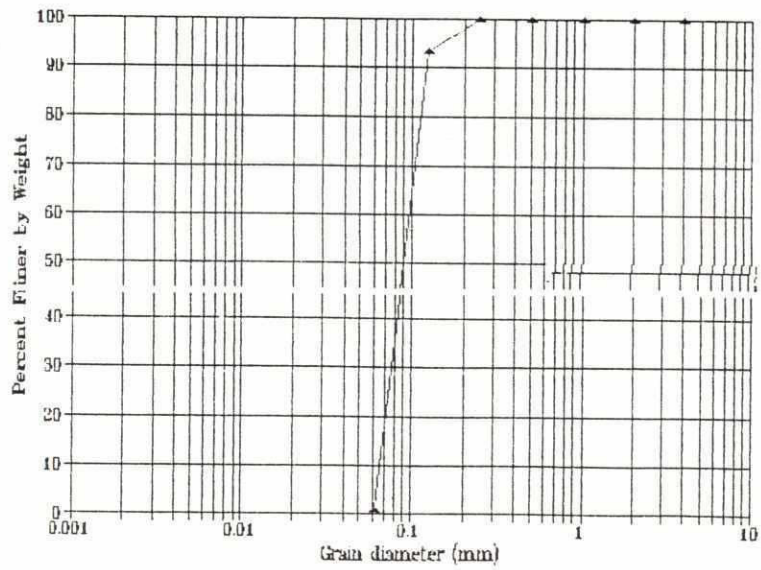


D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.009	0.016	0.021	3.604

Sieve Analysis of Bed Material

Wet/Dry:	② Dry	Total Weight (g):	
River:	BURI	Before sieving	0.4332
Station:	KANIKARA U/S	After sieving	0.4177
Date of collection:	19/01/93	Loss	0.0155
Settling Analysis :	REQUIRED	FILE NAME: BURI-2A	

Sieve Size, d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000		0.0000	100.0000
0.2500		0.0000	100.0000
0.1250	0.0279	6.6794	93.3206
0.0625	0.3863	92.4826	0.8379
Pan	0.0035	0.8379	0.0000

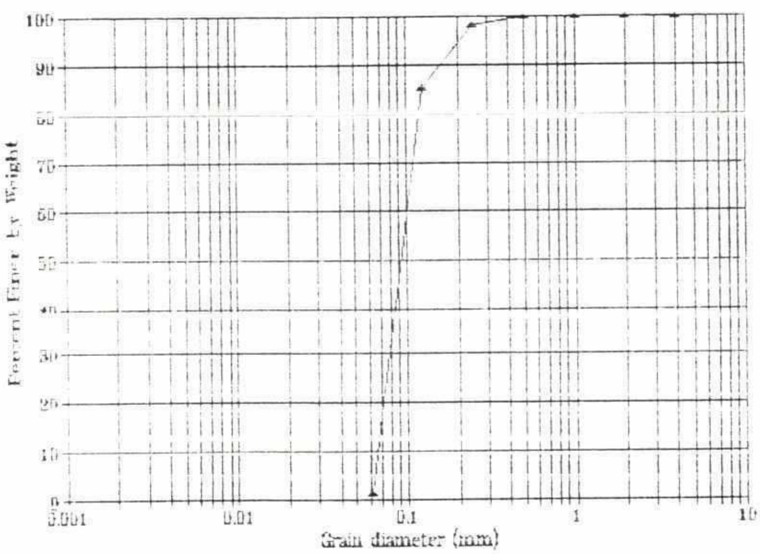


D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.0810	0.0900	0.1010	1.2929

Sieve Analysis of Bed Material

Wet/Dry: (3)	Dry	Total Weight (g):	
River:	TITAS LOWER(CENTE	Before sieving	2.4147
Station	PIKAR	After sieving	2.3165
Date of collection:	11/01/93	Loss	0.0982
Settling Analysis :	NOT REQUIRED	FILE NAME:	TITA-1A

Sieve Size, d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000		0.0000	100.0000
0.2500	0.0436	1.8906	98.1092
0.1250	0.2939	12.6872	85.4220
0.0625	1.9500	84.1787	1.2433
Pan	0.0288	1.2433	0.0000

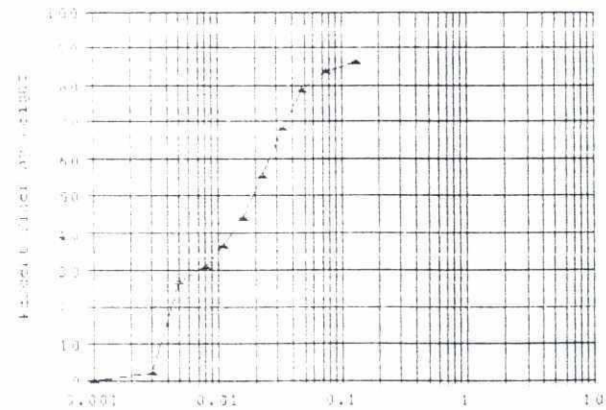


D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.0830	0.0930	0.1060	1.3216

Particle Size Distribution

River:	(3) TITAS LOWER	Date of collection:	11/01/93
Station:	PIKAR	Time of collection:	11:10
Vertical No.:	0	Depth of sampling:	
Bed/Suspended:	BED	FILE NAME:	TITA-1
Perc. of total sample:			

d (mm)	Material < d (% by weight)
0.000	88.01
0.131	86.44
0.075	83.77
0.048	78.72
0.033	68.47
0.023	55.26
0.016	44.18
0.011	36.42
0.008	30.91
0.005	26.98
0.003	2.10
0.000	0



D15 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.010	0.019	0.030	Out of Range

Determination of Grain Size with Settling Tube

River:	③ TITAS LOWER(CEN)	Date of collection:	11/01/93	Salinity (ppt):	0
Station:	PIKAR	Time of collection:	11:10	Initial Temperature (C):	26
Vertical No.:		Depth of sampling from surface:	0	Final Temperature (C):	26
Bed/Suspended:	BED	Depth of water (m):	0	Factor	0.0127
Density:		Volume of Sample (l):	22.318	Multiplying Fraction value (%):	88.01
Water (kg/m3)	997	Dry weight d >= d=0.063mm (g):	2.4147		
Sediment (kg/m3)	2650	Sieve analysis is >	REQUIRED	FILE NAME:	TITA 1

Comments:

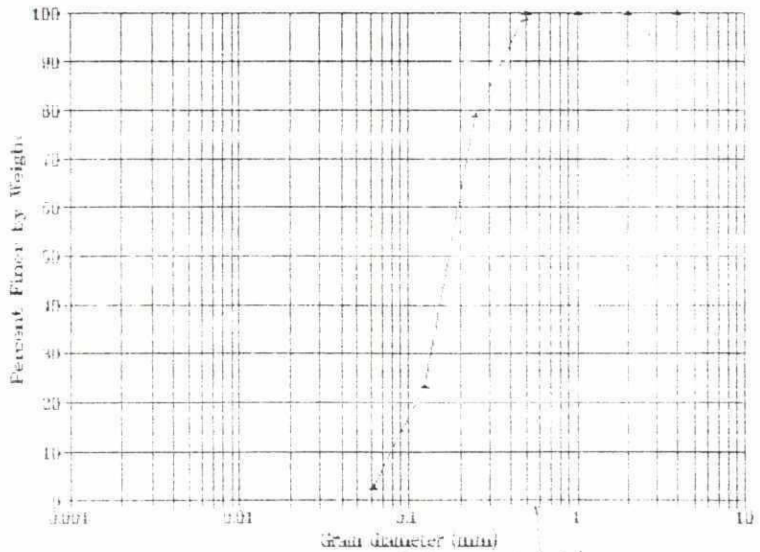
Analysed by: HASET

Time			Time	h	h/t	Volume	Bottle	Filter	Tare	Gross	Net	C	(h/t)^0.5	d	%
Day	hr	min	min	(cm)	(cm/min)	(ml)	No.	No.	(g)	(g)	(g)	(mg/l)	(cm/min)^0.5	(mm)	finer
1	8	50	0	108.0		82	1	L-25	0.0715	0.1366	0.0651	794			88.01
1	8	51	1	106.2	106.20	74	2	L-24	0.0721	0.1298	0.0577	780	10.31	0.131	86.44
1	8	53	3	104.0	34.67	70	3	L-25	0.0721	0.1250	0.0529	756	5.89	0.075	83.77
1	8	57	7	102.0	14.57	69	4	L-26	0.0716	0.1206	0.0490	710	3.82	0.048	78.72
1	9	5	15	100.0	6.67	85	5	L-27	0.0683	0.1208	0.0525	618	2.58	0.033	68.47
1	9	20	30	98.0	3.27	67	6	L-28	0.0676	0.1010	0.0334	499	1.81	0.023	55.26
1	9	50	60	95.8	1.60	69	7	L-29	0.0681	0.0956	0.0275	399	1.26	0.016	44.18
1	10	50	120	94.0	0.78	77	8	L-30	0.0656	0.0909	0.0253	329	0.89	0.011	36.42
1	12	50	240	91.9	0.38	71	9	L-31	0.0674	0.0872	0.0198	279	0.62	0.008	30.91
1	16	50	480	90.0	0.19	76	10	L-32	0.0700	0.0885	0.0185	243	0.43	0.005	26.98
2	8	50	1440	88.0	0.06	76	11	L-33	0.0675	0.0837	0.0162	213	0.25	0.003	23.63
3	0	0	0	0.0	0.00						0.0000	0	0.00	0.000	0.00

Sieve Analysis of Bed Material

Wet/Dry:	④ Dry	Total Weight (g):	
River:	CHITTABANGA	Before sieving	53.8668
Station:		After sieving	53.6127
Date of collection:		Loss	0.2541
Settling Analysis :	NOT REQUIRED	FILE NAME	CHITTA-1

Sieve Size d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000	0.0000	0.0000	100.0000
0.2500	11.4624	21.3800	78.6200
0.1250	29.5277	55.0759	23.5440
0.0625	11.2320	20.9503	2.5938
Pan	1.3906	2.5938	0.0000



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.1440	0.1740	0.2110	1.7532

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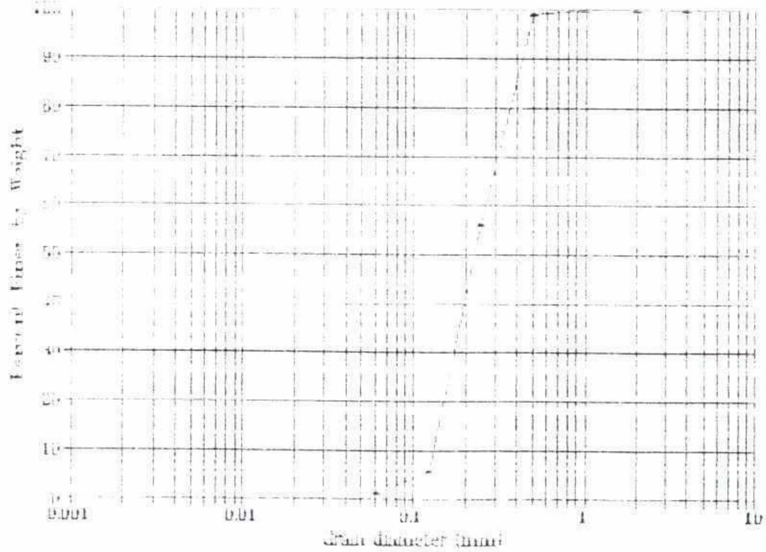
Sieve Analysis of Bed Material

Wet/Dry	(4) Dry	Total Weight (g)	
River	CHITTABANGA	Before sieving	54.1938
Station		After sieving	53.6091
Date of collection		Loss	0.5847
Settling Analysis	NOT REQUIRED	FILE NAME	CHITTA-2

Sieve Size d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000	0.0971	0.1811	99.8189
1.0000	0.0278	0.0519	99.7670
0.5000	0.3857	0.7195	99.0475
0.2500	23.1019	43.0932	55.9543
0.1250	26.9660	50.3012	5.6531
0.0625	2.3637	4.4091	1.2440
Pan	0.6669	1.2440	0.0000

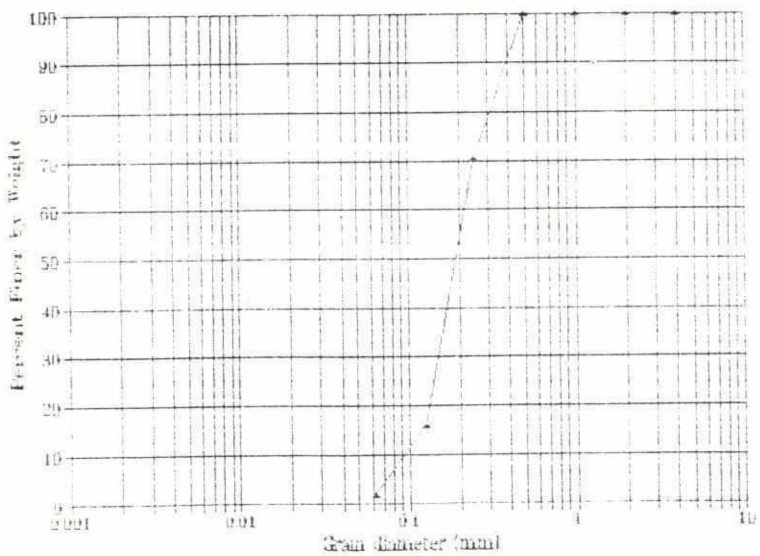


D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.1870	0.2300	0.2890	1.6530

Sieve Analysis of Bed Material

Wet/Dry:	(4) Dry	Total Weight (g):	
River:	CHITTABANGA	Before sieving	52.7322
Station:		After sieving	52.4803
Date of collection:		Loss	0.2519
Settling Analysis	NOT REQUIRED	FILE NAME:	CHITTA-3

Sieve Size d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000	0.0000	0.0000	100.0000
0.5000	0.1219	0.2323	99.7677
0.2500	15.5022	29.5391	70.2286
0.1250	28.5500	54.4014	15.8273
0.0625	7.4031	14.1064	1.7208
Pan	0.9031	1.7208	0.0000



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.1600	0.1930	0.2340	1.6656

Determination of Grain Size with Settling Tube

River:	⑤ MADHUKUPIKHAL(G	Date of collection:	09/01/98	Salinity (ppt):	0
Station:	BIJOYNAGAR(CENT)	Time of collection:	11:10	Initial Temperature (C):	[illegible]
Vertical No.:		Depth of sampling from surface:	0	Final Temperature (C):	[illegible]
Bed/Suspended:	BED	Depth of water (m):	0	Factor	[illegible]
Density:		Volume of Sample (l):	21.585	Multiplying Fraction value (%):	[illegible]
Water (kg/m3)	997	Dry weight d >= d = 0.063mm (g):	14.038		
Sediment (kg/m3)	2650	Sieve analysis is ----------	REQUIRED	FILE NAME	MADHU[illegible]

Comments:

Analysed by: BASFT

Time			Time	h	h/t	Volume	Bottle	Filter	Tare	Gross	Net	C	(h/t) ^ 0.5	d	%
Day	hr	min	min	(cm)	(cm/min)	(ml)	No.	No.	(g)	(g)	(g)	(mg/l)	(cm/min) ^ 0.5	(mm)	[illegible]
1	9	5	0	109.7		74	1	S-34	0.0690	0.0929	0.0239	323			[illegible]
1	9	6	1	107.7	107.70	74.5	2	S-35	0.0734	0.0961	0.0227	305	10.38	0.15[illegible]	[illegible]
1	9	8	3	105.7	35.23	86.5	3	S-36	0.0744	0.0975	0.0231	267	5.94	[illegible]	[illegible]
1	9	12	7	103.7	14.81	78.5	4	S-37	0.0702	0.0875	0.0173	220	3.85	0.048	[illegible]
1	9	20	15	101.5	6.77	80.5	5	S-38	0.0731	0.0876	0.0145	180	2.60	0.03[illegible]	[illegible]
1	9	35	30	99.5	3.32	83.5	6	S-39	0.0722	0.0848	0.0126	151	1.82	0.023	[illegible]
1	10	5	60	97.5	1.63	78	7	S-40	0.0724	0.0836	0.0112	144	1.27	0.016	[illegible]
1	11	5	120	95.1	0.79	75.5	8	S-41	0.0732	0.0814	0.0082	109	0.39	0.011	11.1[illegible]
1	13	5	240	93.0	0.39	72	9	S-42	0.0730	0.0790	0.0060	83	0.62	0.008	[illegible]
1	17	5	480	91.0	0.19	35	10	S-43	0.0744	0.0792	0.0048	56	0.44	0.005	[illegible]
2	9	5	1440	89.0	0.06	33.5	11	S-44	0.0747	0.0781	0.0034	41	0.25	0.003	[illegible]
3	0	3	0	0.0	0.00						0.0000	0	0.00	0.000	[illegible]

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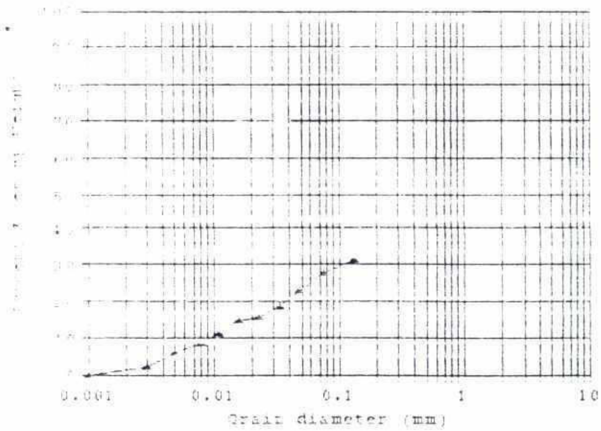
Particle Size Distribution

River: (5) MADHUKUPI K Date of collection: 09/01/93
Station: BIJOYNAGAR Time of collection: 11:10
Vertical No.: 0 Depth of sampling:
Bed/Suspended: BED FILE NAME: MADHU-2
Perc. of total sample:

d (mm)	Material < d (% by weight)
0.000	33.16
0.131	31.29
0.075	27.42
0.048	22.63
0.033	18.40
0.023	15.40
0.016	14.74
0.011	11.15
0.008	8.56
0.005	5.80
0.003	2.10
0.000	0

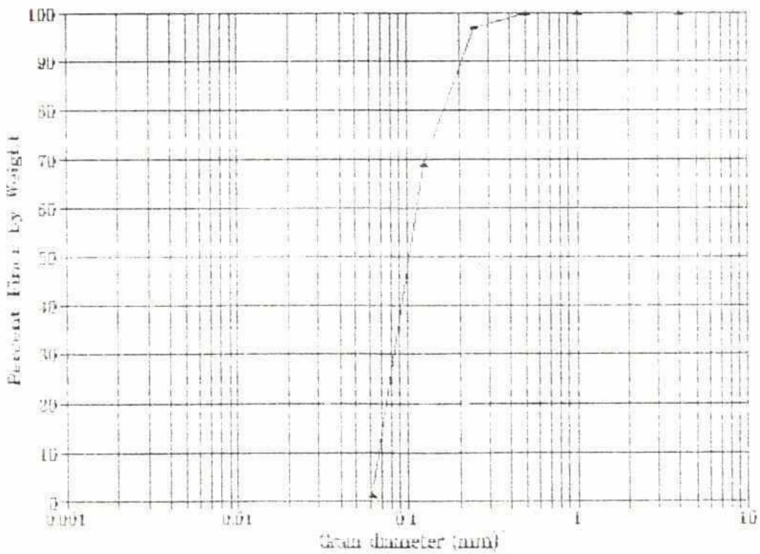


D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
Out of Range	Out of Range	Out of Range	Out of Range

Sieve Analysis of Bed Material

Wet/Dry:	(5) Dry	Total Weight (g):	
River:	MADHUKUPI KHAL(CE	Before sieving	14.0378
Station:	BIJOYNAGAR	After sieving	13.9640
Date of collection:	09/01/93	Loss	0.0738
Settling Analysis:	NOT REQUIRED	FILE NAME.	MADHU-2A

Sieve Size, d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000	0.0161	0.1153	99.8847
0.2500	0.4408	3.1567	96.7280
0.1250	3.8976	27.9118	68.8162
0.0625	9.4556	67.7141	1.1021
Pan	0.1539	1.1021	0.0000



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.0880	0.1030	0.1200	1.5890

Determination of Grain Size with Settling Tube

River:	⑥ TITAS LOWER(L/B)	Date of collection:	09 01 93	Salinity (ppt):
Station:	BATAKANDI	Time of collection:	11:10	Initial Temperature (C):
Vertical No.:		Depth of sampling from surface:		Final Temperature (C):
Bed/Suspended:	BED	Depth of water (m):		Factor [illegible]
Density:		Volume of Sample (l):	21.094	Multiplying Fraction value [illegible]
Water (kg/m3)	997	Dry weight d >= d=0.063mm (g):	3.569	
Sediment (kg/m3)	2650	Sieve analysis is --------------------->	REQUIRED	FILE NAME [illegible]

Comments:

Analysed by: [illegible]

Time			Time	h	h/t	Volume	Bottle	Filter	Tare	Gross	Net	C	(h/t)^0.5	d	[illegible]
Day	hr	min	min	(cm)	(cm/min)	(ml)	No.	No.	(g)	(g)	(g)	(mg/l)	(cm min)^0.5	(mm)	[illegible]
1	3	30	0	106.0		80	1	K-1	0.0765	0.1264	0.0499	624			[illegible]
1	8	31	1	104.1	104.10	76	2	K-2	0.0766	0.1231	0.0468	616	10.20	0.130	[illegible]
1	8	33	3	102.0	34.00	82	3	K-3	0.0759	0.1238	0.0479	584	5.83	0.074	[illegible]
1	8	37	7	100.3	14.33	74	4	K-4	0.0750	0.1123	0.0373	504	3.79	0.043	[illegible]
1	8	45	15	987.3	65.82	77	5	K-5	0.0765	0.1090	0.0325	422	8.11	0.103	[illegible]
1	9	0	30	96.3	3.21	81	6	K-6	0.0766	0.1057	0.0291	359	1.79	0.023	[illegible]
1	9	30	60	94.4	1.57	94.5	7	K-7	0.0768	0.1053	0.0285	302	1.25	0.016	[illegible]
1	10	30	120	92.1	0.77	87	8	K-8	0.0772	0.0993	0.0221	254	0.88	0.011	[illegible]
1	12	30	240	90.5	0.38	87	9	K-9	0.0783	0.0952	0.0169	194	0.61	0.008	[illegible]
1	16	30	480	88.1	0.18	77	10	K-10	0.0795	0.0911	0.0116	151	0.43	0.005	[illegible]
2	8	30	1440	86.1	0.06	76	11	K-11	0.0776	0.0861	0.0085	112	0.24	0.003	[illegible]
3	0	0	0	0.0	0.00						0.0000	0	0.00	0.000	[illegible]

Determination of Grain Size with Settling Tube

[illegible]	⑥ TITAS LOWER(CEN-	Date of collection:	09-01-93	Salinity (ppt):	0
[illegible]	BATAKANDI	Time of collection:	11:10	Initial Temperature (C):	26
[illegible]		Depth of sampling from surface:	0	Final Temperature (C):	26
Bed Sampled:	BED	Depth of water (m):	0	Factor	0.0127
Density		Volume of Sample (l):	21.17	Multiplying Fraction value (%):	85.77
Water (kg/m3)	997	Dry weight d >= d=0.063mm (g):	3.1425		
Sediment (kg/m3)	2650	Sieve analysis is	REQUIRED	FILE NAME:	TITA-4

Comments:

Analysed by: BASET

Time			Time	h	h/t	Volume	Bottle	Filter	Tare	Gross	Net	C	(h/t)^0.5	d	%
Day	hr	min	min	(cm)	(cm/min)	(ml)	No.	No.	(g)	(g)	(g)	(mg/l)	(cm/min)^0.5	(mm)	finer
1	8	30	0	106.3		76	1	E-12	0.0753	0.1433	0.0680	895			85.77
1	8	31	1	104.4	104.40	75	2	E-13	0.0749	0.1401	0.0652	869	10.22	0.130	83.34
1	8	33	3	102.3	34.10	82.5	3	E-14	0.0742	0.1414	0.0672	815	5.84	0.074	78.03
1	8	37	7	100.5	14.36	78	4	E-15	0.0758	0.1322	0.0564	723	3.79	0.048	69.31
1	8	45	15	98.5	6.57	67	5	E-16	0.0768	0.1223	0.0455	679	2.56	0.033	65.10
1	9	0	30	96.5	3.22	77	6	E-17	0.0786	0.1248	0.0462	600	1.79	0.023	57.52
1	9	30	60	94.5	1.58	79	7	E-31	0.0771	0.1174	0.0403	510	1.25	0.016	48.90
1	10	30	120	92.3	0.77	77	8	E-19	0.0755	0.1087	0.0332	431	0.88	0.011	41.33
1	12	30	240	90.4	0.38	80	9	E-20	0.0761	0.1053	0.0292	365	0.61	0.008	34.99
1	16	30	480	88.1	0.18	85	10	E-21	0.0781	0.1051	0.0270	318	0.43	0.005	30.45
2	8	30	1440	86.0	0.06	88	11	E-22	0.0797	0.0986	0.0189	215	0.24	0.003	20.59
3	0	0	0	0.0	0.00						0.0000	0	0.00	0.000	0.00

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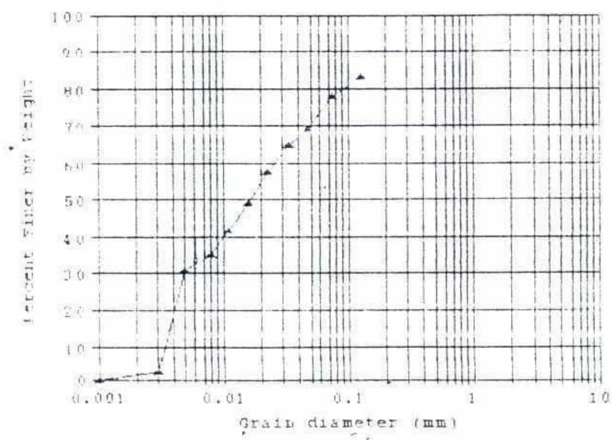
Particle Size Distribution

River: (6) TITAS LOWER(C) Date of collection: 09/01/93
Station: BATAKANDI Time of collection: 11:10
Vertical No.: 0 Depth of sampling:
Bed/Suspended: BED FILE NAME: TITA-4
Perc. of total sample:

d (mm)	Material < d (% by weight)
0.000	85.77
0.130	83.34
0.074	78.08
0.048	69.31
0.033	65.10
0.023	57.52
0.016	48.90
0.011	41.35
0.008	34.99
0.005	30.45
0.003	2.10
0.000	0

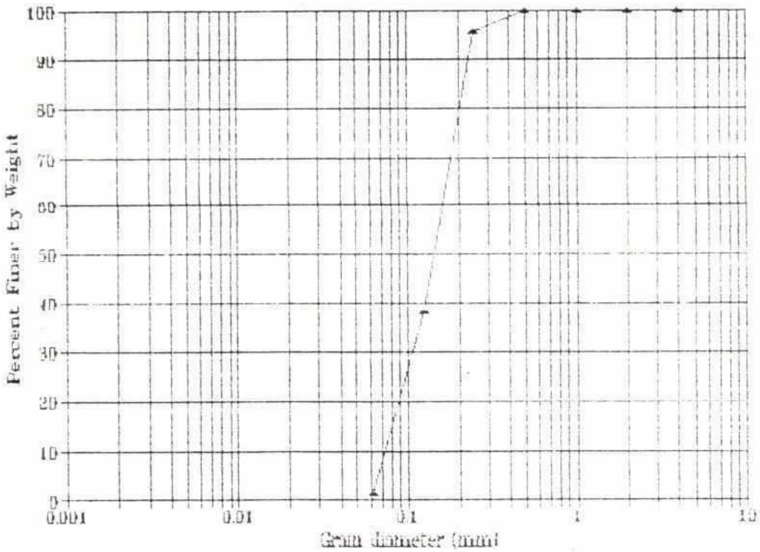


D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.008	0.017	0.033	Out of Range

Sieve Analysis of Bed Material

Wet/Dry:	(6) Dry	Total Weight (g):	
River:	TITAS LOWER(CEN)	Before sieving	3.1425
Station:	BATAKANDI	After sieving	3.0770
Date of collection:	09/01/93	Loss	0.0655
Settling Analysis :	NOT REQUIRED	FILE NAME:	TITA-4A

Sieve Size, d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000		0.0000	100.0000
0.2500	0.1332	4.3289	[illegible]
0.1250	1.7676	57.4456	38.2255
0.0625	1.1355	36.9028	1.3227
Pan	0.0407	1.3227	0.0000

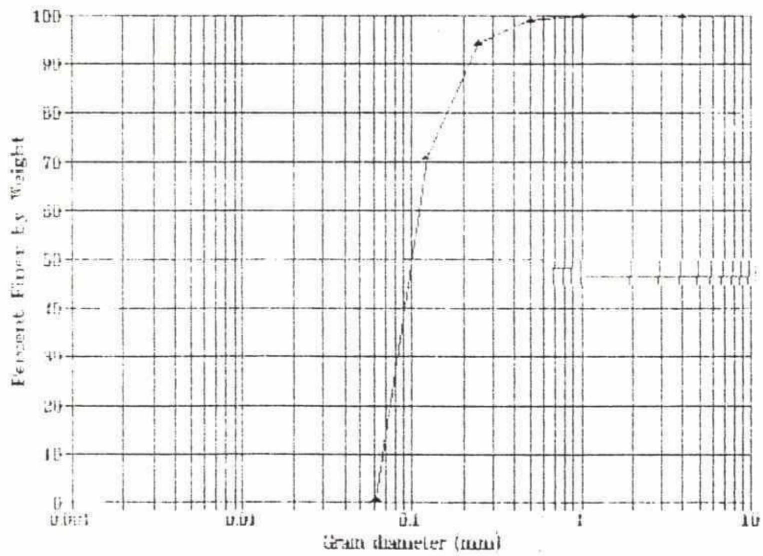


D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.1180	0.1440	0.1730	1.6316

Sieve Analysis of Bed Material

Wet/Dry	(6) Dry	Total Weight (g):	
River:	TITAS LOWER(L/B)	Before sieving	8.3690
Station	BATAKANDI	After sieving	8.3381
Date of collection	09/01/93	Loss	0.0309
Settling Analysis	NOT REQUIRED	FILE NAME	TITA-3A

Sieve Size d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000	0.0950	1.1393	98.8607
0.2500	0.4070	4.8813	93.9794
0.1250	1.9153	22.9705	71.0090
0.0625	5.8545	70.2138	0.7951
Pan	0.0663	0.7951	0.0000

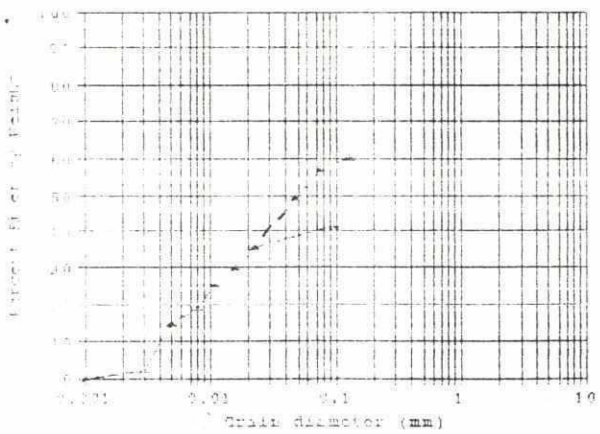


D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.0880	0.1020	0.1180	1.6055

Particle Size Distribution

River: ⑥ TITAS LOWER (L/B) Date of collection: 09/01/93
Station: BATAKANDI? Time of collection: 11:10
Vertical No.: 0 Depth of sampling: 0
Bed/Suspended: BED FILE NAME: TITA-3
[illegible]

d (mm)	Material < d (% by weight)
0.000	61.12
0.130	60.34
0.074	57.24
0.045	49.39
[illegible]	[illegible]
0.023	32.20
0.016	29.55
0.011	24.89
0.008	19.04
0.005	14.76
0.003	2.10
0.000	0



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.023	0.050	Out of Range	Out of Range

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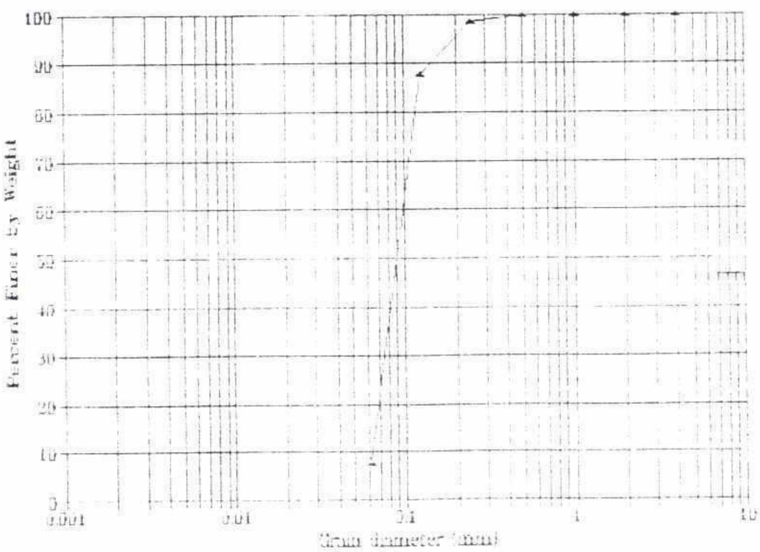
Sieve Analysis of Bed Material

Wet/Dry: (7)	Dry	Total Weight (g):	
River:	GUMTI	Before sieving	52.8713
Station:	DAUDKANDI	After sieving	52.4870
Date of collection:	09/01/93	Loss	0.3843
Settling Analysis:	NOT REQUIRED	FILE NAME.	GUM-1

Sieve Size d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000	0.0000	0.0000	100.0000
0.5000	0.1439	0.2742	99.7258
0.2500	0.5724	1.0906	98.6350
0.1250	5.8325	11.1123	87.5230
0.0625	42.0608	80.1357	7.3874
Pan	3.8774	7.3874	0.0000



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.0790	0.0900	0.1030	1.3439

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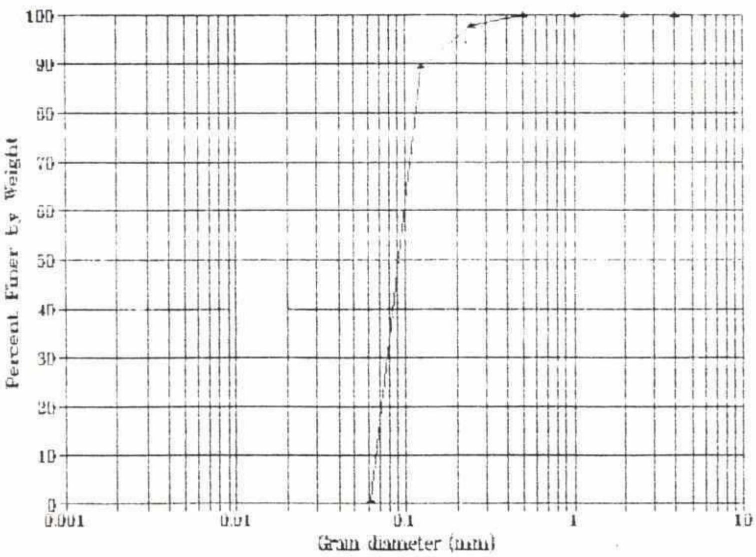
Sieve Analysis of Bed Material

Wet/Dry:	(8) Dry	Total Weight (g):	
River:	CHAPITOLA KHAL(CE	Before sieving	2.7236
Station:	CHAPITOLA	After sieving	2.1923
Date of collection:	20..11/01/93	Loss	0.5313
Settling Analysis :	NOT REQUIRED	FILE NAME:	CHAPI-1A

Sieve Size, d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000		0.0000	100.0000
0.2500	0.0512	2.3354	97.6646
0.1250	0.1825	8.3246	89.3400
0.0625	1.9490	88.9021	0.4379
Pan	0.0096	0.4379	0.0000

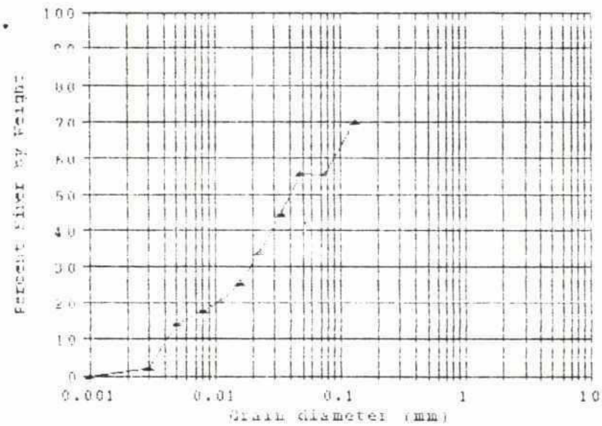


D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.0820	0.0920	0.1030	1.3001

Particle Size Distribution

River:	(8) CHAPITOLA KH	Date of collection:	20/01/93
Station:	CHAPITOLA	Time of collection:	11:10
Vertical No.:	0	Depth of sampling:	
Bed/Suspended:	BED	FILE NAME:	CHAPI-1
Perc. of total sample:			

d (mm)	Material < d (% by weight)
0.000	87.41
0.131	70.01
0.075	55.39
0.048	55.46
0.033	44.17
0.023	33.89
0.016	25.41
0.011	20.30
0.008	17.41
0.005	14.05
0.003	2.10
0.000	0



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.024	0.040	0.108	Out of Range

Determination of Grain Size with Settling Tube

River:	⑧ CHAPITOLA KHAL(C	Date of collection:	26/01/93	Salinity (ppt):	0
Station:	CHAPITOLA	Time of collection:	11:10	Initial Temperature (C):	27
Vertical No:		Depth of sampling from surface:	0	Final Temperature (C):	26
Bed/Suspended:	BED	Depth of water (m):	0	Factor	0.0127
Density:		Volume of Sample (l):	22.371	Multiplying Fraction value (%):	87.41
Water (kg/m3)	997	Dry weight d >= d=0.063mm (g):	2.7236		
Sediment (kg/m3)	2650	Sieve analysis is -------------------->	REQUIRED	FILE NAME	CHAPI-1

Comments:

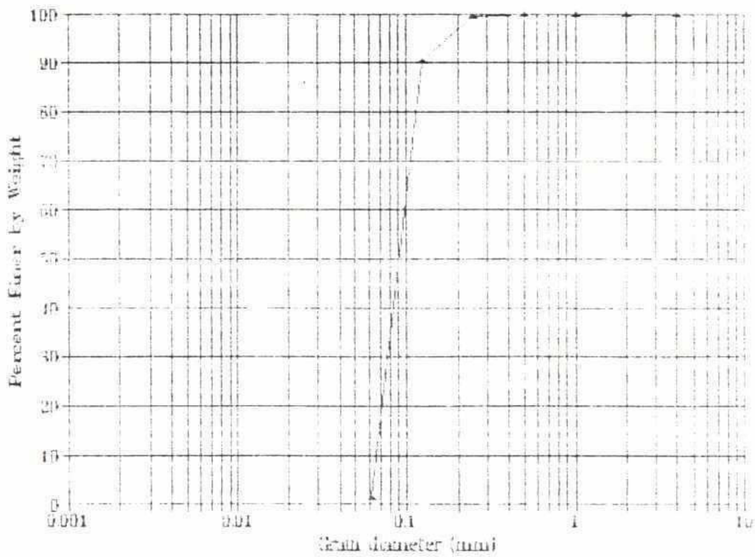
Analysed by: BASET

Day	Time hr	Time min	Time min	h (cm)	h/t (cm/min)	Volume (ml)	Bottle No.	FILTER No	Tare (g)	Gross (g)	Net (g)	C (mg/l)	(h/t)^0.5 (cm/min)^0.5	d (mm)	% finer
[illegible]	[illegible]	[illegible]	0	103.3		80	1	S- 23	0.0670	0.1346	0.0676	845			87.41
	[illegible]	[illegible]	1	105.9	105.90	82	2	S- 24	0.0637	0.1242	0.0555	677	10.29	0.131	70.01
[illegible]	[illegible]		3	104.0	34.67	76	3	S- 25	0.0688	0.1095	0.0407	536	5.89	0.075	55.39
[illegible]	[illegible]	12	7	101.6	14.51	83	4	S- 25	0.0711	0.1156	0.0445	536	3.81	0.048	55.46
[illegible]	[illegible]	20	15	99.5	6.63	85	5	S- 27	0.0719	0.1082	0.0363	427	2.58	0.033	44.17
[illegible]	[illegible]	35	30	97.3	3.24	87	6	S- 28	0.0719	0.1004	0.0285	328	1.80	0.023	33.89
[illegible]	1[illegible]	5	60	95.0	1.53	81	7	S- 29	0.0720	0.0919	0.0199	246	1.26	0.016	25.41
[illegible]	1[illegible]	5	120	92.9	0.77	79.5	8	S- 30	0.0715	0.0871	0.0156	196	0.83	0.011	20.30
	13	5	240	90.9	0.38	82	9	S- 31	0.0711	0.0849	0.0138	168	0.62	0.008	17.41
[illegible]	1[illegible]	5	480	88.9	0.19	81	10	S- 32	0.0713	0.0823	0.0110	136	0.43	0.005	14.05
	[illegible]	5	1140	87.0	0.06	83	11	S- 33	0.0699	0.0779	0.0080	96	0.25	0.003	9.97
[illegible]	[illegible]	0	0	0.0	0.00						0.0000	0	0.00	0.000	0.00

Sieve Analysis of Bed Material

Wet/Dry:	(9) Dry	Total Weight (g):	
River:	TITAS (GN-5)	Before sieving	3.8713
Station:	RAMKRISHNAPUR	After sieving	3.8260
Date of collection:	11/01/93	Loss	0.0453
Settling Analysis :	REQUIRED	FILE NAME:	TITA-7A

Sieve Size, d (mm)	Material (g)	Material (%)	Material Finer (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000		0.0000	100.0000
0.2500	0.0195	0.5097	99.4903
0.1250	0.3579	9.3544	90.1359
0.0625	3.3946	88.7240	1.4114
Pan	0.0540	1.4114	0.0000

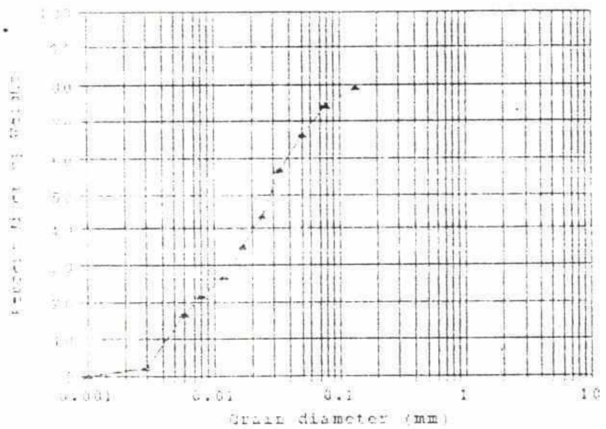


D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.0810	0.0910	0.1030	1.3038

Particle Size Distribution

River:	(9) TITAS(GN-5)(2E	Date of collection:	11/01/93
Station:	RAMKRISHNAP	Time of collection: 11:10	
Vertical No.:	0	Depth of sampling:	
Bed/Suspended:	BED	FILE NAME:	TITA-7
Perc. of total sample:			

d (mm)	Material < d (% by weight)
0.000	81.24
0.156	79.13
0.077	74.32
0.050	66.52
0.034	56.84
0.024	44.19
0.017	34.80
0.012	26.95
0.008	21.53
0.006	16.57
0.003	2.10
0.000	0



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.017	0.028	0.047	Out of Range

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Determination of Grain Size with Settling Tube

River:	⑨ TITAS(GN [illegible])(CEN)	Date of collection:	11-01-93	Salinity (ppt):	0
Station:	RAMKRISHNAPUR	Time of collection:	11:10	Initial Temperature (C):	[illegible]
[illegible]		Depth of sampling from surface	0	Final Temperature (C):	[illegible]
[illegible]	BED	Depth of water (m):	0	Factor	[illegible]
[illegible]		Volume of sample (l):	12.004	Multiplying Fraction value (%)	[illegible]
[illegible]	997	Dry weight of s = d=0.063mm (g):	[illegible]		
[illegible]	2630	Sieve analysis is	REQUIRED	FILE NAME	TIT[illegible]
Comments:				Analysed by:	BASE[illegible]

[illegible]	Time hr	min	Time min	h (cm)	h/t (cm/min)	Volume (ml)	Bottle No.	FILTE No		Tare (g)	Gross (g)	Net (g)	C (mg/l)	(h/t)^0.5 (cm/min)^0.5	d (mm)	% finer
[illegible]	[illegible]	[illegible]	0	111.3		77	1	O	1	0.0769	0.13[illegible]	0.0535	7.50			[illegible]
[illegible]	[illegible]	1	1	109.9	109.90	35	2	O	2	0.0713	[illegible]	[illegible]	[illegible]	10.48	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]		107.8	35.93	30	3	O	3	0.0759	0.131[illegible]	[illegible]	[illegible]	5.99	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]		106.1	15.16	68	4	O	4	0.0743	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	15	15	103.9	6.93	76	5	O	5	0.0742	[illegible]	[illegible]	[illegible]	2.63	[illegible]	[illegible]
[illegible]	[illegible]	30	30	101.6	3.39	90.5	6	O	6	0.0705	[illegible]	[illegible]	[illegible]	1.84	0.024	[illegible]
[illegible]	[illegible]	0	60	99.8	1.66	77	7	O	7	0.0636	[illegible]	[illegible]	[illegible]	1.29	[illegible]	[illegible]
[illegible]	[illegible]	0	120	97.4	0.81	73	8	O	8	0.0674	[illegible]	[illegible]	[illegible]	0.90	[illegible]	[illegible]
[illegible]	[illegible]	0	240	95.5	0.40	76	9	O	9	0.0693	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	0	480	93.5	0.19	71	10	O	10	0.0713	[illegible]	0.0110	1.55	0.44	0.006	[illegible]
[illegible]	[illegible]	0	1440	91.5	0.06	76	11	O	11	0.0719	[illegible]	[illegible]	1.11	0.25	0.003	[illegible]
[illegible]	0	0	0	0.0	0.00							[illegible]	0	0.00	0.000	[illegible]

Determination of Grain Size with Settling Tube

River:	(10) BURI	Date of collection:	20/01/93	Salinity (ppt):	0
Station:	MADHABPUR	Time of collection:	11:10	Initial Temperature (C):	27
Vertical No.:		Depth of sampling from surface:		Final Temperature (C):	27
Bed/Suspended:	BED	Depth of water (m):		Factor	0.0126
Density:		Volume of Sample (l):	21.42	Multiplying Fraction value (%):	9872
Water (kg/m3)	997	Dry weight d >= d=0.063mm (g):	2.0841		
Sediment (kg/m3)	2650	Sieve analysis is --------------------->	REQUIRED	FILE NAME:	BURI-5

Comments:

Analysed by: BASET

Time			Time	h	h/t	Volume	Bottle	Filter	Tare	Gross	Net	C	(h/t)^0.5	d	% finer
Day	hr	min	min	(cm)	(cm/min)	(ml)	No.	No.	(g)	(g)	(g)	(mg/l)	(cm/min)^0.5	(mm)	
1	9	0	0	108.3		75	1	S-12	0.0699	0.1336	0.0637	849			9872
1	9	1	1	106.1	106.10	82	2	S-13	0.0702	0.1366	0.0664	810	10.30	0.130	5854
1	9	3	3	104.2	34.73	79	3	S-14	0.0734	0.1308	0.0574	727	5.89	0.074	6275
1	9	7	7	102.2	14.60	82	4	S-15	0.0724	0.1232	0.0508	620	3.82	0.048	56.4
1	9	15	15	100.3	6.69	79	5	S-16	0.0691	0.1055	0.0364	461	2.59	0.033	84.7
1	9	30	30	98.2	3.27	76	6	S-17	0.0679	0.0933	0.0254	334	1.81	0.023	5311
1	10	0	60	96.1	1.60	80	7	S-18	0.0703	0.0902	0.0199	249	1.27	0.016	6283
1	11	0	120	94.1	0.78	72	8	S-19	0.0739	0.0875	0.0136	189	0.89	0.011	9925
1	13	0	240	91.8	0.33	80.5	9	S-20	0.0754	0.0864	0.0110	137	0.62	0.008	4834
1	17	0	480	89.7	0.19	86	10	S-21	0.0754	0.0841	0.0087	101	0.43	0.005	0659
2	9	0	1440	87.6	0.06	75.5	11	S-22	0.0750	0.0806	0.0056	74	0.25	0.003	7 84
3	0	0	0	0.0	0.00						0.0000	0	0.00	0.000	0 00

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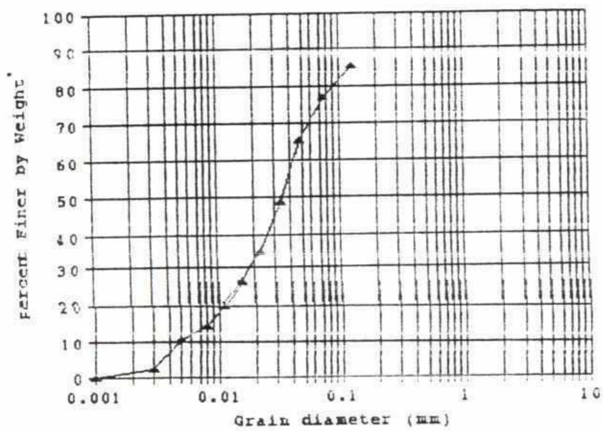
Particle Size Distribution

River: (10) BURI — Date of collection: 20/01/93
Station: MADHABPUR — Time of collection: 11:10
Vertical No.: 0 — Depth of sampling:
Bed/Suspended: BED — FILE NAME: BURI-5
Perc. of total sample:

d (mm)	Material < d (% by weight)
0.000	89.72
0.130	85.54
0.074	76.75
0.048	65.44
0.033	48.67
0.023	35.31
0.016	26.28
0.011	19.95
0.008	14.43
0.005	10.69
0.003	2.10
0.000	0



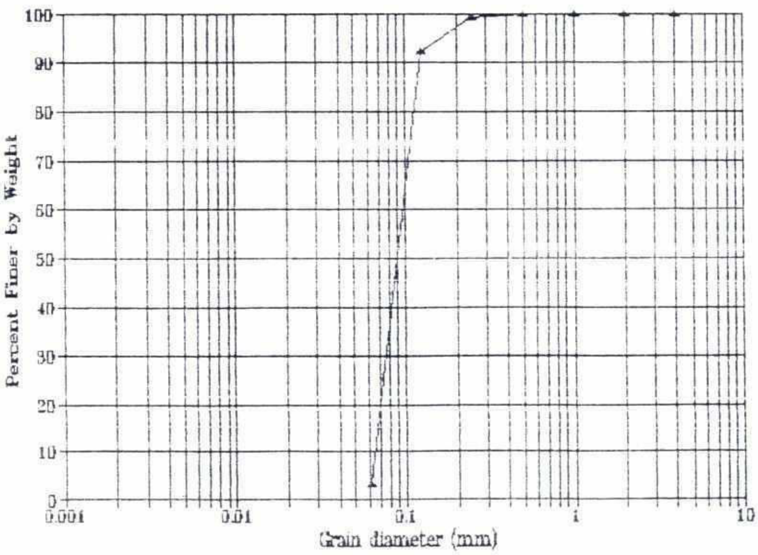
D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.023	0.034	0.048	3.624

2602

Sieve Analysis of Bed Material

Wet/Dry: (10)	Dry	Total Weight (g):	
River:	BURI	Before sieving	2.0841
Station:	MADHABPUR	After sieving	2.0812
Date of collection:	20/01/93	Loss	0.0029
Settling Analysis :	NOT REQUIRED	FILE NAME:	BURI-5A

Sieve Size, d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000		0.0000	100.0000
0.2500	0.0167	0.8024	99.1976
0.1250	0.1444	6.9383	92.2593
0.0625	1.8571	89.2322	3.0271
Pan	0.0630	3.0271	0.0000



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.0800	0.0900	0.1010	1.3022

Determination of Grain Size with Settling Tube

River:	(10) BURI	Date of collection:	20/01/93	Salinity (ppt):	0
Station:	MADHABPUR	Time of collection:	11:10	Initial Temperature (C):	26
Vertical No.:		Depth of sampling from surface:	0	Final Temperature (C):	26
Bed/Suspended:	BED	Depth of water (m):	0	Factor	1.01127
Density:		Volume of Sample (l):	21.282	Multiplying Fraction value (%):	19.05
Water (kg/m3)	997	Dry weight d >= d=0.063mm (g):	1.8458		
Sediment (kg/m3)	2650	Sieve analysis is ------------------>	REQUIRED	FILE NAM BURI-1	

Comments:

Analysed by: BSAEIT

Time			Time	h	h/t	Volume	Bottle	Filter	Tare	Gross	Net	C	(h/t)^0.5	d	[illegible]
Day	hr	min	min	(cm)	(cm/min)	(ml)	No.	No.	(g)	(g)	(g)	(mg/l)	(cm/min)^0.5	(mm)	[illegible]
1	9	5	0	108.0		79	1	K-34	0.0707	0.1404	0.0697	382			19.05
1	9	6	1	106.0	106.00	80	2	K-35	0.0706	0.1363	0.0657	321	10.30	0.131	[illegible]
1	9	8	3	104.0	34.67	79	3	K-36	0.0700	0.1259	0.0559	703	5.39	0.075	[illegible]
1	9	12	7	101.9	14.56	85	4	K-37	0.0718	0.1198	0.0480	565	3.82	0.048	[illegible]
1	9	20	15	99.8	6.65	85	5	K-38	0.0707	0.1083	0.0376	442	2.58	0.033	[illegible]
1	9	35	30	97.7	3.26	85	6	K-39	0.0701	0.0977	0.0276	325	1.30	0.023	[illegible]
1	10	5	60	95.4	1.59	83	7	K-40	0.0695	0.0887	0.0192	231	1.26	0.016	[illegible]
1	11	5	120	93.3	0.78	83	8	K-41	0.0663	0.0804	0.0141	170	0.38	0.011	[illegible]
1	13	5	240	91.4	0.38	84	9	K-42	0.0642	0.0743	0.0101	120	0.62	0.008	[illegible]
1	17	5	480	89.6	0.19	86	10	K-43	0.0640	0.0708	0.0068	79	0.43	0.005	[illegible]
2	9	5	1440	87.7	0.06	82	11	K-44	0.0644	0.0681	0.0037	45	0.25	0.003	[illegible]
3	0	0	0	0.0	0.00						0.0000	0	0.00	0.000	[illegible]

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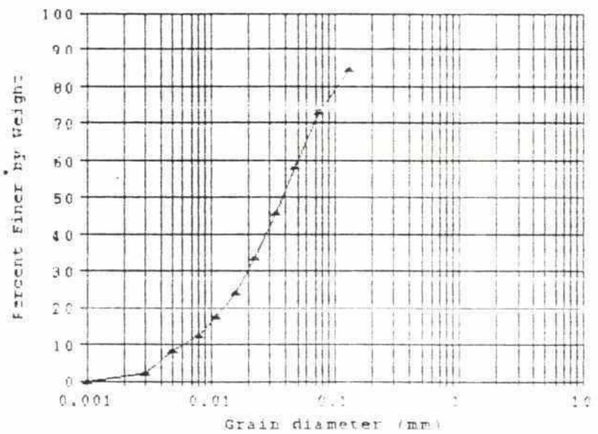
Particle Size Distribution

River:	(10) BURI	Date of collection:	20/01/93
Station:	MADHABPUR	Time of collection:	11:10
Vertical No.:	0	Depth of sampling:	0
Bed/Suspended:	BED	FILE NAME:	BURI-1
Perc. of total sample:			

d (mm)	Material < d (% by weight)
0.000	91.05
0.131	84.75
0.075	73.02
0.048	58.28
0.033	45.65
0.023	33.51
0.016	23.87
0.011	17.53
0.008	12.41
0.005	8.16
0.003	2.10
0.000	0



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.024	0.038	0.059	3.558

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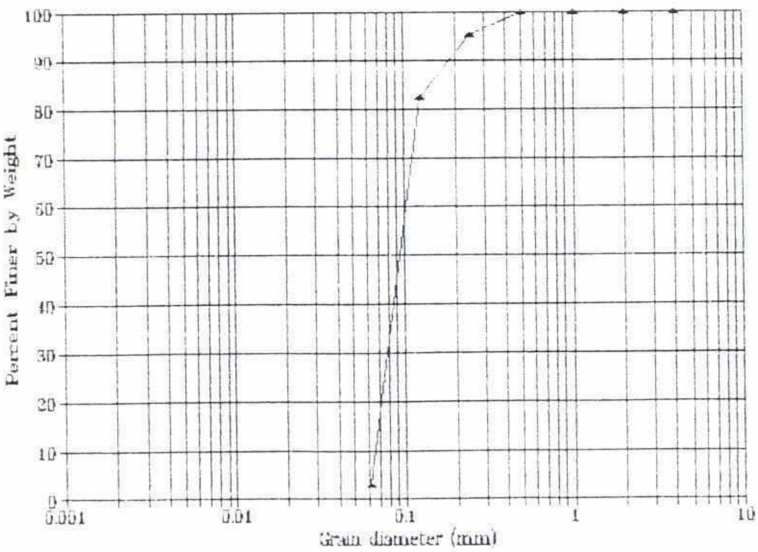
Sieve Analysis of Bed Material

Wet/Dry:	(10) Dry	Total Weight (g): 0	
River:	BURI	Before sieving	1.8458
Station:	MADHABPUR	After sieving	1.7773
Date of collection:	20/01/93	Loss	0.0685
Settling Analysis :	REQUIRED	FILE NAME:	BURI-1A

Sieve Size, d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000		0.0000	100.0000
0.2500	0.0842	4.7375	95.2625
0.1250	0.2303	12.9579	82.3046
0.0625	1.4104	79.3563	2.9483
Pan	0.0524	2.9483	0.0000



D36 (mm)	D50 (mm)	D66 (mm)	Standard Deviation
0.0830	0.0940	0.1070	1.4002

Determination of Grain Size with Settling Tube

River:	(11) SALDA	Date of collection:	20/01/93	Salinity (ppt):	0
Station:	MANDABAG BAZA	Time of collection:	11:10	Initial Temperature (C):	26
Vertical No.:		Depth of sampling from surface:	0	Final Temperature (C):	26
Bed/suspended:	BED	Depth of water (m):	0	Factor	0.0127
Density:		Volume of Sample (l):	21.32	Multiplying Fraction value (%):	41.79
Water density:	997	Dry weight d >= d=0.063mm (g):	.118808		
Sediment density:	2650	Sieve analysis is ------------------>	REQUIRED	FILE NAM SAL-2A	
Comments:				Analysed by:	BASET

Time Day	Hr	Min	Time min	h (cm)	h/t (cm/min)	Volume (ml)	Bottle No.	Filter No.	Tare (g)	Gross (g)	Net (g)	C (mg/l)	(h/t)^0.5 (cm/min)^0.5	d (mm)	% finer
[illegible]	[illegible]	15	0	107.7		77	1	L-12	0.0731	0.01039	0.0308	400			41.79
[illegible]	[illegible]	16	1	105.5	105.50	78	2	L-13	0.0726	0.01023	0.0297	381	10.27	0.130	39.78
[illegible]	[illegible]	18	[illegible]	103.4	34.47	82	3	L-14	0.0717	0.01000	0.0283	345	5.87	0.075	36.05
[illegible]	[illegible]	[illegible]	[illegible]	101.5	11.50	70	4	L-15	0.0726	0.00926	0.0200	286	3.31	0.048	29.35
[illegible]	[illegible]	[illegible]	[illegible]	99.5	6.63	81	5	L-16	0.0730	0.00904	0.0174	215	2.58	0.033	22.44
[illegible]	[illegible]	[illegible]	30	97.4	3.25	72.5	6	L-17	0.0622	0.00733	0.0111	153	1.80	0.023	15.99
[illegible]	[illegible]	45	60	94.9	1.58	88	7	L-18	0.0703	0.00803	0.0095	108	1.26	0.016	11.23
[illegible]	[illegible]	45	120	92.8	0.77	81	8	L-19	0.0721	0.00784	0.0063	78	0.88	0.011	8.13
[illegible]	[illegible]	[illegible]	240	90.6	0.38	84	9	L-20	0.0718	0.00765	0.0047	56	0.61	0.008	5.85
[illegible]	[illegible]	45	480	88.3	0.18	95.5	10	L-21	0.0701	0.00740	0.0039	41	0.43	0.005	4.27
[illegible]	[illegible]	[illegible]	1440	86.3	0.06	86.5	11	L-22	0.0721	0.00745	0.0024	28	0.24	0.003	2.90
[illegible]	[illegible]	0	0	0.0	0.00						0.0000	0	0.00	0.000	0.00

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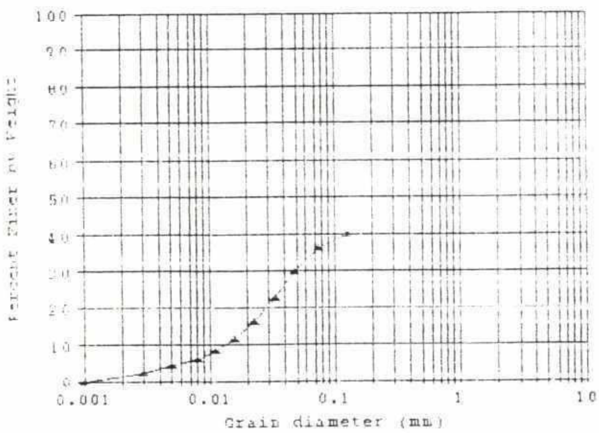
Particle Size Distribution

River: (11) SALDA
Date of collection: 20/01/93
Station: MANDABAG BA
Time of collection: 11:10
Vertical No.: 0
Depth of sampling:
Bed/Suspended: BED
FILE NAME: SAL-2A
Perc. of total sample:

d (mm)	Material < d (% by weight)
0.000	41.79
0.130	39.78
0.075	36.05
0.048	29.85
0.033	22.44
0.023	15.99
0.016	11.28
0.011	8.13
0.008	5.85
0.005	4.27
0.003	2.10
0.000	0



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.070	Out of Range	Out of Range	Out of Range

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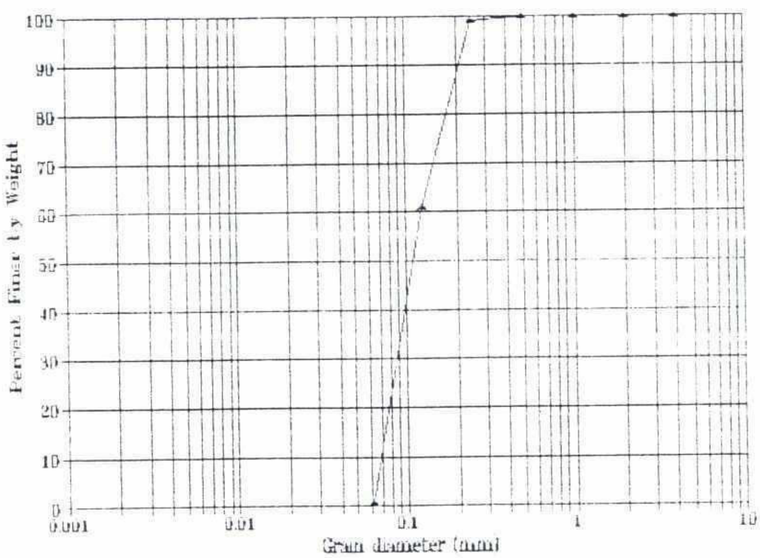
Sieve Analysis of Bed Material

Wet/Dry:	(11) Dry	Total Weight (g):	
River:	SALDA	Before sieving	11.8808
Station:	MANDABAG BAZAR	After sieving	11.7899
Date of collection:	20/01/93	Loss	0.0909
Settling Analysis:	NOT REQUIRED	FILE NAME:	SAL-2AB

Sieve Size, d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000		0.0000	100.0000
0.2500	0.1075	0.9118	99.0882
0.1250	4.5050	38.2107	60.8775
0.0625	7.1328	60.4992	0.3783
Pan	0.0446	0.3783	0.0000



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.0930	0.1100	0.1350	1.5970

Determination of Grain Size with Settling Tube

River:	(12) CHANDLA KHAL	Date of collection:	20/01/93	Salinity (ppt):	0
Station:	GUNGUR	Time of collection:	11:10	Initial Temperature (C):	26
Vertical No.:		Depth of sampling from surface:	0	Final Temperature (C):	25
Bed/Suspended:	BED	Depth of water (m):	0	Factor	0.0127
Density:		Volume of Sample (l):	21.97	Multiplying Fraction value (%):	84.65
Water (kg/m3)	997	Dry weight d >= d=0.063mm (g):	3.1425		
Sediment (kg/m3)	2650	Sieve analysis is ---------------------->	REQUIRED	FILE NAM CHAND-1	

Comments:

Analysed by: BASET

Time			Time	h	h/t	Volume	Bottle	Filter	Tare	Gross	Net	C	(h/t)^0.5	d	%
Day	hr	min	min	(cm)	(cm/min)	(ml)	No.	No.	(g)	(g)	(g)	(mg/l)	(cm/min)^0.5	(mm)	finer
1	8	35	0	106.0		76	1	K-23	0.0798	0.1398	0.0600	789			84.66
1	8	36	1	103.8	103.80	79	2	K-24	0.0789	0.1385	0.0596	754	10.19	0.129	80.90
1	8	38	3	101.6	33.87	77	3	K-25	0.0675	0.1190	0.0515	669	5.82	0.074	71.72
1	8	42	7	99.7	14.24	84	4	K-26	0.0664	0.1118	0.0454	540	3.77	0.048	57.96
1	8	50	15	97.5	6.50	80	5	K-27	0.0654	0.1014	0.0360	450	2.55	0.032	48.26
1	9	5	30	95.4	3.18	68	6	K-28	0.0654	0.0913	0.0259	381	1.78	0.023	40.84
1	9	35	60	93.4	1.56	67	7	K-29	0.0659	0.0871	0.0212	316	1.25	0.016	33.93
1	10	35	120	91.4	0.76	80	8	K-30	0.0702	0.0918	0.0216	270	0.87	0.011	28.95
1	12	35	240	89.4	0.37	73	9	K-31	0.0655	0.0825	0.0170	233	0.61	0.008	24.97
1	15	35	480	87.0	0.18	87	10	K-32	0.0713	0.0890	0.0177	203	0.43	0.005	21.82
2	8	35	1440	85.0	0.06	86.5	11	K-33	0.0696	0.0838	0.0142	164	0.24	0.003	17.60
3	0	0	0	0.0	0.00						0.0000	0	0.00	0.000	0.00

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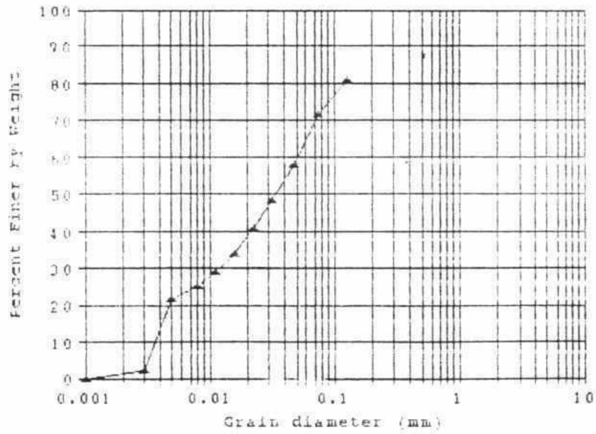
Particle Size Distribution

River:	(12) CHANDLA KHA	Date of collection:	20/01/93
Station:	GUNGUR	Time of collection:	11:10
Vertical No.:	0	Depth of sampling:	
Bed/Suspended:	BED	FILE NAME:	CHAND-1

Perc. of total sample:

d (mm)	Material < d (% by weight)
0.000	84.66
0.129	80.90
0.074	71.72
0.048	57.96
0.032	48.26
0.023	40.84
0.016	33.93
0.011	28.95
0.008	24.97
0.005	21.82
0.003	2.10
0.000	0



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.017	0.034	0.060	Out of Range

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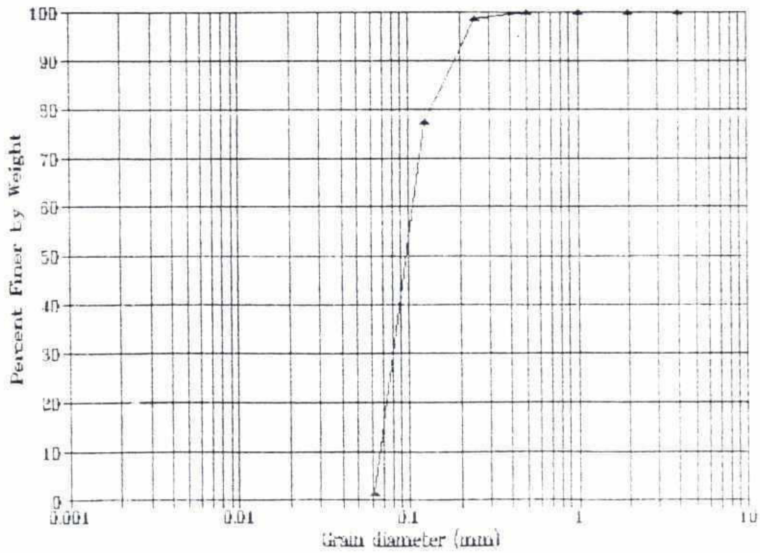
Sieve Analysis of Bed Material

Wet/Dry:	(12) Dry	Total Weight (g):	
River:	CHANDLA KHAL(CEN)	Before sieving	2.9049
Station:	GUNGUR	After sieving	2.8937
Date of collection:	20/01/93	Loss	0.0112
Setting Analysis :	NOT REQUIRED	FILE NAME.	CHAND-1A

Sieve Size d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000		0.0000	100.0000
0.2500	0.0430	1.4860	98.5140
0.1250	0.6160	21.2876	77.2264
0.0625	2.2002	76.0341	1.1922
Pan	0.0345	1.1922	0.0000



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.0850	0.0980	0.1120	1.4765

Determination of Grain Size with Settling Tube

River:	(13) BARA KHAL(GN-12)	Date of collection:	21/01/93	Salinity (ppt):	[illegible]
Station:	D/S of GUNGUR	Time of collection:	11:10	Initial Temperature (C):	[illegible]
Vertical No.:		Depth of sampling from surface:	0	Final Temperature (C):	[illegible]
Bed/Suspended:	BED	Depth of water (m):	0	Factor	[illegible]
Density:		Volume of Sample (l):	21.63	Multiplying Fraction value (%):	[illegible]
Water (kg/m3)	997	Dry weight d >= d=0.063mm (g):	4.5399		
Sediment (kg/m3)	2650	Sieve analysis is --------------------->	REQUIRED	FILE NAME	BALA-[illegible]

Comments:

Analysed by: BASET

Time			Time	h	h/t	Volume	Bottle	Filter	Tare	Gross	Net	C	(h/t) ^ 0.5	d	[illegible]
Day	hr	min	min	(cm)	(cm/min)	(ml)	No.	No.	(g)	(g)	(g)	(mg/l)	(cm/min) ^ 0.5	(mm)	[illegible]
1	9	0	0	109.2		76	1	K-1	0.0706	0.1249	0.0543	714			[illegible]
1	9	1	1	107.2	107.20	81	2	K-2	0.0710	0.1276	0.0566	699	10.35	0.131	[illegible]
1	9	3	3	105.2	35.07	70	3	K-3	0.0703	0.1117	0.0414	591	5.92	0.075	[illegible]
1	9	7	7	103.2	14.74	76	4	K-4	0.0701	0.1159	0.0458	603	3.84	0.049	[illegible]
1	9	15	15	101.3	6.75	89	5	K-5	0.0710	0.1014	0.0304	342	2.60	0.033	[illegible]
1	9	30	30	99.1	3.30	70	6	K-6	0.0693	0.1010	0.0317	453	1.82	0.023	[illegible]
1	10	0	60	97.1	1.62	74	7	K-7	0.0696	0.0985	0.0289	391	1.27	0.016	[illegible]
1	11	0	120	94.3	0.79	72	8	K-8	0.0728	0.0943	0.0215	299	0.89	0.011	[illegible]
1	13	0	240	92.8	0.39	71	9	K-9	0.0754	0.0923	0.0169	238	0.62	0.008	[illegible]
1	17	0	480	90.9	0.19	80	10	K-10	0.0759	0.0908	0.0149	186	0.44	0.006	[illegible]
2	9	0	1440	89.0	0.06	70	11	K-11	0.0757	0.0850	0.0093	133	0.25	0.003	[illegible]
3	0	0	0	0.0	0.00						0.0000	0	0.00	0.000	[illegible]

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Determination of Grain Size with Settling Tube

River:	(13) BARA KHAL GN-12)	Date of collection:	21/01/93	Salinity (ppt):	0
Station:	D/S of GUNGUR	Time of collection:	11:10	Initial Temperature (C):	26
Vertical No.:		Depth of sampling from surface	0	Final Temperature (C):	26
Bed/Suspended	BED	Depth of water (m):	0	Factor	0.00[illegible]127
Density		Volume of Sample (l):	21.63	Multiplying Fraction value (%):	7[illegible].29
Water (kg/m3)	997	Dry weight d >= d=0.063mm (g):	4.5399		
Sediment (kg/m3)	2650	Sieve analysis is ---------------------->	REQUIRED	FILE NAME	BA[illegible]-1

Comments:

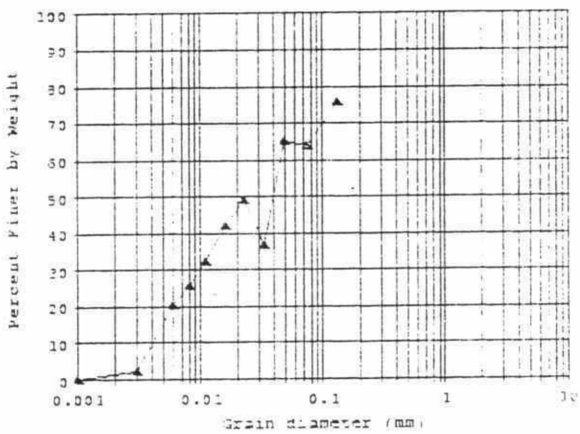
Analysed by: BA[illegible] T[illegible]

Time			Time	h	h/t	Volume	Bottle	Filter	Tare	Gross	Net	C	(h/t)^0.5	d	%
Day	hr	min	min	(cm)	(cm/min)	(ml)	No.	No	(g)	(g)	(g)	(mg/l)	(cm/min)^0.5	(mm)	finer
1	9	0	0	109.2		76	1	K-1	0.0706	0.1249	0.0543	714			7[illegible].29
1	9	1	1	107.2	107.20	81	2	K-2	0.0710	0.1276	0.0566	699	10.35	0.131	7[illegible].59
1	9	3	3	105.2	35.07	70	3	K-3	0.0703	0.1117	0.0414	591	5.92	0.075	6[illegible].92
1	9	7	7	103.2	14.74	76	4	K-4	0.0701	0.1159	0.0458	603	3.84	0.049	6[illegible].19
1	9	15	15	101.3	6.75	89	5	K-5	0.0710	0.1014	0.0304	342	2.60	0.033	3[illegible].95
1	9	30	30	99.1	3.30	70	6	K-6	0.0693	0.1010	0.0317	453	1.82	0.023	4[illegible].99
1	10	0	60	97.1	1.62	74	7	K-7	0.0696	0.0985	0.0289	391	1.27	0.016	4[illegible].25
1	11	0	120	94.8	0.79	72	8	K-8	0.0728	0.0943	0.0215	299	0.89	0.011	3[illegible].30
1	13	0	240	92.8	0.39	71	9	K-9	0.0754	0.0923	0.0169	238	0.62	0.008	2[illegible].75
1	17	0	480	90.9	0.19	80	10	K-10	0.0759	0.0908	0.0149	186	0.44	0.006	2[illegible].15
2	9	0	1440	89.0	0.06	70	11	K-11	0.0757	0.0850	0.0093	133	0.25	0.003	1[illegible].37
3	0	0	0	0.0	0.00						0.0000	0	0.00	0.000	[illegible].00

Particle Size Distribution

River:	BARA KHAL(GN-1	Date of collection	21/01/95
Station:	D/S of GUNGUR	Time of collection:	11:10
Vertical No.:	0	Depth of sampling:	0
Bed/Suspended:	BED	FILE NAME:	BARA-1
Perc. of total sample:			

d (mm)	Material < d (% by weight)
0.300	77.29
0.131	72.59
0.075	63.92
0.049	65.19
0.033	36.95
0.023	49.99
0.016	42.25
0.011	32.30
0.008	25.75
0.006	20.15
0.003	2.10
0.000	0

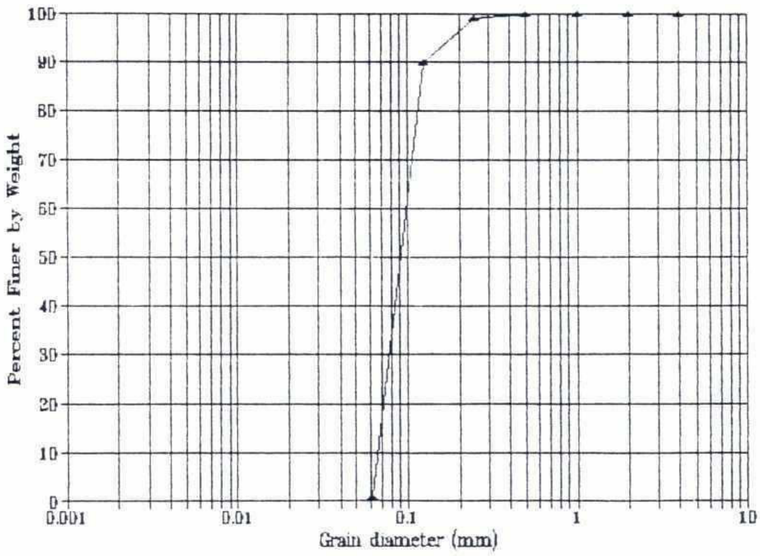


D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.012	0.040	0.079	Out of Range

Sieve Analysis of Bed Material

Wet/Dry:	(13) Dry	Total Weight (g):	
River:	BARA KHAL(GN-12)	Before sieving	4.5399
Station:	GUNGUR D/S	After sieving	4.4673
Date of collection:	21/01/93	Loss	0.0726
Settling Analysis :	NOT REQUIRED	FILE NAME:	BARA-1A

Sieve Size, d (mm)	Material (g)	Material (%)	Material < d (%)
4.0000		0.0000	100.0000
2.0000		0.0000	100.0000
1.0000		0.0000	100.0000
0.5000		0.0000	100.0000
0.2500	0.0404	0.9043	99.0957
0.1250	0.4187	9.3726	89.7231
0.0625	3.9736	88.9486	0.7745
Pan	0.0346	0.7745	0.0000



D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.0820	0.0920	0.1030	1.3093

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APPENDIX I.III

INVENTORY AND SURVEY OF EXISTING ROAD INFRASTRUCTURE

TABLE I.III.1

EXISTING ROAD BRIDGES / CULVERTS

Sl. Nr.	Name of Road .	Zone	Length (km)	Nr. of Structures		Resp. Agency
				Existing	Proposed	
1.	Sylhet Highway – Buri River to Salda River	A	10.20	22		R&HD
2.	Burichang Bazar–Kabila Bazar.	A	7.00	18	2	LGED
3.	Brahmanpara–Dulalpur	A	4.11	6		LGED
4.	Comilla–Burichang–Brahmanpara–Mirpur	A	32.00	56		R&HD
5.	Sylhet Highway – Salda River to Dharkhar	B	13.70	14		R&HD
6.	Kasba–Narayanpur	B	9.10	8		LGED
7.	Kasba–Saidabad	B	5.40	6		LGED
8.	Kasba–Kuti	B	4.10	4		R&HD
9.	Tinlakpir–Ballabpur	B	8.50	15		LGED
10.	Kutihat–Simaril	B	8.55	9	13	LGED
11.	Companiganj–Nabinagar	C	28.26	36		R&HD
12.	Companiganj–Ramkrishnapur	C	17.00	21	4	LGED
13.	Bholachang–Srighar	C	14.34	28	13	LGED
14.	Bancharampur–Ujanchar–Kalikapur	D	10.90	13	5	LGED
15.	Bancharampur –Marichabazar	D	10.00	8	5	LGED
16.	Bancharampur–Jibanganj	D	13.04	21	2	LGED
17.	Konaghat–Sreenagar–Salimganj	D	17.36	42		LGED
18.	Homna–Rughnathpur	D	9.80	20	1	LGED
19.	Homna–Ranakrishpur	D	11.96	16	2	LGED
20.	Homna–Manikchar Bazar	D	7.91	1	16	LGED
21.	Bagmara–Ramkrishnapur	D	9.27	8	8	LGED
22.	Gouripur–Homna	D	18.00	24		R&HD

R&HD – Roads & Highways Department
LGED – Local Government Engineering Department

TABLE I.III.2

ZONE 'A'

COMPANIGANJ–BRAHMANBARIA HIGHWAY FROM BURI RIVER BRIDGE TO SALDA RIVER BRIDGE (R&HD)

Sl. Nr.	Chainage	Clear Opening	Width (m)	Height (m)	Span Nr.	Bridge type	Materials & Condition		
							Abutment	Pier	Top Slab
1.	0.300	13.00	8.20	3.00	2	Box	RCC	RCC	RCC
2.	1.000	29.30	8.80	4.60	3	Bridge	RCC	RCC	RCC
3.	1.500	4.90	9.25	2.70	1	Bridge	RCC		RCC
4.	1.700	6.70	9.25	2.70	1	Bridge	RCC		RCC
5.	2.400	3.20	8.20	4.90	3	Box	RCC	RCC	RCC
6.	3.100	9.85	8.20	3.70	2	Box	RCC	RCC	RCC
7.	3.500	9.80	8.35	2.65	2	Box	RCC	RCC	RCC
8.	4.100	9.90	8.00	3.75	2	Box	RCC	RCC	RCC
9.	4.400	3.05	8.00	2.50	1	Box	RCC		RCC
10.	5.000	9.90	8.20	4.15	2	Box	RCC	RCC	RCC
11.	5.700	35.40	8.60	6.20	3	Box	RCC	RCC	RCC
12.	6.400	9.14	8.20	3.70	2	Box	RCC	RCC	RCC
13.	6.700	6.10	9.25	2.70	1	Box	RCC		RCC
14.	7.200	13.40	8.20	5.00	2	Box	RCC	RCC	RCC
15.	7.400	13.40	8.20	5.12	3	Box	RCC	RCC	RCC
16.	7.900	13.40	8.20	5.00	3	Box	RCC	RCC	RCC
17.	8.200	4.57	9.25	2.70	1	Box	RCC		RCC
18.	8.400	4.57	9.25	2.70	1	Box	RCC		RCC
19.	9.000	13.20	8.20	4.00	3	Box	RCC	RCC	RCC
20.	9.500	6.10	9.25	2.70	1	Box	RCC		RCC
21.	10.200	20.60	9.00	6.00	1	Bridge	RCC		RCC
22.		54.25	9.00	8.50	3	Bridge	RCC	RCC	RCC

TABLE I.III.3

Zone – 'B'

a) KASBA–NARAYANPUR ROAD (LGED)

Sl. N	Chainage	Clear Opening	Width (m)	Height (m)	Span No.	Bridge type	Materials & Condition		
							Abutment	Pier	Top slab
1.	1.2	6.86	3.73	4.75	1	Bridge	Brick	–	RCC
2.	2.6	7.24	6.17	5.00	1	Bridge	Brick	–	RCC
3.	3	6.25	3.73	4.48	1	Bridge	Brick	–	RCC
4.	4.1	14.80	5.00	5.00	2	Bridge	Brick	RCC	RCC
5.	6.8	9.68	4.73	5.88	1	Bridge	Brick	–	RCC
6.	8.1	6.25	5.95	4.51	1	Bridge	Brick	–	RCC
7.	9.1	1.00	9.30	1.22	1	Bridge	Brick	–	RCC
8.	9.1	1.90	9.30	1.83	1	Bridge	Brick	–	RCC

b) KASBA – SAIDABAD ROAD (LGED)

1.	0.1	8.54	3.66	5.95	1	Bridge	Brick	–	RCC
2.	1.7	1.83	4.65	1.83	1	Bridge	Brick	–	RCC
3.	2.7	9.30	3.73	5.12	1	Bridge	Brick	–	RCC
4.	4.7	4.57	4.34	4.12	1	Bridge	Brick	–	RCC
5.	4.8	6.86	4.19	3.35	1	Bridge	Brick	–	RCC
6.	5.4	12.65	4.15	3.40	1	Bridge	Brick	–	RCC

c) KASBA – KUTI CHAUMUHONI (R&HD)

1.	0.3	12.42	4.27	4.27	1	Bridge	Bridge	–	RCC
2.	2.5	14.34	8.08	4.73	3	Bridge	Bridge	RCC	RCC
3.	3.4	12.27	4.12	3.81	1	Bridge	Bridge	–	RCC
4.	4.1	34.15	5.00	6.10	3	Bridge	Steel	Steel	Steel

d) ROAD ALONG ODER KHAL FROM TINLAKPIR TO BALLABPUR (LGED)

1.	0.3	3.05	10.98	4.57	1	Bridge	RCC		RCC
2.	0.4	9.45	4.42	6.10	2	Bridge	RCC	RCC	RCC
3.	0.3	6.71	4.42	4.73	1	Bridge	Brick		RCC
4.	1.5	3.13	3.13	3.66	1	Bridge	Brick		RCC
5.	1.7	6.86	4.42	3.66	1	Bridge	Brick		RCC
6.	2	10.67	3.54	5.43	1	Bridge	RCC		RCC
7.	2.5	3.34	3.81	4.27	1	Bridge	Brick		RCC
8.	2.9	3.06	3.73	4.73	1	Bridge	Brick		RCC
9.	4	6.28	4.42	4.57	1	Bridge	Brick		RCC
10.	4.6	15.24	4.42	6.09	1	Bridge	RCC		RCC
11.	5.7	12.57	3.66	5.49	3	Bridge	Brick	RCC	RCC
12.	5.85	24.48	3.81	6.49	3	Bridge	Brick	RCC	RCC
13.	6.7	130.88	3.81	6.00	3	Bridge	RCC	RCC	RCC
14.	8.2	3.27	4.73	3.20	1	Bridge	RCC		RCC
15.	8.5	10.82	3.81	5.03	1	Bridge	Brick		RCC

TABLE I.III.3 (Contd.)

Zone 'B'

e) COMPANIGANJ–BRAHMANBARIA HIGHWAY FROM SALDA RIVER–DHARKHAR (R&HD)

Sl. No	Chainage	Clear Opening	Width (m)	Height (m)	Span Nr.	Bridge type	Materials		
							Abutment	Pier	Top Slab
1.	0.500	36.57	9.30	7.62	3	Bridge	RCC	RCC	RCC
2.	0.800	18.30	8.38	4.73	3	Box	RCC	RCC	RCC
3.	1.400	6.10	9.60	4.42	1	Box	RCC	RCC	RCC
4.	2.800	15.24	9.00	7.62	1	Bridge	RCC	RCC	RCC
5.	3.700	12.20	8.38	4.42	2	Box	RCC	RCC	RCC
6.	4.800	12.20	8.38	5.34	2	Box	RCC	RCC	RCC
7.	5.300	15.24	8.38	4.73	3	Box	RCC	RCC	RCC
8.	6.700	12.20	8.38	3.66	2	Box	RCC	RCC	RCC
9.	7.000	18.30	9.14	7.00	3	Box	RCC	RCC	RCC
10.	8.000	18.30	8.30	5.79	3	Box	RCC	RCC	RCC
11.	8.700	48.78	7.39	9.15	3	Bridge	RCC	RCC	RCC
12.	9.500	36.30	8.30	3.81	6	Box	RCC	RCC	RCC
13.	11.300	9.14	9.14	4.50	1	Box	RCC	RCC	RCC
14.	11.600	4.57	9.68	3.88	2	Box	RCC	RCC	RCC

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TABLE I.III.4

Zone 'C'

COMPANIGANJ – NABINAGAR ROAD (R&HD)

Sl. Nr.	Chainage	Clear Opening	Width (m)	Height (m)	Span Nr.	Bridge type	Materials & Condition		
							Abutment	Pier	Top slab
1.	–	15.00	2.50	6.50	3	Wooden	RCC Poor	RCC Poor	Wood poor
2.	28+262	10.00	6.25	5.75	1	RCC	Brick Good	–	RCC Good
3.	27+762	14.00	6.00	6.36	3	RCC	RCC Good	Brick Good	RCC Good
4.	26+598	6.20	6.50	3.72	1	RCC	Brick Good	–	RCC Good
5.	25+403	21.40	6.50	5.50	3	RCC	RCC Good	Brick Good	RCC Good
6.	24+131	9.00	6.10	4.88	3	RCC	Brick Good	Brick Good	RCC Good
7.	23+343	59.55	6.75	10.19	3	RCC	RCC Good	RCC Good	RCC Good
8.	23+045	10.20	5.25	6.55	1	RCC	Brick Good	–	RCC Good
9.	20+968	47.20	3.50	8.50	1	Bailey	RCC Good	–	Steel Good
10.	19+650	17.90	3.50	5.27	1	Bailey	RCC Good	–	–
11.	18+750	5.90	5.65	3.98	1	RCC	Brick Good	–	RCC Good
12.	18+468	5.00	5.75	4.10	1	RCC	Brick Good	–	RCC Good
13.	18+028	4.50	6.10	4.60	1	RCC	Brick Good	–	RCC Good
14.	17+232	4.80	6.40	4.00	1	RCC	Brick Good	–	RCC Good
15.	16+899	15.40	6.60	7.60	3	RCC	Brick Poor	Brick Good	RCC Good
16.	15+606	23.60	3.50	6.50	1	Bailey	RCC Good	–	Steel Good
17.	14+964	23.80	3.40	6.31	1	Bailey	RCC Good	–	Steel Good
18.	13+474	26.70	3.50	5.80	1	Bailey	RCC Good	–	Steel Good
19.	–	–	–	–	–	–	–	–	–
20.	12+801	?	6.00	5.86	?	RCC	RCC Good	RCC Good	RCC under
21.	12+301	18.10	3.50	5.00	1	Bailey	RCC Good	–	Steel Good
22.	11+697	17.40	3.50	4.65	1	Bailey	RCC Good	–	Steel Good
23.	11+302	25.70	3.80	5.80	1	Bailey	RCC Good	–	Steel Good
24.	10+638	10.00	6.00	5.07	1	RCC	Brick Good	–	RCC Good
25.	10+229	22.60	3.40	5.50	1	Bailey	RCC Good	–	Steel Good
26.	9+492	21.20	6.00	5.94	3	RCC	RCC Good	Brick Good	RCC Good
27.	8+917	3.00	6.90	3.10	1	RCC	RCC Good	–	RCC Good
28.	7+837	14.00	6.00	5.60	2	RCC	Brick Good	Brick Good	RCC Good
29.	6+796	29.90	6.00	6.01	3	RCC	Brick Good	Brick Good	RCC Good
30.	5+916	5.20	6.50	3.78	1	RCC	Brick Good	–	RCC Good
31.	5+565	12.00	6.00	5.80	1	RCC	Brick Good		
32.	4+718	9.60	6.60	5.25	1	RCC	Brick Good		
33.	3+000	10.20	6.20	4.60	1	RCC	Brick Good		
34.	2+438	11.90	6.50	5.06	1	RCC	Brick Good		
35.	1+763	15.00	6.50	5.41	3	RCC	RCC Good		
36.	1+0.80	15.30	6.50	6.22	3	RCC	RCC Good		

TABLE I.III.5

ZONE D

GOURIPUR–HOMNA ROAD (R&HD)

Sl. Nr.	Location/Crossing	Clear Opening	Width (m)	Height (m)	Span Nr.	Bridge type	Materials		
							Abutment	Pier	Top slab
1.	GUMTI	109.76	3.82	13.50	3	BRIDGE	RCC	RCC	STEEL
2.	TITAS	85.90	3.82	10.00	3	BRIDGE	RCC	RCC	STEEL
3.	TITAS	30.48	7.00	9.20	1	BRIDGE	RCC	RCC	RCC
4.	TITAS	60.96	4.10	9.50	3	BRIDGE	RCC	RCC	STEEL
5.	BATAKANDI	73.15	3.45	12.00	3	BRIDGE	RCC	RCC	STEEL
6.	MADUKUPI	73.15	3.45	9.00	3	BRIDGE	RCC	RCC	STEEL

Note: Only those structures onchannels affected by development proposals are included.

APPENDIX I.IV

REPORTS OF THANA INFRASTRUCTURE AND BUILDING SURVEY TEAMS

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HOMNA THANA (25.04.1993)

Comments of inspection team consisting of Architects and Engineers.

i. Mr. Alfaz Hossain, Architect, Consultant.

ii. Mr. A.H.M. Kamal, Engineer, Consultant.

In connection with the feasibility study of Gumti Phase II, the Team made a discussion meeting at the chamber of the Thana Engineer of Homna Thana where the following officials and representatives were present at the meeting:

1. Mr. Saiful Islam Saheed., Thana Engineer.

2. Mr. Nazrul Islam., Statistics Officer.

3. Mr. Mosharraf Hossain Mollah.
   Chairman, 7 No. Chandarchar (East) Union Perishad.

4. M. Islam, S.A.E.

On discussion with the above official's, it revealed that 90% of the Thana complex area were flooded during 1988 highest flood. Besides Thana complex area, the entire Thana area were submerged under water ranging from 1.22 m (4' ft) to 2.13 m (7 ft) depths. Even in 1991, 1992, Bahasania Union area was flooded. No embankment has been constructed in this area. An embankment from Kariparampur to Bagsitarampur about 5km was constructed along the left bank of Titas river. One sluice gate at Nagerchar across the Nagarchar Khal was constructed to act as drainage outlet when there is drainage congestion inside the project area and on the other hand, the sluice serves as flushing inlet for irrigation during irrigation demand period. Irri crops are cultivated in this area for one time only. Charkuria Khal starting from Ramnagar and endue at Kalagachia for a length of about 6 km. which covers three unions namely (i) Chandarchar (East), (ii) Ghagutia No. 5 and (iii) Chandarchar (West).

The Thana Engineer opined that one embankment is required along the left bank of Titas river to protect the area from flood water accumulated in the Titas river due to heavy rainfall, water congestion and untimely flood water due to heavy rainfall allow only ¼th area, approximately 10,000 acres to be under cultivation out of a total net cultivable land of about 40,000 acres.

One sluice gate is required over Madlar Khal near Goaribhanga road to preserve water from Kathalia river. Several existing rural roads require immediate development.

Growth Center Connecting (G.C.C.) road from Homna to Dulalpur and partly from Homna to Raghunathpur is under construction by JICA. Formation level of this road varies from 6.5m to 6.75m whereas level of flood plane area varies from 2m to 3m. The area is therefore subjected to deep flooding every year.

One bridge of length 55 m has been constructed by LGED at Bagmara and another bridge of length 61 m has been constructed by JICA at Alipur over the Khals of Homna Dulalpur road.

The low income groups and weavers who are residing in the low lying areas are under high risk caused by the early flood due to heavy rainfall.

One 3 (three) storied School Building and one 2 (two) storied private building exist in the Thana Head Quarters. Most of the Houses in the Thana Head Quarter are tin shaded, some new pucca building are under construction. The internal roads of the town area need improvement. Gauripur - Homna D.C. road (17.5km) is the only road communication system with the Comilla district Head Quarter

Homna Thana base map was collected to prepare existing infrastructure inventory profile from Thana Engineer, Homna.

Flood damage data as required by MACDONALD office. Dhaka during the month of Feb/1993 was sent to Dhaka office on 06.03.1993 by Thana Engineer.

DEBIDWAR THANA (25.04.1993)

We had discussed with the following officials:

1. Mr. Monirul Haque, Thana Engineer.
2. Mr. Harun - Ar - Rashid, Sub-Asstt. Engineer.
3. Mr. Abdul Jalil, Statistics Officer.
4. Mr. Abu Bakr Siddique, Sub - Divisional Engineer, Gumti W.D. Division.
5. Mr. Fulmiah, Work Assistant.

The following Union Parishads are under Gumti Phase - II area as per statement of Thana Engineer.

1. Boroshalgar (North)
2. Boroshalgar (South)
3. Subil
4. Rasulpur
5. Fatehabad.

The entire area was flooded during the 1988 highest flood due to the breach in the Gumti Right embankment. Subsequent after providing Gumti Rt. bank embankment by Gumti Phase - I Sub-Project, the area is now protected from flood and is one of the highest priority item for improving the security for crops, lives and properties.

But except the Gumti right bank embankment and Burinadi Central structure, no other drainage channel improvements, sluice construction, and other flood control infrastructures have been done which resulted in drainage congestion incase of heavy rainfall.

Due to the construction of Buri Nadi control structure the adjoing area under Gumti Phase - II becomes dry even in rainy season and the people are now facing difficulties to cultivate broad cast Aman. Buri Nadi is not active in dry season. Bed level is approximately 3 m to 4 m higher than the Titas river bed level at Nabinagar. Re-excavation to sufficient depth is required to flow water from Titas river.

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During the rainfall, congested water drain out to the Titas river through Ramprassad Khal, Morzona Khal and Buri Nadi but these Khals require re-excavation.

In 1988 highest flood only 10% of Thana complex area were flooded but the adjoining area on the north west of Debidwar Thana Head Quarter was flooded due to sudden collapse of two major bridges on Comilla - Companigonj highway. Feeder Roads B type are not sub-merged under normal flood but other smaller rural roads are sub-merged during heavy rainfall.

Debidwar Thana base map has been collected which will help to prepare existing infrastructure profile.

We have also collected flood damage data required by MacDonald office during the month of February.

MURADNAGAR THANA (26.04.1993)

We made a discussion meeting in the chamber of Thana Engineer with the following officials and representatives.

1. Mr. Serajul Islam, Thana Engineer,

2. Mr. Jahirul Haque, Project Implementation Officer (P.I.O)

3 Mr. Abdul Jalil, Statistics Officer.

4. Mr. Sultan Ahmed Bhuiyan, Accounts Officer and Local Person.

5. Mr. Tofazzal Haque, Draftsman.

During 1988 highest flood, the entire thana complex was sub-merged under water. During winter season Gumti river water is utilized through Buri Nadi (river) for irrigation purpose. But in dry season water level goes down for which Gumti River water cannot be made available throughout the full crop season. In the rainy season, the 2 - vent Buri Nadi control structure on the right embankment of Gumti river is closed to protect the area from flood water. Thana Engineer opined that Buri Nadi should be re-excavated to keep water throughout the year for Irrigation om tje Gumti Phase - II area. Arsi river and Chapitala Khal are now silted up and require re-excavation upto 2 M depth approximately. The length of Arsi river is about 30 km and the average width is about 30 M. Embankment on both banks of Buri Nadi is required for protection of the area from floods during rainy season.

There is no major water control structure except 5 - 6 inlet structures on the right embankment of Gumti river. These are provided to lift the water from the Gumti by L.L.P for irrigation.

Flood water from the Upper Titas River enterers into the Oder Khal and the north area of Muradnagar. So embankment on both banks of Oder Khal is required. As there is no adequate drainage facilities flood water remains in the field for about six months. Oder Khal separates the Muradnagar and Nabinagar thanas.

Project implementation officer and local people expressed that the entire area can be utilized for cultivating 2 - 3 crops a year if the existing canals are re-excavated for using as feeder irrigation canal. Some new canals are also to be required excavation.

Out of 21 unions, 16 unions fall under Gumti Phase - II Sub-Project. According to the PIO's statement 50 km rural roads are under construction this year through the CARE under the FFW programme. Average height of these road is about 2m from existing flood plain. 300 km road were constructed since 1977 by the CARE. About 20% of the land area is submerged under water during normal floods. On the eastern side of Companygonj-Nabinagar Road double crops are being cultivated and on the western side single crops are being cultivated. There is one sluice gate at Ramchandrapur.

Inventory of Existing Infrastructure and Public Buildings.

Pucca road	:	22.33 km.
Semi Pucca road	:	35.00 km
Kachcha road	:	458 km
Water ways navigation (dry season)	:	64.57 km.
wet season	:	310.50 km
High School	:	32
College	:	4
Primary School	:	115

About 70% of the structures are public buildings at the Muradnagar Thana complex area. Some of the public buildings are semi-pucca or buildings or Tinsheds.

We have collected Thana map to prepare inventory profile and flood damage data.

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DAUDKANDI THANA (27.04.1993)

We had a discussion meeting in the chamber of Thana Engineer with the following officials and representatives.

1. Mr. Sharifuzzaman, Thana Engineer.

2. Mr. Fazlul Haque, Sub-Asstt. Engineer.

3. Mr. Nurul Haque, Statistics Officer.

4. Abu Taher, Sub-Asstt. Engineer.

1988 was the highest flood year. 100% of the Thana complex were submerged under water upto an average depth of 0.90 m. Daudkandi - Chandina Highway had gone under water.

Flood affected people took shelter in Daudkandi High School, Primary Schools, first floor of Hassanpur College. Existing crops were damaged.

Gauripur - Homna and Daudkandi - Comilla Highway are the main road communication. Besides, several rural roads existing.

Inventory of Existing Infrastructure and Public Buildings

High School	-	32 nos.
College	-	5 nos.
Primary School	-	208 nos.

70% of the thana complex area is public buildings.

We have collected thana maps to prepare the inventory profiles.

According to Statistics :

Pucca road - 35 km.
Kachcha road - 544 km. since 1976-77

Of these Kachcha road 3 nos. G.C.C road for a length of about 20 km is under improvement by the LGED. The roads are;

1. Gauripur - Kachina road 10.345 km
2. Daudkandi RHD road to
   Joranpur Bazar via Goalmari - 6.45 km.
3. Batakandi - Masimpur road - 3.45 km.

On the East of Gauripur - Homna road, the land area is flooded by Titas river. Due to right embankment of Gumti river under Phase-I upto Asmania Bazar the land of this area is protected from Gumti flood; but remaining portion from Asmania to Gauripur is not protected. The areas of Narandia, Karikandi and Balarampur are affected by the flood water from Gumti and Titas river. So embankment is required on both the banks of these two rivers.

On the West of Gauripur - Homna road the entire area is affected by flood water coming from Meghna and Kathalia river. Thana Engineer expressed that flood embankment are required on both the banks of two rivers. Khals within this area require re-excavation. Karikandi Khal is under re-excavation by FFW progamme. Another 3 khals namely Jalla khal, Harinabhabanipur - Kirtonkhola Khal and Rajapur Khal are also now under re-excavation by CARE. Another 4 nos of khals, namely Motopi khal, Rampur khal, Jiarkandi Gopalpur Khal and khirai khal have been under re-excavation by the JICA. Bridges and culverts are about 1000 nos.

50% of the thana complex area is pucca buildings.

We have collected thana maps to prepare the inventory profiles.

NABINAGAR THANA (26.04.1993)

We had a discussion meeting with the following officials and representatives.

1. Mr. Kazi Nurul Islam, Sub - Asstt. Engineer (Thana Engineer was on leave)
2. Mr. Abdul Aziz, Surveyor.
3. Mr. Fazlul Haque, Primary School Teacher & local representative.
4. Mr. Abdus Satter, P.I.O.
5. Mr. Sanaullah Sarker, Statistics Officer.

During the 1988 floods, the entire Nabinagar Thana complex was sub-merged under water upto a depth of 2 M. People had no other alternatives of taking shelter but to make bamboo platforms themselves. Even in normal flood, the area except homesteads is sub-merged under water. The area is flooded by the Meghna river through the Titas river. The Meghna is flowing about 5 km north-west of Nabinagar Thana complex. Flood embankment is required from Taleswar Bazar to Morchakandi for a length of about 20 km. Two major water control structures will have to be provided at the confluence of the Pagla river and the Titas river. At present about 500 meter length is blocked at the mouth of Pagla river.

As the area is too low, embankment on both banks of Pagla and Titas river are required for protection against the flood water. No water control structure exists.

One time IRRI crops are cultivated in the area. So lower income people are to suffer very much. Net cropped area is 28915 ha construction of one G.C.C road for a length of about 10 km from Konaghat to Selimgary, has been started by LGED. On the eastern side of Companygonj - Nabinagar road (now under re-construction by RHD), a vast area of land is flooded during heavy rainfall in the catchment of Titas river. There is no water control structure across the Highway except some newly constructed bailly bridges.
9 nos feeder road constructions and 3 nos feeder canal digging are now going on by CARE and GOB for a length of about 40 km.

Inventory of Existing Infrastructure and Public Buildings.

Pucca Road	:	4.00 km
Kachcha Road	:	418.00 km
Semi Pucca road	:	13.00 km
Bridges & Culverts	:	133.00 km
College	:	5 Nos
High School	:	42 Nos (approx.)
Primary School	:	210 nos

About 70% buildings are public buildings.

Thana map could not be collected as the Thana Engineer was on leave. District map has been collected.

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BURICHANG THANA (09-12-1992)

Comments of inspection team consisting of Architects and Engineers.

i. Mr. Alfaz Hossain, Architect, Consultant.

ii. Mr. Abu Jalal, Engineer, Consultant.

iii. Mr. R.I. Ansari, Executive Engineer, BWDB.

According to our Programme in connection with the feasibility study of Gumti Phase II, we have made a discussion meeting at the chamber of the Thana Engineer of Homna Thana and the following officials and representatives were present at the meeting:

1. Mr. Faqrul Islam, TNO
2. Mr. Mobarak Hossain, Statistics Officer.
3. Mr. A K M Akhter Hossain, Assistant Engineer, LGED.
4. Mr. Tofazzal Hossain, SAE.
5. Mr. Sazzad Hossain Chairman (Bakshimul Union Perished)
6. Mr. Baharul Islam, BNP Secretary (Sadar Thana)

After with discussion the above personnel, I would like to draw the following points:

The year 1988, was the highest flood year in this Thana. Vast areas of this Thana including 70% of the Town area were flooded and the flood level was 1 meter higher than normal for a period of two weeks. In the east side of the Thana "Burichang-Anandapur" Kutcha Road was submerged to depths ranging from 0.4 to 0.6 meters and above. But the Thana complex was free from the floods.

Before providing Embankment along the right bank of the Gumti River, the people were regularly affected every year by floods. The Gumti Right embankment protects the area from floods and is one of the highest priority item for improving the security for crops, lives and properties.

But except the Embankment no other developments e.g. drainage channel improvements, sluices and no other flood control infrastructures have been done which resulted in drainage cognation. In case of any rainfalls, the waters remains stagnant in low-lying area for a long period.

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The low income groups and slum dwellers who are residing in the low-lying areas are under high risk, due to the instability and erosion failure of Embankment.

The immediate and shor-term activities are required to minimize the risk of failure due to erosion and side sliding of the Gumti Phase I Embankment.

Erosion protection and detailed drainage system are essential for the whole area. Raising the Burichang-Anandapur Road to the 50 year flood level, and constructing associated drainage, sluices, providing the bridge over the Ghungar Khal near Bakshimul Village along the Anandapur-Shyampur. Road Bridge also required at Loribag over Ghungar Khal along the Bareshor-Pachora Road.

The hazardous earthen roads made by CARE and other such agencies must have adequate cross-drainage facilities for easy passage of flood water.

About 35 km long Gumti-Ghungur connection Khal dredging is badly needed for reducing the regular severe flooding.

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BRAHMANPARA THANA 09/12/1992

We had discussed with Mr. AKM Akhter Hossain, Thana Engineer (In-charge) Thana statistics Officer, Mr. Tofazzal Hossain Sub-Assistant Engineer, Mr. Ala Uddin. Other related officials were not available in the office. According to their information no development work has been done in this Thana. The Burichang-Brahmmanpara main Road about 30 km long is still an earthen/Kutcha Road.

One set of questionnaire on population and other data collection are handed over. About 8 km is roughly prepared by the thana statistics officer and one set of thana educational institutions are attached herewith

KASBA THANA 10/12/1992

At Kasba Thana we have discussed with the following officials:

1. Mr. AKM Moin Uddin Ahmmad
2. Mr. Bazlur Rahman, Sub-Asstt Engineer
3. Mr. Mostafa Kamal Pasha Work Asst.
4. Mr. Lutfur Rahman PIO
5. Mr. Motahar Hossain, Junior statistics Officer
6. Mr. Habibur Rahman PPI

All most all the area about 90% out of ten Union perished are regularly flooded ever during minor rainfalls, and also extensively inundated for several months each year by overflows of the surrounding rivers, small khals and channels which come form India. Actually the inadequate access and out fall of the existing River, Khal and channels are the main cause of regular floods. All existing rivers and khals are silted up which resulted in accumulation of stagnant polluted water and which also damage standing crops regularly in low-lying areas. To reduce the severity of floods, river dredging, re-excavation and restoration of canals and providing marginal dike along the banks are required in view of the urgency of the flood protection works.

About 1.5 km long Raja Khal excavation programme has been under taken by mass participation. Construction work of about 5.10 km out of 9.68 km of Kasba-Nayanpur road and FFW is going on. Bridges and two culverts on the said road are in good condition. But instead of two existing narrow culverts they want to have one 3.5 m span culvert. During the 1988 flood Kuti-Kasba road was submerged under 0.6m. Kasba-Nuton Bazar was also submerged. Bridge at Chargasn was damaged and two bridges along the Kasba Akhaura Road were also damaged during the 1988 flood.

During the 1988 floods water from the Titas, Meghna flew into the Ghunguri. The flood duration was 15 days. The flood affected people about 500 took shelter in the existing thana flood centre. This centre constructed by the Government after 1974 flood. People also took shelter at the T. Ali College, Kasba Girls High School, Shahapur High School and Shahapur Primary School during 1988 flood.

AKHAURA THANA

We discussed with the Thana Engineer Mr. Liaquat Ali, Asstt. Agriculture Extension officer Kanulal Mojumder Junior Agriculture officer Abdul Karim Chowdhury and Agriculture office MLSS Firuz Ali.

Source of floods is the same as that of Kasba Thana, Every year crops are damaged by the flashy floods coming from India, through the Hawra river. For any rainfall in the of Indian hills cause floods and heavy siltation.

Mora Hawra river re-excavation project has been undertaken by thana LGED for a length of about 2 km from Hawra Railway bridge to Titas river.

The 1988 flood submerged the T&T office, college and entire town. The flood effected people took shelter on Sharak Bazar along the C&B road.

To facilitate relief supplies during floods, a helipad size of 400' x 500' was constructed by the LGED in 1990-91. One flood shelter is existing at Sharak Bazar constructed by GOB after the 1974 floods. The floors of the Thana complex is also used as flood shelter.

Four out of five unions are in the east side of the Railway. The union laying on the western side of the Rail is low and is affected regularly by floods.

BANCHARAMPUR THANA

Bancharampur Thana is a low lying area and is prone to flooding and even in normal flooding, the land surface except homesteads, is submerged under water. Bancharampur thana was severely affected by 1986 and 1987 flood. About 90% of the Thana Complex went under water during 1988 flood. The remaining area of the Thana is reported to have been submerged under 2m to 3m depth of water and in some low areas ever more than 3m. Meghna is on the west of Bancharampur and flows North to South.

IRRI crops during Boro season and long stem Aman are the main crops in the Thana. Due to flooding every year, high yielding variety paddy cannot be grown during monsoon.

The communication system in Bancharampur Thana is mainly through water routes.

APPENDIX I.V

COMPUTER PROGRAM FOR DESIGN OF SUBMERSIBLE EMBANKMENTS

Appendix I.V

Computer Program for Design of Submersible Embankments

I.V.1 Introduction

Full protection against the maximum annual flood requires high and costly embankments, especially in low lying areas. Another, less costly, solution for protection against annual flood is to provide a submersible embankment. Possible submersible embankments were considered in two locations within the Gumti Project Area. They are illustrated in the main Annex in Figure I.6.20.

The submersible embankment is designed to protect agricultural land against the rising flood until the boro crop has been harvested or the transplanted aman has been established. At this point in time, generally in April or May (or June for HYV T aman), the embankment is allowed to overtop. Thus the boro crop or T aman early stage crop is protected, but the protection does not extend to full protection for the aus or aman crops.

The advantage of the submersible embankment is that the height will be much less than the height of a full protection embankment. The cost of embankment construction and land required for building will therefore be much reduced. In addition, where floodplain capture fisheries are important, the high floodplain water levels will be available at the height of the monsoon season.

I.V.2 Engineering Considerations

Although the initial cost of construction of the submersible embankment will be low, the annual cost of maintenance will be extremely high; estimates run as high as 30% of cost of initial construction per annum. This is mainly due to the heavy erosion of the embankment which occurs when it is overtopped each year.

It is BWDB policy to provide large gated structures at the low point(s) of the perimeter of the submersible embankments. These are then opened once the boro crop has been harvested, in order to raise the inside water level and prevent scouring flow over the embankment. In practice, the gates are not opened at the correct time and large scale erosion does occur.

In order to prevent this large scale erosion, it is proposed to provide one or more lowered sections (spillways) of embankment. These lowered portions of embankment would be protected by herring bone brickwork on the top, with brickwork gabions on the side. The purpose of the spillway is to direct the initial overtopping flow through a protected region. By the time the water level outside the embanked area has reached the level of the unprotected bank top, the inside water level will be the same as the outside water level. Thus there will be no high velocity flow over the unprotected embankment. This solution therefore avoids the requirement for large regulators and also eliminates operating errors.

The slopes between spillway level are shallow (approximately 1 vertical to 5 horizontal) in order to allow the conveyance of vehicles. However, where no vehicles are expected, the side slope may be made steeper, thereby saving costs. The parameters of embankment level, spillway level, spillway length and side slope will require careful optimization to allow boro crop protection as well as parity of water levels at embankment top level. A further constraint is to make sure that the water level rise within the protected area at the time of overtopping does not exceed the maximum growing capacity of the aman crop.

I.V.3 Drainage

When the flood recedes in October and November, the embankment will impede drainage once the flood level reaches spillway level. This will prevent planting of rabi crops. It is therefore important to incorporate a gate system at the lowest point along the line of embankment. Once the river (outside) water level is lower than the country (inside) water level, the drainage gates may be opened.

There will also be the option of closing the drainage gates at a particular countryside water level. This will trap a volume of water which can be used, by means of low lift pumps, to irrigate the rabi crops.

I.V.4 Fisheries

There are at present two existing submersible embankment schemes within the Gumti Phase II project area. In both these schemes the embankments, or high ground, encompass a beel which is linked to the main river system by a khal. During site visit discussions in the area, fishermen stated that fish migrated from the river to the beel between the months of April and May. It is during this time that the embanked area will need to be sealed off, to prevent inundation of the boro crop.

It will therefore be necessary to consider the use of gates which can be opened at critical times to let fish into the beel area. As fish and spawn tend to be near the water surface, the gates will have to be either swing or Romijn types as opposed to the sluice gates used for drainage.

FAP 17 have informed us that in order to be completely fish friendly, gates need to be open with no significant water level difference on either side. Preferably water needs to flow in both directions at some stage during the day, so fish may swim against the flow to their destination. This would in fact be possible at the submersible embankment locations, as there is a small tidal effect which would produce alternating daily flow. However, it does mean that gates need to be fully open, and the solution of following the Meghna water levels up by gradually raising a movable weir (Romijn gate) is therefore inapplicable.

I.V.5 Navigation

Additional problems will occur if the submersible embankment is situated across a navigable khal. In this case the gate described in section I.V.4 would not serve to convey boats. This is because a gate sufficiently large to allow passage of a boat would allow too great a discharge into the protected area, resulting in early inundation of the boro crop.

The solutions to this problem lie either in a lock, or if only small boats are involved, by providing an area where the boats may be dragged overland for a small distance into the next water body. The cost of the first solution may prove prohibitive and the second impractical, so the selection of a site for a submersible embankment scheme will favour locations which do not intercept navigation routes.

I.V.6 Optimization Procedure

There are many variable parameters involved with the design of a submersible embankment.

The spillway level determines at what stage river water level can start to enter the protected area in large quantities.

The embankment level will need to be of a sufficient height above the spillway level to allow sufficient time for inside water level to match outside water level at time of overtopping. The spillway length will also be important in this equation to determine the speed of inundation of the protected area. Thus, for each proposed submersible embankment the cheapest combination regarding spillway length and embankment height was calculated.

All the necessary parameters were placed in the computer model and varied until the optimum values were obtained. The model contained both the average and 1 in 5 year water level hydrographs relevant to each area, along with the area elevation curve for each protected region.

In addition, the model contained level and dimension details for the drainage sluice gate and the fish passage gate. The fish passage gate remained open until inside water level reached the top of khal level, and before the boro crops become inundated. If the fish already passed through to the beel by this time, the fish gate was closed to spillway level. If the fish still require entrance, the gate can be closed to top of beel level, so fish and spawn can enter over the gate. The volume of water entering the protected area and the additional land lost will be determined by the model. The fish gate width and operation will be determined by fish behaviour patterns, but obviously the narrower the gate, and least volume of water allowed through it will maximise the area of protected land.

At the end of the monsoon, the protected area will have to be drained. Using the downward limb of the hydrograph, along with the drainage gate and fish gate sizes, the water level within the protected area will be computed.

Therefore, for each set of engineering and operation parameters, the computer programme modelled the water level and area of inundation within the protected area. It also produced discharges through the gates and over the spillways. It was possible to vary these parameters and thus optimise the greatest protected area within the embankment and minimum erosion over the unprotected embankments. It was also possible to obtain the least cost solution regarding embankment height and spillway length. The computer program used to carry out the optimisation is discussed in section I.V.7.

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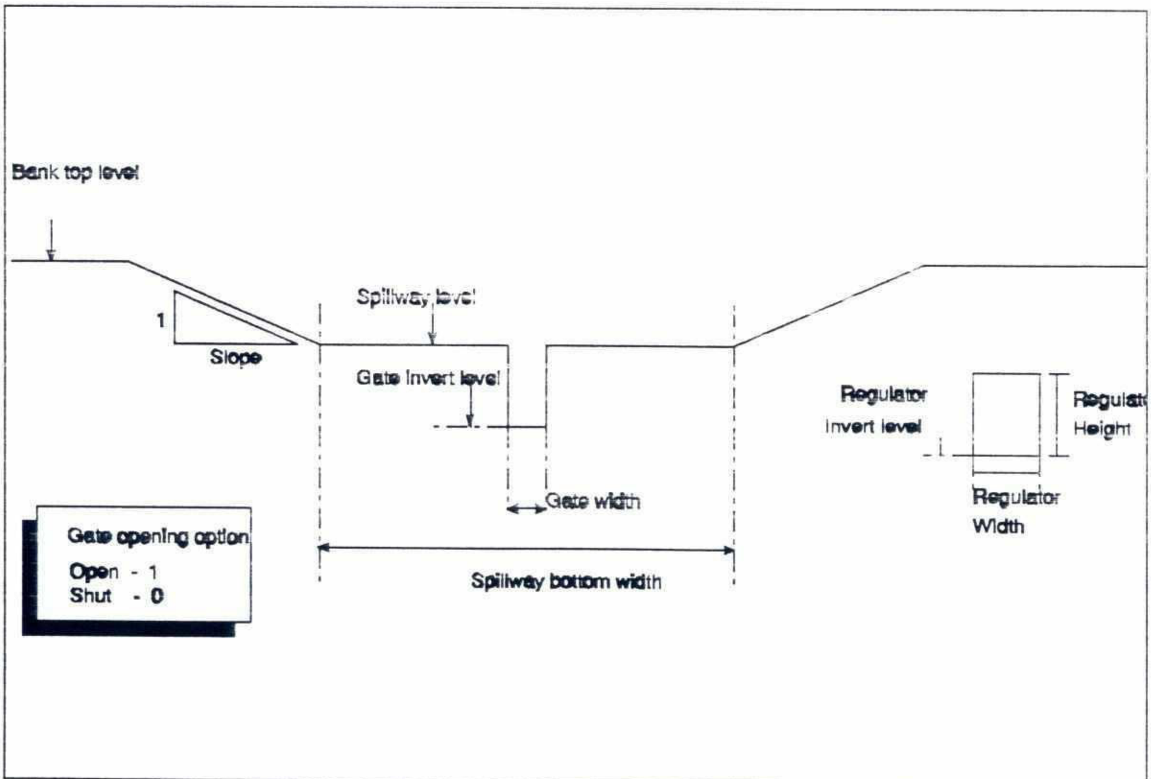
I.V.7 Program SUBMER

PURPOSE:-

To model the inundation of an area surrounded by a submersible embankment.

REQUIRED INPUT PARAMETERS:-

1) Bank top level
2) Spillway level, bottom width and side slopes
3) Fish gate invert level, width and whether the gate is closed after inundation
4) Number of drainage regulator gates and the day on which the gates are opened
5) The height and width of the drainage regulator gates
6) The invert level for the regulator gates
7) The times at which results for rising limb and falling limb of the hydrograph need to be printed
8) The time steps for the calculation and printouts
9) Initial DSWL (countryside level) for 1 March
10) Area - Elevation curve for the protected area
11) The time and water level points defining the river hydrograph



Required Parameters for Program SUBMER

METHODOLOGY:-

1) The elevation - volume curve is computed from the area - elevation using the following equations:

$$H = elevation(2) - elevation(1)$$ Equ 1

$$Volume(2) = \frac{H}{3} * (area(1) + \sqrt{area(1) * area(2)} + area(2)) + Volume(1)$$ Equ 2

2) These curves are then used to determine the area of inundation and volume of water within the empoldered area at time zero, based on the initial DSWL.

3) The programme then progresses one time step. The new river level is calculated from the hydrograph and new time (original time plus 1 time step). The discharge through (a) the fish gate, (b) the spillway and (c) through the regulator gate(s) are computed, based on this increase of USWL over DSWL. If the increase in USWL is, say 0.2 m over the full time step, then for discharge purposes a value of half this (0.1 m) is taken over the time step. This is the average of the increase of zero at the start of the time step and 0.2 m at the end of the time step.

4) Discharge through the gate for unsubmerged flow is determined by the following broad crested weir equation :-

$$Q = 1.71 * Cd * B(H1 + \frac{V^2}{2g})^{\frac{3}{2}}$$ Equ 3

Where Cd is taken as 0.94 (narrow bridge opening with or without floors)
B is Width of gate
H1 is Upstream water depth
V is velocity of approach
g is acceleration due to gravity

Discharge through the gate for submerged flow is determined by the following submerged orifice flow equation :-

$$Q = Co * \sqrt{2g} * B * H2 * (h + (1 + e) * \frac{V^2}{2g})^{\frac{1}{2}}$$ Equ 4

Where Co and e, the obstruction coefficients are taken as 1 and 0 respectively
H2 is downstream water depth
h is USWL-DSWL

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The unsubmerged flow equation is adopted when h is greater than H2/4

The fish gate has two options. Once it has been overtopped it can be closed, to reduce discharge entering the protected area. Or the gate can remain open, which enhances the discharge into the area, but also facilitates fish and boat traffic.

5) Discharge over the spillway for unsubmerged flow adopts equation 3, except that Cd is taken as 0.96 (wide bridge opening with floors). Also, the width of flow is recalculated for each time step, as it increases with height above spillway crest level.

The method considered for the submerged spillway discharge calculations used unsubmerged flow with a coefficient (based on an empirical relationship from USBR data, see Ref[1]). The method was adopted as it was considered to model the spillway system more accurately, especially during the transition from free flow to submerged flow.

The coefficient is shown in Ref [1]. The parameters of the curve, varying with Hd/H, were placed in the program. Each time flow over the weir is calculated, the value of Hd/H is determined and the coefficient interpolated from the curve parameters.

6) The regulator gate discharge assumes an undershot sluice gate and is calculated from Ref[2]. The discharge formula is :-

$$Q = NG * B * Cd * A * \sqrt{2g(H1 - H2)} \qquad \text{Equ 5}$$

Where	NG	= Nr of gates
	B	= Width of gate
	A	= Height of gate
	Cd	= Coefficient of discharge
	H1	= Upstream water level
	H2	= Water level immediately downstream of the gate

The Coefficient of discharge is shown as a curve, related to H1/A. This is represented by the following polynomial:-

$$0.2364 * X^2 - 0.0685 * X + 0.5995 \qquad \text{where} \quad X = \frac{A}{H1} \qquad \text{Equ 6}$$

If the tailwater level is sufficiently low for free flow to occur then the value of H2 is determined by :-

$$H2 = A * Cc \quad \text{Where } Cc = 0.61 \qquad \text{Equ 7}$$

If the flow is submerged, then H2 is given by :-

$$\frac{H2}{Y0} = \frac{2(X-1)}{X} + \sqrt{\frac{4(X-1)^2}{X^2} + X^2 - \frac{4(X-1)Y}{X}} \qquad \text{Equ 8}$$

Where X = Yt/Y0

Y = H1/Y0

Y0= Cd*A

and Yt is the tailwater depth

If Y2 is greater than the tailwater depth, then free flow occurs. Y2 is determined by :-

$$Y2 = 0.5 * Y0 * (\sqrt{\frac{16 * H1}{Y0} - 15} - 1) \qquad \text{Equ 9}$$

7) Once the total discharge has been ascertained for the time step, the amount of flow is converted into a volume of water. Using the program elevation - area - volume curves the new countryside water level is computed, along with the new area of inundation. A check is made to ensure that the DSWL is not higher than the USWL at the end of the time step. The area of inundation and volume of water relative to the checked DSWL are recalculated and displayed in the output.

8) The same procedure is then carried out for the next time step, until the required duration for the model has been reached. Once the river water level exceeds the bank top level, the water level inside and outside the protected area are assumed to be the same, with zero discharge going through the structures.

9) The model computes the downward limb of the hydrograph in exactly the same way. This time, however, the countryside water level is higher than the river water level. It is during this stage that the drainage regulator is likely to be opened.

I.V.8 Results of the Program Runs for the Northern Scheme

Table I.V.1 shows the final parameters and results from the program runs. The comparative hydrographs for river level and countryside water level are shown in Figure I.V.1. The elevation - area - volume curve is shown in Figure I.V.2.

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The area - elevation curves were taken from the FINNMAP 1:16000 maps. The topographic data was fed into a database from which the sets of elevations and their associated areas were computed. From these data points, the program computed the associated value of volume, as discussed in section I.V.7.

TABLE I.V.1

Parameters for Northern Submersible Scheme

Run Nr	River Hydrograph	Bank top Level	Spillway Invert Level	Spillway Width	Max Rate of Rise	Day Spill Started	Day of Inundation
1	1 in 5 YR RP	4.3 m	3.3 m	2.5 m	12 cm/day	1 June	1 July
2	Average	4.3 m	3.3 m	2.5 m	11 cm/day	11 June	8 July

The spillway level was chosen to be as low as possible (for reasons of cost) but high enough to defer inundation until the end of June in a 1 in 5 wet year, so the B aman crop could be properly established. The top of embankment level was chosen to be sufficiently high to ensure it was overtopped from both river and countryside at the same time. From Figure I.V.1, had the embankment been only 4 m high, then the head across the embankment at inundation would have been approximately 0.5 m. This would have brought about high cross flow velocities, which would have damaged the embankment.

The program used the hydrographs generated by the General Model (GM) but was also tested with the historic water levels from Daudkandi. The difference in output from the two hydrographs was negligible.

The countryside water level is shown to start at a higher stage than the river level. This is because the lowest part of the ground in the area is at 1.76 m (PWD) as opposed to the March 1 river level of 1.48 m (1 in 5 year) and 1.3 (average year). Figure I.V.1 also shows that there is not much difference in the countryside hydrograph for a 1 in 5 return period or for an average year. As the 1 in 5 year hydrograph is more critical, this has been used for determination of the design parameters.

Different sizes of drainage regulator gates were used in the model. Use of a single 1.83 m x 1.52 m gate showed that the downward limb was just the same for countryside and river water levels. The gate used for the results shown in Figure I.V.1 was 1.0 m by 1.0 m. This does have very small negative impact on drainage around day 241, but reverts to normal river levels after day 250. Any standard sized gate, not smaller than 1.0 m x 1.0 m is therefore recommended in the design.

The maximum rise in water level within the protected area is shown to be 12 cm for the 1 in 5 year return period. This is high and will require a species of rice which can attain this level of growth. Further refining may be carried out at design stage, to optimise yield from high growing rice varieties with costs for spillway design.

Figure IV.1

Hydrographs from the Northern Submersible Embankment Scheme

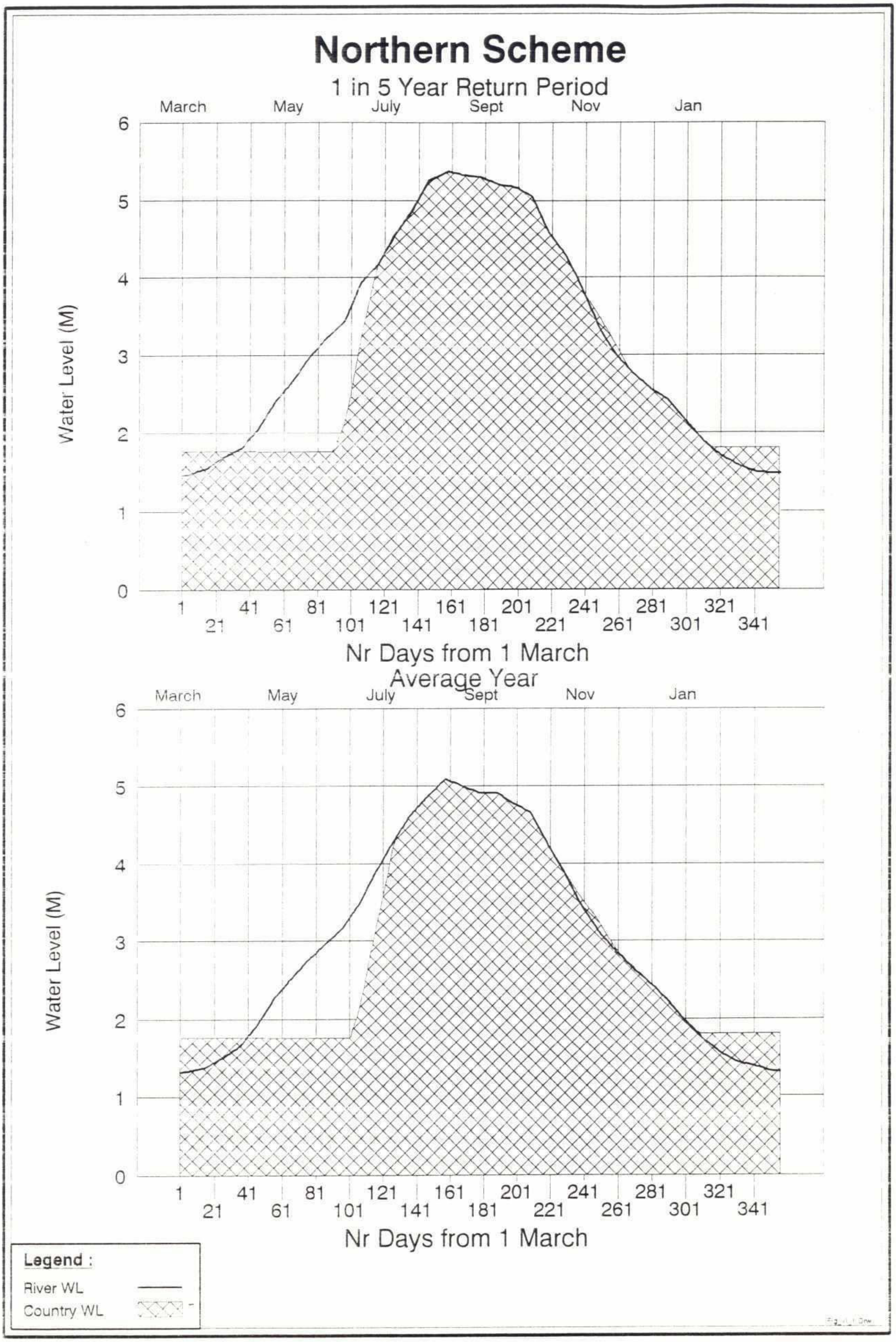
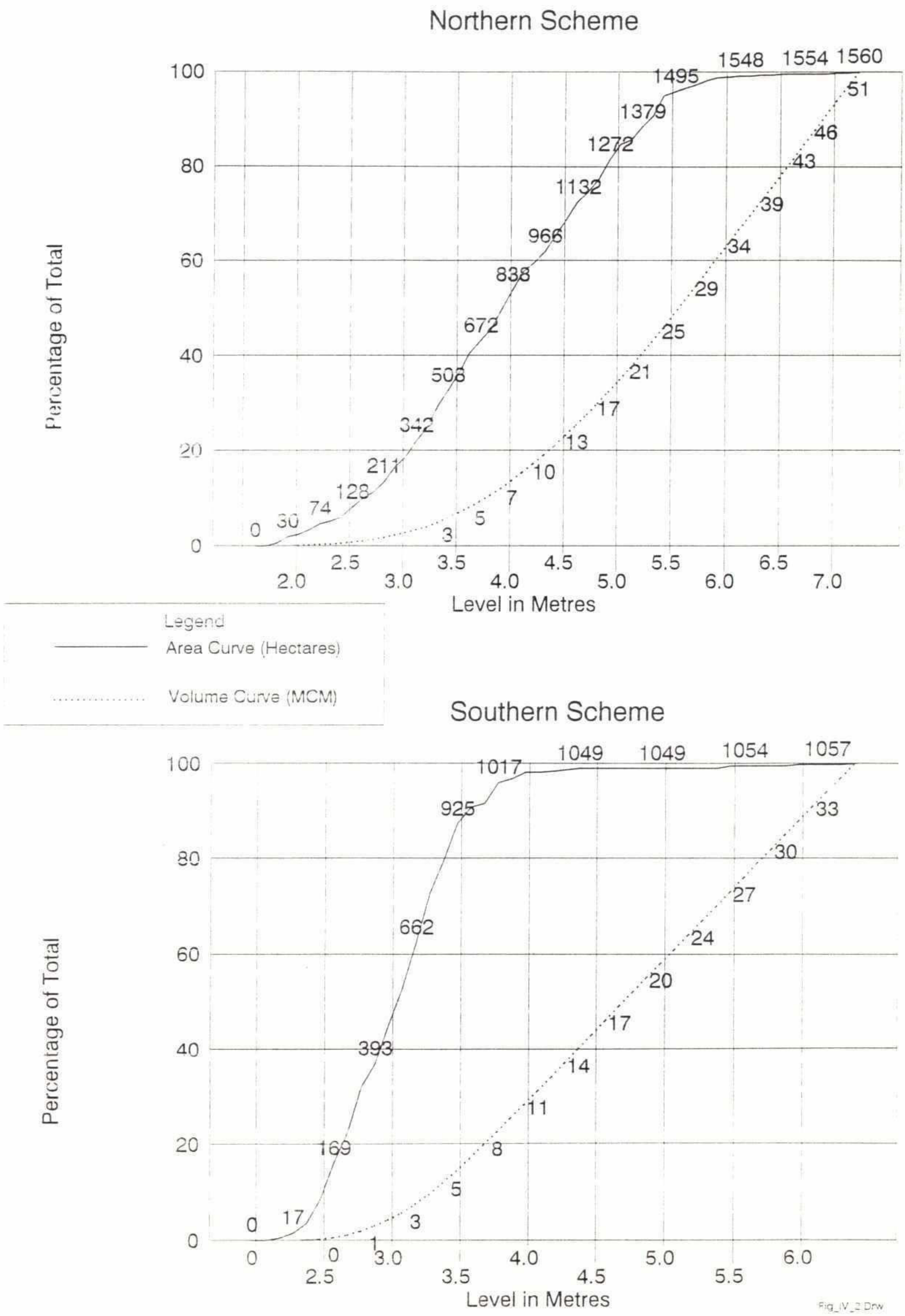


Figure I.V.2

Elev-Area-Volume Curves for Northern and Southern Schemes



I.V.9 Results of the Program Runs for the Southern Scheme

Table I.V.2 shows the final parameters and results from the program runs. The comparative hydrographs for river level and countryside water level are shown in Figure I.V.3. The elevation - area - volume curve is shown in Figure I.V.2.

TABLE I.V.2

Parameters for Southern Submersible Scheme

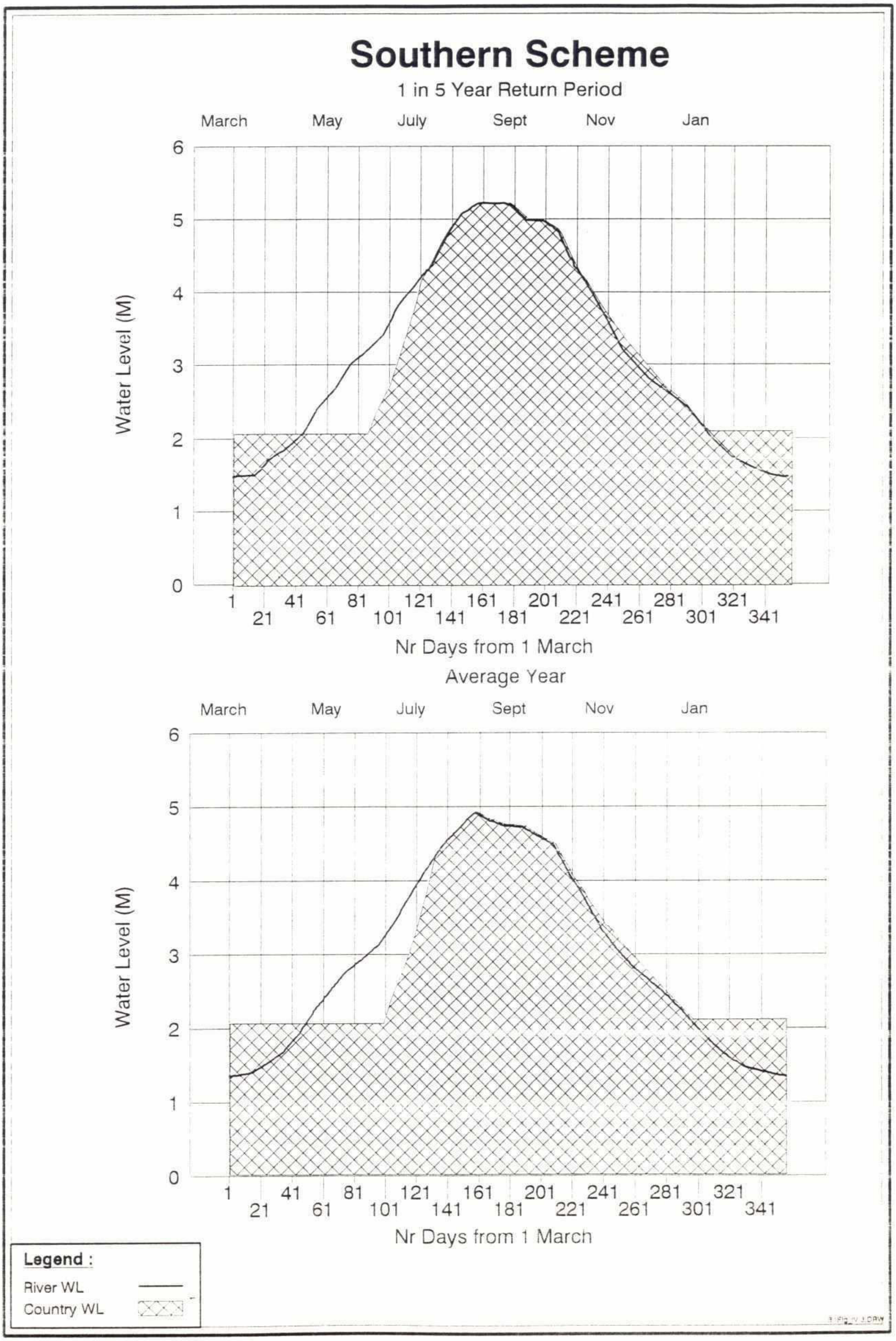
Run Nr	River Hydrograph	Bank top Level	Spillway Invert Level	Spillway Width	Max Rate of Rise	Day Spill Started	Day of Inundation
1	1 in 5 YR RP	4.2 m	3.2 m	3.0 m	9 cm/day	28 May	1 July
2	Average	4.2 m	3.2 m	3.0 m	10 cm/day	9 June	11 July

The parameters were chosen in just the same way as described in section I.V.8. However, in the southern scheme, the retardation of drainage was unacceptable with a gate of dimension 1.0 m x 1.0 m, so the programme results were run with a gate 1.22 m x 1.22 m (4 ft x 4 ft).

The maximum rate of rise is 10 cm per day in this run. This will allow a slightly slower rice variety than that used in the northern scheme.

Figure : IV.3

Hydrographs from the Southern Submersible Embankment Scheme



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References

Ref [1] Civil Engineers Reference Book, 4th Edition, edited by Blake

Ref [2] Practical Problems of Sluice Gate Flow by N. Rajaratnam and K. Subramanya

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APPENDIX I.VI

HYDRAULIC GATES AND OTHER ELECTRO-MECHANICAL PLANT

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APPENDIX I.VI

HYDRAULIC GATES AND OTHER ELECTRO-MECHANICAL PLANT AND EQUIPMENT

1 PREAMBLE

Two pumping stations and a variety of control structures have been conceived in the feasibility design of the Gumti Phase II Sub-Project.

Designs, specifications and feasibility drawings of hydraulic gates, gate hoists, pumps, and other plant and equipment necessary for these structures have been finalised. This report describes the design philosophy adopted for designing these works, their modes of operation, selection of materials and finishes, manufacturing methodology wherever pertinent, and unit cost estimates.

2 DESIGN PHILOSOPHY

Standard gate designs of the BWDB have been suitably adapted wherever possible.

The structures for this project have been designed with small to medium sized vents. Hence, the gates required for the project could be easily manufactured locally and this aspect was given priority when detailing design features.

The recommendations of the following International Standards and standard references have been adopted in the designs of gates and other appurtenant steel structures:

a) Design Supplement Nr 7 to Part 2, Engineering Design, Reclamation Volume X: **Valves, Gates and Steel Conduits,** United States Department of Interior, Bureau of Reclamation. Volume X.

b) Indian Standard 4622-1978: **Recommendations for Structural Design of Fixed Wheel Gates,** Indian Standards Institution.

c) Indian Standard 5620-1968: **Recommendations for Structural Design Criteria for Low Head Gates,** Indian Standards Institution

d) Indian Standard 6938-1973: **Code of Practice for Design of Drum and Chain Hoists for Hydraulic Gates,** Indian Standards Institution.

e) Baumeister, T: **Marks' Standard Handbook for Mechanical Engineers,** McGraw Hill Book Company.

f) Deutsche Normen DIN 19 704-1976: **Hydraulic Steel Structures: Criterion for Design and Calculation,** Deutsches Institut fur Normung.

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The structural layouts of gate leaves were optimised with the main load carrying beams oriented horizontally. They were spaced out vertcally in such a manner that they received equal loads from the triangularly distributed hydrostatic pressure. Loads on the horizontal beams were distributed in the vertical direction by means of two load distribution beams located at one fourth the span from each end. A typical gate leaf is shown in Figure 1. Standard rolled steel angles and T-sections were combined with the skin plate (to the extent permitted by relevant standards) to form economical composite beams. Additional stiffeners were provided wherever deflections of the unsupported skin plate panels were found excessive. In all the gates the skin-plate is designed to be located on the sealing side of the gates.

Moulded rubber seals are manufactured locally to a good standard. Hence, unreinforced rubber J-seals are incorporated in the larger gates while metal-to-metal seals are adopted for the smaller gates. The top and bottom corners of rubber sealing arrangements could be formed by vulcanized joints as indicated in the drawings. However, the more expensive moulded corner joints are recommended for longer seal life.

In all gates the metal seal bars and seats are not specified to be surface machined. The rationale is that (a) the resulting leakage will be of an "acceptable" level, and (b) there are machine tool limitations in Bangladesh.

Multi-stage reduction screw hoists (similar to Armco design) and cable winches are specified since these are manufactured in Bangladesh. Ratchet-and-pawl link-chain hoists of the type shown in Figure 2 or similar are to be provided for small structures wherever removable gate hoists are recommended.

All gates shall be sand-blasted to a standard specification. Gates smaller than 2 m x 2 m shall be pickled and hot-dip galvanized. The larger gates shall be painted with a suitable marine quality paint to an adequate dry film thickness. The final finishes are of utmost importance since proper preventive maintenance measures do not appear to be implemented at existing schemes due to budget constraints.

All exposed parts of embedded structures shall be of stainless steel. All pivot pins of hinged gates shall be machined from stainless steel bar stock. All hinge bearings shall be of a suitable bronze with provision for lubrication except in the case of bottom hinged gates described in Sections 5.4 and 5.5.

All embedded parts are designed and costed for installing in two stages. In the first stage the Civil Contractor is to install pre-embedded parts supplied by the Gate Contractor leaving blockouts for embedded parts. In the second stage, the Gate Contractor is to attach the embedded parts to the pre-embedded parts, align them to the required tolerance, and cast the second stage concrete in the blockouts. Thus, the onus is on the Gate Contractor for ensuring that the embedded parts are properly aligned.

3 SCOPE OF SCHEME

Feasibility of the following hydraulic structures is being considered for the Gumti Phase II Sub-project:

a) Pumping Station No 1 on Jamuna River;
b) Pumping station Nr 2 at Aliabad Crossing near Nabinagar;
c) Drainage and Flushing Regulators;
d) Single and double barrel drainage and flushing sluices;

Figure 1

Typical Gate Leaf Layout

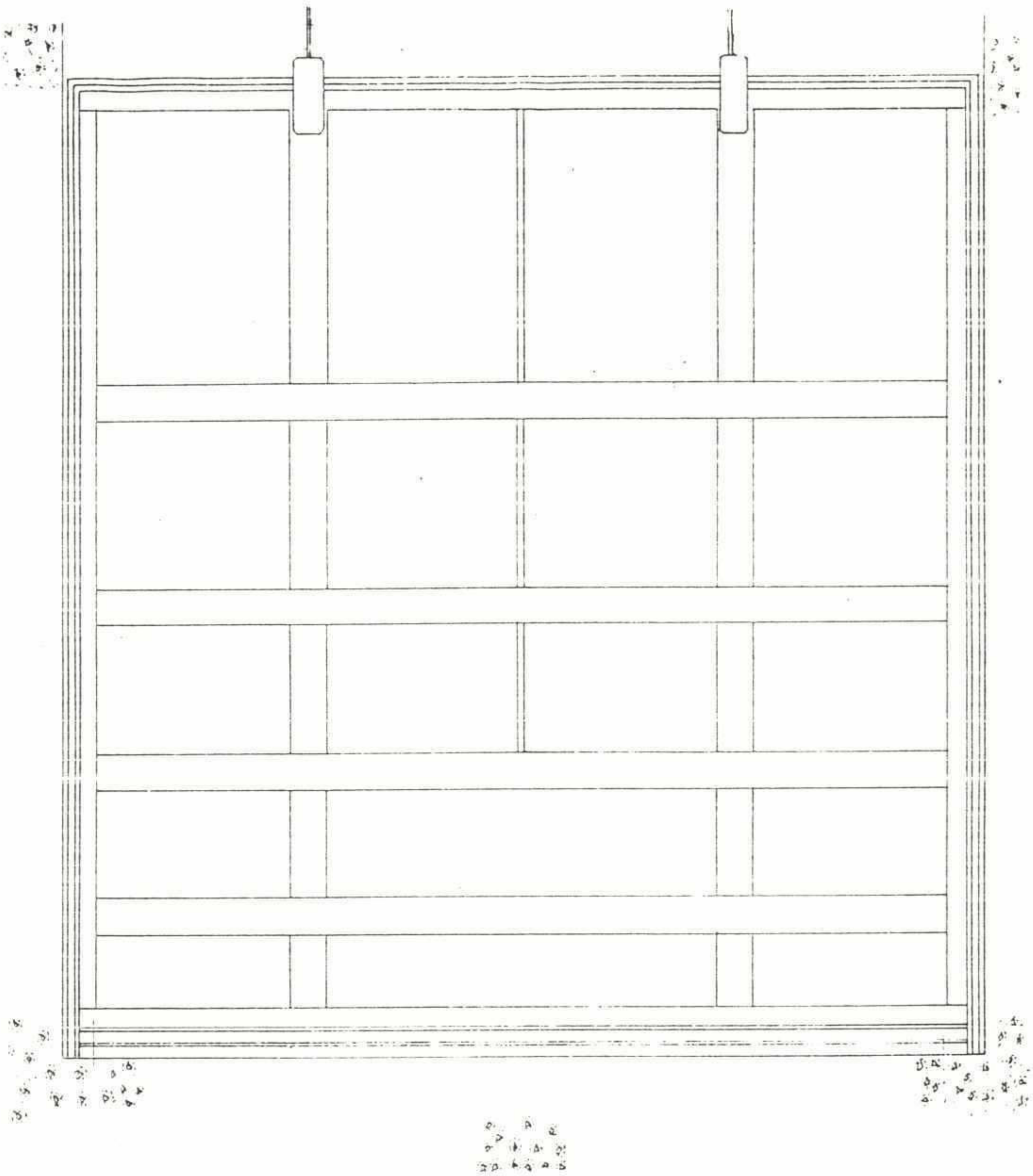
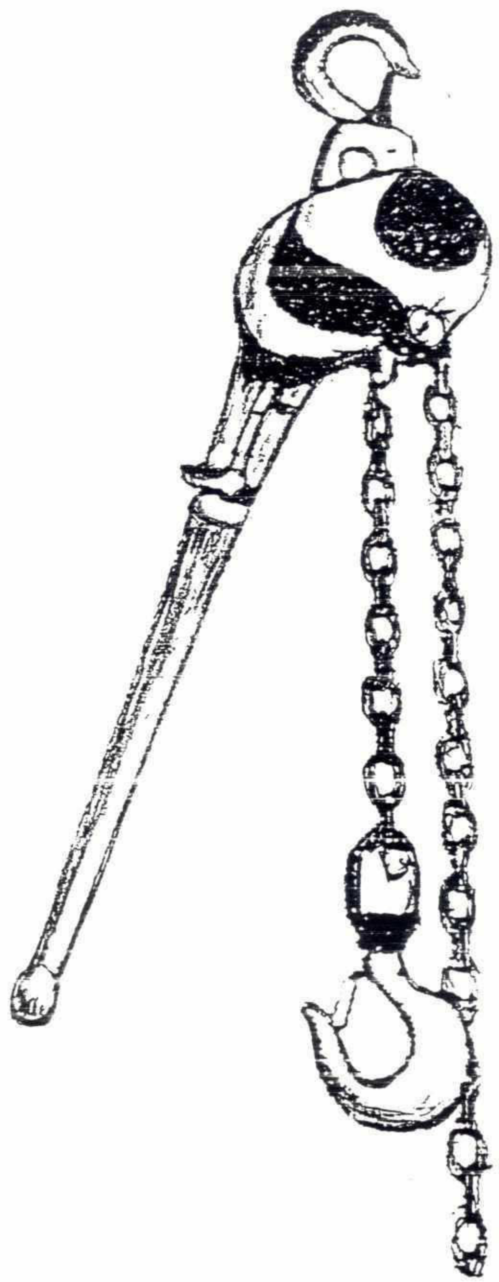


Figure 2
Type of Recommended Hand Hoist



e) Head gate of canal extension;

f) Check Structures with vertical slide gates;

g) Check Structures with collapsible, bottom-hinged gates for navigation convenience; and

h) Fish friendly drainage/flushing regulators.

4 PUMPING STATIONS

Pumps required for both pumping stations were found to be in the axial-flow range. The general layout of the two Pumping Stations designed for the project is shown in the Figure 3. This configuration is essentially the layout proposed in the 1990 Feasibility Study, with some modifications.

The dimensions of the pump suction chamber were sized according to standard practice.

4.1 PUMPS

4.1.1 PUMPING STATION Nr 1

Pumping Station Nr 1 is situated on the River Jamuna, about 500 m south-east from its off-take from the Meghna River, east of Nabinagar.

The pumping requirement of this installation is 7.56 m^3/s against a maximum static head of 3.3 m. This requirement shall be met with three identical pumps (2 to 4 is an economical range). Hence, each pump will have a discharge rate of 2.52 m^3/s.

Assuming the fluid velocity in the pump line to be approximately 2.3 m/s (1.5 to 3.0 m/s is recommended for irrigation and drainage pumping), the pump diameter is fixed at 1.2 m. The corresponding pipe velocity is 2.26 m/s. At this velocity, the total loss in the system is 0.5 m. Thus the total design pumping head works out to be 3.8 m.

With allowances for efficiencies of the pump and electric motor, power factor losses, etc the motor capacity is found to be 140 kW. On this basis, the total power requirement for the pumping station estimated to be 750 kVA.

4.1.2 PUMPING STATION Nr 2

The second pumping station is at the Aliabad Crossing, Nabinagar, on the Pagla River. The layout of this pumping station is identical to the first pumping station.

This installation is designed with 4 axial-flow pumps of 3.65 m^3/s capacity having a total discharge of 14.6 m^3/s. Based on a pump suction line diameter of 1.4 m, the total pumping head is estimated at 5.1 m and the motor capacity is found to be 275 kW.

The total power requirement for the pumping station is estimated at 1 500 kVA.

2×4

4.2 AUXILIARY EQUIPMENT

An overhead travelling crane of 15 tonne capacity is provided for each pumping station. This is required for handling the pumps and motors during installation and for maintenance. Other auxillary equipment includes (a) bilge pumps for de-watering, (b) a mobile gantry crane for lifting the control gates from their slots for maintenance, and (c) a 25 kW three-phase stand-by generator for operating the auxillary equipment and for lighting in case of a power failure.

Pumping Station Nr 2 is to be provided with a well equipped maintenance workshop, which will serve both pump stations.

4.3 HT SWITCHGEAR

In keeping with current standard practice of the BWDB, 3.3 kV electric motors have been selected for the pumps. The estimated capacities of the two sub-stations are given in the Table 1.

Table 1

Power Requirements

Sub-station	Capacity kVA
Pump Station 1	750
Pump Station 2	1 500

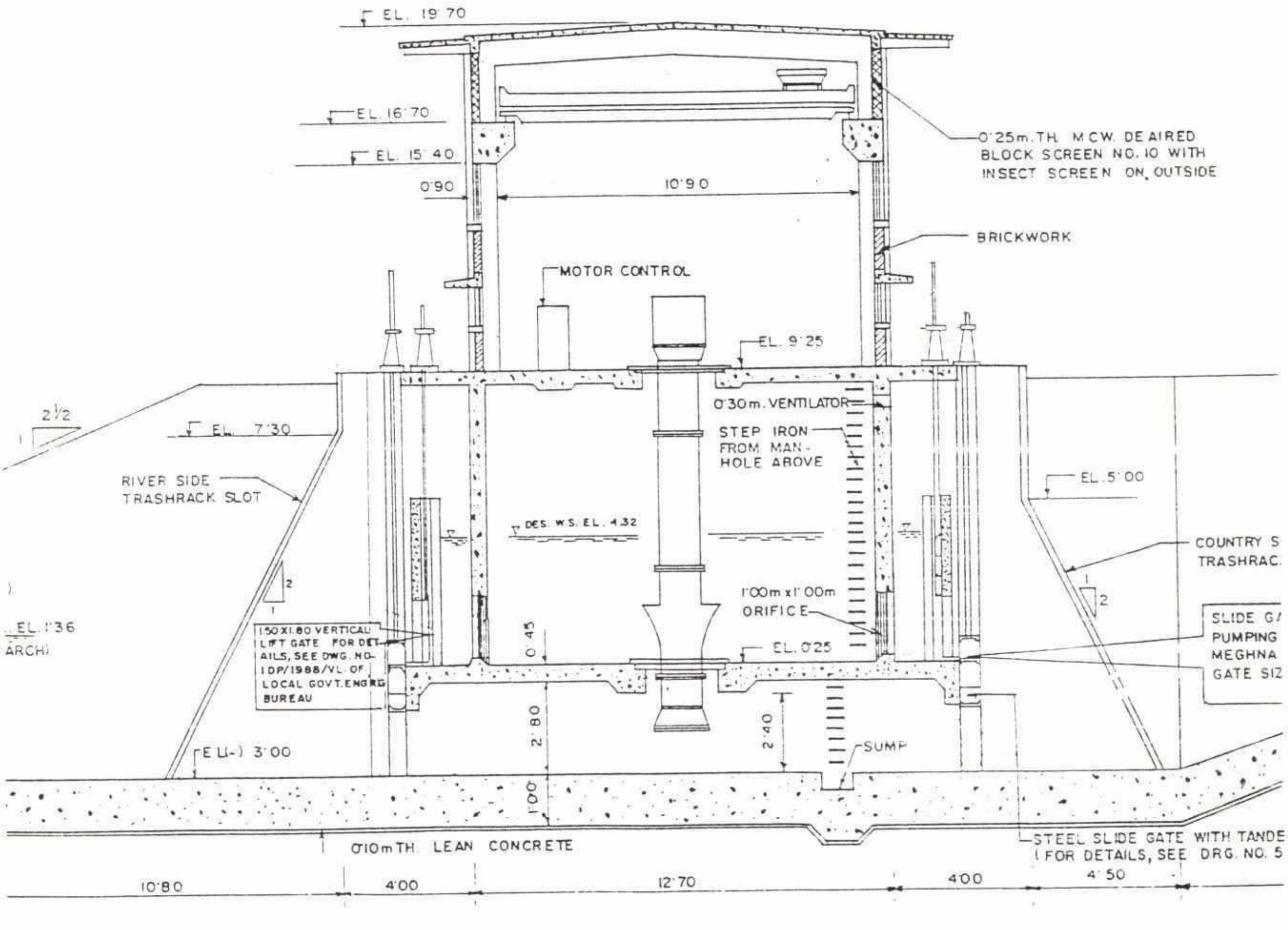
HT sub-stations are required at each pumping station. The closest high tension power supply is at Bancharampur and an estimated total length of 30 km of 33 kV HT line has to be laid to the two pumping stations. Each sub-station shall have a 33kV/3.3kV transformer for supplying the pumps and a 3.3kV/440V transformer for the LT requirements.

4.4 CONTROL GATES

Four sets of slide gates are required at each pumping station. As seen in Figure 3, two sets are needed at the pump inlets for selecting either the country side (for drainage pumping) or the river side (for irrigation pumping), and two sets on the delivery side.

Standard 1.5 m x 1.8 m slide gates of the BWDB design (Drawing Nrs IDP/1988 VL-01 and VL-02) are adopted for the delivery gates of Pumping Station Nr 1. Other vertical lift gates for the pumping stations are of special design. Drawing Nr 5138-M005 shows their structural arrangement, methods of hoisting and sealing. Criteria for their structural design were discussed in Section 2.

Figure 3
Typical Pumping Station Layout



The intake gates are made narrower than the pump sump in order that spanning widths of the gates are kept small. The worst head conditions encountered during irrigation pumping were considered for the design. The design heads along with other parameters are scheduled in the Table 2.

Bronze seal bars on the gate frame bear directly on stainless steel embedded frames. These bars are connected to the gate frame by means of countersunk stainless steel bolts. Sealing is provided by means of moulded, unreinforced, rubber J-seals on all four sides. Details of the sealing arrangement are shown in the Drawing Nr 5138-M003.

Hoisting is by means of two screw hoists fixed at the two ends of the gates to avoid the delivery jets. They are mechanically coupled in tandem as shown in the drawing, so that perfectly synchronised tilt-free lifting is possible. The hoists are motorised with provision for manual operation, if found necessary.

Table 2

Pump House Gates

Station Nr	Vent Size W x H m	Gate Size W x H m	Design Head m	Gate Weight kg	Hoist Cap. kN
1	2.5 x 2.0	2.8 x 2.2	4.0	1,200	200
2	2.8 x 2.5	3.1 x 2.7	5.0	1,600	340

The discharge gates of Pumping Station Nr 2 are similar to the intake gates.

4.5 TRASH RACKS AND RAKES

Inclined trash racks provide protection for both inlets to the pumping station to exclude debris from entering the suction chamber. In addition, a simple floating debris collector is to be installed on both sides of the pumping station.

The trash racks are inclined at 26 degrees to the vertical. Their estimated weights are given in the Table 3.

2fn

Table 3

Trash Racks

Station Nr	Area of Racks m^2	Estimated Weight kg
1	210	35
2	323	55

Trash removal will be carried out manually and no mechanical means is provided.

5 CONTROL STRUCTURES

Control structures include drainage cum flushing regulators, drainage regulator with flume, drainage cum flushing sluices, headgate for canal extension, and check structures of various configurations.

Although tidal effects in the project area are not very significant, top-hinged flap gates were originally considered for several options, although they have now been omitted.

Inland fisheries is recognized as an important industry and special consideration has been given to designing structures with "fish-friendly" gates.

5.1 CRITERIA FOR FISH FRIENDLY GATES

Fish are said migrate into the polders during the months of May and June. The small fish fry are also supposed to swim only along the two banks, and very close to the surface. Hence, there must be free flow through the outer vents of control structures during the fish migration period to make the structures fish-friendly.

Several structures have been designed with the gates on the two extreme sides taller than the centre gates to ensure free-flow through them during May and June. Both vertical lift and bottom-hinged gates have been designed for these side vents. In the event, only the bottom hinged gates have been adopted in "fish-friendly" structures.

Even top-hinged flap gates (especially the balanced-type) when discharging under free-flow conditions would be fish-friendly if the wing walls were to be sharply flared out immediately downstream of the gates so that the migrating fish swimming along the banks could get through the gap between the wing wall and the partially open flap gate.

5.2 FLAP GATES

Flap gates in several sizes have been designed for the project, although in the event none have been incorporated. All are of the balanced type where approximately 80% of the weight of the gate leaf is counter-balanced with pre-cast concrete kentledge. With this degree of counter-balancing, a 3m x 3m gate, for instance, would begin to open under a static head difference as small as 75 mm.

Figure 4 depicts a typical arrangement of a balanced flap gate. Details of the structural layout, sealing, and the hinges are given in Drawings Nrs 5138-M001 and 5138-M006.

For proper seating of all flap gates, a double hinge arrangement has been provided. The main pivot action is about the upper hinges marked A in the Figure 4. Limited flexibility when seating is provided by the bottom hinges marked B.

The sealing arrangement for the smaller flap gates up to but excluding 2 m x 2 m nominal size is with metal-to-metal sealing. The seal bars shall be in bronze and they seal against embedded stainless steel seats. The leakage that would arise from seating of un-machined metal surfaces is recognized to be acceptable.

In the case of the larger gates (2 m x 2 m and above), better sealing is achieved with moulded rubber J-seals.

The arms of the flap gate are aligned with their bottom hinges B mounted on the vertical distribution beams of the gate. They are extended beyond the upper hinges A as seen in the Figure 4, and counter-balanced so that the weight of the gate is partially balanced. With 80% counter-balancing the system could be adjusted for the gate to open under a static head difference as low as 75 mm.

The counter balance weights are pre-cast concrete slabs. The system is designed so that the balance weights could be assembled and adjusted with the gate leaf lifted up to its limit, in the horizontal position. The weights could be moved on the arms until the desired balance is achieved and clamped into position. After this once-and-for-all operation steel limits are welded to the arms.

By inclining the barrel face (along with the embedded seal seat), the gate leaf is given a small inclination (1 in 15) so that a positive closing moment is built into the system. This feature is especially important in tidal zones. It must be appreciated that the resulting effect would be negated by perfect counter-balancing of the gate leaf. Hence, a reasonable out of balance moment (20% is suggested) should be maintained as a compromise. Furthermore, the position of the centre of gravity of the counterweight could be so adjusted as to give a positive closing moment when the gate is in its fully closed position but offers counter-balanced operation as soon as the gate is opened.

With the gate properly balanced, the effort required to raise it will be quite small. In the case of the smaller flap gates this could be done even by one man without mechanical assistance. For the larger gates (2 m x 2 m and above), a simple ratchet-and-pawl type chain hoist would be adequate for a single operator to manually raise the gate and lock it into position.

Figure 4

Arrangement of Balanced Flap Gate

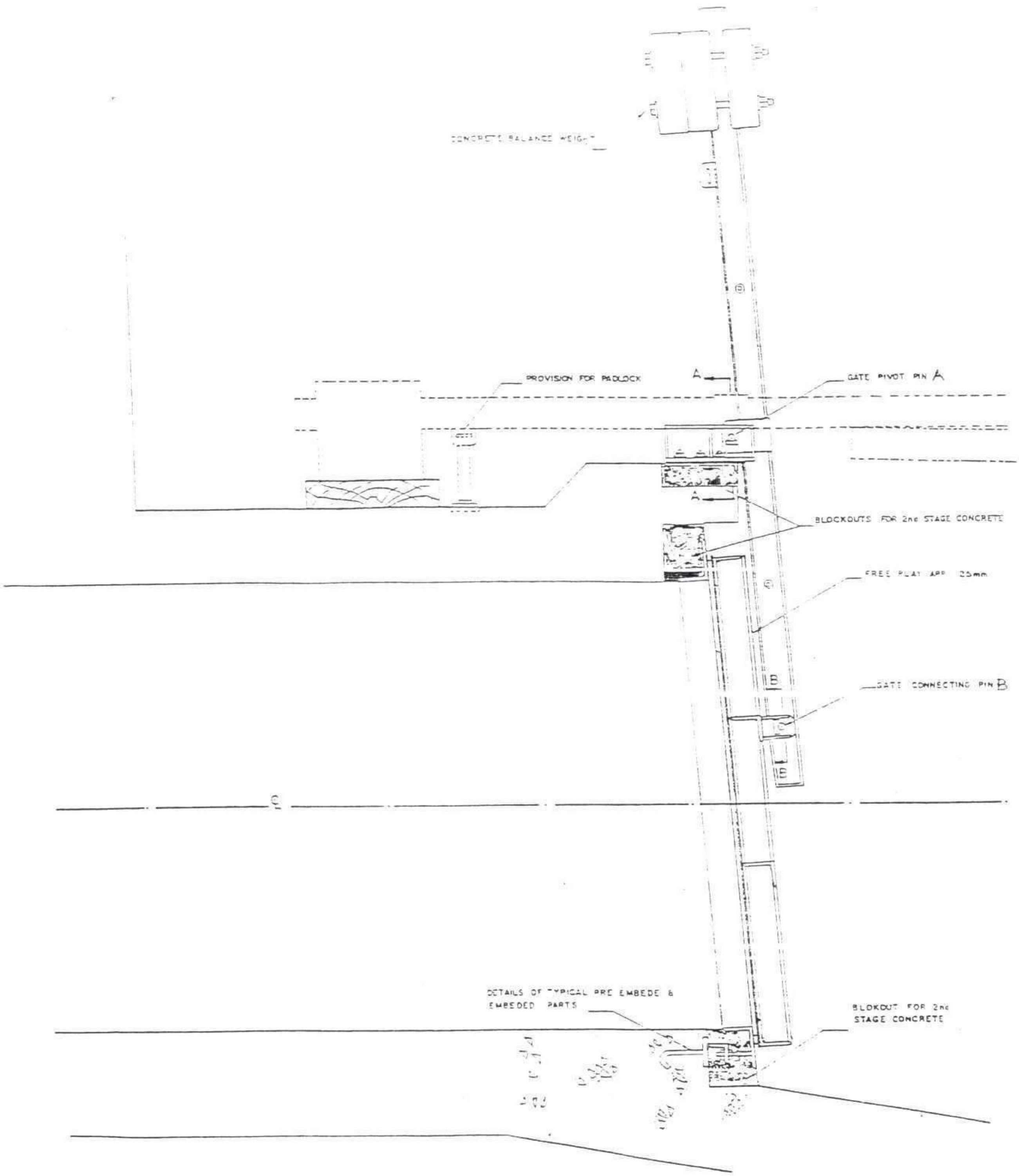


Table 4 gives the relevant information pertaining to all flap gates designed for the project.

Table 4

Sizes of Flap Gates

Gate Size W x H m	Weight kg
1.0 x 1.0	230
1.5 x 1.5	435
1.5 x 1.8	590
2.0 x 2.0	680
3.0 x 3.0	1,690
3.0 x 3.5	1.900

The structural design of gate leaves was carried out as described in Section 2.

5.3 SLIDE GATES

Outfall regulators requiring slide gates on the country side have been designed to fit the standard BWDB slide gate size of 1.52 m x 1.82 m (Drawing Nrs IDP/1988 VL-01 and VL-02). The standard single screw hand hoists are provided for oprating these gates. This size is typically used in Drainage and Flushing Sluices and the Chute Drop in Zone C.

Two sizes of vertical lift gates have been designed for fish friendly Drainage cum Flushing Sluices. In the first type the inner vents are gated with 3.0 m x 3.0 m slide gates while the outer gates are bottom hinged and close upward with weir flow (see Section 5.4).

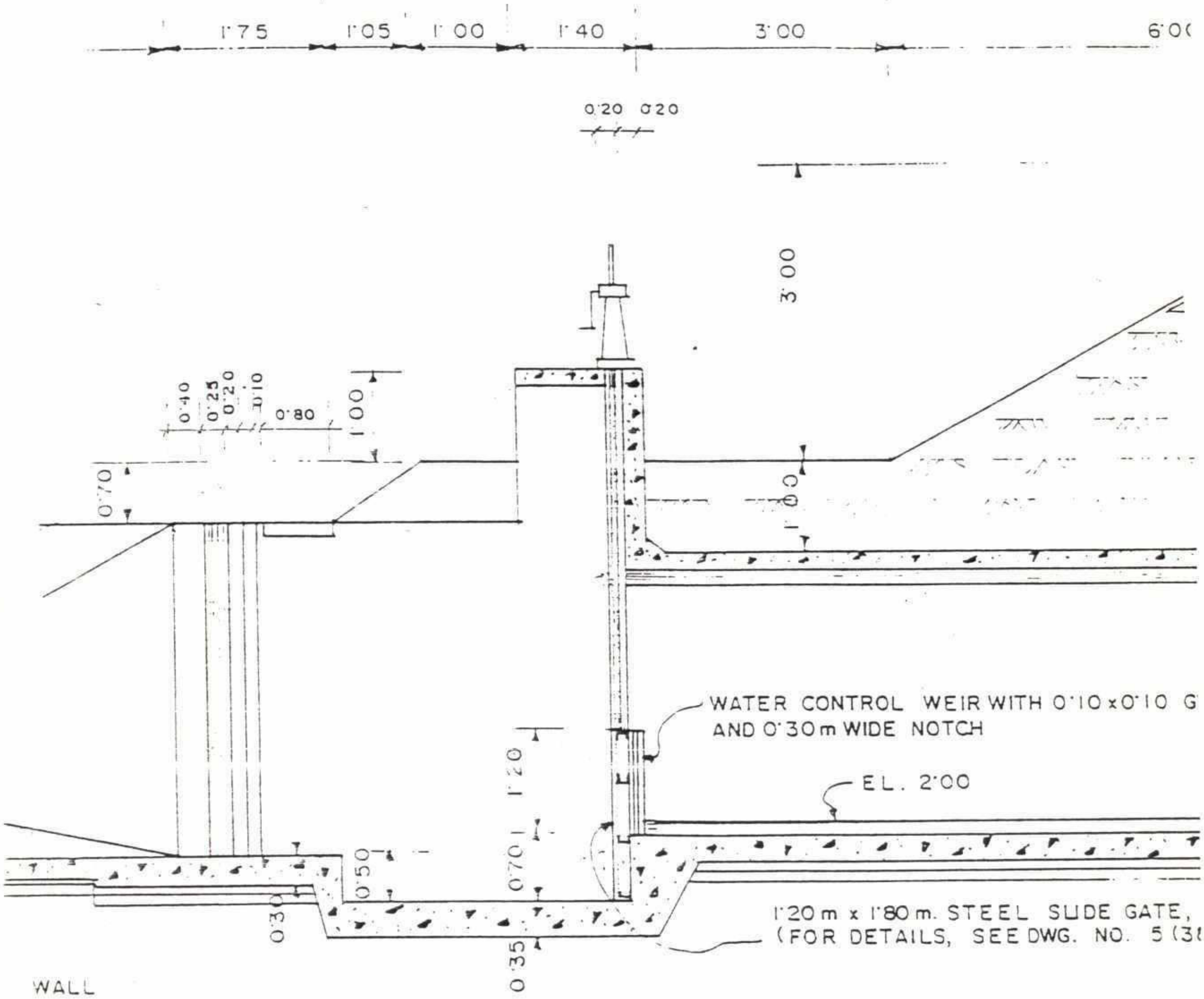
The second type of structure is provided with two vents, each 1.2 m x 1.8 m, with slide gates closing upward against a weir flow as shown in the Figure 5. This type of structure was not in the event adopted in any of the proposals.

The 3.0 m x 3.0 m slide gates are estimated to weigh 1.550 kg and are provided with double drum type, manually operated cable hoists as shown in Drawing Nr 5138-M004. The 1.2 m x 1.8 m gate is estimated to weigh 390 kg. This size of gate is provided with a simple screw and hand wheel for operation.

The larger gate is designed with moulded rubber J-seals while the smaller gate is to have only a metal-to-metal seal bar.

Figure 5

Small Slide Gates for Weir Flow



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The configu ration of the smaller gate is considered fish friendly since the conditions discussed in Section 5.1 are met.

5.4 BOTTOM HINGED GATES FOR NAVIGATION STRUCTURES

Canal check structures are required at several locations in Zone C. A specification for two structures is that the khal must be navigable by small country boats during the pre-monsoon period. A navigation lock is not feasible. A simple vertical lift gate arrangement is also not economical since a very tall structure would be required to lift the gates above high flood level. Hence, a bottom hinged gate has been designed with considerable economy.

The gate opening is 3m wide which is adequate for country boats to ply the khal without hindrance at the structure. Markers mounted on the piers and protruding above high water level will act as beacons to boats when the structure is submerged later in the monsoon season. The arrangement of the structure and design details of the gate are shown in Drawing Nr 5138-M002.

The gate is raised and lowered by means of two ratchet-and-pawl type link-chain hand hoists mounted on the two piers as shown in Figure 6. Two hoisting cables are permanently fixed to the top corners of the gate, labelled A in the figure. The lengths of these cables are such that the ends B would clear the top of the guide walls and could be kept hooked onto the side walls at point C. When the gate is to be raised, the cables are unhooked from the wall and coupled to the chain hoist. The hoists are then hung on the piers at points D and the gates are ratcheted up. The gates are thereafter locked in the raised position, the chain hoists removed from the piers, and the lifting cables re-hooked to the guide walls at point E. The gates are lowered after the harvesting period is over in preparation for the monsoon period. Navigation activities would begin at this stage. A reverse sequence of operations is adopted for lowering the gates. Since there is no walkway across the structure on account of navigation requirements, the structure has to be approached by boat for gate operations.

The gate leaf is designed for a maximum head difference equal to the height of the gate opening (2 m). The structural design was carried out as described in Section 2.

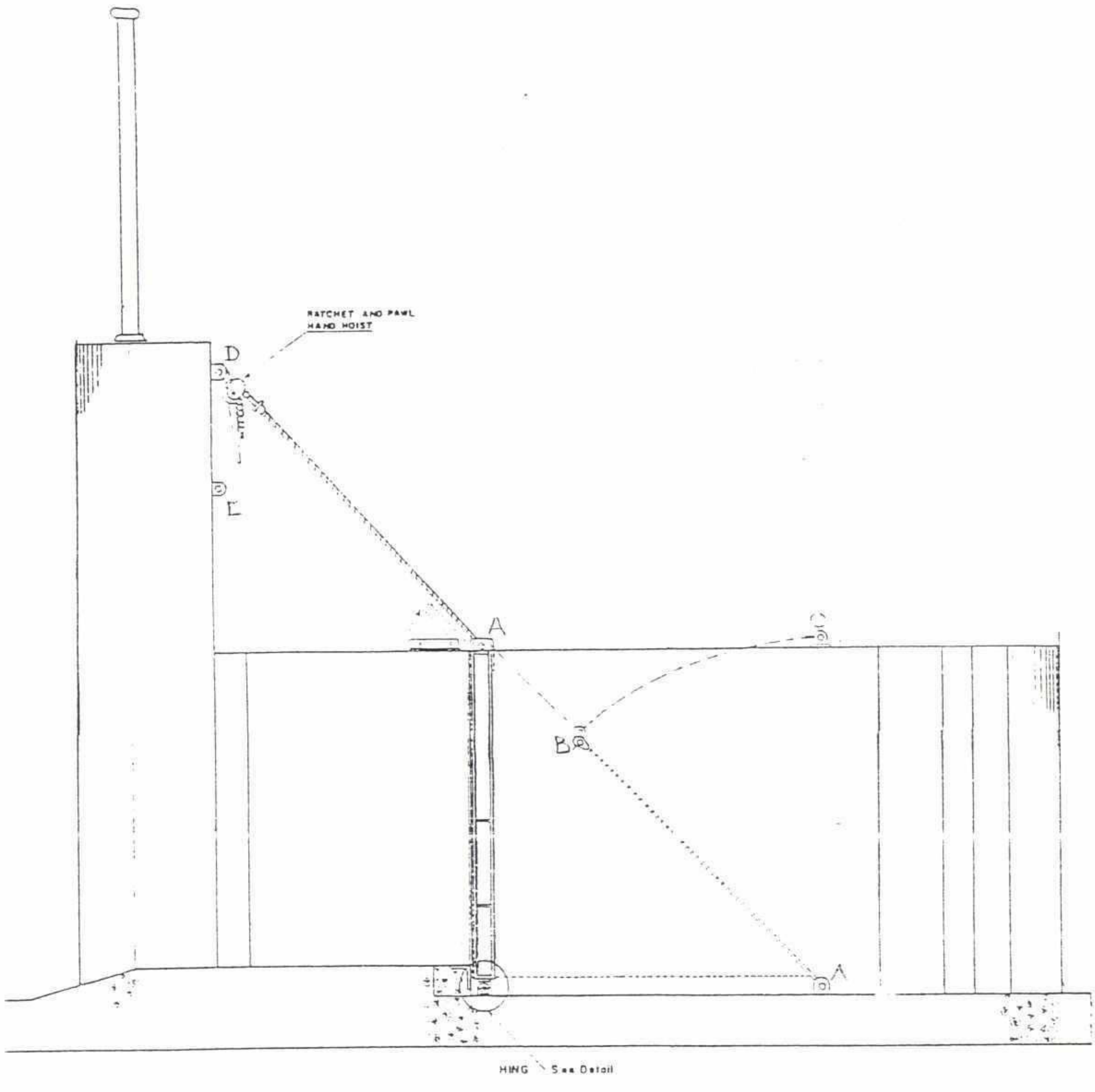
Both parts of the hinge assemblies are designed in cast iron. The bearings will be machined cast iron surfaces and the pins machined from stainless steel bar stock. The bearings will be lubricated with water. With these gates being operated only twice a year, the bearing assemblies are expected to last the lifetime of the gate.

The side seals are designed with metal-to-metal seating since the attendent level of leakage is regarded as acceptable.

5.5 BOTTOM HINGED GATES FOR FISH FRIENDLY STRUCTURES

A special Drainage cum Flushing Regulator has been designed for areas where fish migration into the polder during the pre-monsoon period is considered important. The typical structure has three vents with a 3 m x 3 m vertical lift gate for the centre vent as described in Section 5.3, and two 3.0 m x 3.5 m, bottom hinged collapsible gates (Ref. Drawing Nr 5138-M005) for the side vents. Different numbers of vents may however be specified, provided that the outer vents are bottom hinged.

Figure 6
Collapsible Gates for Navigation



SECTION- A-A

A requirement that would be met by this gated structure is that the two side gates could be gradually closed during the pre-monsoon period maintaining a head of only 20-30 cm in the weir flow, allowing fish to move but without admitting excessive flood water. The vents are tall enough to permit free flow throughout the critical (for fish movement) months of May and June.

The structural layout of the bottom hinged gate is similar to the navigation gate discussed in Section 5.4, except in the following details:

a Moulded rubber J-seals are provided on all four sides since adverse head conditions are met during both seasons;

b The gate is maintained in the closed position with the gate leaf inclined to the vertical by approximately 10 degrees so that the gate can be opened easily;

c The bottom hinges are placed off-centre in order to maintain the same level in the vent when the gate is fully open (lowered); and

d A more robust hoisting arrangement is provided fo controlled lifting of the gate and maintaining an adequate closing force during the monsoon period.

6 CONCLUSION

Feasibility design drawings have been prepared for the various gates designed for this project. These are:

a Drawing Nr 5138-M001: Balanced Flap Gates (Small);

b Drawing Nr 5138-M002: Collapsible Navigation Gate;

c Drawing Nr 5138-M003: Steel Gates for Pumping Stations;

d Drawing Nr 5138-M004: Slide Gates for Control Structures;

e Drawing Nr 5138-M005: Collapsible Gates for Control Structures; and

f Drawing Nr 5138-M006: Flap Gates for Control Structures.

A3 size reproductions of the drawings are included at the end of this Appendix.

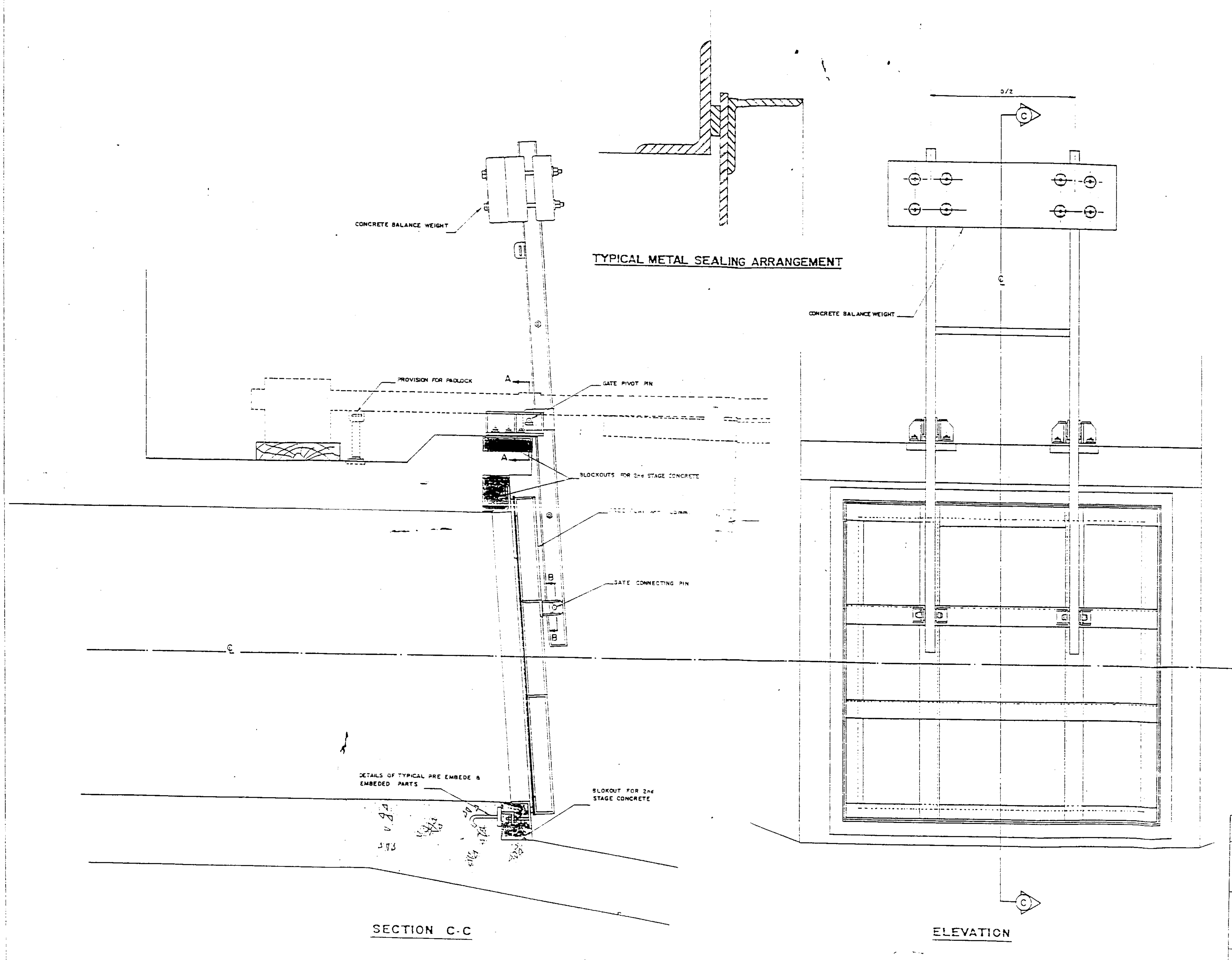
Unit cost estimates of the gates, miscellaneous steel structural works, and pump station requirements are given in Table 5.

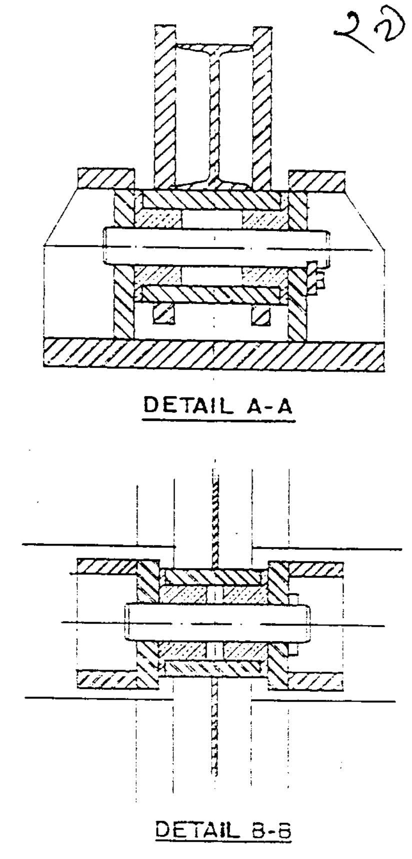
2027

TABLE 5

Unit Rates for Electrical and Mechanical Equipment

Item	Description	Unit	Unit rate Tk 000
1	Axial flow pump of 2.52 m^3/s @ 3.8 m capacity for P.S. Nr 1	Nr	13 657
2	Auxiliary equipment for Pump Station Nr 1	Item	5 000
3	Trash racks for Pump Station Nr 1	Item	3 500
4	HT Transformer station with switch gears for P.S. Nr 1	Nr	5 000
5	Axial flow pump of 3.65 m^3/s @ 5.1 m capacity for P.S. Nr 2	Nr	22 844
6	Auxiliary equipment for Pump Station Nr 2	Item	7 500
7	Trash racks for Pump Station Nr 2	Item	5 500
8	HT Transformer Station with Switch gears for P.S. Nr 2	Item	7 500
9	1.0 m x 1.0 m flap gate with embedded parts	Nr	15
10	1.5 m x 1.5 m flap gate with embedded parts	Nr	30
11	2.0 m x 2.0 m flap gate with embedded parts	Nr	56
12	3.0 m x 3.0 m flap gate with embedded parts and hand hoist	Nr	165
13	3.0 m x 3.5 m flap gate with embedded parts and hand hoist	Nr	183
14	1.52 m x 1.82 m slide gate with embedded parts and hand hoist	Nr	80
15	1.5 m x 3.0 m slide gate with embedded parts and hand hoist	Nr	100
16	2.5 m x 2.0 m slide gate with embedded parts and hand hoist	Nr	110
17	2.8 m x 2.5 m slide gate with embedded parts and hand hoist	Nr	140
18	3.0 m x 3.0 m slide gate with embedded parts and hand hoist	Nr	160
19	3.0 m x 2.0 m hinged gate with embedded parts and hand hoist	Nr	63
20	3.0 m x 3.5 m hinged gate with embedded parts and hand hoist	Nr	185





[illegible] M	[illegible] GATE M	SEAL	WEIGHT Kg	DEVICE
1·00 x 1·00	1·20 x 1·20	METAL	230	MANUAL
1·50 x 1·50	1·70 x 1·70	METAL	435	MANUAL
2·00 x 2·00	2·20 x 2·20	METAL	680	MANUAL

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GUMTI PHASE II SUB-PROJECT

BALANCED FLAP GATE FOR DRAINAGE REGULATORS AND SLUICES

MOTT MACDONALD LTD. UK.
NIPPON KOEI CO. LTD. JAPAN
HOUSE OF CONSULTANTS LTD. BANGLADESH
DESH UPODESH LTD. BANGLADESH

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CHECKED	[signatures]	DRAWING NO.
DATE	[illegible]-04-93	5138 - M001

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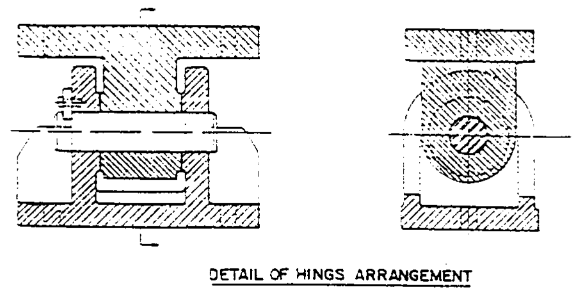

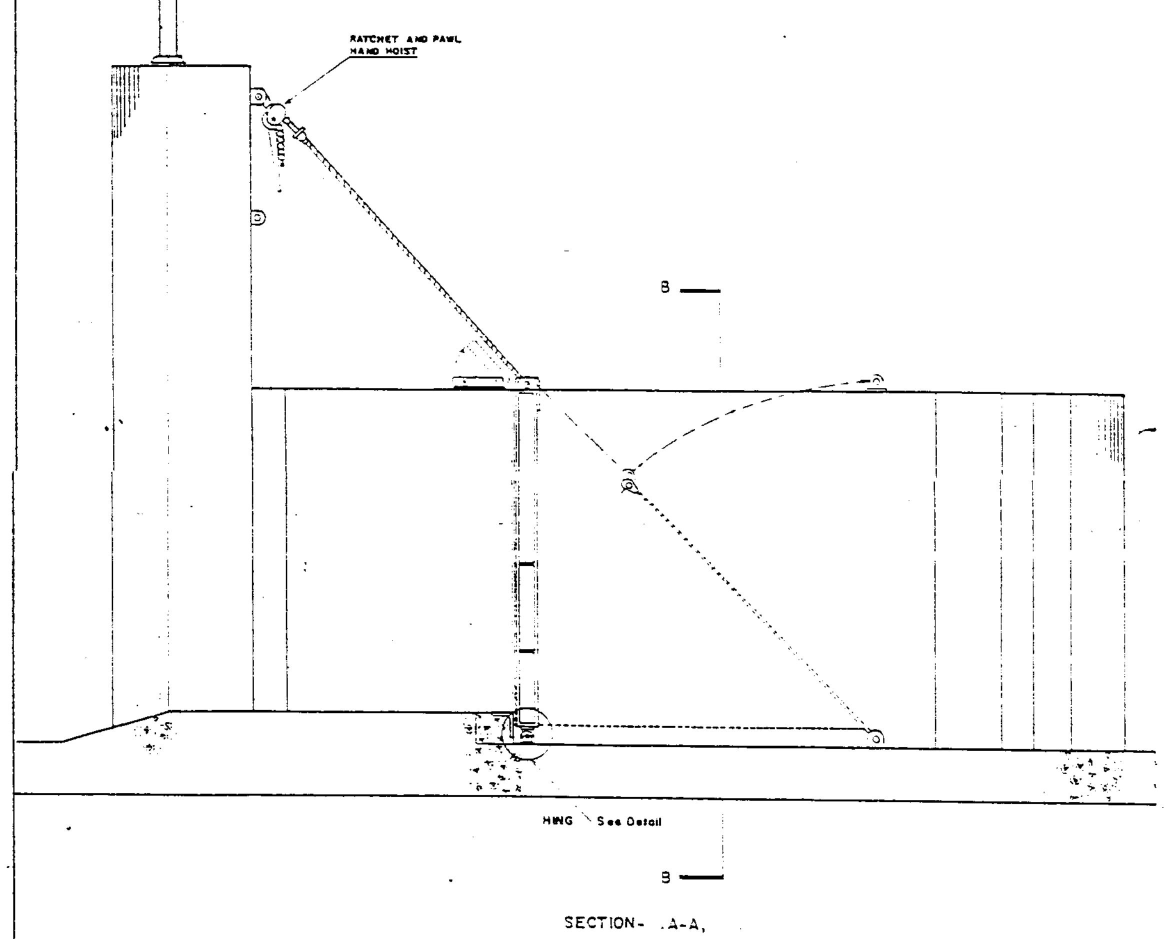

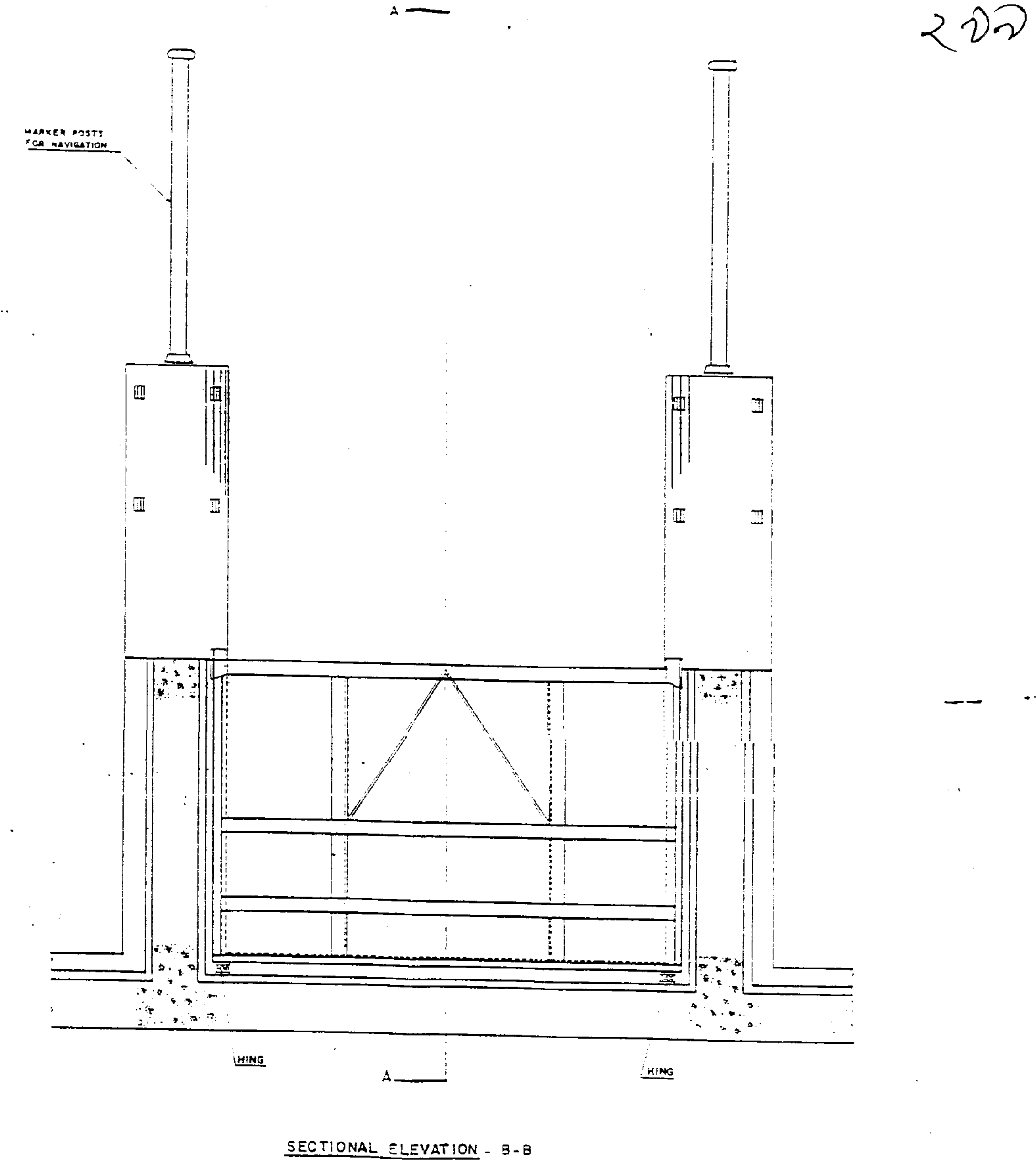

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GUMTI PHASE II SUB-PROJECT

COLLAPSIBLE NAVIGATION GATE

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HOUSE OF CONSULTANTS LTD. BANGLADESH
DESH UPODESH LTD. BANGLADESH

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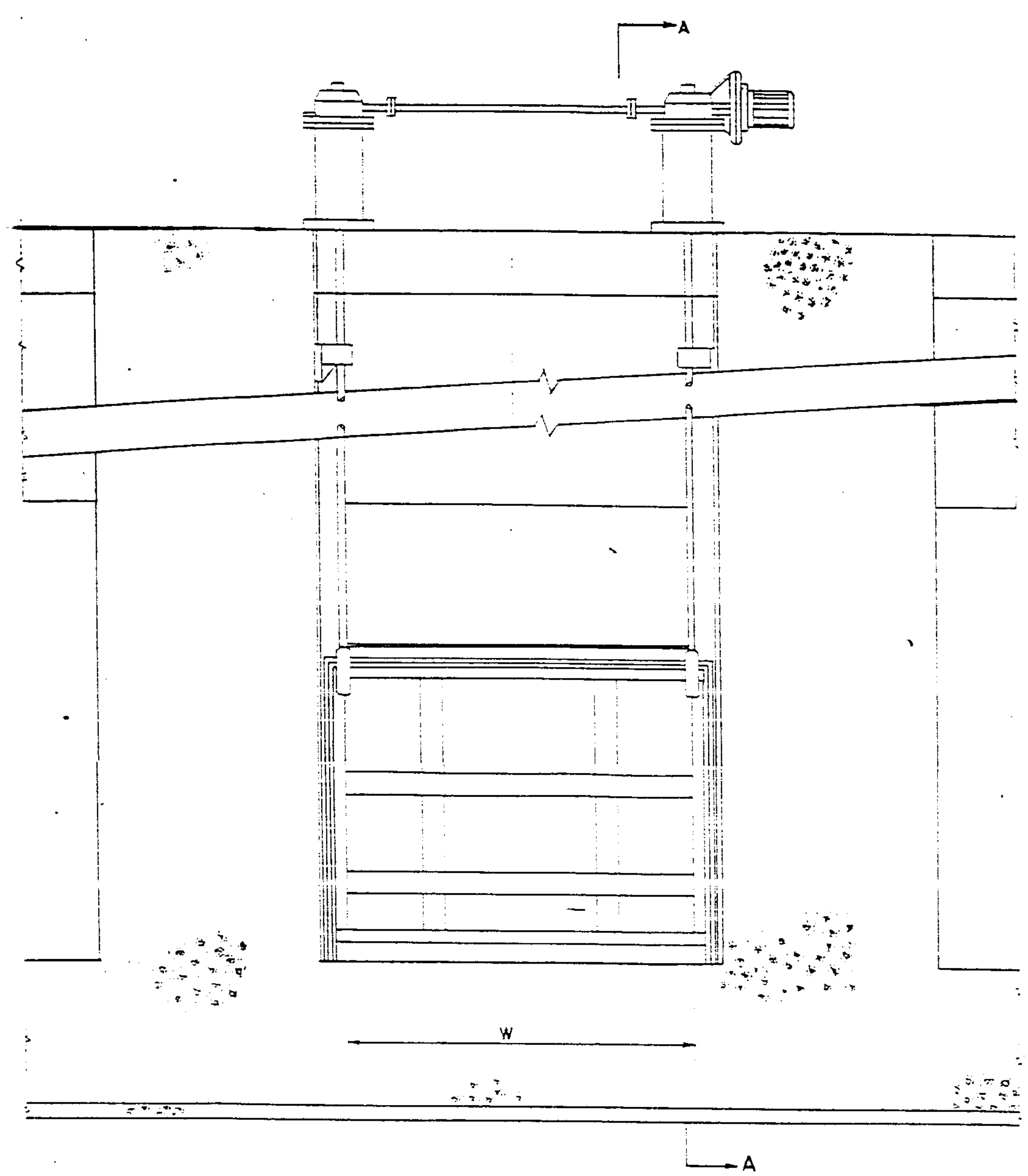
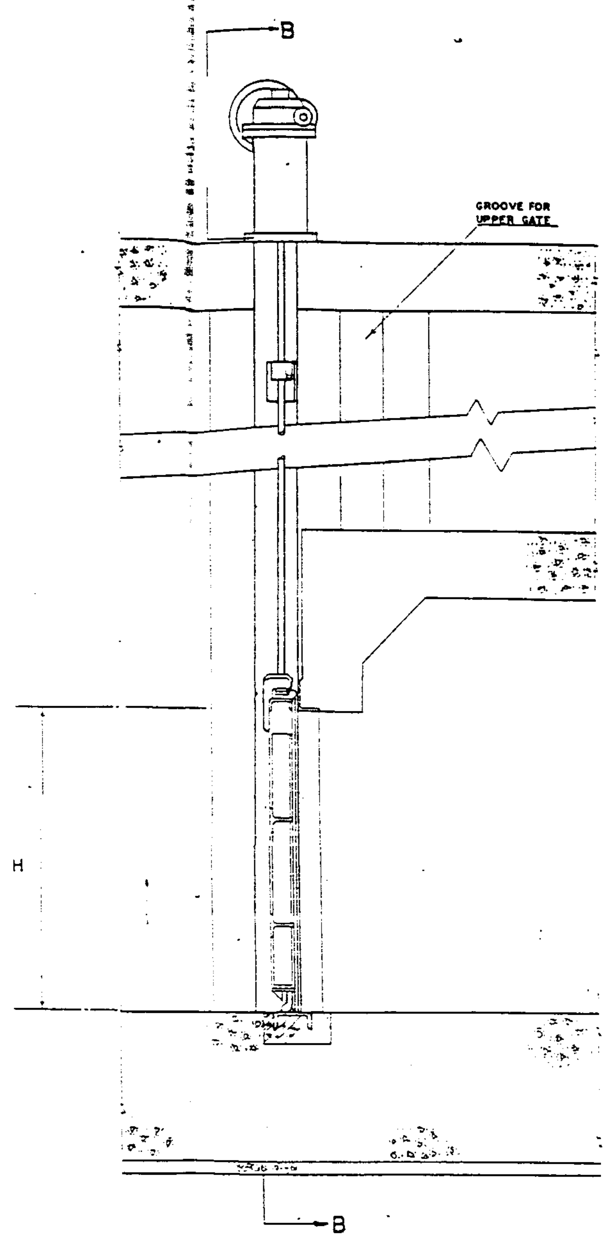
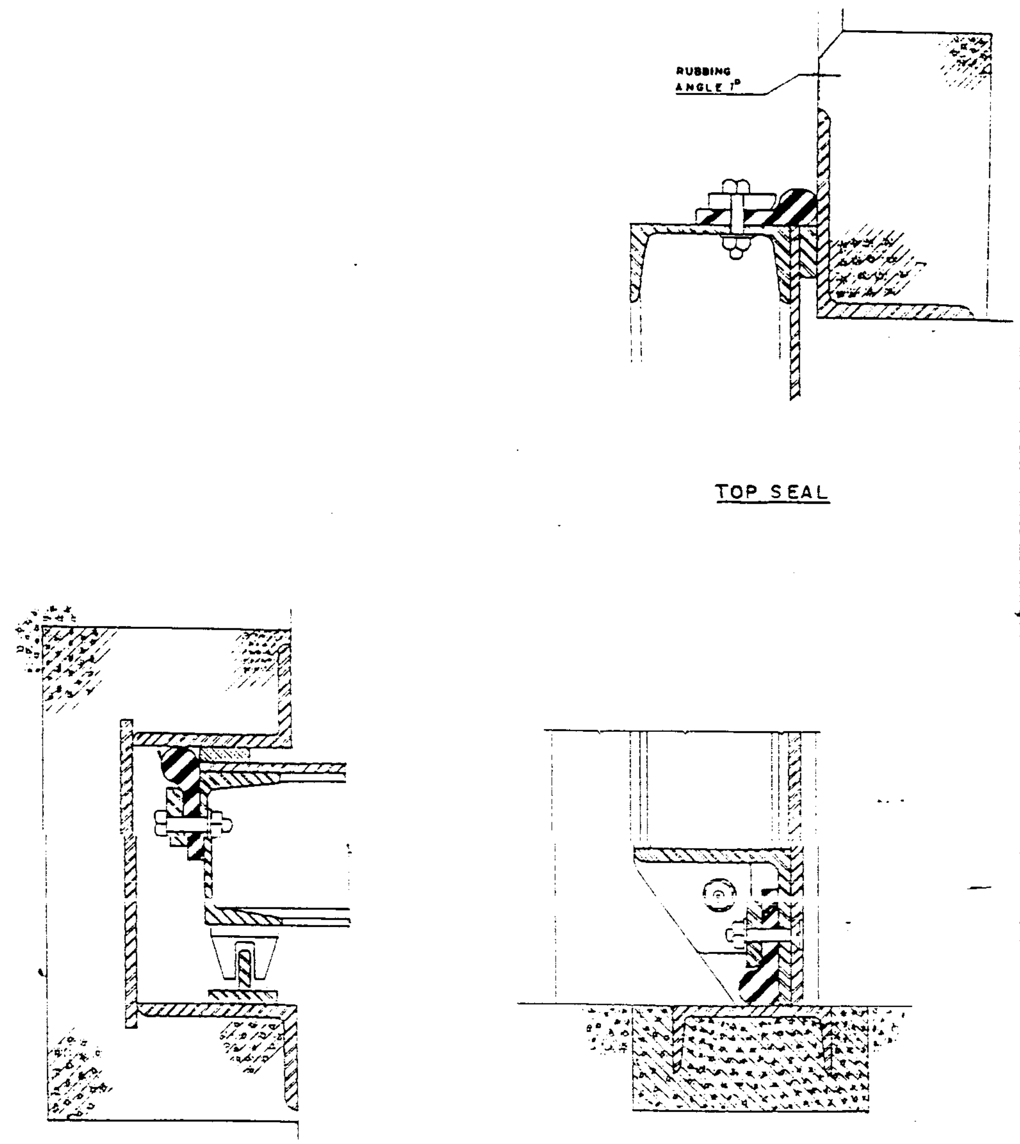


SECTION A-A



SECTION B-B

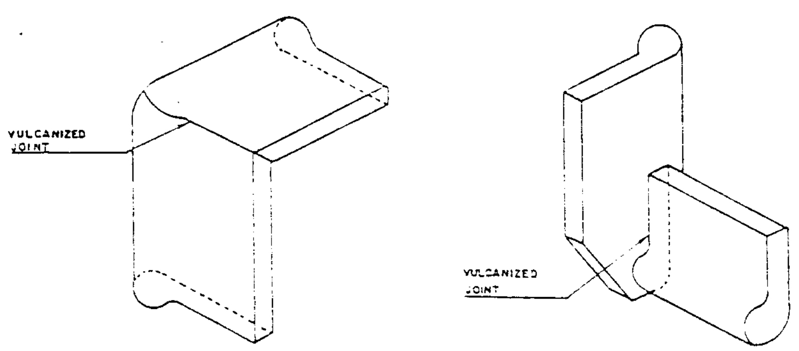


TOP SEAL

SIDE SEAL

BOTTOM (SILL) SEAL

SEALING ARRANGEMENTS



TOP CORNER

BOTTOM CORNER

RUBBER SEAL CORNER ARRANGEMENTS

GATE OPENING W X H M.	GATE SIZE W X H M	ESTIMATED HOIST CAPACITY KN	ESTIMATED WEIGHT KG
2.5 x 2.0	2.8X2.2	200	,200
2.8 x 2.5	3.1 X 2.7	340	1,500

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GUMTI PHASE II SUB-PROJECT SLIDE GATE ARRANGEMENT FOR PUMPING STATIONS	
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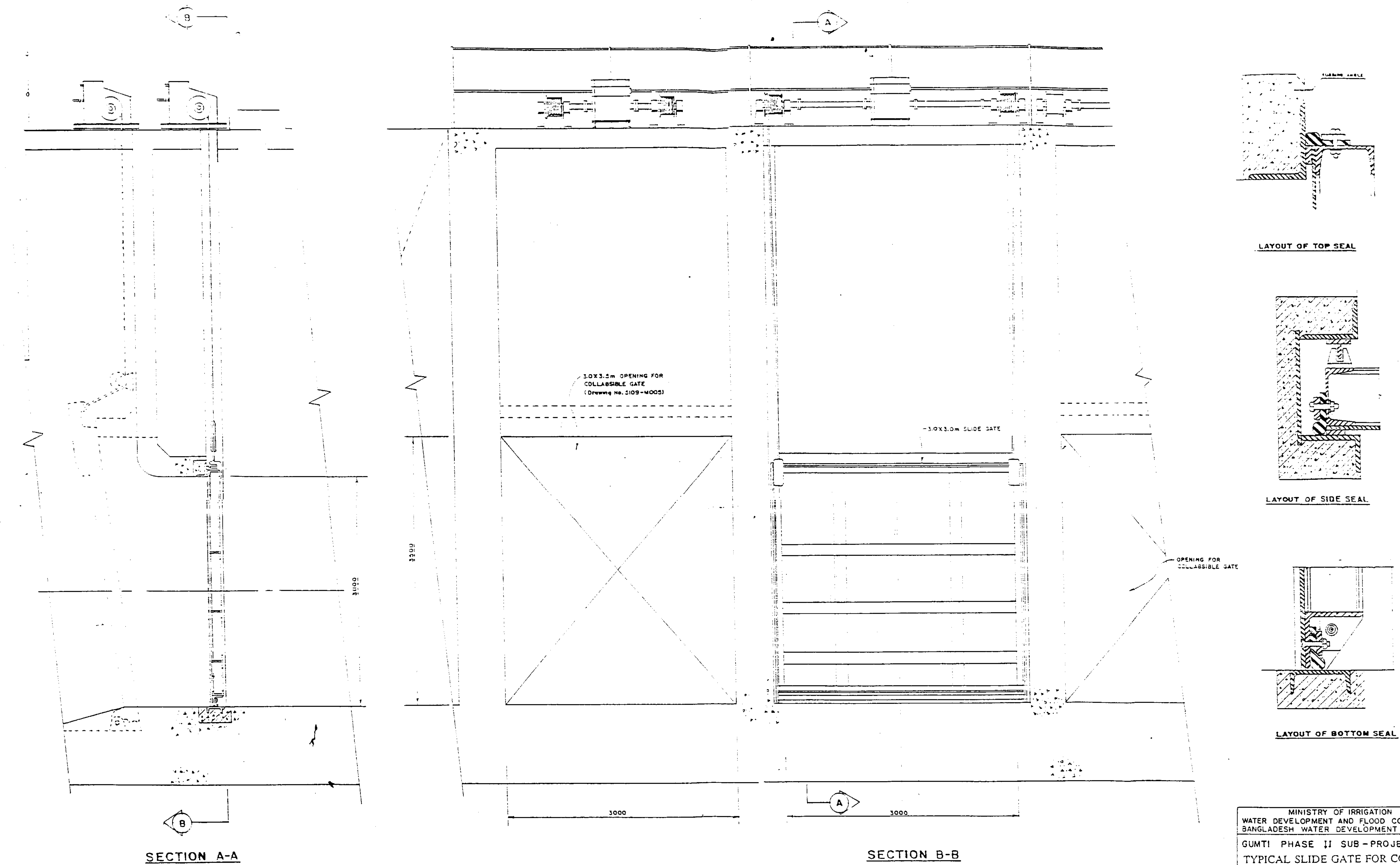

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GUMTI PHASE II SUB-PROJECT

TYPICAL SLIDE GATE FOR CONTROL STRUCTURES

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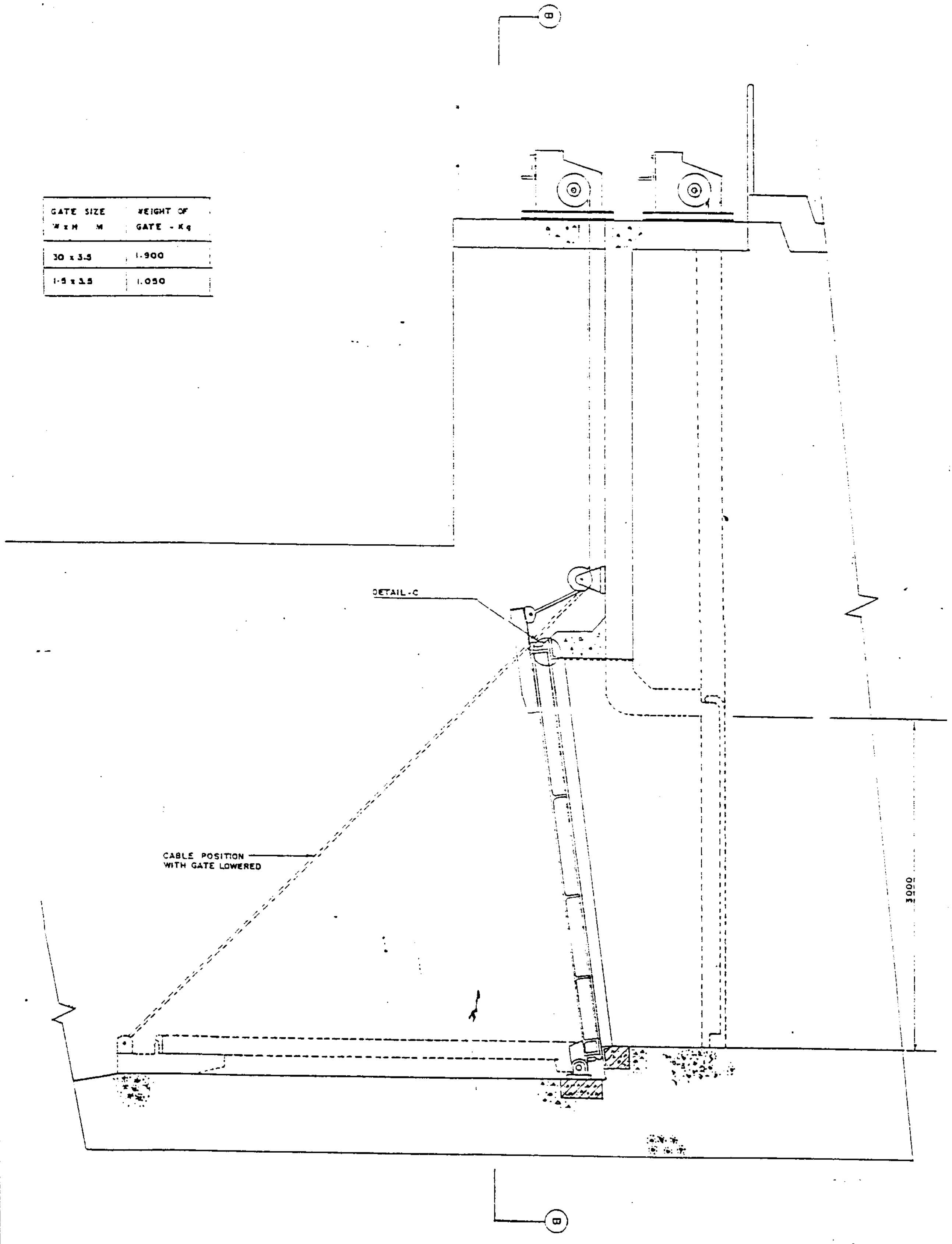
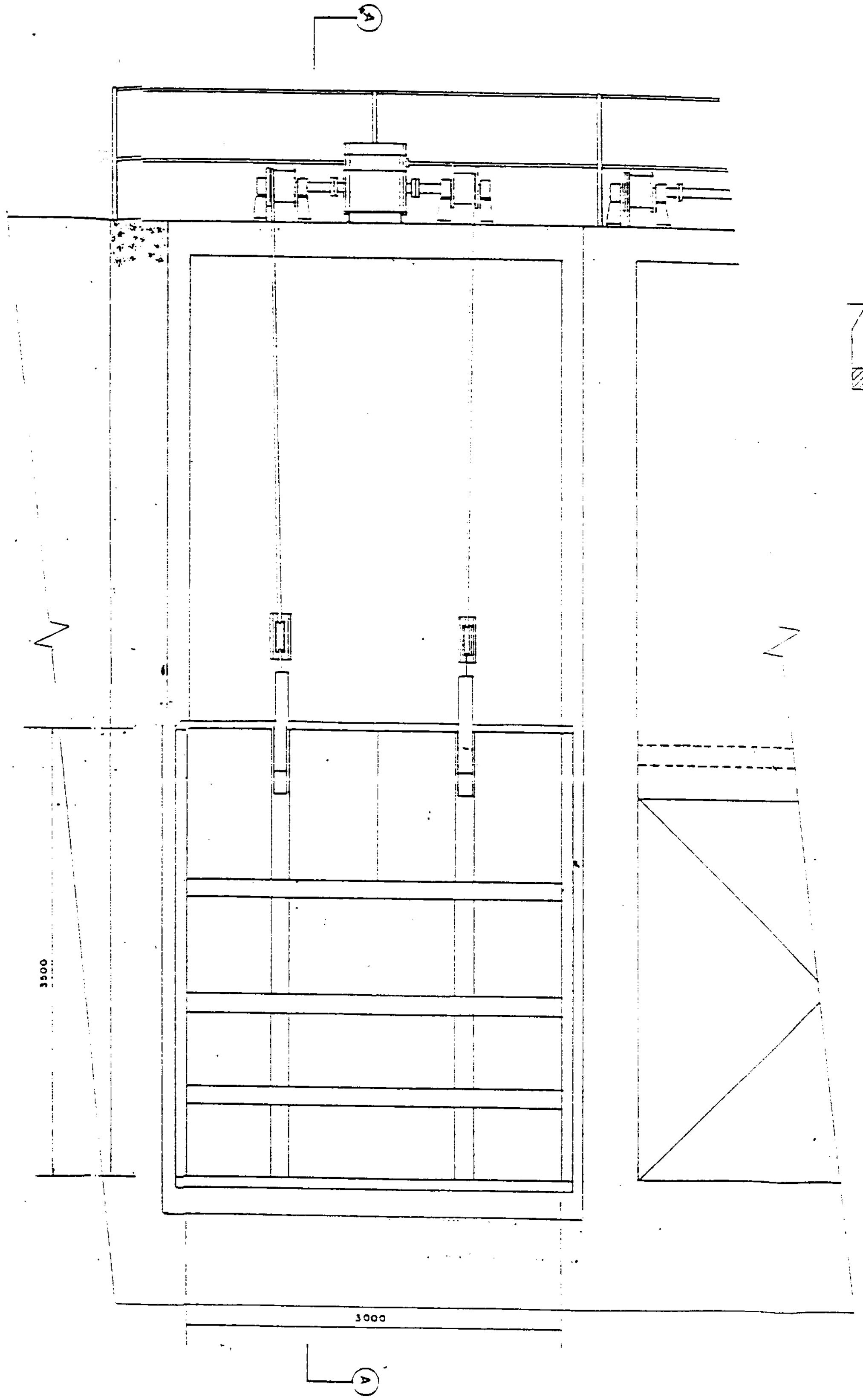
DRAWN	S.I. BHUIYAN	
CHECKED		DRAWING NO
DATE	17-04-93	5138 - M004

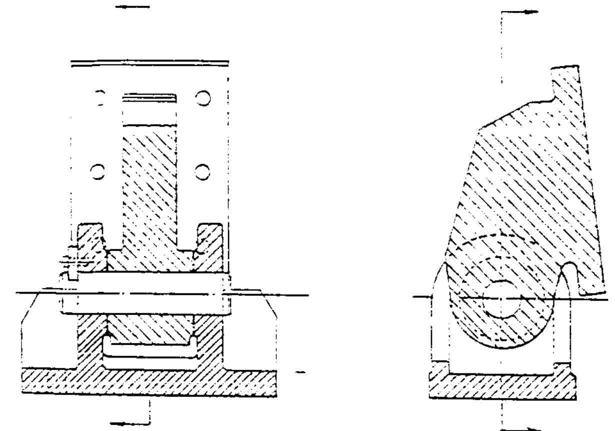
GATE SIZE W x H M	WEIGHT OF GATE - Kg
30 x 3.5	1.900
1.5 x 3.5	1.050



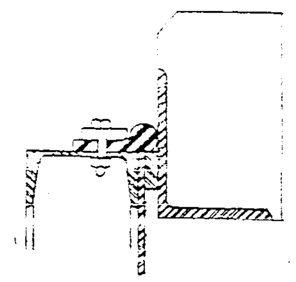
SECTION A-A



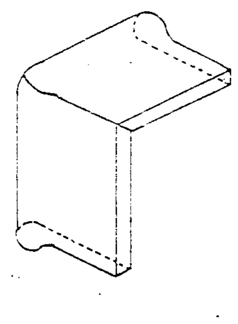
SECTION B-B



DETAIL OF HINGE ARRANGEMENT



DETAIL-C - SEALING ARRANGEMENT



CORNER JOINT OF RUBBER SEAL

MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD

GUMTI PHASE II SUB-PROJECT

TYPICAL COLLAPSIBLE GATE FOR CONTROL STRUCTURES (FISH FRIENDLY)

MOTT MACDONALD LTD. UK.
NIPPON KOEI CO. LTD. JAPAN
HOUSE OF CONSULTANTS LTD. BANGLADESH
DESH UPODESH LTD. BANGLADESH

DESIGNE : A.P. JAYASINGHE, M. RAHMAN	APPROVED :
DRAWN : S.I. BHUIYAN	
CHECKED :	DRAWING NO : 5138 - M005
DATE : 17-04-93	

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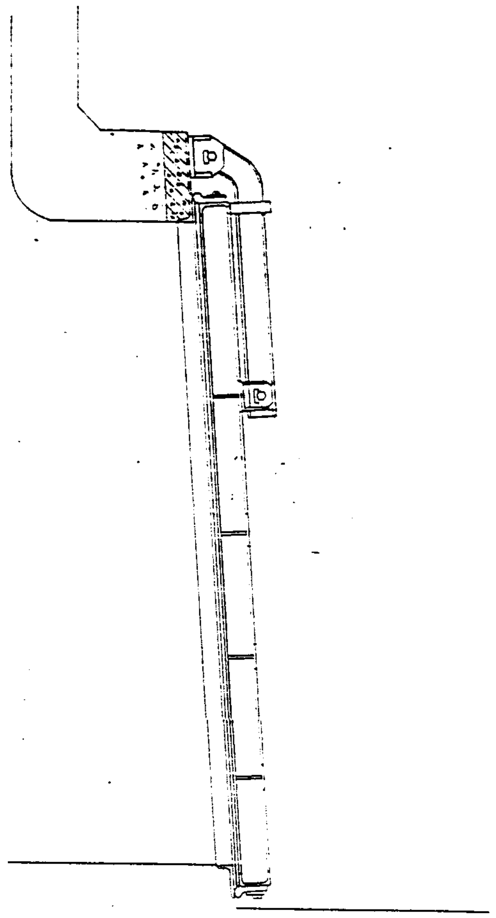
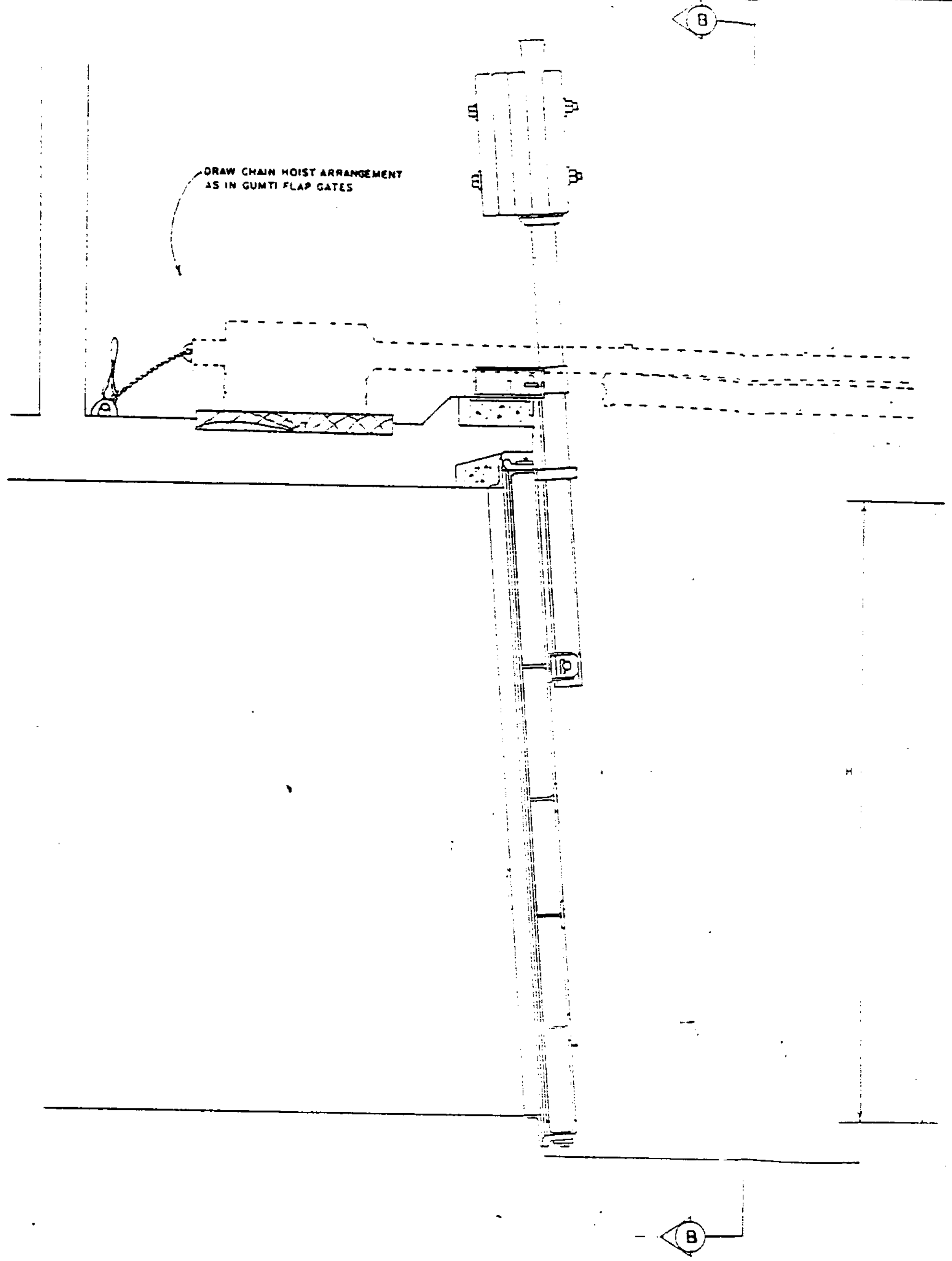
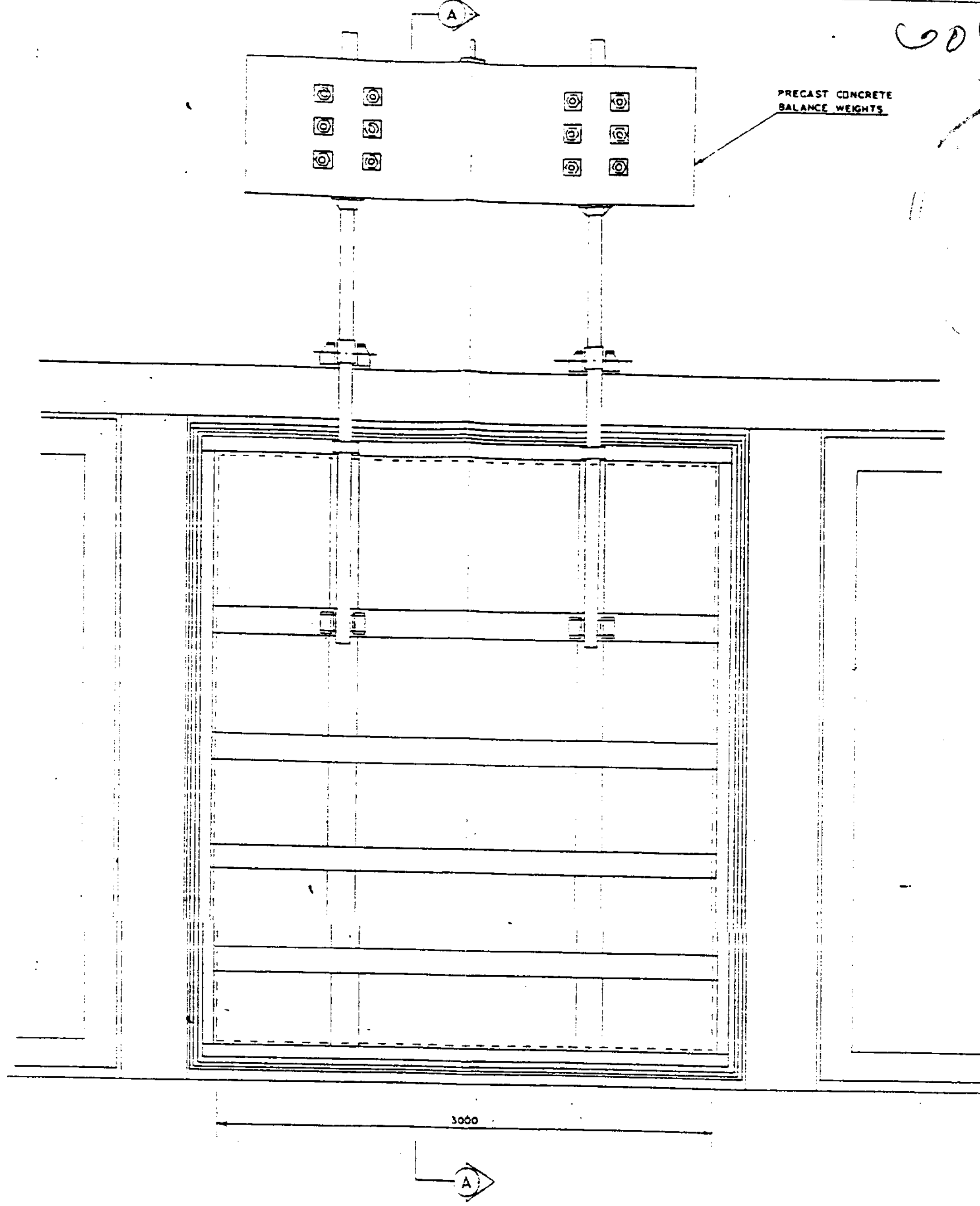


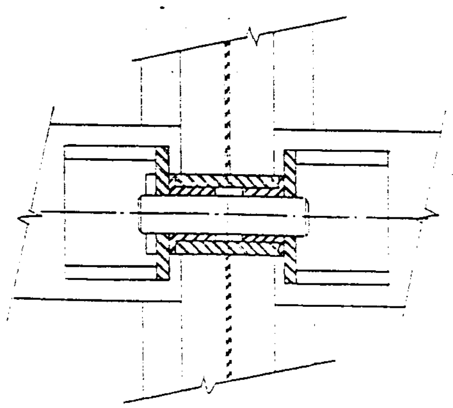
SECTION A-A FOR NONBALANCED



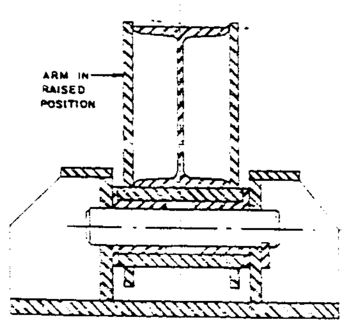
SECTION A-A OF COUNTER-BALANCED GATE

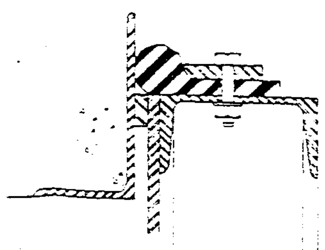


TYPICAL END ELEVATION B-B



TYPICAL HINGE ARRANGEMENT





SEALING ARRANGEMENT

GATE SIZE W x H m	GATE TYPE	WEIGHT kg
3.0x3.0	BALANCED	1690
3.0x3.5	BALANCED	1900
2.8x3.00	BALANCED	1620
3.0x3.5	NONBALANCED	1750

MINISTRY OF IRRIGATION
WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD

GUMTI PHASE II SUB-PROJECT

LAYOUT OF FLAP GATES

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HOUSE OF CONSULTANTS LTD. BANGLADESH
DESH UPODESH LTD. BANGLADESH

DESIGNE A. P. JAYASINGHE
M. RAHMAN
APPROVED
DRAWN S. I. BHUIYAN
CHECKED
DRAWING NO.
DATE
5128 - M686

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APPENDIX I.VII

ADDITIONAL SURVEYS AND INVESTIGATIONS

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APPENDIX I.VII

ADDITIONAL SURVEYS AND INVESTIGATIONS

1 General

A number of additional surveys and investigations are required before detailed design and implementation can proceed, and these are discussed below for each of the five schemes identified in Chapter I.9 of this annex. It is desirable that hydrological data collection in particular be commenced as soon as possible, so that by the time detailed design is commenced, records are available for one or more complete water years. Engineering aspects only are covered here; environmental surveys are discussed in Annex H.

2 Scheme A

Scheme A includes the whole of the recommended proposals for Zones A and B, as described in Chapter I.6 of this annex. The following surveys and investigations are required.

(i) Gauging

Automatic Water level gauges should be placed near each of the 7 structures under the railway line adjacent to the Ghungur River. Stage discharge curves should be plotted for each recorder and the computed discharges should then be correlated to the River Gumti discharges. Flash flood characteristics can thus be determined more accurately as input for the refined hydraulic model.

(ii) Sediment Sampling

A programme of suspended sediment sampling should be initiated at stations in the Ghungur, Salda and Buri Nadi Rivers. The results will be used as both input to the hydraulic model and for more accurate determination of the likely requirements for maintenance re-excavation.

(iii) River and Embankment Survey

A longitudinal survey, with bed levels at 100 metre intervals and associated cross sections at 200 metre intervals should be taken along the Nalia River (Ghungur, Salda and Buri Nadi). The total length is approximately 50 km. The sections would be used for the computer hydraulic model as well as a "before project" measurement for design and estimation of quantities.

For the Ghungur and Salda Rivers, this survey should cover the left bank to 20 m beyond the proposed line of the embankment. A cadastral survey will be required along the line of the proposed embankment and where river excavation is required, in order to establish land ownership for possible compensation. The surveyors should mark the location of any dwellings, infrastructure, graveyards etc on the maps, to help determine the exact line of re-excavation and embankment.

A survey along the existing Roads and Highways Dept road (Comilla to Sylhet), forming the north-east embankment within Zone A is to be carried out. This reach is approximately 15 km in length. This should include a survey of existing structures along the reach, as well as sections every 200 m and cadastral surveys where land acquisition is required.

A similar survey will be required for approximately 32 km of existing road (and 5.5 km of new embankment) forming the embankment in Zone B.

(iv) Flood-proofing Surveys

A survey of village heights of the area to the east of Gunghur River should be carried out. Only those villages which are susceptible to flooding (less than 7.5 m above PWD) need to be checked. This information is to be used with the refined hydraulic model, using more accurate river sections and flood hydrographs, in order to check the feasibility study assumption that no flood proofing measures are required.

(v) Khal Survey

The internal khals (approximately 85 km in Zone A and 58 km in Zone B) should be surveyed. Longitudinal bed levels will be required every 100 m and cross sections every 200 m. Cadastral surveys will also be required for land ownership.

(vi) Subsoil Surveys

At least 3 subsoil boreholes should be taken at each regulator site. There are 8 regulator sites in Zone A and 6 in Zone B. However a check should be made with the R&H Department to see if existing test results are available at the structure sites under their road. The depths of the boreholes should be approximately 20 metres.

The field work should include the following:

- disturbed and undisturbed soil samples,
- Standard Penetration Tests,
- determination of water table level, and
- determination of natural ground level at borehole location.

The laboratory tests should include the following:

- determination of natural moisture content,
- determination of unit weight and specific gravity,
- particle size analysis,
- unconfined compression tests,
- Atterberg Limits,
- consolidation tests, and
- direct shear tests.

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3 Scheme B

Scheme B consists of the extension of the Gumti right embankment as a submersible embankment, as described under the Zone D schemes in Chapter I.6 of this annex. The following surveys and investigations are required.

(i) Embankment Survey

A longitudinal survey, with bed levels at 100 metre intervals and associated cross sections at 200 metre intervals should be taken along the line of the proposed embankment between the end of the existing embankment and Gouripur. The sections would be used for the computer hydraulic model as well as a "before project" measurement for design and estimation of quantities.

A cadastral survey will be required along the line of the proposed embankment in order to establish land ownership for possible compensation. The surveyors should mark the location of any dwellings, infrastructure, graveyards etc on the maps, to help determine the exact line of re-excavation and embankment.

(ii) Subsoil Surveys

Surveys as described for Scheme A in Section 2(vi) above should be carried out at each of the 2 flushing sluice sites.

4 Scheme C

This scheme comprises khal excavation in Zone D, for irrigation improvement.

(i) Khal Survey

The 79 km approx length of khals should be surveyed. Longitudinal bed levels will be required every 100 m and cross sections every 200 m.

5 Scheme D

This scheme comprises the Zone C FCDI works described in Chapter I.6 of this annex.

Surveys along the lines of those mentioned above will be required, but it is not recommended to start with these until the conditions for implementation of the scheme have been met.

Meanwhile, it is very important that a pilot programme should be carried out in Zone C, in order to promote and prove Force Mode Tubewell technology in the area. It is recommended that this should be carried out under NMIDP, although it is understood that at the present time there is no plan to carry out such a programme in the Gumti Phase II area.

6 Scheme E

Two submersible embankment schemes were identified in Zone D, one north-west of Gouripur (Motopi) and the other north-east of Homna (Dari Char).

FAP 6 should complete its model studies and determine if its proposed interventions will adversely affect the timing of the floods. If the flood hydrograph is elongated, due to its proposals, then Scheme E should be considered by FAP 6 as part of its mitigation measures.

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