8.3.3 Flood Phases

Table 8.2 presents the model predicted flood phases, for the Without Project simulation, for the project areas in the Lower Atrai basin. These are also shown in Figure 8.6.

TABLE 8.2
Without project simulation flood phases for project areas in the Lower Atrai basin

	F0	F1	F2	F3 + F4
Bogra Polder 2	50 %	22 %	19 %	9 %
Bogra Polder 3	68 %	10 %	12%	10 %
Bogra Polder 4	39 %	8 %	14 %	39 %
Chalan Beel Polder A	45 %	14 %	17 %	24 %
Chalan Beel Polder B	44 %	24 %	20 %	12 %
Chalan Beel Polder C	33 %	14 %	22 %	31 %
Chalan Beel Polder D	17 %	21 %	27 %	35 %
SIRDP	24 %	10 %	24 %	42 %

These clearly indicate that the worst flooded areas lie within the backwater dominated zone, SIRDP and Bogra Polder 4. The flooding is also seen to be severe in Polder C; this is due to the assumption that public cuts would continue to occur in the future like they do at present. Deep flooding also occurs in Polder D. As discussed in Section 8.2, this is due to raised levels in the Shib-Barnai and, again, the assumption that cuts in the western embankment will continue to occur.

These flood phase figures form a baseline measure against which proposed developments and scenarios may be assessed.

8.4 Morphology

8.4.1 The Atrai river system

The Atrai rises in the north-west of the region and initially flows south passing through India. A short distance downstream of Mohadevpur it turns eastward and outfalls to the Brahmaputra through the Hurasagar. In the lower reaches flow in the Atrai is affected by high water levels in the Brahmaputra. A number of rivers such as the Little Jamuna and the Nagor run southward parallel to the Atrai and then enter the Atrai where it takes a more easterly course. All these rivers carry sediment through the Atrai system. The Fikirni spills from the Atrai at Jotebazar and carries a significant quantity of flow and sediment. The Little Jamuna and the Nagor contribute sediment to the Atrai.

To study the morphology of the river system the sediment transport module of MIKE11 was run for selected years to indicate the quantity of sediment transport that occurs throughout the system.

The sediment transport rates in the Lower Atrai system are high, this means that the timescale for morphological change in the system is likely to be rapid, probably of the order of 20 to 50 years. This means that any intervention which alters the sediment transport rates is likely to generate a rapid morphological response.

Much of the sediment which is transported into and through the Lower Atrai system will be deposited in the downstream reaches of the river where the backwater influence from the Jamuna exerts an influence.

A study of the present regime of the system was considered by using the flow module of MIKE11 to provide information on discharges throughout the system. Regime calculations were then carried out to determine the regime width, depth and slope of the rivers. These regime predictions were then compared with the observed channel cross-sections. The general agreement between the observations and the regime predictions was good indicating that the regime theory provided a reasonable description of the river system. This further suggests that the present system is more or less in equilibrium. Any changes in either the magnitude or distribution of flows, or, the size and supply of sediment is likely to upset this dynamic equilibrium. Because of the high sediment transport rates in the system any change to a new equilibrium is likely to be rapid.

Impact of sealing Naogaon Polder

The sealing of Naogaon polder will not have any significant morphological impact on the Atrai river system.

Impact of closing the Barnai project

The closing of the Barnai project results in an increase in water level along the Shib-Barnai river and in the lower reaches of the Fikirni river. By preventing runoff reaching the river it also causes a reduction in flows in the Shib-Barnai.

The closing of the Barnai project is unlikely to affect the quantity of sediment which passes into the Fikirni from the Atrai. The increases in water level and reductions in discharge which result from closing the Barnai project will reduce the sediment transporting capacity in the affected reaches.

The majority of the sediment which passes into the Fikirni is likely to be deposited in the lower reaches of this river and in the Shib-Barnai immediately downstream of Bagmara. This morphological change is likely to occur over a period of 5 to 10 years given the large quantities of sediment being transported.

The Middle Bangali river system

The morphology of the rivers in the Middle Bangali basins under present conditions and with the breaches in the BRE sealed is described in Chapter 7.

The baseline conditions for the study of the impact of proposed developments on river morphology will be taken to be those in which there are no spills from the Brahmaputra, that is, the condition similar to those that existing prior to the development of breaches in the early 1980's.

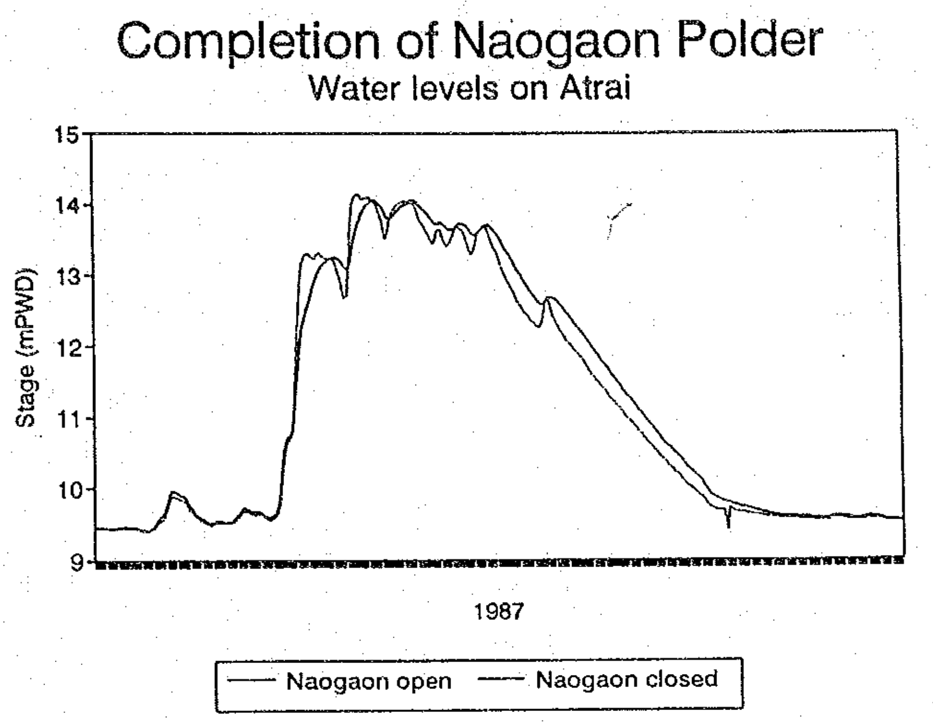


Figure 8.1 **Impact of Completion of Naogaon Polder**

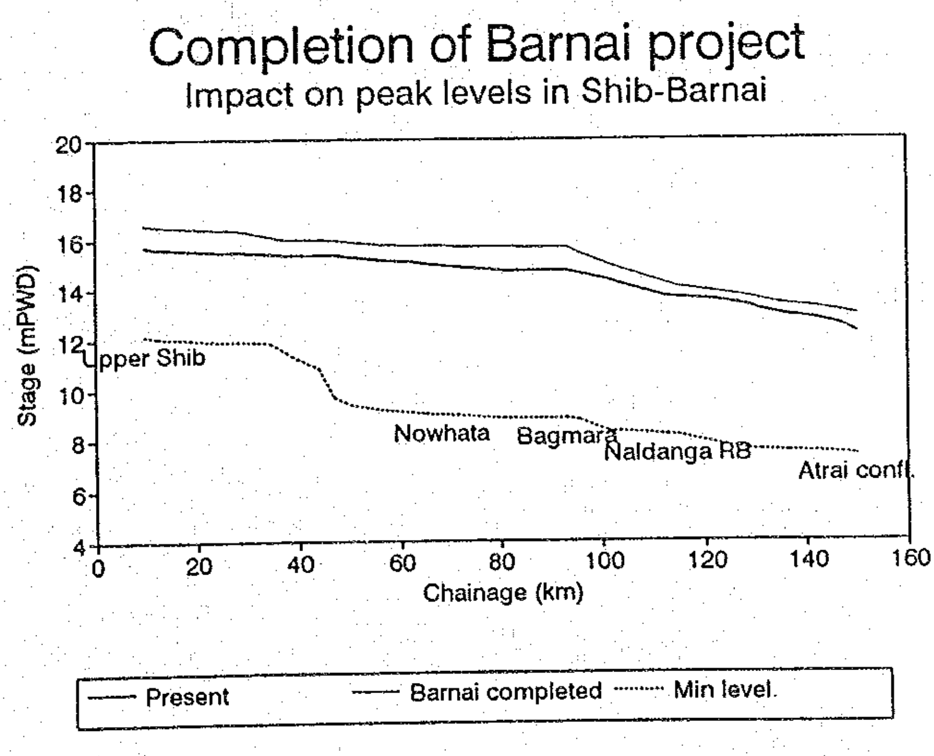


Figure 8.2 **Impact of Completion of Barnai Project**

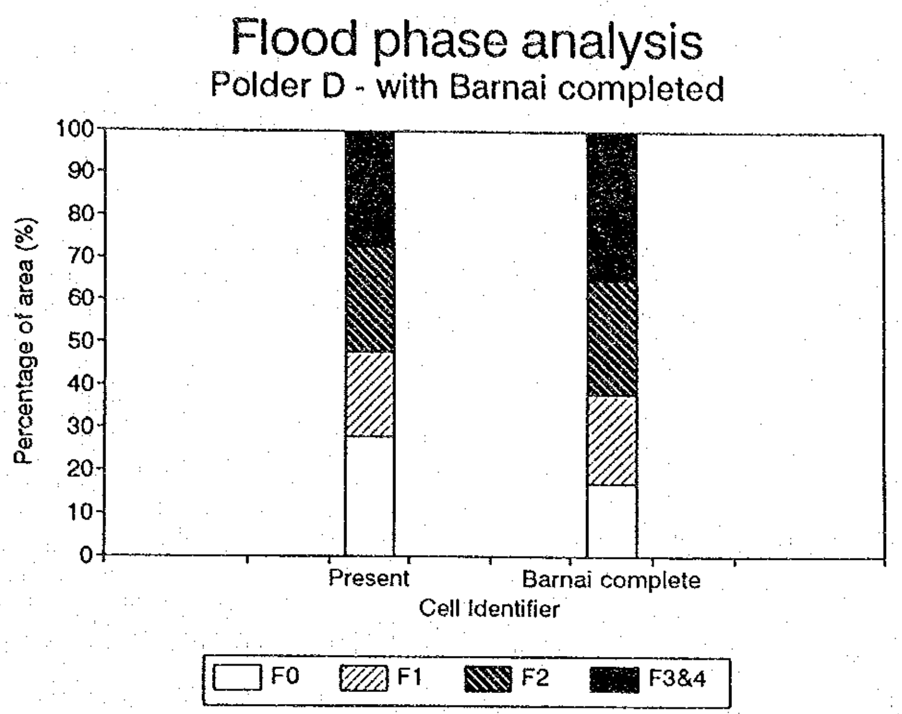


Figure 8.3 **Change in flood phase in Polder D**

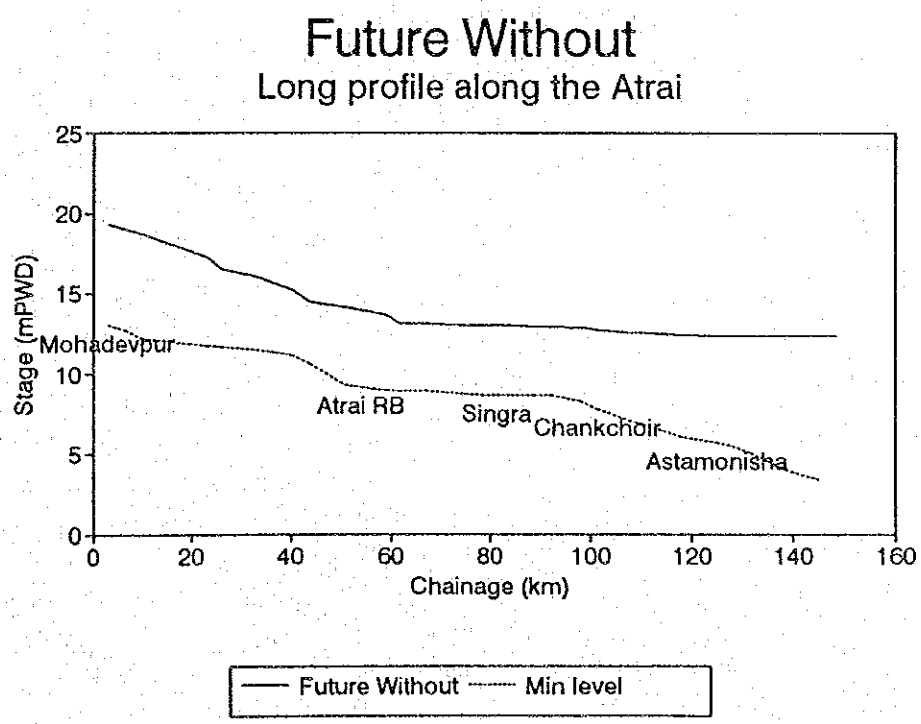
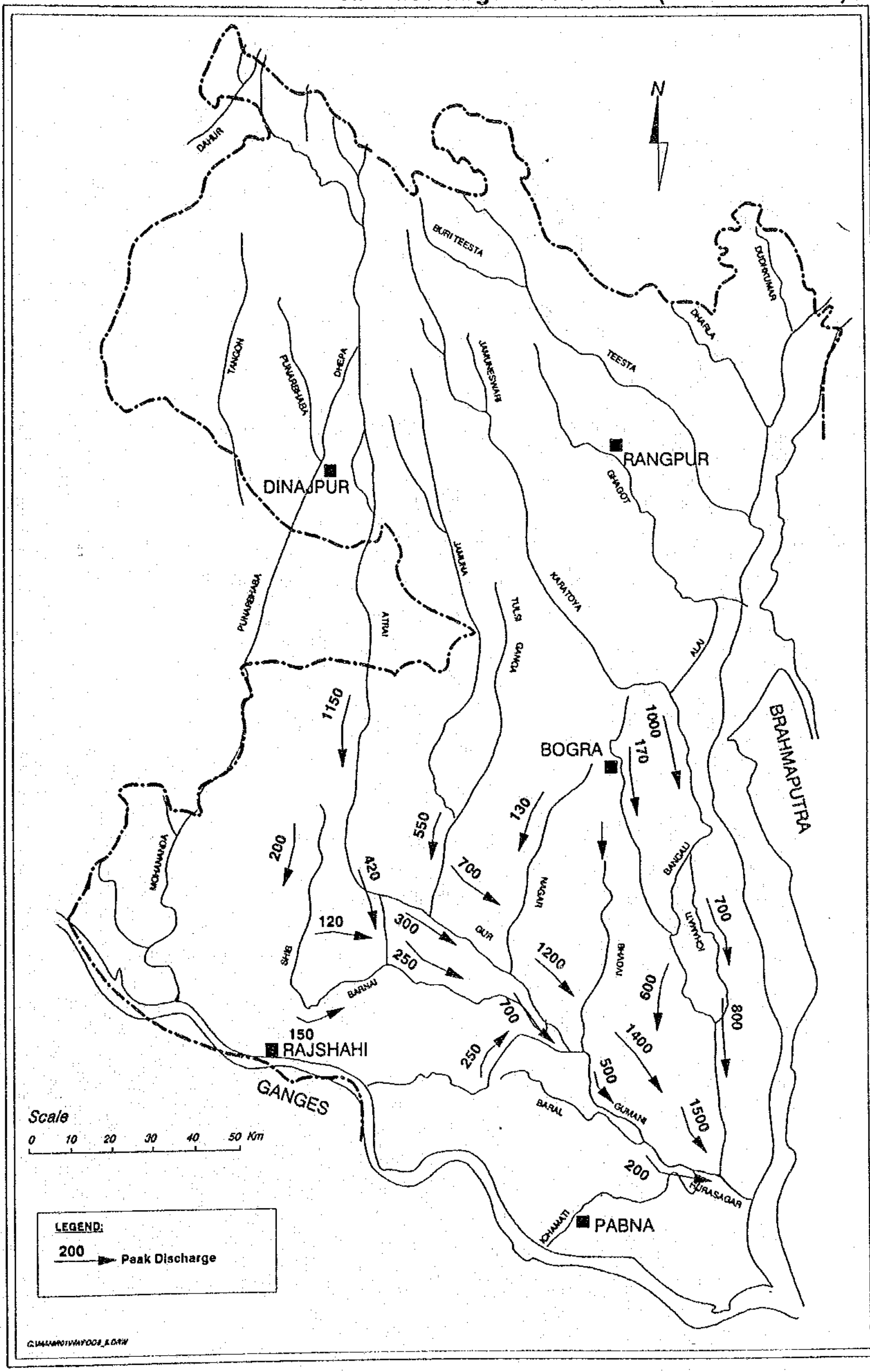


Figure 8.4 **Long profile along the Atrai**

Figure 8.5

Peak Discharge Distribution (Future Without)



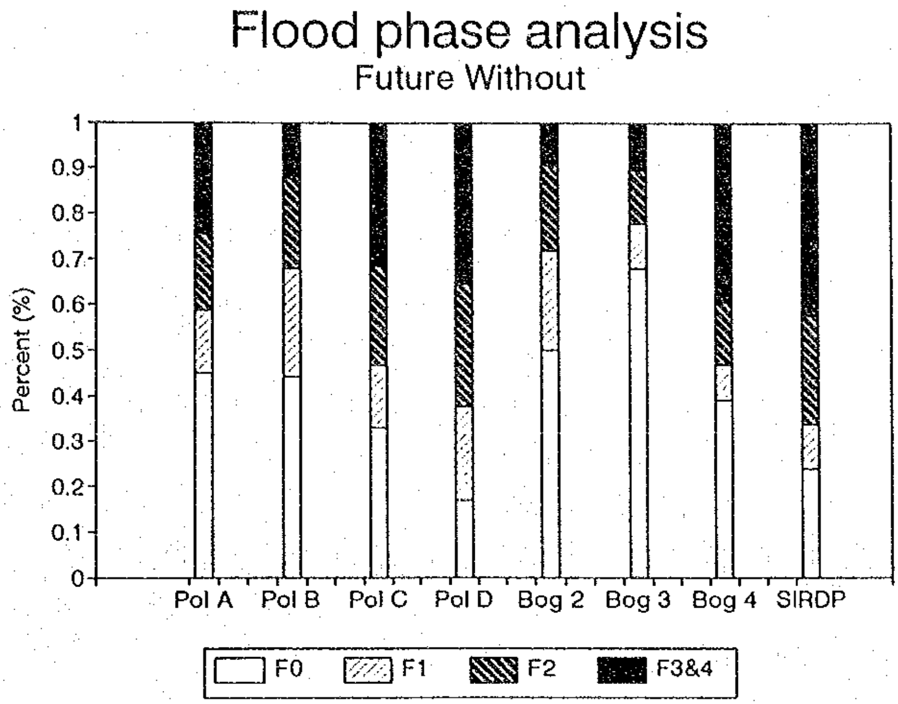


Figure 8.6 Flood phases in Lower Atrai -Future Without

CHAPTER 9

SUB-REGIONAL MODEL -DESIGN OPTION SIMULATIONS

9.1 Selection of design years

For the purposes of assessing the relative merits of different options prior to undertaking the With Project model run, which would include the selected options, representative years were selected for each planning unit (see Figure 2.1) covered by the sub-regional model. These years represent the closest approximation available to the 1 in 20, 1 in 10, 1 in 5 and 1 in 2 year events, averaged over each planning unit. The procedure is summarized below, together with the list of years selected.

Within each planning unit a number of model nodes were selected to represent conditions across the area of the unit. This ranged from 8 nodes in Pabna (Unit 15) to 21 nodes in Atrai Right Bank (Unit 13). For each node the model results were analysed to determine the maximum levels exceeded in each year for a range of durations from 1 day to 90 days, and the years were ranked. The rankings calculated for each selected node within the planning unit were then averaged; this information may alternatively be given as a return period for each year for each duration.

In each planning unit the years most closely approximating to the four required return periods were selected; this was based on the results for a duration of 10 days, but note was taken of other durations. The estimated return periods of the years selected as "1 in 20 year" range from 11 years to 39 years, but the difference in water level between these and the actual 20 year event would be fairly small. For the 2 year return period there are a number of potential years in each planning unit. The years selected are as follows:

TABLE 9.1
Return periods and hydrologic years in the Planning Units

Unit	1 in 20	1 in 10	1 in 5	1 in 2
8	1988	1973	1970	1976
12	1987	1974	1973	1976
13	1987	1988	1970	1976
14	1988	1987	1970	1967
15	1988	1974	1970	1967

A total of seven years were initially selected - 1967, 1970, 1973, 1974, 1976, 1987 and 1988. Analysis of model results for the final design options will present details of these seven years and users will select the four years corresponding to the planning unit under consideration.

For the Without Project simulation the 25 years of hydrological data were divided into five blocks each of which consisted of 5 years. To simplify the running of the design option simulations it would be convenient if the sub-regional model could be run for one or two five year blocks of hydrological

years. Based on the analysis described above the 1970-74 and 1985-89 blocks were selected for the design option simulations of the sub-regional model. By using these blocks two of the selected design years, 1967 and 1976, are excluded. These years have water level return periods of 1 in 2 years. Other years within the selected five year blocks have water level return periods of 1 in 2 years. The two selected five year blocks cover the same water level return periods as the selected design years; these blocks are appropriate for the analysis of the design options

TABLE 9.2

Estimated return periods of years selected for option assessment

Planning Unit Number

Year	8	12	13	14	15
1967	*	*	*	<u>2</u>	<u>2</u>
1970	4	3	<u>4</u>	<u>4</u>	5
1973	<u>8</u>	<u>5</u>	4	3	3
1974	8	<u>13</u>	8	17	<u>10</u>
1976	<u>2</u>	<u>2</u>	<u>2</u>	*	2
1987	6	<u>16</u>	<u>24</u>	<u>9</u>	10
1988	<u>11</u>	<u>5</u>	<u>8</u>	21	39

Notes:

1) * represents a return period of less than 1.5 years.

2) Underlining indicates years selected as design years for each planning unit.

3) The extreme value of 39 years for unit 15 in 1988 occurs because it is the year with the highest levels at each node; 39 years is the return period allocated to the highest year in a 24-year data set. At several nodes 1988 was only the highest year by a matter of millimetres, so an error of only a couple of mm at two nodes in one year could have produced an estimated return period of about 28 years; such margins are of course well within model accuracy. Hence 1 in 20 year water levels would only be very slightly lower than those in the "1 in 39 year" case.

4) In unit 8 the occurrence of severe levels varied substantially over the area of the unit, and consequently no one year represents conditions as extreme as 1 in 20 years over the unit as a whole.

9.2 Impact of confinement in Lower Atrai

Construction of polders in the Lower Atrai basin and confinement of the river system in general has been going-on for many years. As described in Chapters 5 and 8 the present status of the embankments varies from polder to polder but in general none of the embankments are fully complete and most suffer from annual breaches and public cuts. The effect of this is allow considerable spillage on to the flood plains adjacent to the river system and for large storage and flow areas to be available which attenuate the discharge peaks passing through the system. The overall effect of these breaches and public cuts is to reduce water levels in the Lower Atrai basin.

The current situation in the Lower Atrai basin can be thought of as consisting of three parallel drainage paths with the central one being the Atrai. On the southern side the drainage path is across the Chalan Beel Polders whilst on the northern side it is across the Bogra Polders and into SIRDP.

Full confinement in the Lower Atrai basin refers to the completion of all existing polder developments and the embanking of areas, as yet unplanned, along the left bank of the Atrai including Bogra Polder 4. This represents a worst case in that it will result in the maximum rise in water levels in the Lower Atrai basin. There are alternative development scenarios, such as leaving Bogra polder 4 unembanked, which also involve significant confinement in the Lower Atrai basin.

A number of model simulations were carried out to investigate the impact confinement would have on water levels in the Lower Atrai. These simulations were carried out for the 1987 and 1988 monsoon seasons; the results are presented in Figure 9.1 and 9.2 in the form of peak water level profiles along the Atrai.

Full confinement : This simulation assumed full confinement throughout the Lower Atrai basin. Along the Atrai river the maximum spacing between the embankments on either side of the river was taken to be approximately 500 m. Elsewhere in the Lower Atrai basin the embankments were assumed to be located at the river bank; this resulted in embankment spacings of less than 300 m in general. Full confinement results in a substantial increase in peak water levels, relative to present conditions, from approximately 10 km upstream of Baghabari to Jotebazar where the Fikirni spills from the Atrai, Figure 9.1. Hence an increase in peak water levels occurs over a distance of some 130 km. The maximum rise in peak water level is between 2 m and 3 m; this occurs in the vicinity of Chankchoir. The maximum water levels are only raised marginally in the upper reaches of the Atrai where the flow is dominated by fluvial flow. In the lower reaches there is again only a minor rise in level because of the backwater influence of the Brahmaputra.

Full confinement without SIRDP : This simulation assumed full confinement throughout the Lower Atrai basin except for the SIRDP area which was assumed to be left open. This results in marginally lower water levels in the Lower Atrai than with full confinement, Figure 9.1. The water levels are predicted to be lower as far as a short distance upstream of Astamonisha; the maximum reduction in water level is of the order of 0.5 m. The leaving open of SIRDP allows the backwater influence of the Brahmaputra to extend some 10 km to 15 km further upstream.

Full confinement without SIRDP and Bogra Polder 4 : This simulation assumed full confinement throughout the Lower Atrai basin except for the SIRDP area and Bogra Polder 4 which were assumed to be left unembanked, Figure 9.1. This results in large reductions in peak water level in the Middle Atrai compared for fully confined conditions. The maximum reduction in water level relative to fully confined conditions is between 2 m and 3 m. All the rise in water level due to confinement as far upstream as Chankchoir can be accounted for by SIRDP and Bogra Polder 4. Between Chankchoir

and Jotebazar approximately 50 % of the rise in water level which results from full confinement can be attributed to Bogra Polder 4.

Full confinement without SIRDP, Bogra Polder 4 and Chalan Beel Polder C : This simulation assumes full confinement throughout the Lower Atrai basin except for the SIRDP area, Bogra Polder 4 and Chalan Beel Polder C which are assumed to be left unembanked, Figure 9.2. Leaving Chalan Beel Polder C open results in a maximum reduction in peak water level of between 1m and 2m, see Figure 9.2, between Chankchoir and Jotebazar. The rise in water level between Chankchoir and Jotebazar which does not result from sealing Bogra Polder 4 can be attributed to the closure of Chalan Beel Polder C.

9.2.5 Summary of confinement tests in the Lower Atrai basin

Almost all the rise in peak water level which results from confinement in the Lower Atrai basin can be attributed to SIRDP, Bogra Polder 4 and Chalan Beel Polder C. The closure of Bogra Polder 4 has the greatest single effect. The sealing of SIRDP results in a small rise in peak water level in the lower reaches of the Atrai. Closure of Chalan Beel Polder C results in a further increase in water level in the middle reaches of the Atrai.

It must be noted that as well as affecting water levels in the Atrai river confinement will result in a significant rise in water level in all the tributaries and distributaries of the Lower Atrai system.

9.3 The Green River with partial protection

The results of the confinement tests described above indicate that confinement in the Lower Atrai is likely to result in large rises in water level throughout most of the system. In particular the closure of SIRDP, Bogra Polder 4 and Chalan Beel Polder C will result in large increases in water level in different reaches on the Lower Atrai.

The large rises in water level which could result from closure of the various polders is likely to cause drainage congestion within the embanked areas. These rises in water level are also likely to increase the potential for public cutting. Erosion of, and structural damage to, the high embankments would also present serious maintenance problems.

Given these conditions full confinement in the Lower Atrai basin is an unacceptable development scenario for this area.

The Green River concept of the Lower Atrai basin is designed to bring the river system close to its original drainage conditions and hydraulic characteristics prior to the development of the area by empoldering and embanking. The drainage paths within the Green River are taken to be similar to those which occur at present and are simulated in the Without project run. These drainage paths are in part due to breaches and public cuts; the Green River formalises these as the main drainage paths.

Within the Green River concept partial protection is provided in areas where it is viable. The level of protection can be selected to prevent damage to the boro crop or can be extended to present rapid rises in water level until late July to allow the establishment of a t aman crop.

On the basis of experiences in the Lower Atrai it is clear that full confinement is not achievable in the lower units of Bogra Polders 2 and 3, and Chalan Beel Polders A and B. The confinement tests described in Section 9.2 illustrate that full confinement is not desirable in SIRDP, Bogra Polder 4 and Chalan Beel Polder D. CFD in Chalan Beel Polder D would result in flooding problems in the Shib

river as a result of runoff from the Barind Tract. Flow across Chalan Beel Polder D to alleviate this is desirable.

A ten year design option run was carried out with the sub-regional model to simulate the Green River concept with a low level of partial protection, the key features in this model were,

-	Polder A	: Sub-poldering. CFD in higher areas with flow across the lower areas. Partial protection in lower areas.
-	Polder B	: Sub-poldering. CFD in higher areas with flow across the lower areas. Partial protection in lower areas
-	Polder C	: Flow through the polder with higher areas sub-poldered for CFD protection. Partial protection of the flow area.
-	Polder D	: Flow across central part of polder with higher areas sub-poldered for CFD protection. Partial protection of the flow area.
-	Bogra 2	: Upper part of polder CFD. Flow in part adjacent to Atrai.
-	Bogra 3	: Upper part of polder CFD. Flow in part adjacent to Atrai.
-	Bogra 4	: No development
-	SIRDP :	Upper unit CFD; this involves embankments on the Lower Bangali right bank. Flow in part adjacent to Atrai. Closure of spills from Bengali right bank.

The conditions simulated in this run are illustrated in Figure 9.3 and summarised in Table 9.3.

TABLE 9.3
Conditions simulated in Green River concept run with partial protection

	CFD in upper units	Flow in lower units	Partial protection in lower units	Closure of drainage channels
Chalan Beel Polder A	X	X	X	
Chalan Beel Polder B	X	X	X	
Chalan Beel Polder C	X	X	X	
Chalan Beel Polder D	X	X	X	
Bogra Polder 2	X	X	X	
Bogra Polder 3	X	X	X	
Bogra Polder 4				
SIRDP	X	X	X	X

Figure 9.5 shows longitudinal profiles along the Atrai river for Without project conditions and the Green River with partial protection. The impact of the proposed developments is to cause a small rise in water levels in the middle reaches of the Lower Atrai.

The flood phases for three project areas of the Lower Atrai for the Green River with partial protection are presented in Table 9.4. In brackets in this table are the corresponding figures for Without project conditions. In areas where flow occurs the flood phases have been calculated directly from the model results. In areas of CFD the flood phases have been calculated by engineering drainage analysis. This drainage analysis uses model predicted water levels in the external rivers at the drain outfalls. The flood phases for the entire project area are combination of those calculated directly from model results and those calculated by engineering drainage analysis.

In polders A and B the percentage of F0+F1 land is increased in the Green River with partial protection simulation relative to Without project conditions. There is minimal change in the flood phases in Bogra Polder 4 since no developments are planned in this area.

TABLE 9.4
Flood phases in Green River concept run with partial protection

	F0	F1	F2	F3 + F4
Bogra Polder 4	(40 %)	(6 %)	(9 %)	(45 %)
Chalan Beel Polder A	(54 %)	(9 %)	(14 %)	(23%)
Chalan Beel Polder B	(66 %)	(17 %)	(8 %)	(9%)

Notes: 1) Future Without figures in brackets
1) Future Without figures based on a 1:5 year level from a 25 year simulation
2) Green river figures based on a 1:5 year level from a 10 year simulation

9.4 The Green River with partial protection and additional CFD protection

The Green River with partial protection excludes any poldering in the deepest flooded areas adjacent to the Atrai; the CFD embankments are assumed to be at the limits of this deeply flooded zone. Experience has shown that poldering in these areas is extremely difficult; part of the problem is public cutting.

Within the Green River concept it may be possible to construct embankments to polder some of these deeply flooded areas. A 10 year design option simulation was carried out which represented the feasible limit of CFD within the Green River concept, the key features in this simulation were,

- Polder A : CFD.
- Polder B : CFD.
- Polder C : Flow through the polder with higher areas sub-poldered for CFD protection. Partial protection of the flow area.
- Polder D : Flow across central part of polder with higher areas sub-poldered for CFD protection. Partial protection of the flow area.
- Bogra 2 : Upper part of polder CFD. Flow in part adjacent to Atrai and partial protection.
- Bogra 3 : Upper part of polder CFD. Flow in part adjacent to Atrai and partial protection.
- Bogra 4 : Upper part of polder CFD. Flow in part adjacent to Atrai.
- SIRDP : Upper unit CFD; this involves embankments on the Lower Bangali right bank. Flow in part adjacent to Atrai and partial protection. Closure of spills from Bangali right bank.

The conditions simulated in this run are illustrated in Figure 9.4 and summarised in Table 9.5.

Figure 9.6 shows longitudinal profiles along the Atrai river for Without project conditions and the Green River with partial protection and with additional CFD areas. The impact of the proposed developments is similar to that for the Green River with partial protection.

TABLE 9.5
Conditions simulated in Green River concept run with partial protection and additional CFD areas

	CFD in upper units	Flow in lower units	Partial protection in lower units	Closure of drainage channels	Full CFD
Chalan Beel Polder A					X
Chalan Beel Polder B					X
Chalan Beel Polder C	X	X	X		
Chalan Beel Polder D	X	X	X		
Bogra Polder 2	X	X	X		
Bogra Polder 3	X	X	X		
Bogra Polder 4	X	X	X		
SIRDP	X	X	X	X	

The flood phases for three project areas of the Lower Atrai with the Green River with partial protection and CFD in Chalan Beel Polders A and B are presented in Table 9.6. In brackets in this table are the corresponding figures for Without project conditions. In areas where flow occurs the flood phases have been calculated directly from the model results. In areas of CFD the flood phases have been calculated by engineering drainage analysis. This drainage analysis uses model predicted water levels in the external rivers at the drain outfalls. The flood phases for the entire project area are combination of those calculated directly from model results and those calculated by engineering drainage analysis.

In this case, thee has been a modest increase in the F0+F1 land in Bogra Polder 4 due to the CFD areas in its upper reaches. In Polder A there is also a substantial increase in F0+F1 land due to the CFD protection. Polder B, on the other hand, has remained almost the same as the previous simulation which suggests that drainage congestion accurse within the CFD area due to the high external water levels and accumulation of rain waters in its area of low ground.

TABLE 9.6
Flood phases in Green River concept run with partial protection and additional CFD protection

	F0	F1	F2	F3 + F4
Bogra Polder 4	(47 %)	(10%)	(13%)	(40%)
Chalan Beel Polder A	(71%)	(14 %)	(9 %)	(6 %)
Chalan Beel Polder B	(62 %)	(19 %)	(13 %)	(6 %)

Notes: 1) Future Without figures in brackets
1) Future Without figures based on a 1:5 year level from a 25 year simulation
2) Green river figures based on a 1:5 year level from a 10 year simulation

9.5 Summary of Lower Atrai design option simulations

The results of the two ten year design option simulations for the Lower Atrai are very similar as far as water levels are concerned; this suggests that the selection between these options cannot, and should not, be made on entirely hydraulic grounds.

As far as flood phases are concerned the results with maximum CFD are better than those without. In Chalan Beel Polders A and B, and Hurasagar this is because of CFD. In Bogra Polder 4 it is because of sub-poldering which results in CFD in the upper units.

CFD in Chalan Beel polder A and B, and Hurasagar may not be feasible since this involves poldering deeply flooded areas which experience has shown to be unsuccessful.

There is currently no development in Bogra Polder 4; the proposed sub-poldering would be expensive and would only have limited benefits. The confinement impact analysis described in Section 9.2 has shown that confinement of Bogra Polder 4 has a major impact on water levels throughout the middle Atrai; any poldering in this area may result in undesirable effects as far as water levels are concerned.

The Green River concept with partial protection was selected as the With project condition. The With project simulation is described in Chapter 10.

9.6 Bangali Floodway

9.6.1 Description

CFD developments in the Upper Karatoya basin will result in increases in discharge in this river. In order to avoid passing these increases in flow into the Middle Bangali basin where they may result in a worsening of flood conditions the construction of a new outfall to the Brahmaputra was considered; this channel is referred to as the Bangali Floodway.

9.6.2 Residual flow

The Bangali Floodway was designed to carry flow in excess of a predefined magnitude directly to the Brahmaputra with the residual flow being diverted into the Middle Bangali system.

A high residual flow would mean that the Bangali Floodway would only function occasionally and may result in both increased flooding and morphological change in the Middle Bangali basin.

A low residual flow would mean that the Bangali Floodway would function most of the time and would reduce the flooding risk in the Middle Bangali basin. A low residual flow may result in major siltation problems in the rivers of the Middle Bangali system.

Based on a consideration of morphology and flooding risk in the Middle Bangali basin a residual flow of 500 m^3/ was selected. It was assumed that all flow in excess of this passed along the Bangali Floodway directly to the Brahmaputra.

9.6.3 Options considered

Initially two routes for the Bangali Floodway were considered; these are shown in Figure 9.7. Based on cost of construction Route 2, the one with its outfall further upstream on the Brahmaputra, was preferred.

Two cross-section shapes were considered for the Bangali Floodway.

- trapezoidal which is the most hydraulically efficient shape; this involves re-sectioning along approximately 100 km of channel.

- a two stage channel. This involved no change to the natural low flow channel of the Upper Karatoya river.

Both cross-section shapes also involved the construction of flood embankments.

9.6.4 Impact of Bangali Floodway on water levels in the Upper Karatoya

A MIKE11 model which extended from Siraj on the Upper Karatoya to the outfall was used to investigate the impact of the Bangali Floodway on water levels.

A ten year model simulation from 1980 to 1989 was carried out with the two cross-section shapes described above. Figure 9.8 shows the peak water levels along the Bangali Floodway during 1987. Peak water levels for 1987 are used in this figure since in 1987 flooding problems resulted from high river flows rather than backwater effects. Also shown on Figure 9.8 are the minimum bed levels for the two cross-section shapes; the trapezoidal section shape results in a significant regrading of the channel bed.

In the downstream reaches of the Bangali Floodway the impact of cross-section shape is minimal. Water levels in these reaches are dominated by backwater effects from the Brahmaputra. It should be noted that since the Bangali Floodway opens the Upper Karatoya to the Brahmaputra a backwater embankment must be provided to give protection against 100 year return period water levels in the Brahmaputra.

In the reaches which are outside the backwater effect of the Brahmaputra the trapezoidal cross-section shape results in some reduction in peak water levels but these are less than 1m throughout its full length.

9.6.5 Morphological impact

The sediment transport module of MIKE11 was used to investigate the morphological impact of the two options for the Bangali Floodway. This analysis was carried out for the 1988 hydrological year.

Trapezoidal cross-section

The total quantity of sediment transported into the Bangali Floodway at Siraj was approximately 200,000 m^3; a very large percentage of this sediment transport occurred during the flood season. Upstream of the backwater zone there was some erosion and deposition but there was no net deposition of sediment.

Within the backwater zone there was net sediment deposition. All the sediment was deposited over a channel length of approximately 30 km. The bed width of the trapezoidal channel is approximately 80 m. Given this bed width and the length over which sediment is deposited it is estimate that the bed level of the Bangali Floodway will rise by approximately 7 cm a year in this reach.

Since the sediment deposition occurs in the backwater zone the impact of the bed level rises on water levels will, at least in the short term, be small.

Two stage channel

Because the two stage channel does not alter the low channel the quantity of sediment transported into the Bangali Floodway is reduced; the total quantity, in the 1988 hydrological year, is approximately 120,000 m^3.

Upstream of the backwater zone there was some erosion and deposition but there was no net deposition of sediment. Within the backwater zone there was net sediment deposition. All the sediment was deposited over a channel length of approximately 25 km. The bed width of the lower stage of the two stage channel is approximately 60 m. Given this bed width and the length over which sediment is deposited it is estimate that the bed level of the Bangali Floodway will rise by approximately 8 cm a year in this reach.

Since the sediment deposition occurs in the backwater zone the impact of the bed level rises on water levels will, at least in the short term, be small.

Summary of morphological impacts

The quantity of sediment deposited with the two stage channel is less than that with the trapezoidal channel shape. But, the small width of the lower stage of the two stage channel means that the rate of bed level rise is similar.

The opening of the Upper Karatoya to the Brahmaputra by the construction of the Bangali Floodway creates a potential route for the Brahmaputra to flow into the internal rivers of the North West region. Great care must be taken to reduce this risk to a minimum. The structures in the Bangali Floodway will help to reduce this risk. It is recommended that further detailed design studies, possibly using physical models, are carried out to investigate this problem.

9.7 Middle Bangali

In Chapter 7 it was shown that the sealing of the breaches in the BRE alleviated most of the flooding problems in the Middle Bangali basin.

If CFD developments take place in the Upper Karatoya basin the flows into the Middle Bangali basin are likely to increase. If these developments are accompanied by the construction of the Bangali floodway this will lead to a reduction of peak flows in the Middle Bangali.

Two one year design option simulations were carried out with the sub-regional model to investigate the impact of developments in the Upper Karatoya. These simulations were carried out for 1987 since that year flooding problems resulted from high river flows rather than backwater effects.

9.7.1 Impact of developments in the Upper Karatoya with no Bangali Floodway

Impact on discharges

If the Bangali Floodway is not constructed the impact of CFD developments in the Upper Karatoya will be to increase the flows into the Middle Bangali basin. Figure 9.9 present the discharge hydrographs at Mohimaganj, for 1987, with and without the developments in the Upper Karatoya. The peak discharge is increased by more than 100%, from 600 to 1400m^3/s by the developments in the Upper Karatoya.

Impact on water levels

A long profile along the Bangali river is shown in Figure 9.10. This compares peak levels along the Bangali with and without CFD developments in the Middle Karatoya. Water levels increase throughout the Bangali system with the greatest impact is in the more northerly reaches of the Middle Bangali. This would lead to a significant worsening of the flood situation in the Middle Bangali.

Morphological impact

The CFD developments in the Upper Karatoya are likely to result in an increase in the dominant discharge in the Middle Bangali basin. If the increase in dominant discharge is assumed to be around 20% general regime theory indicates the following,

- a 10% increase in channel width.
- a 8% increase in channel depth
- a 4% reduction in the regime slope, this is likely to result in a more meandering channel.

CFD developments in the Upper Karatoya without the Bangali Floodway is likely to result in the Middle Bangali becoming deeper, wider and more meandering.

9.7.2 Impact of developments in the Upper Karatoya with the Bangali Floodway

Impact on discharges

If the Bangali Floodway is constructed the impact of CFD developments in the Upper Karatoya will be to decrease the flows into the Middle Bangali basin. The size of this decrease will depend on the design of the structures in the Bangali Floodway and the residual flow which is allowed into the Bangali system.

The analysis described in Section 9.6 assumed that all flow in excess of 500 m^3/s passes along the Bangali Floodway to the Brahmaputra. Figure 9.11 presents the discharge hydrographs near Mohimaganj, for 1987, assuming this residual flow. The peak discharge is decreased by approximately 15% falling from around 600 to 500m^3/s.

Impact on water levels

With the Bangali floodway in place, the reduction in peak discharges entering the Bangali leads to a corresponding reduction in peak levels. Water levels will therefore marginally reduced throughout the Bangali system, see Figure 9.12.

Morphological impact

The CFD developments in the Upper Karatoya together with the Bangali Floodway will result in a decrease in the dominant discharge in the Middle Bangali basin.

If this decrease in dominant discharge is assumed to be 50 %, the same as the decrease in peak discharge, general regime theory indicates the following,

- a 29% increase in channel width.
- a 24% increase in channel depth
- a 17% increase in the regime slope, this is likely to result in a straighter channel.

CFD developments in the Upper Karatoya together with the Bangali Floodway is likely to result in the Middle Bangali becoming shallower, narrower and straighter.

9.7.3 Middle Bangali developments for the With project simulation

For the With project simulation the same conditions as for the Without project simulation were assumed.

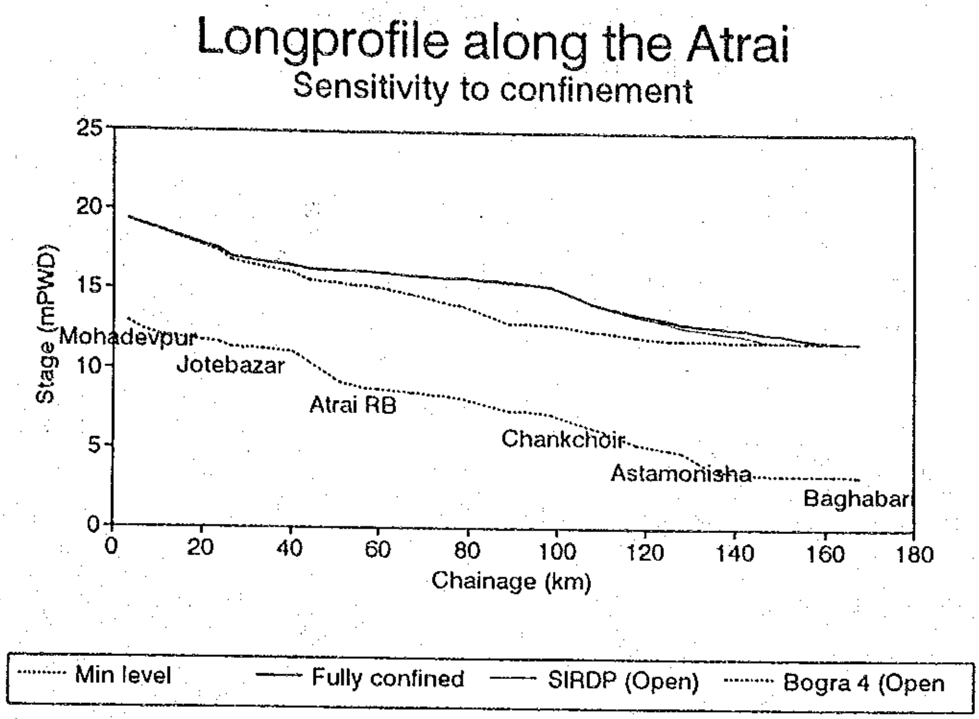


Figure 9.1 Sensitivity to confinement in SIRDP and Bogra 4

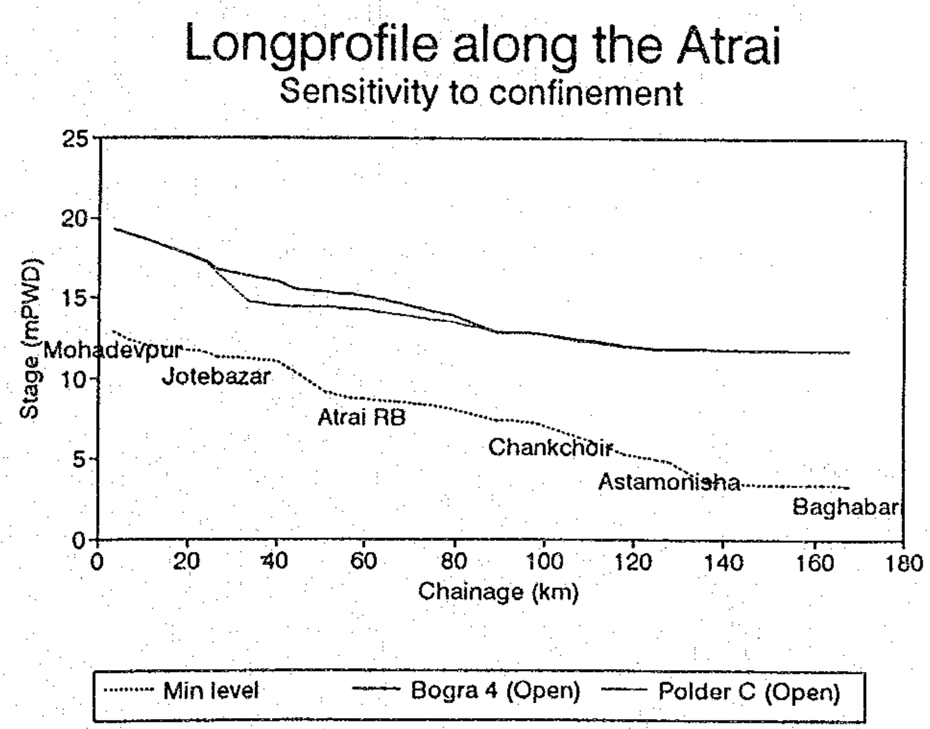


Figure 9.2 Sensitivity to confinement in Polder C

Figure 9.3

The Green River with Partial Protection

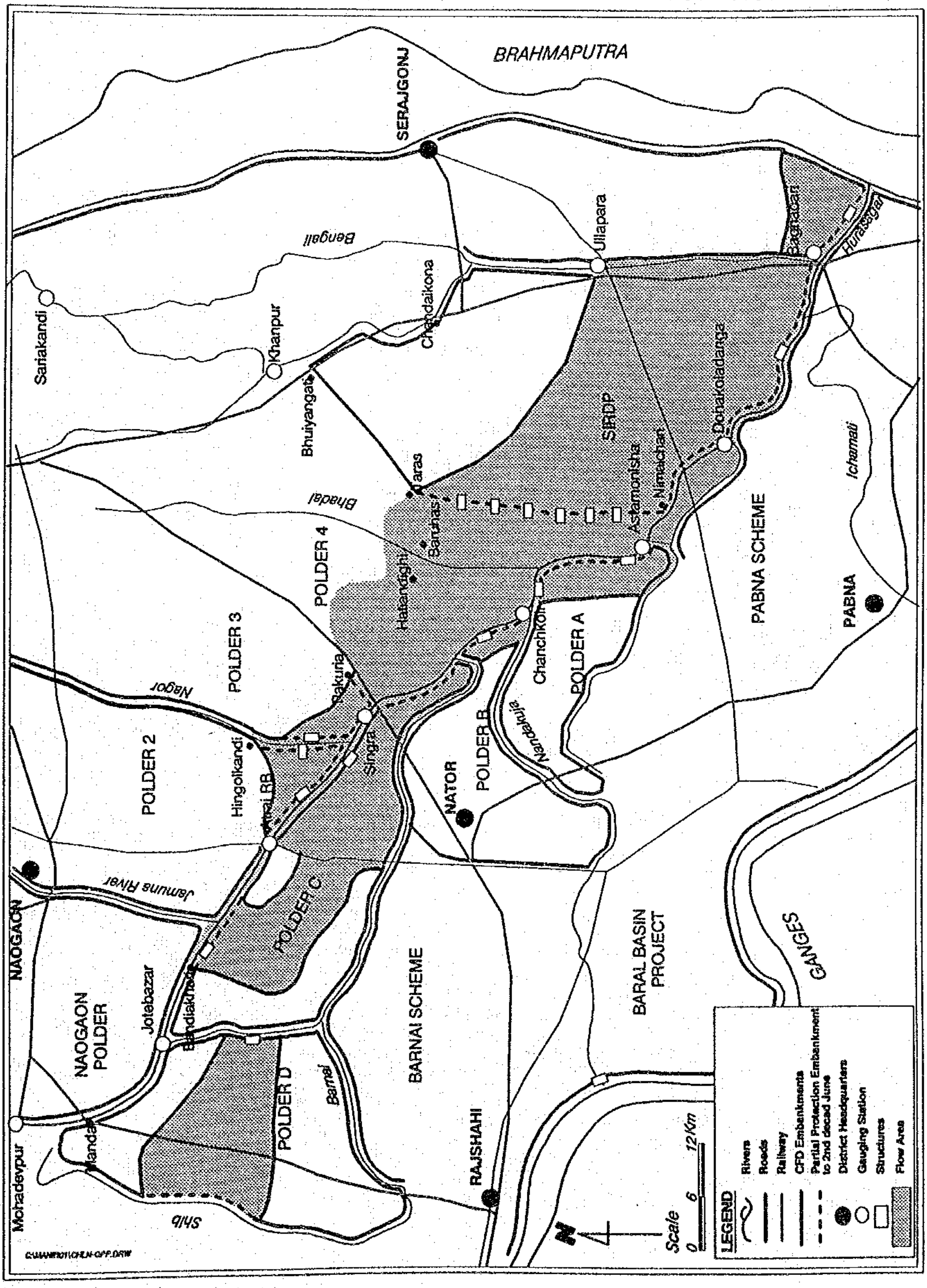
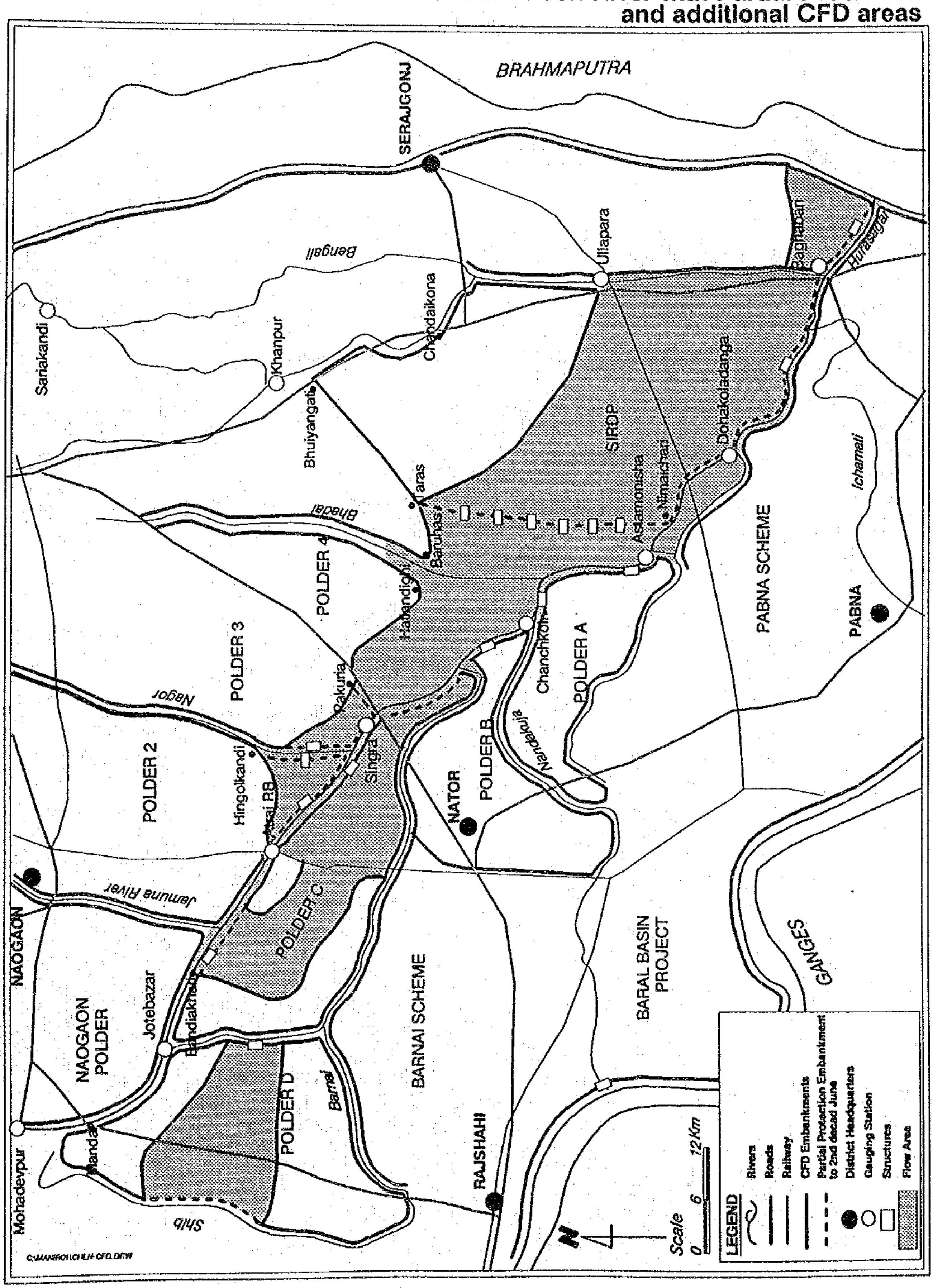


Figure 9.4
The Green River with Partial Protection and additional CFD areas



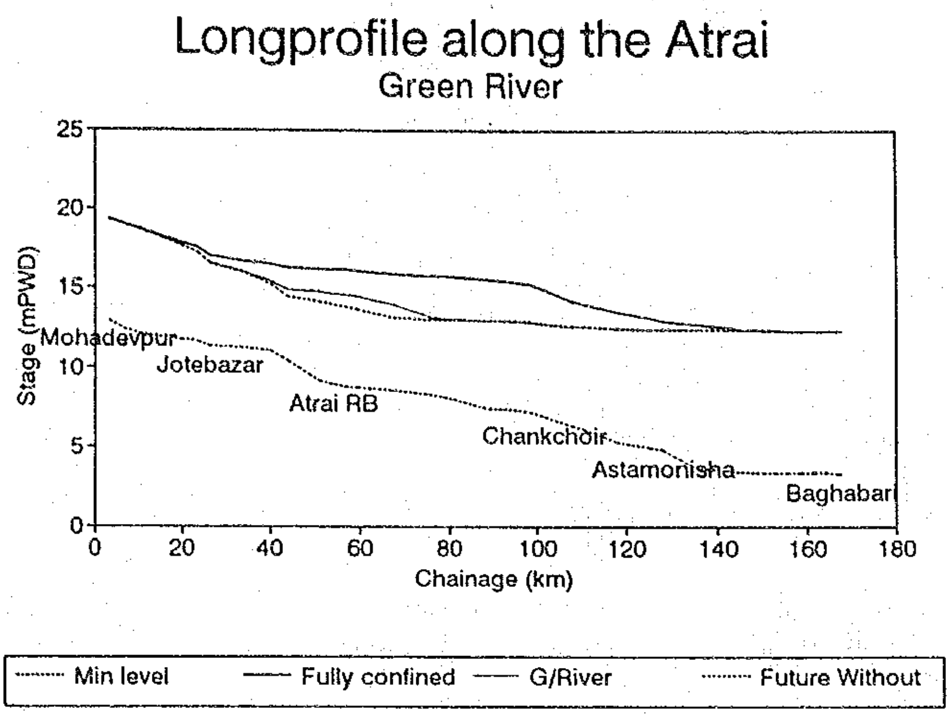


Figure 9.5 **Peak levels along the Atrai - Green River with partial**

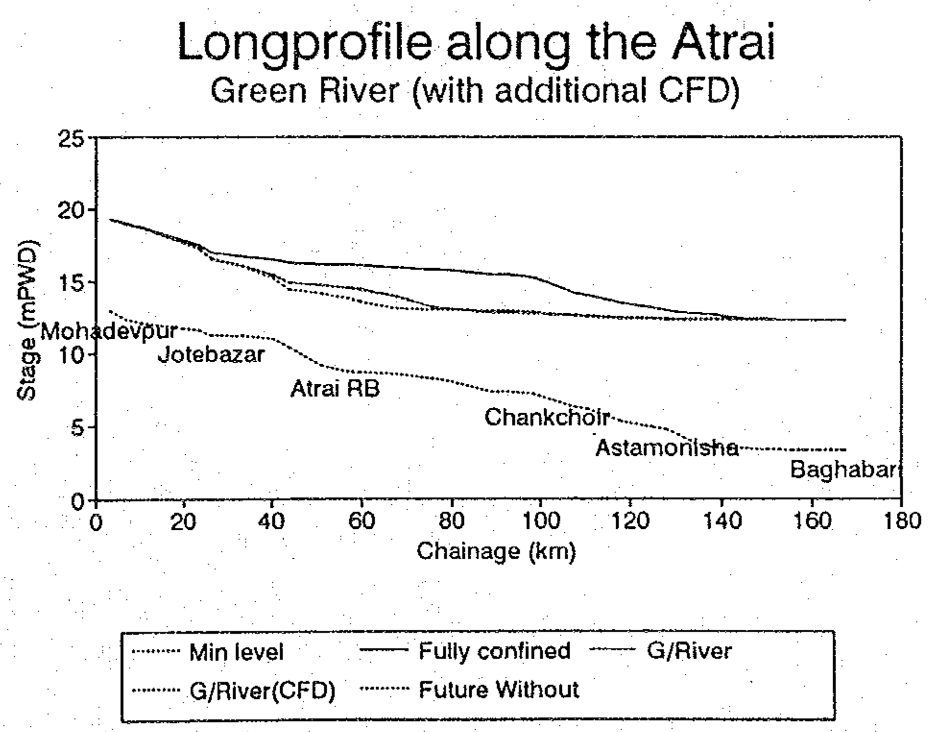
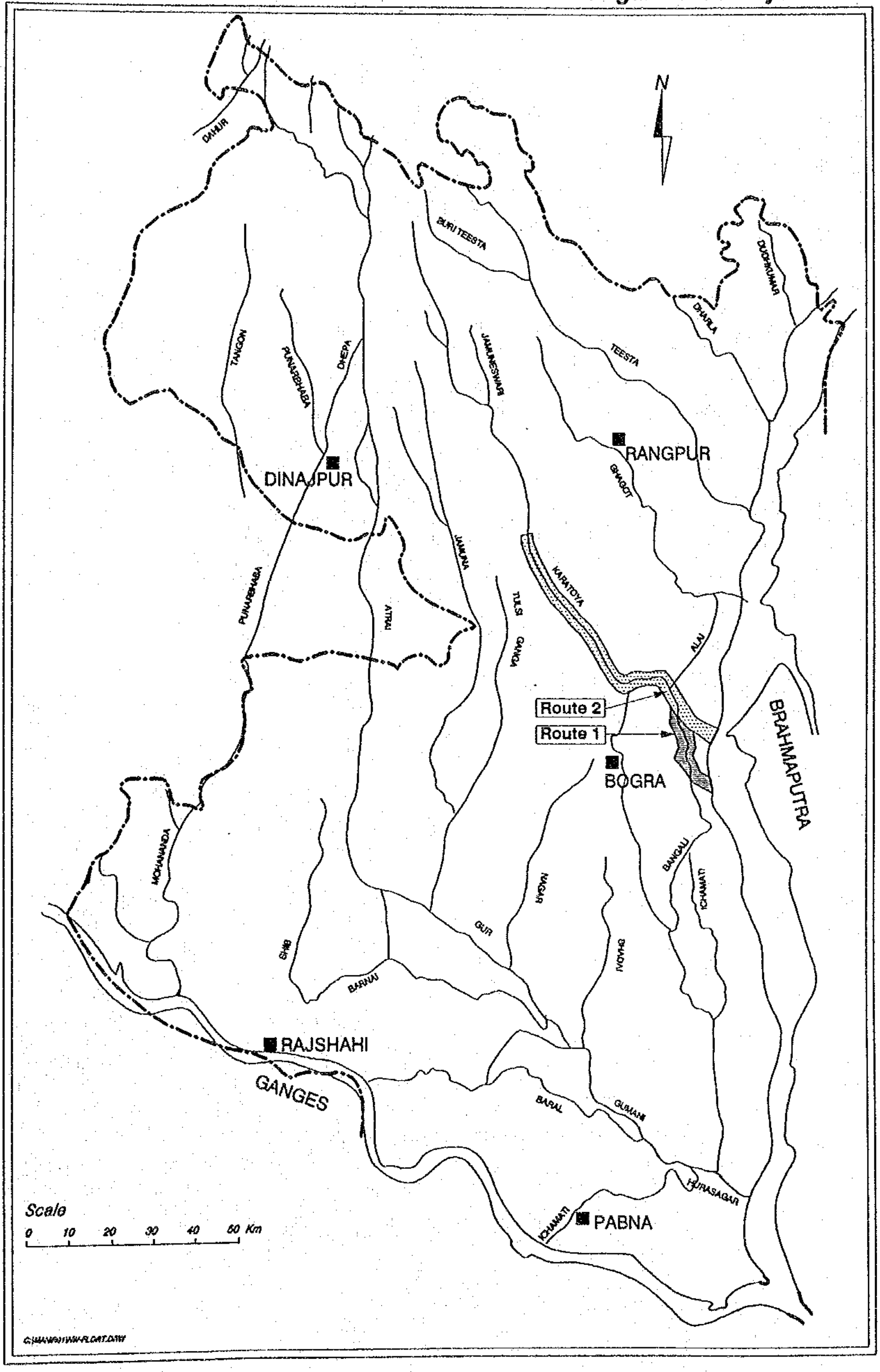


Figure 9.6 **Peak levels along the Atrai - Green River with partial protection and additional CFD areas**

Figure 9.7

Bangali Floodway Routes



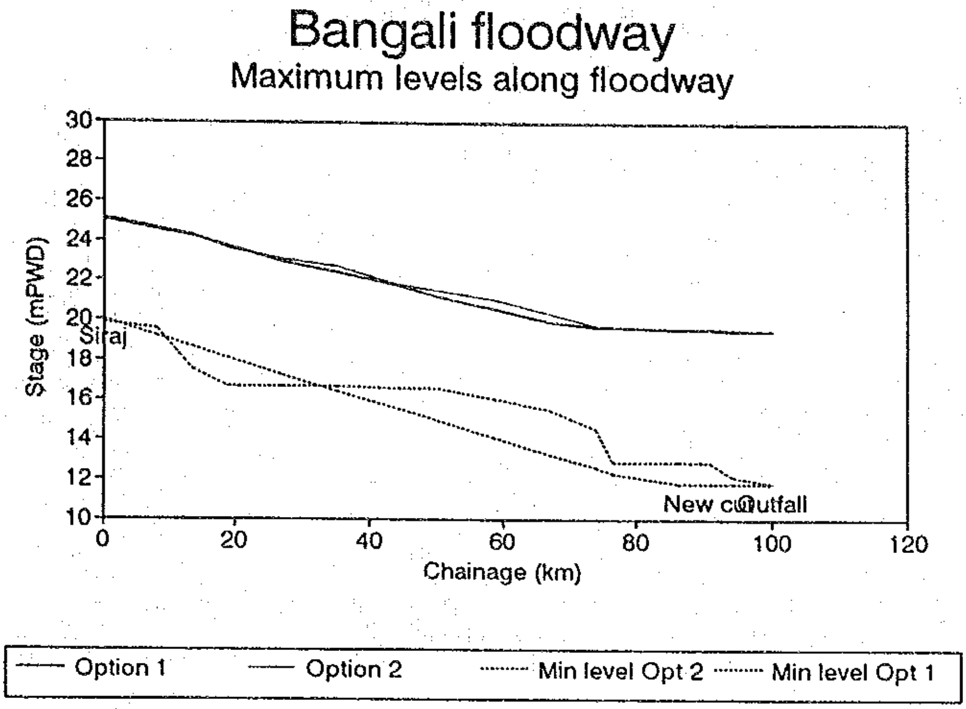


Figure 9.8 Long profile along the Bangali Floodway

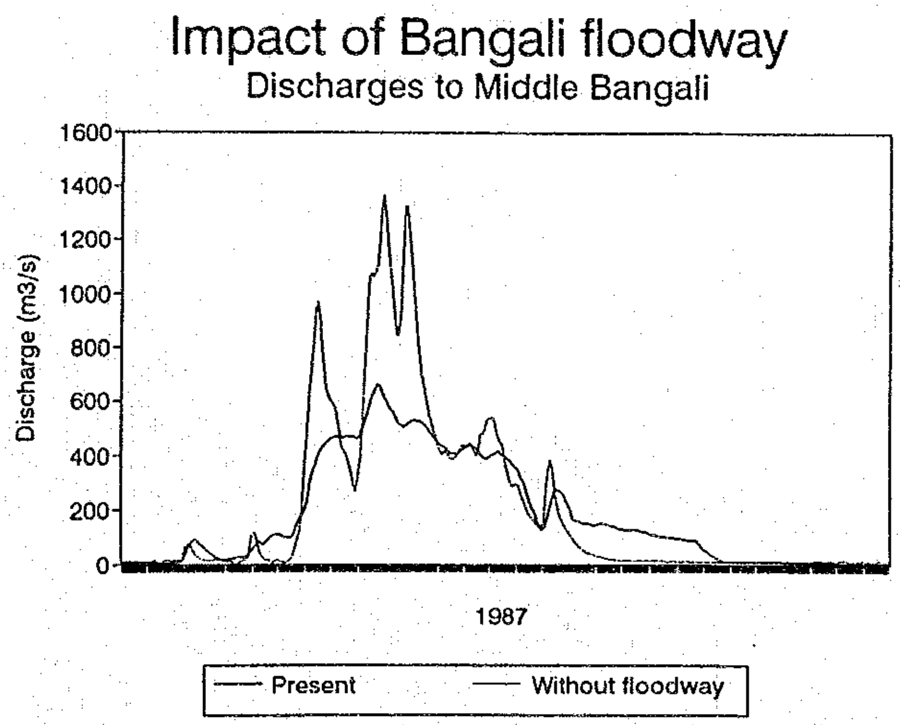


Figure 9.9 Imapct of upstream developments on discharges in the Middle Bangali

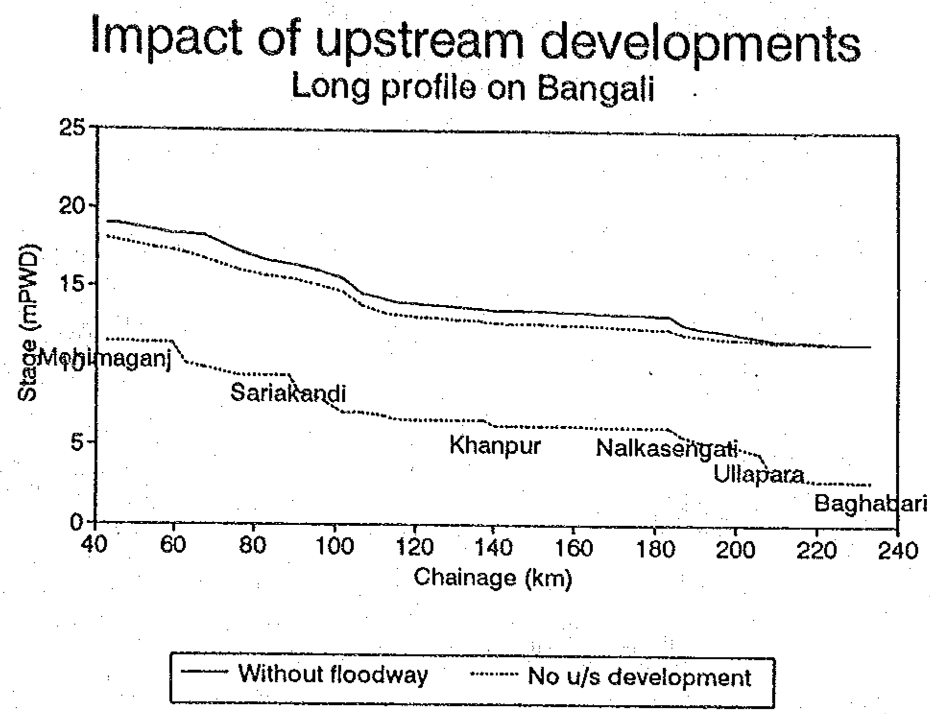


Figure 9.10 **Imapct of upstream developments on water levels in the Middle Bangali**

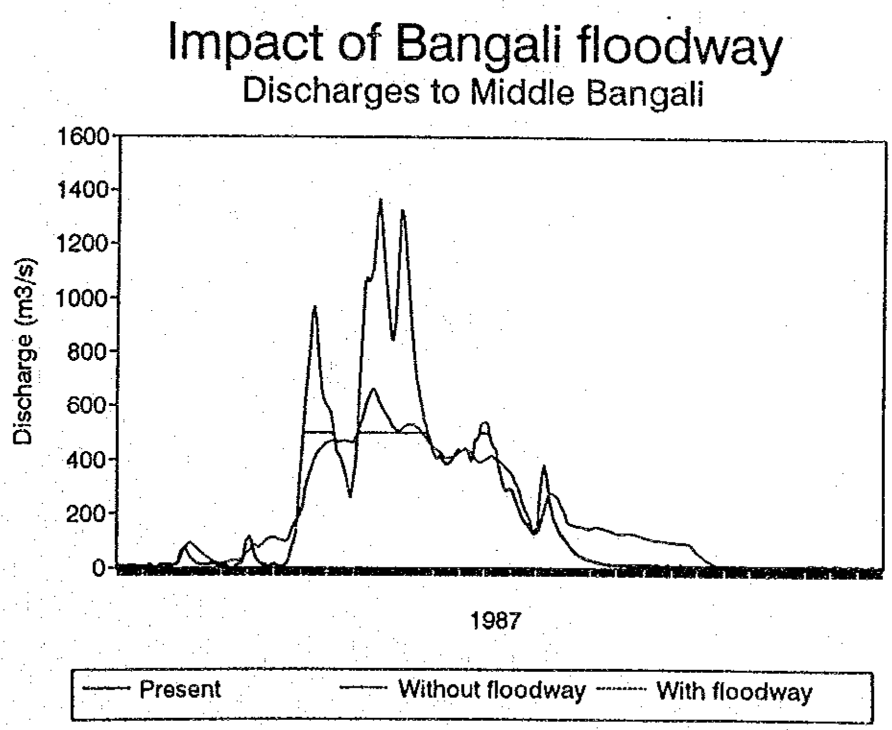


Figure 9.11 **Discharges in the Middle Bangali with Bangali Floodway**

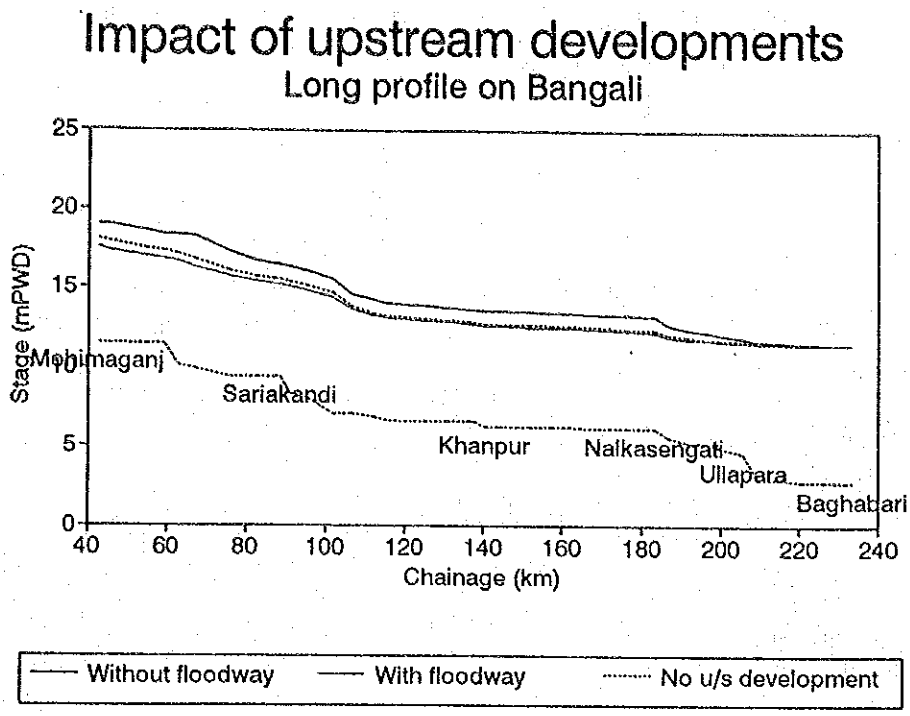


Figure 9.12 **Water levels in the Middle Bangali with Bangali Floodway**

CHAPTER 10

SUB-REGIONAL MODEL -WITH PROJECT SIMULATION

10.1 Description

10.1.1 General

Following the design option simulations a development plan for the sub-regional model area was formulated. A With Project simulation was carried out with this development plan in place.

The With Project simulation used the hydrological data for the period from 1965 to 1989. The impact of the proposed development plan was investigated by comparing the results of the With Project simulation with the results of the Without Project simulation.

The With Project simulation looked at the impact of proposed developments within the modelled area. For the With Project simulations the same external developments, the sealing of the Brahmaputra right embankment, as for the Without Project simulation were assumed. Naogaon Polder and the Barnai project were assumed to be complete as was the case for the Without Project simulation.

10.1.2 Proposed developments

The formulated development plan for the Lower Atrai basin consisted of the Green River with partial protection, the key features of this plan are,

- Chalan Beel Polder A : Sub-poldering. CFD in higher areas with flow across the lower areas. Partial protection in lower areas.

- Chalan Beel Polder B : Sub-poldering. CFD in higher areas with flow across the lower areas. Partial protection in lower areas

- Chalan Beel Polder C : Flow through the polder with higher areas sub-poldered for CFD protection. Partial protection of the flow area.

- Chalan Beel Polder D : Flow across central part of polder with higher areas sub-poldered for CFD protection. Partial protection of the flow area.

- Bogra Polder 2. Upper part of polder CFD. Flow in part adjacent to Atrai with partial protection.

- Bogra Polder 3. Upper part of polder CFD. Flow in part adjacent to Atrai with partial protection.

- Bogra Polder 4. No development

- SIRDP. Upper unit CFD; this involved embankments on the right bank of the Lower Bangali. Flow in part adjacent to Atrai with partial protection. Closure of spills from Bangali right bank.

The With Project simulation differed from the design option simulation which investigated the Green River with partial protection. The heights of the partial protection embankments/structures were increased to achieve the desired partial protection. The heights of these embankments/structures were based on the results of the design option simulation of the Green River with partial protection. The impact of partial protection, which is provided by either low embankments or a long fixed crest structure, was to delay the rising limb of the hydrograph until late July. The partial protection structure means that water retained in the area at the end of the flood season need to be evacuated by suitable gated structures.

No developments are proposed for the Middle Bangali basin.

Figure 10.1 presents the proposed developments in the sub-regional model area pictorially.

10.2 Results of the With project simulation

10.2.1 Water levels

Figure 10.2 shows longitudinal profiles of peak water levels along the Atrai river for With and Without project conditions. The water levels in the middle reaches of the Lower Atrai increase by up to 1 m. This is because the partial protection embankments/structures for Chalan Beel Polder C are limiting the spillage in to this area and are forcing the flows to pass down the main Atrai channel. This suggests that although the partial protection is having a beneficial impact during the rising limb of the flood it is at the cost of raising levels in the Atrai during the peaks.

Long profiles along the Shib-Barnai for With and Without project conditions are shown in Figure 10.3. In the lower reaches of the Shib, near its confluence with the Atrai, there is a fairly marked increase in peak levels which is partially accounted for by the completion of the CFD embankments along the lower reaches of the Barnai, Polders A and B. This has a reduced impact upstream of Bagmara whereby levels are again higher, but to a lesser degree, for the With Project conditions.

10.2.2 Discharges

The maximum discharges, simulated in the With Project run during 1987, in the main drainage channels of the sub-regional model area are shown in Figure 10.4. 1987 discharges are used in this figure since in 1987 flooding problems resulted from high river flows. Also shown in Figure 10.4 are the magnitude of the spills from the rivers.

Approximately 50% of the flow in the Upper Shib-Barnai river passes over the partial protection structure in the west embankment of Chalan Beel Polder D. This flow passes across the polder, spills into the Fikirni river and rejoins the Shib-Barnai at Bagmara. This peak flow is the same as with the Without project simulation but during earlier part of the flood season it shows a reduction in flow because of the level of partial protection and the fact that it is designed to prevent spillage in to Chalan Beel Polder D until late July.

As in the Without Project simulation approximately 30% of the flow in the Atrai passes down the Fikirni. The water flows into the Shib-Barnai at Bagmara and rejoins the Atrai at Chanchkoir.

A short distance downstream of Jotebazar approximately only 10% of the remaining flow in the Atrai spills into Chalan Beel Polder C through the partial protection structure. This flows passes across the polder and rejoins the Atrai a short distance downstream of Singra. This spillage is much lower than in the Without Project simulation because of the height of the hydraulic characteristics of the partial protection structure, which for Chalan Beel Polder C is a fixed height weir with a relatively short crest width.

A large discharge flows parallel to the Atrai river across the lower parts of Bogra Polders 2 and 3. This flow continues across Bogra Polder 4, through the Taras embankment and into the lower parts of SIRDP. This flow is similar to that which occurs in the Without project simulation despite the fact the upper units of Bogra Polders 2 and 3, and SIRDP now have CFD. This implies that the upper units of these areas were not carrying a significant volume of flow under Without project conditions. The flows in the lower part of the SIRDP area are however reduced as flows down the Durgadah and the other distributaries from the right bank of the Bangali have been cut off as part of the SIRDP developments. In the Bengali, downstream of where the flows down the Durgadah and Barnai have been cut-off, the discharge is increased whereas in the Middle Bangali peak discharges are the same as under Without project conditions.

Flows and spillage across the upper parts of Chalan Beel Polders B and A is reduced by the provision of CFD embankments in these areas and the flow area is now restricted to the partially protected flow areas in the lower parts.

10.2.3 Flood phases

The flood phases for the project areas of the sub-regional model under With project conditions are presented in Table 10.1 and shown in Figure 10.5. In brackets in this table are the corresponding figures for Without project conditions. In areas where flow occurs the flood phases have been calculated directly from the model results. In areas of CFD the flood phases have been calculated by engineering drainage analysis. This drainage analysis uses model predicted water levels in the external rivers at the drain outfalls. The flood phases for the entire project area are combination of those calculated directly from model results and those calculated by engineering drainage analysis.

In most of the project areas in the Lower Atrai basin the percentage of F0+F1 land is increased under With project conditions. This is due to the provision of CFD in the upper parts of the polders. It should be noted that both CFD and partial protection can result in some drainage congestion so the improvement relative to Without project conditions may not be as great as might be expected.

In some project areas the percentage of F0+F1 land is decreased because of the rise in water level in the middle reaches of the Lower Atrai.

There is minimal change in the flood phases in Bogra Polder 4 since no developments are planned in this area.

TABLE 10.1
With project simulation flood phases for projects in the Lower Atrai

	F0	F1	F2	F3+F4
Bogra Polder 2	68% (50%)	13% (22%)	10% (19%)	9% (9%)
Bogra Polder 3	67% (68%)	8% (10%)	12% (12%)	13% (10%)
Bogra Polder 4	39% (39%)	5% (8%)	12% (14%)	44% (39%)
Chalan Beel Polder A	56% (45%)	8% (14%)	14% (17%)	22% (24%)
Chalan Beel Polder B	65% (44%)	17% (24%)	9% (20%)	9% (12%)
Chalan Beel Polder C	39% (33%)	12% (14%)	20% (22%)	29% (31%)
Chalan Beel Polder D	66% (17%)	13% (21%)	13% (27%)	8% (35%)
SIRDP	27% (24%)	7% (10%)	27% (24%)	39% (42%)
Middle Bangali				

10.3 Sensitivity analysis

10.3.1 Confinement of the Upper and Middle Atrai

Both the magnitude and temporal distribution of flows in the Lower Atrai will be affected by confinement of the Middle Atrai in India. To investigate the sensitivity of water levels in the Atrai to these changes the discharge hydrograph at the Mohadevpur boundary was replaced by that at Bushirbandar, a discharge gauging site in the upper reaches of the Atrai north of the Indian border.

Confinement of the Middle reaches of the Atrai results in an increase in peak water level in the upper reaches on the Lower Atrai of about 1m. This is illustrated in Figure 10.6 which shows a longitudinal profile of peak levels from the period 1985-89. The maximum rise in level occurs at Mohadevpur. The impact of diminishes further downstream but extends to around Atrai RB/Singra. There is no increase in water level downstream of this is because of backwater effects from the Brahmaputra.

10.3.2 Rise in Brahmaputra water level

Developments external to the North West region are likely to have an effect on water levels in the Brahmaputra. A sensitivity analysis was carried out to investigate the impact of a rise in peak water level of 0.6 m in the Brahmaputra; it was assumed that the minimum water level did not change.

The increase in peak water level in the Brahmaputra results in an increase in peak water level in the lower reaches on the Lower Atrai since it extends the influence of the backwater effect. This is also illustrated in Figure 10.6 The maximum increase in water level, which is 0.5m, occurs at the downstream boundary, Baghabari. Upstream the influence of the rise in Brahmaputra levels diminishes and is almost negligible at Singra, which is the limit of the backwater zone.

10.4 Morphological impact

10.4.1 Lower Atrai basin

The impact of the proposed developments on the Lower Atrai system is to increase the sediment movement down the Atrai. This could lead to erosion in the Mohadevpur area.

Regime calculations suggest that the increased flow down the Atrai would lead to an increase in the size of the channel; an increase in width of between 5 and 15% could be expected. The largest changes would occur in the reach from Jotebazar to Singra with the largest being in the Atrai Railway bridge area where the changes could approach 40%. There would be corresponding increases in channel depth of 5 to 12%. The changes would be accompanied by an increased tendency to meander, particularly in the area of Atrai railway bridge. These changes would in the long-term help the performance of the scheme.

Reduced discharges in the Fikirni would lead to long-term siltation in the river. The reduced sediment input to the Fikirni may affect the timescale of this process. A reduction in channel width of 10 to 12% could be expected and a corresponding reduction in depth of approximately 10%. This would have an adverse effect on water levels in this area.

10.4.2 Lower Bangali

In the Bangali, downstream of where the flows down the Durgadah and Barnai have been cut-off, the discharge and the sediment transport rate is increased. This increase is made greater by the embankments constructed on the right bank of the Lower Bangali as part of the CFD for the upper unit of SIRDP. The increased will have the impact of increasing the channel width by approximately 10% and increasing the depth by between 5 and 8%. The effect on the plan form of the river will be small. The increase in the size of the river channel will increase its conveyance and hence there should be a long-term improvement in the performance of the scheme in this area. Until the increase in channel size has taken place there will be a backwater affect upstream in the Bangali. This will, therefore, temporarily cause deposition upstream in the Bangali. This deposition could lead to a local increase in flood levels.

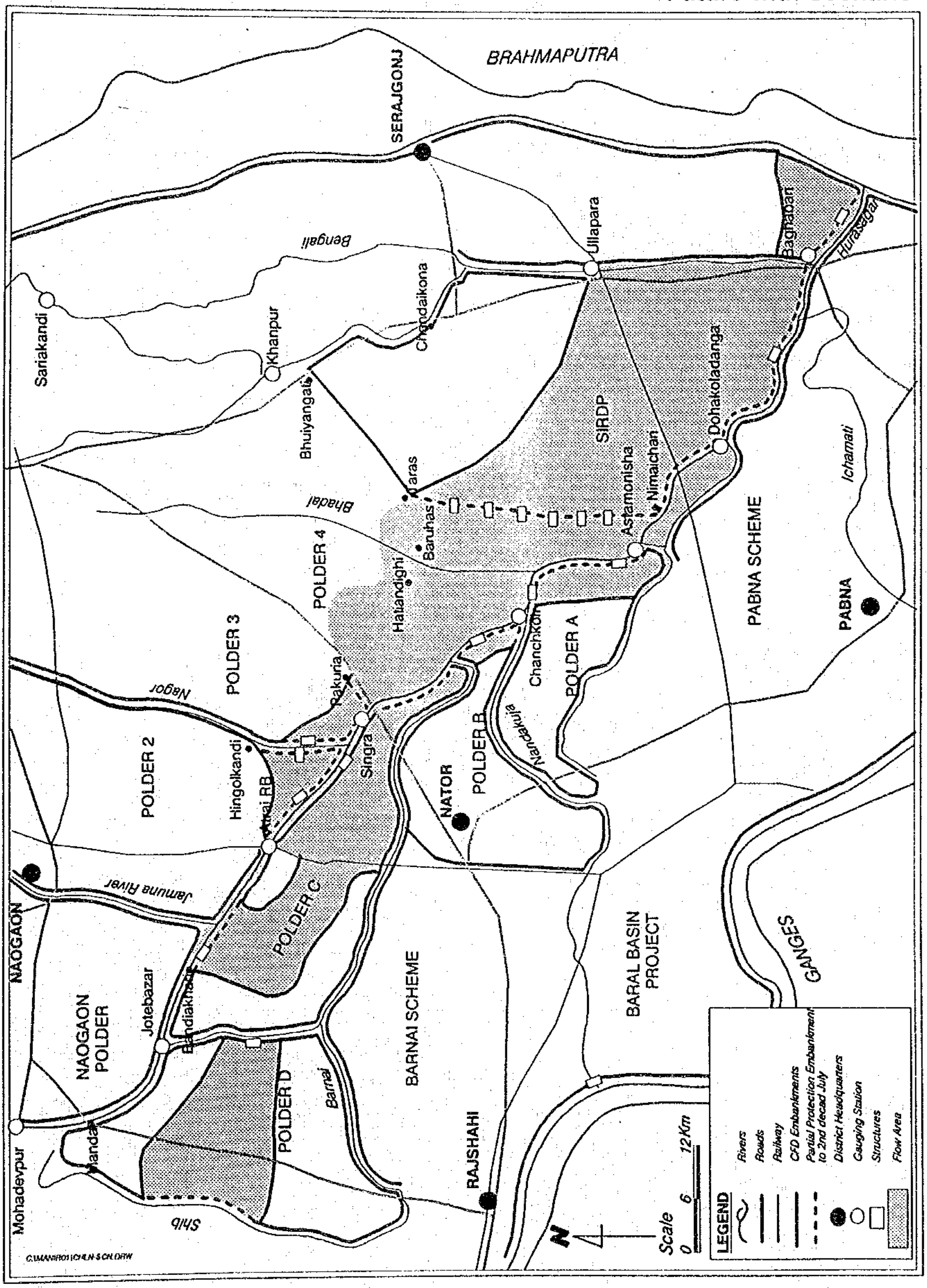
In the Durgadah and Barnai downstream of where they are beheaded there will be a large reduction in the dominant discharge; this will result in sedimentation in these rivers. The channels of the Durgadah and Barnai will become narrower and shallower; these channels will tend to follow a straighter course.

10.4.3 Middle Bangali

The discharges in the Middle Bangali are unchanged since there are no developments in the Middle Bangali basin. There will be no change in sediment transport rates and hence no morphological change.

Figure 10.1

Future with Scenario



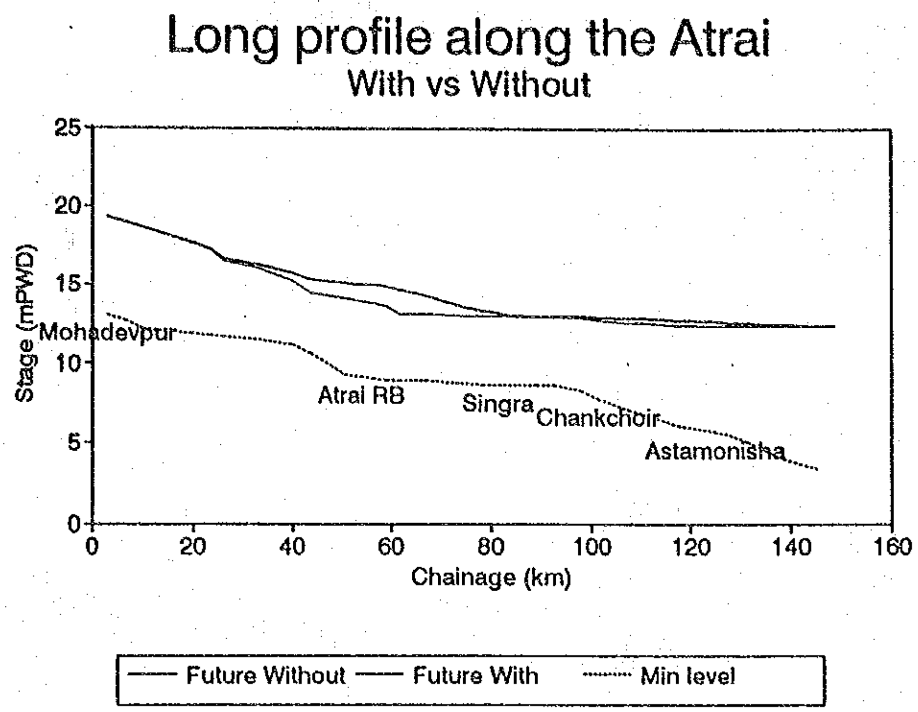


Figure 10.2 Long profile along Atrai - With vs Without

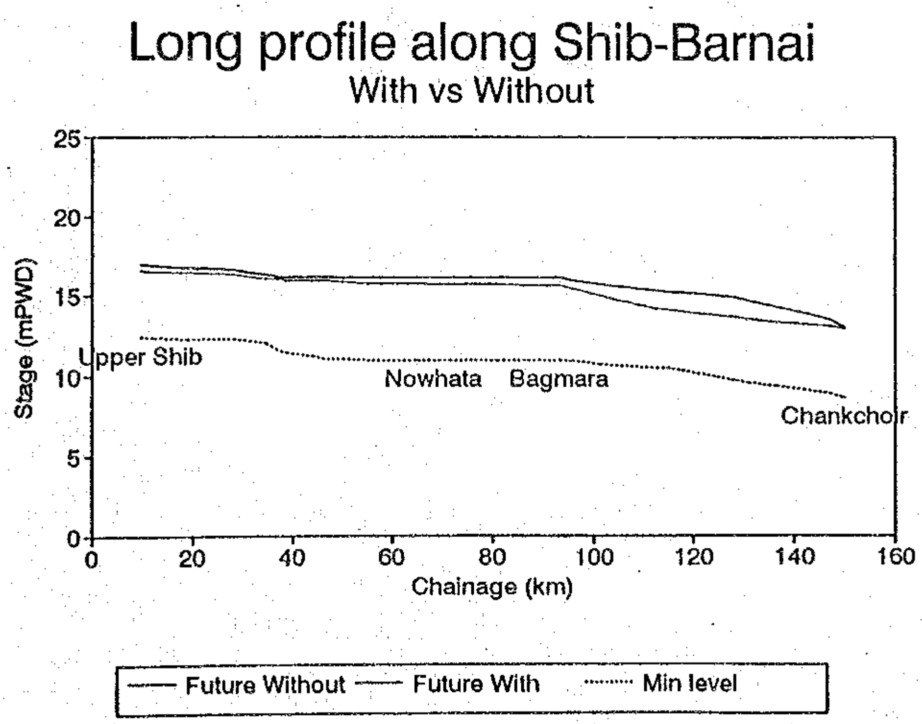
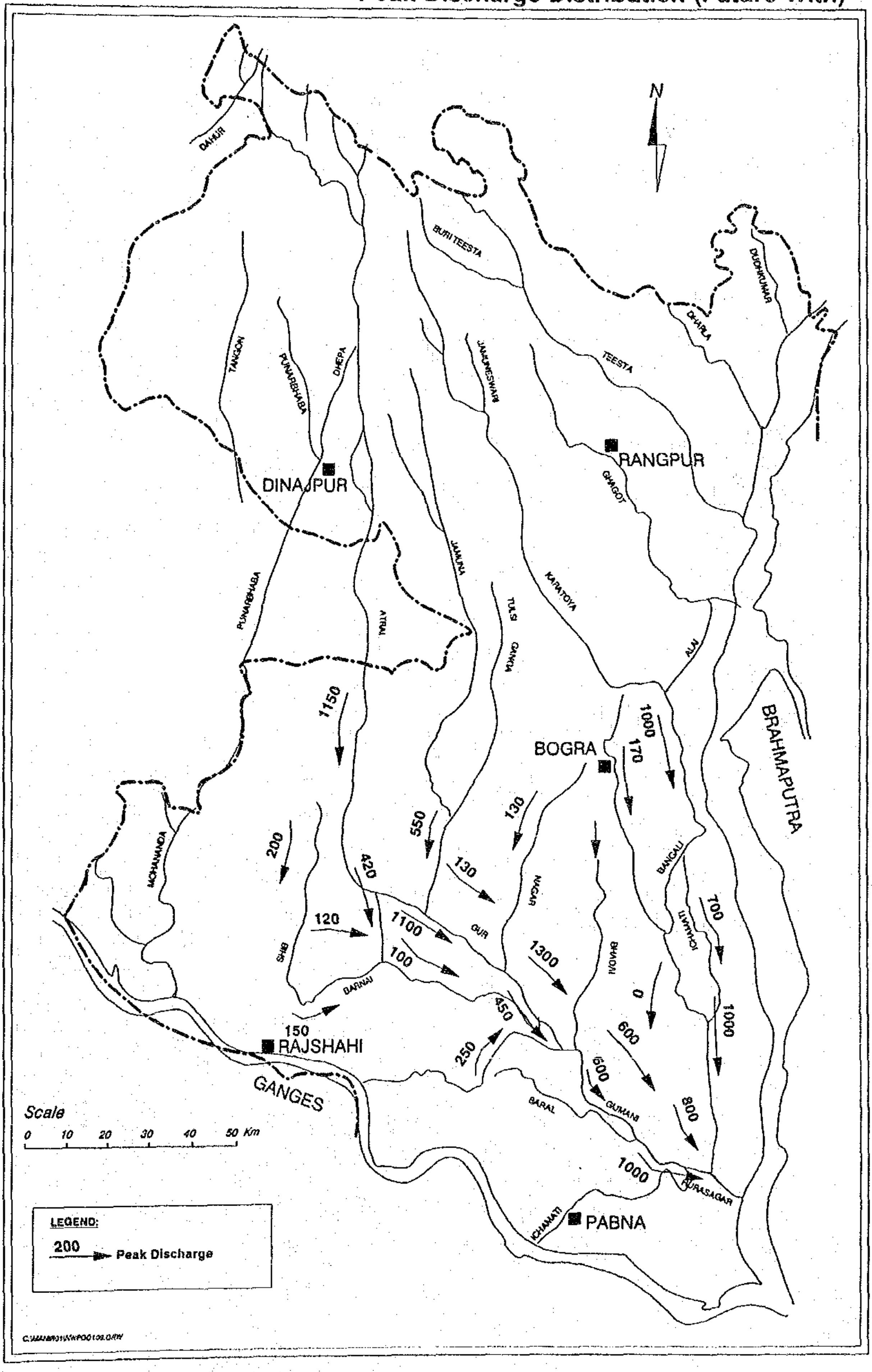


Figure 10.3 Long profile along Shib-Barnai - With vs Without

Figure 10.4
Peak Discharge Distribution (Future With)



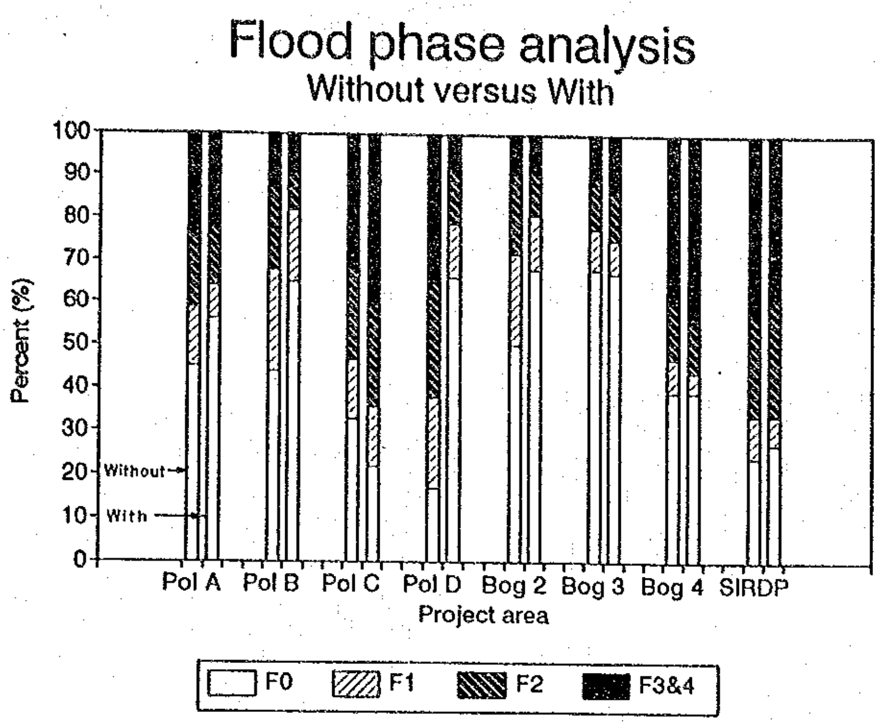


Figure 10.5 **Flood phase analysis - With vs Without**

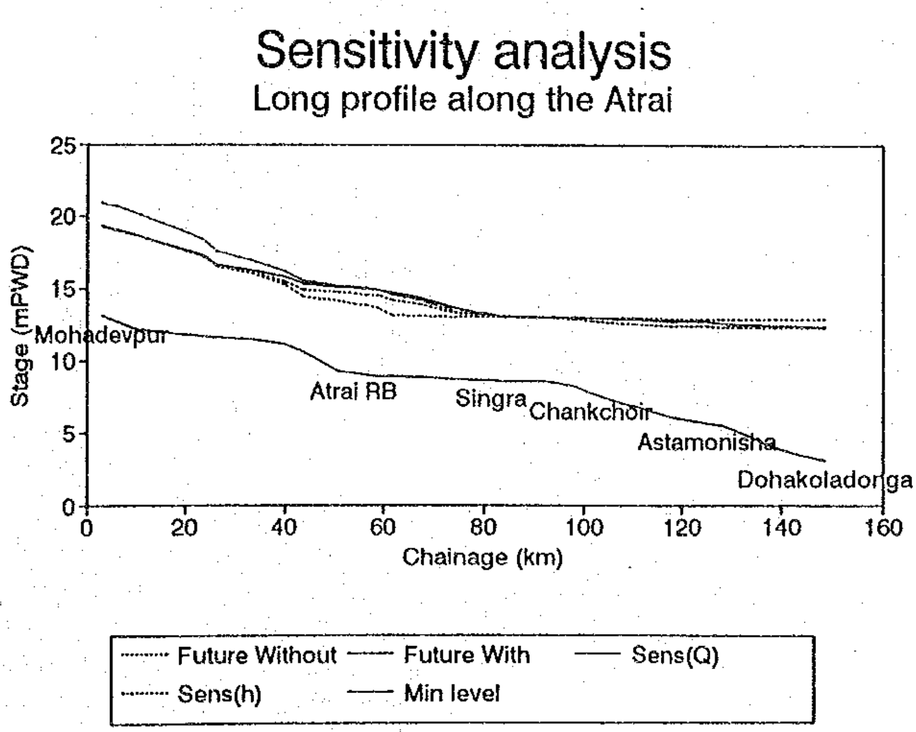


Figure 10.6 **Sensitivity to rise in Brahmaputra levels and embanking of Middle Atrai**

SECTION D

GAIBANDHA MODEL

CHAPTER 11

DEVELOPMENT AND CALIBRATION OF THE GAIBANDHA IMPROVEMENT PROJECT MODEL

11.1 Introduction

This Chapter covers the development and calibration of the Gaibandha Improvement Project (GIP) model. This model covers the Gainbandha Improvement Project area together with flows in the rivers Ghagot, Manas, Teesta, Alai Nadi, Karatoya, Alai Kumari, Akhira and Naleya. On the Eastern side the model is bounded by the Jamuna.

The model was calibrated for the 1990 and 1991 flood seasons. Much greater emphasis was placed on the latter flood season since this was the year with the best topographic and hydrologic data; most was also known about the flooding regime in this year together with the location of breaches and cuts. In a hydrological context 1991 was a reasonable high flood year. Additional verification of the model was carried out by simulating the five year period between 1985-89.

Since the model was calibrated against flood season water levels and flow rates it can only be used with confidence to study developments under these conditions. If a study which required the investigation of lower water levels and flow rates were required the suitability of the developed model to simulate these conditions must be reassessed.

Following the calibration and verification of the model it was used in the 25 year simulation run for a future 'without' project condition; this simulation is reported in Chapter 12.

11.2 Gainbandha Improvement Project model development

The GIP model was developed by the North West Regional Study modelling team.

Topographic data on the major rivers was collected by surveyors on the North West Regional Study. Information was also collected on the location, size and sill levels of regulators within the area.

Representation of the flooding regime inside the GIP was based on information collected by members of the NWRS team during numerous visits to the area. This information included the location of roads and embankments which inhibit flow, the location and sizes of culverts together with details of the flooding regime within the area.

The GIP model was calibrated in the FAP-2 offices during May and June 1992. The results of this calibration were passed to the NWRM modelling team at the SWMC.

11.3 GIP model set-up

11.3.1 The GIP model area

The area covered by the GIP model includes the Gainbandha Improvement Project area together with the rivers Ghagot, Manas, Teesta, Alia Nadi, Karatoya, Alai Kumari, Akhira and Naleya. On the Eastern side the model is bounded by the Jamuna. Figure 2.2 illustrates the extent of the GIP model and the project area under consideration is shown in Figure 11.1.

The general drainage pattern within the area is also depicted in Figure 11.1. The key features include spillage from the right bank of the Ghagot which passes through a low lying, depressed area before entering the Karatoya/Alai river systems. Spillage also occurs on the left bank upstream of Bamandanga which enters the project area. On the eastern side, large breaches in the Teesta Right Embankment (TRE) enter the area during high levels in the Teesta. Internally, drainage is generally northwest-southeast with the majority of the internal drainage making its way towards the Ghagot/Manas link channel and the Manas regulator. The Manas regulator can discharge flows to the Brahmaputra when external levels otherwise the flow passess southwards through the Alai river which connects with the Katakhali upstream of Mohimaganj.

11.3.2 The model set-up

Figure 11.2 is a schematic of the flow system represented in the GIP model. The important features included within this model are as follows,

- the internal drainage area of Gainbandha is represented in the model by 23 flood cells. Elevation-area relationships were developed for each of these flood cells using spot heights from 4 inch to 1 mile maps. This resolution was much greater than that used for defining elevation-area relationships in the sub-regional model. The flood cells were delineated based on information collected by NWRS staff during visits to the area. This information included details of roads, railway embankments and other embankments in the area which restrict free drainage.

- the flood cells were linked together by artificial channels which allowed flow between adjacent flood cells. The locations of these link channels was based on information on drainage routes. Broad crested weirs were incorporated into the artificial channels to control the flow of water between adjacent flood cells. As far as was possible the size and crest level of these broad crested weirs was based on the dimensions and invert levels of culverts.

- at a number of locations the internal flood cells were linked to the main rivers of the area.

- Flow in the channels which linked the internal flood cells to the main rivers was controlled in one of two ways;

  a) where the link channel represented a breach a broad crested weir was used to control the flow. The crest level of the weir was taken to be the ground level in the adjacent flood cell. This representation allowed flow both out of and into the flood cell from the main rivers. This form of representation was used to link flood cells to the Ghagot to the North of Bamandanga, and also where the Teesta Right Embankment (TRE) is breached.

  b) regulators were placed in the rest of the channels which linked the internal flood cells to the main rivers. These regulators prevented flow entering the area from the main rivers and allowed flow out of the area when there was a positive head difference between the internal water levels and the water level in the main rivers. The dimensions of the regulators and their sill levels were based on information collected in the field.

- at a point a short distance to the North of the Manas regulator a public cut occurs most years. Usually this cut is made after the monsoon season as the water levels in the Jamuna recede; the cut is made to relieve drainage congestion in the GIP area. This public cut was represented in the model as a regulator. This regulator prevented flow from the Jamuna into the GIP area and allowed flow out of the area when there was a positive head difference of 1 m.

- the Manas river which drains the internal area of the GIP was included in the model. This river was linked to the internal flood cells along its length and connected to the Ghagot river at downstream limit.

- the Alai Kumari which drains an area on the left bank of the Ghagot, behind the TRE was represented in the model. The topography of this river was based on information supplied by the SWMC.

- the Ghagot from Jafarganj gauging station to the Manas regulator was represented in the model.

- the Manas regulator was represented as a regulator which prevented flow from the Jamuna into the Ghagot. When there was a positive head difference the Manas regulator was assumed to be open. The dimensions and sill level of the Manas regulator was based on information collected by NWRS staff.

- the Teesta from Kaunia bridge to its confluence with the Jamuna at Haripur is represented in the model.

- the Jamuna is not explicitly represented in the model. Water levels in the Jamuna form boundary conditions on the Eastern side of the modelled area.

- the Alai Nadi from where it spills from the Ghagot to where it joins the Karatoya is represented in the model.

- the Karatoya from Siraj to Mohimaganj is represented in the model.

- the topography of the Ghagot, Manas, Teesta, Alai Nadi and Karatoya was based on cross-section data collected by FAP-2 surveyors.

- the Naleya which links the Ghagot to the Karatoya upstream of Gainbandha town was represented in the model. The topography of this river was based on information supplied by the SWMC.

- the Akhira river was represented in the model. This river drains the area on the right bank of the Ghagot; it enters the Karatoya some distance downstream of Siraj gauging station. At its upstream end the Akhira was assumed to be linked to the Ghagot; this was to allow it to collect water from the Ghagot and transfer it to the Karatoya. A broad crested weir was inserted in the Akhira to control the flow from the Ghagot. This weir had a crest level which corresponded to the bank height of the Ghagot.

The internal flood cell delineations and identifiers, which are referenced in discussion of the model results in later Chapters, are shown in Figure 11.3.

11.3.3 Incorporation of flood plains

In the GIP model flood plains were attached to the river cross-sections at locations where embankments which prevented spillage onto the flood plain were not present. Flood plains were not attached to the left bank of the Ghagot or the right bank of the Teesta; the flood cells used to simulate flows within the GIP represent these flood plains. The topography of the flood plains were based on the MPO 1 sq. km. database of levels.

The roughness of the flood plain was taken to be twenty times that in the river channels to which the flood plain was attached.

11.3.4 Model boundaries

There are 12 external boundaries in the GIP model; the schematic location of the main boundaries can be seen in Figure 11.2.

Discharges boundaries at the heads of ungauged catchments, at the head of the Alai Kumari and the head of the two drainage channels which enter the north of the modelled area, were based on catchment area weightings of the discharges recorded at Jafarganj. NAM input was not used at these boundaries since this would not include spillage from the Teesta; the observed discharges at Jafarganj include Teesta spillage.

The water levels at the downstream end of the drainage channels which enter the Jamuna between the Manas regulator and Haripur were interpolated from the observed water levels at Manas regulator river side and Haripur; a linear variation in water level between these two points was assumed.

11.4 Model calibration

11.4.1 Methodology

Having set up the basic structure of the model, there follows a process of proving that it is adequate to reproduce the system which it is intended to represent. This process is two stage, one of calibration and thence verification. For the GIP model calibration was carried out for the 1991 flood season and verification for the 1990 flood season. Further model verification was carried out for the period from 1985-89. In the calibration exercise, the model is adjusted such that a given set of observed values is reproduced by the model. The verification of the model follows by checking its performance against an additional set of observed values which were not included in the original data set used for calibration. It is often found that the deviations of the model results for verification runs are greater than those during calibration. It is difficult to define objective criteria for assessing the quality of a model calibration. Often the modeller must rely on his experience and subjective judgement to decide whether or not to halt the calibration. A further constraint on model calibration is the time scale of the project and the requirement of model results by other disciplines within the study. There has been no work done in the NWRS in the definition of objective criteria for model calibration adequacy, purely subjective judgement has dictated the progress of the modelling.

Model calibration was carried out for the monsoon period; this is the period of greatest significance for the NWRS. The objective of calibration was to minimise difference between the modelled and observed data during this period. It is clear from the model verification that if the study were to be concerned with water levels and discharges during the dry season, much additional work would be required to give satisfactory calibration during these periods.

The main parameter which was adjusted as part of the calibration process was the roughness in the river channels. In all cases physically reasonable values of roughness coefficients were used. In some cases these were either higher or lower than values which would normally be expected for the rivers being simulated. This was probably because they were simulating the effect of features which it was not possible to explicitly represent in a one dimensional hydrodynamic model such as MIKE11.

In order to get reasonable water level calibration at Islampur and Mirjapur gauging stations the flood plains which had been attached to the right bank of the Ghagot had to be removed. With these flood plains attached there was too much flood peak attenuation between Islampur and Mirjapur. Spills still occur on the right bank of the Ghagot into the Akhira and Naleya rivers via Beel areas; model calibration showed that a significant amount of water was passing from the Ghagot into the Karatoya through these rivers. Spills also occur on the left bank of the Ghagot to the North of Bamandanga. These spills occur through artificial channels which link the Ghagot to the flood cells which are used to represent the internal drainage of the GIP.

In order to get reasonable water level calibration at Gainbandha town and Manas regulator country side the flood plains which had been attached to the left and right banks of the Alai Nadi had to be removed. With these flood plains attached the water level variations at the two gauging stations was less than that observed. The removal of these flood plains was reasonable since a railway embankment restricts the flood plain width on the right bank of the Alai Nadi and the Sonail embankment restricts the flood plain width on the left bank of the Alai Nadi.

11.4.2 Model results

Water level and discharge hydrographs

Results of the model calibration are presented in this section; these results are for the 1991 monsoon season. Where observations were not available for 1991 calibration results for 1990 are presented. Minor adjustments were made to the model based on the results for 1990. Given this situation the calibration data set was effectively extended to include both 1991 and 1990; 1990 could not really be referred to as a verification year since data for this year was used, at least partially, during the calibration. The period from 1985 to 1989 was used for model verification; the results of this is described in Section 11.5.

Jafarganj (Figure 11.4) : Jafarganj is on the Ghagot river, it is a discharge boundary station for the GIP model. A comparison of the simulated and observed water levels, for 1991, at Jafarganj is shown in Figure 11.4. With the exception of the peak water level which occurs in September the model produces a good simulation of peak water levels. The September peak water level is under estimated by approximately 0.7 m. The model tends to over estimate the lower water level by up to 1 m. The model produces a good simulation of the recessions which occur after each water level peak.

Islampur (Figure 11.5) : Islampur is on the Ghagot river a short distance upstream of the confluence with the Alai Kumari. A comparison of the simulated and observed water levels, for 1991, at this station is shown in Figure 11.5. With the exception of the water level peak which occurs in mid-June, which is over predicted by approximately 0.5 m, the model produces a good simulation of peak water levels. The model tends to over estimate lower water levels by approximately 0.5 m. The model produces a good simulation of the recessions which occur after each water level peak.

A comparison between the observed and simulated discharges at Islampur for the 1991 monsoon season showed that the model under estimates the discharge peak in mid-September and slightly over

estimates the discharge peak in mid-June. For the remainder of the monsoon season the agreement between the observed and simulated discharges is extremely good.

Mirjapur (Figure 11.6) : Mirjapur is one the Ghagot river in the vicinity of Bamandanga. A comparison of the simulated and observed water levels, for 1991, at Mirjapur is shown in Figure 11.6. With the exception of the water level peak which occurs in mid-June, which is over predicted by approximately 0.5 m, the model produces a good simulation of peak water levels. The model tends to over estimate lower water levels by approximately 0.5 m. The model produces a good simulation of the recessions which occur after each water level peak.

Gainbandha (Figure 11.7) : Gainbandha is on the Ghagot river a short distance upstream of the Alai Nadi offtake. A comparison of the simulated and observed water levels, for 1991, at this station is shown in Figure 11.7. With one exception the agreement between the simulated and observed water level hydrographs is extremely good. In late August the model predicts a water level trough approximately 10 days earlier than it occurred. The operation of the Manas regulator has a considerable influence on the water levels at this location. The discrepancy in the timing of the water level trough may be a result of operation of the Manas regulator in a different manner to that which the model assumes.

Manas regulator country side (Figure 11.8) : The observed water levels at this location are taken from a gauge a short distance upstream of the Manas regulator. Immediately downstream of the Manas regulator there is a water level boundary condition in the model.

A comparison of the simulated and observed water levels, for 1991, at this location is shown in Figure 11.8. The agreement between the observed and simulated water level hydrographs at this location is extremely good. The model shows a tendency, during the latter part of the flood season, to simulate water level recessions which are quicker than those which actually occur. This may be due to operation of the Manas regulator in a different manner to that which the model assumes. The operation of the Manas regulator to maintain a pond of water for irrigation would produce this effect.

Manas regulator flow (Figure 11.9 and Figure 11.10) : Figure 11.9 shows the observed water levels of gauges on the countryside and river side of the Manas regulator. In the model, when the head difference is positive (countryside higher) the Manas regulator is assumed to open, otherwise the regulator remains closed. Adopting this operating policy it can be seen clearly from Figures 11.9 and Figure 11.10 that the periods when the regulator discharges to the Brahmaputra have been accurately reproduced and this gives confidence in the operaing policy adopted at Manas regulator.

Figure 11.10 shows the model predicted flow through the Manas regulator throughout the 1991 calibration period. Zero flow indicates that conditions in the model are such that the Manas regulator would be closed; this occurs when the water level in the Brahmaputra on the downstream side of the regulator is higher than the water level in the Ghagot on the upstream side of the regulator. Figure 11.10 indicates that the Manas regulator would only have been closed for a total of approximately 6-8 weeks during the simulated period. For the remainder of the flood season water was discharged from the Ghagot/Manas into the Brahmaputra through the regulator.

Kaunia (Figure 11.11) : Kaunia is located on the river Teesta, it is a discharge boundary station for the GIP model. A comparison of the simulated and observed water levels, for 1990, at Kaunia is shown in Figure 11.11. Up until early June the model over estimates the water levels. For the remainder of the monsoon season the agreement between the simulated and observed water level hydrographs is extremely good.

Chakrahimpur (Figure 11.12 and Figure 11.13) : Chakrahimpur is on the Karatoya river a short distance upstream of the confluence with the Alai Nadi. A comparison of the simulated and observed water levels, for 1990, at this location is shown in Figure 11.12. In the early part of the flood season the model predicts the observed water levels extremely well. Later in the monsoon season the model shows a tendency to under estimate the water levels. The model simulates the discharge peak in mid-October extremely well.

Figure 11.13 shows a comparison between the observed and simulated discharge hydrographs at Chakrahimpur for the 1990 monsoon season. Throughout the monsoon season the model significantly under predicts the discharges. This is surprising since, as described above, the model, on the whole, predicts the water levels at this location well. This suggests that the rating at Chokrohimpur may be suspect.

Mohimaganj (Figure 11.14) : Mohimaganj is on the Karatoya river, it is the downstream water level boundary location for the GIP model. A comparison between the observed and simulated discharges at Mohimaganj for the 1991 monsoon season is presented in Figure 11.11. The simulated and observed discharge hydrographs exhibit similar phasing. The model accurately predicts the first discharge peak in mid-June. For the remainder of the monsoon season the model over estimates the discharges at Mohimaganj. The model under estimates the mid-September discharge peak.

Depth of flooding

Figure 11.15 is a plan which indicates the depth of flooding within each flood cell of the GIP model based on peak water levels predicted by the model in 1991. It should be noted that these these area the maximum depth of flooding within each flood cell based on minimum elevations derived from the area/elevation curves. The lowest points in the area/elevation curves are often 1 to 2m below the general ground elevation. Therefore, in many of the areas the average flood depth within the cell is likely to be much lower than indicated by these figures.

The deepest flooding occurs in the following areas:

- the Manas basin which forms the southern part of the GIP area
- the area behind the breaches in the Teesta right embankment (TRE)
- the area adjacent to the Brahmaputra right embankment (BRE)

In general, the depth of flooding decreases with distance away from these areas of maximum flood depth.

There is no quantitative information on the depth of flooding within the GIP area. The distribution of flooded depths presented in Figure 11.15 agrees well with the qualitative information collected on flooding during the extensive field surveys and public participation exercises carried out as part of the North West Regional Study.

11.4.3 Summary of model calibration results

Taken as a whole the agreement between the simulated and observed water level and discharge hydrographs is good. The model calibration has concentrated on fitting observed water levels. This is reflected in the fact that the agreement between the observed and simulated water level hydrographs is, in general, better than the agreement between the observed and simulated discharges. The agreement between the simulated and observed discharge are sufficiently good to indicate that the split

of flows between the different rivers in the Gainbandha Improvement Project model area is simulated reasonably in the model.

The greatest discrepancy between the simulated and observed water levels occurs in the upper reaches of the Ghagot river. At these locations the model tends to over estimate the lower water levels which occur during the monsoon season. This may be due to a poor rating curve being used to derive the discharges at this location thereby over-predicting the discharge at high levels. This would also be supported by the fact that the calibration for low flows also shows some discrepancies.

The model predicted distribution of flooded depths internal to the area agrees well with the qualitative information collected on flooding during the extensive field surveys and public participation exercises carried out as part of the North West Regional Study.

The calibration results are, in general, within the guidelines given by the Flood Action Plan Model Coordinating Committee (FAPMCC) for pre-feasibility modelling. These guidelines are,

- peak water levels are matched to within 0.5 m.
- peak discharges are matched to with 25 %.

The calibration results and the correlation between field information and depth of flooding give confidence that the model is suitable for undertaking simulations to investigate the impact of proposed developments in the area covered by the Gainbandha Improvement Project.

11.5 Comparison with 1985-89 observations

Because of temporal changes in flow routes which are not represented in the model no direct comparison should be made between the model results and observations for the period 1985-89. However, the dominant drainage patterns are similar from one year to the next although the magnitude of flows along different drainage routes will vary.

Comparisons between modelled and observed water levels and discharges at key locations for the period 1985-89 were, in general, also found to give an acceptable correlation with the observed results. This gives further confidence that the model is suitable for undertaking simulations for the full 25 year period from 1964-89.

Figure 11.1

Drainage Patterns in GIP Area

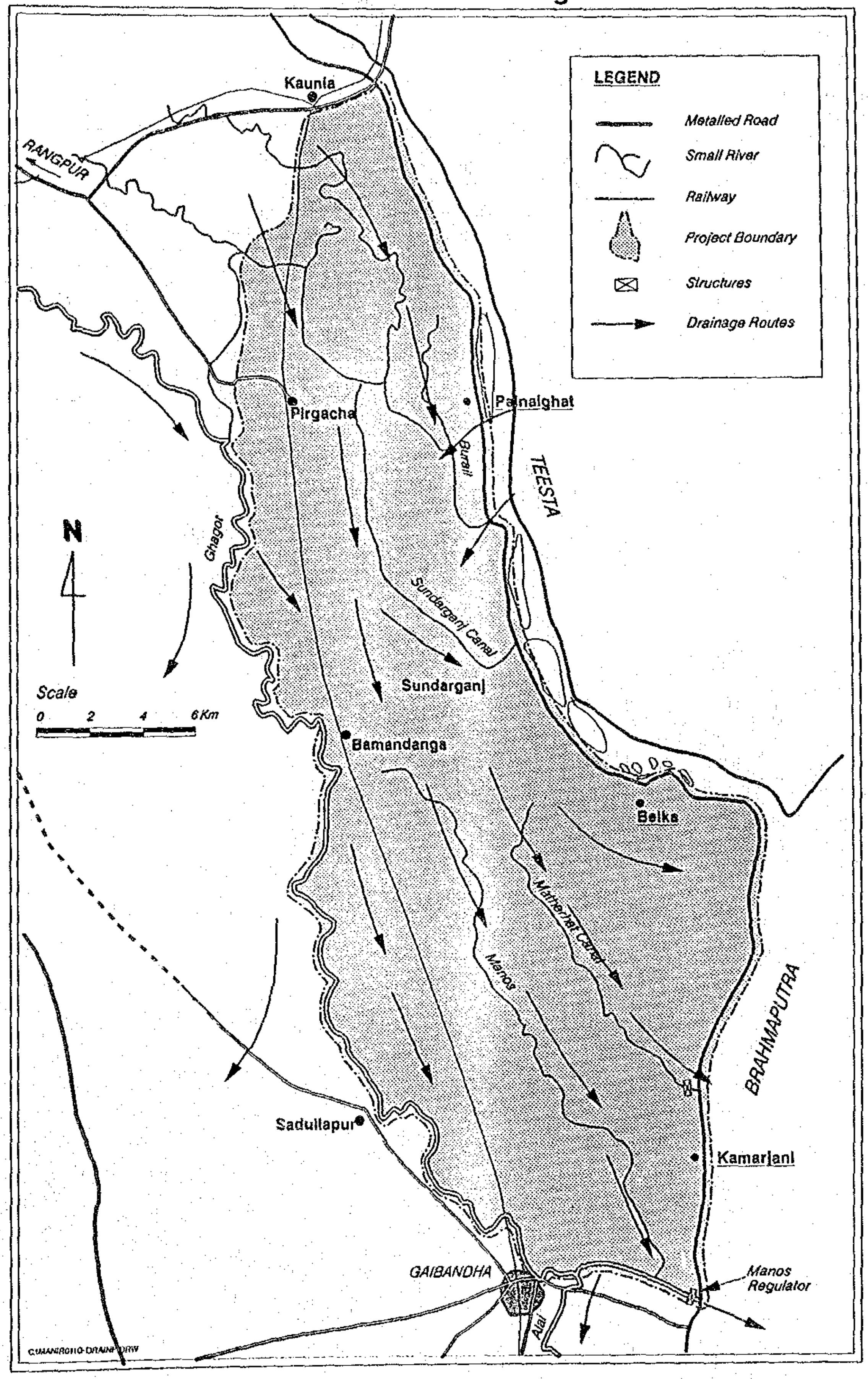


Figure : 11.2

Schematic of GIP Model

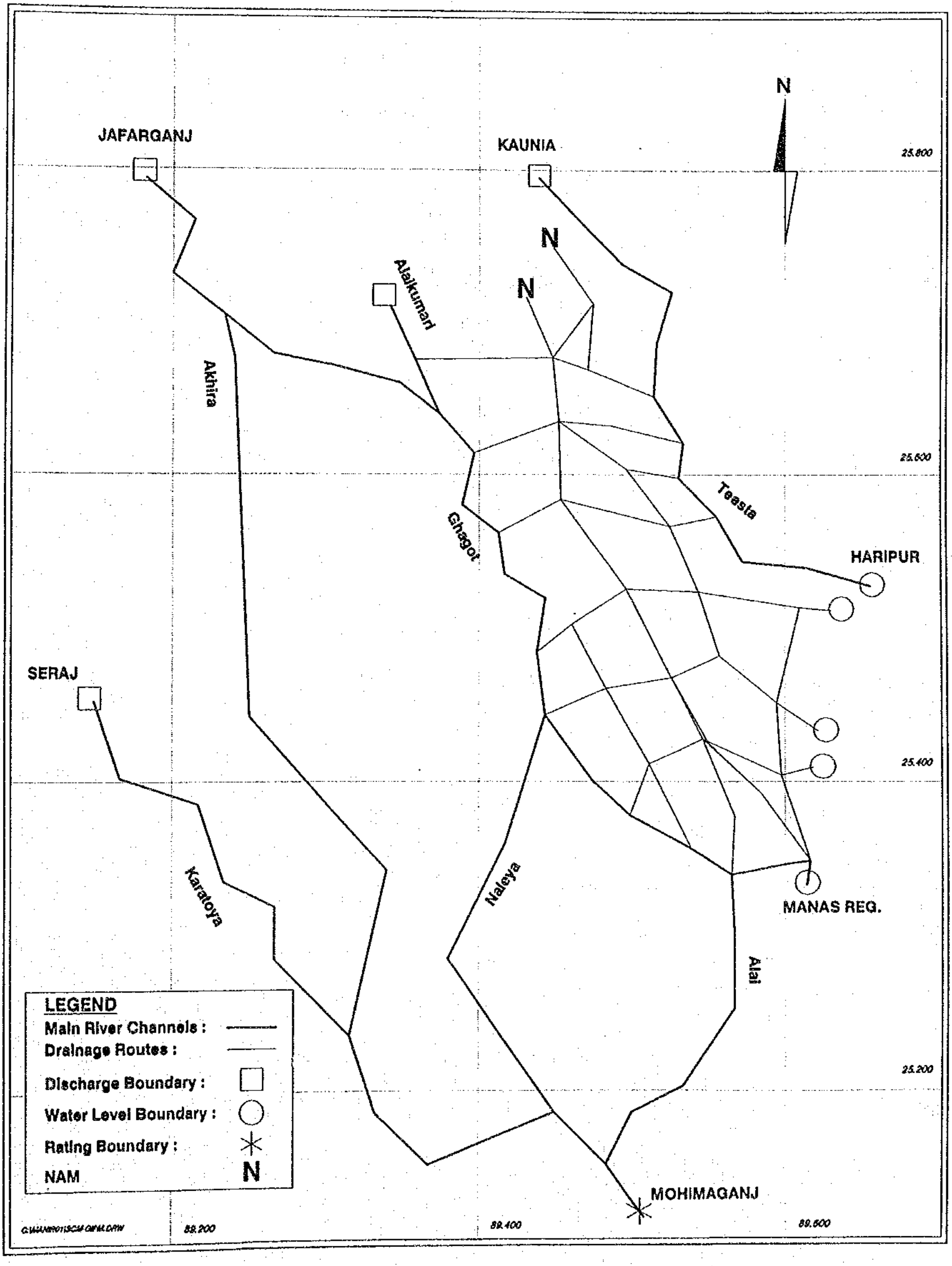
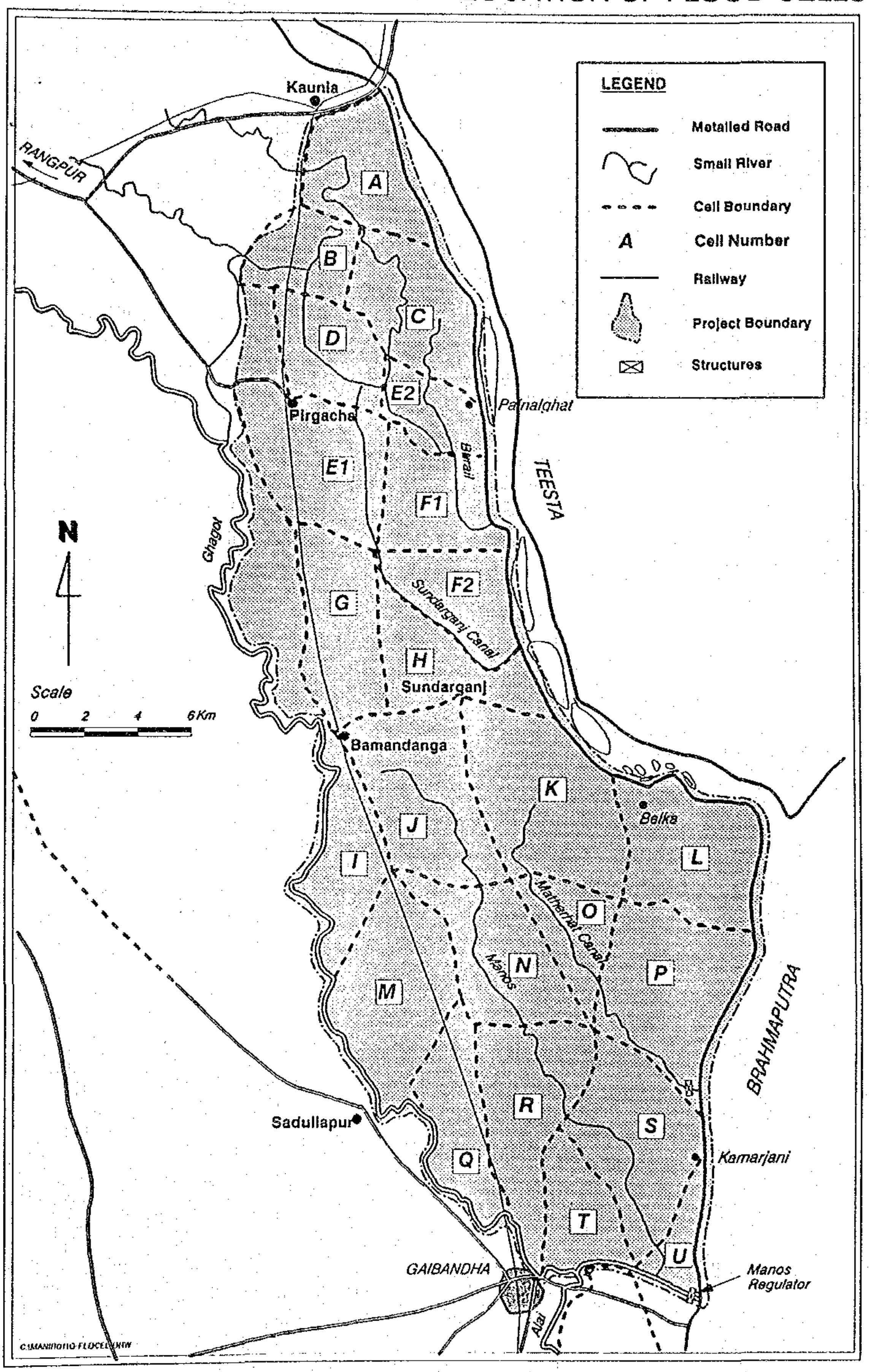


Figure 11.3

LOCATION OF FLOOD CELLS



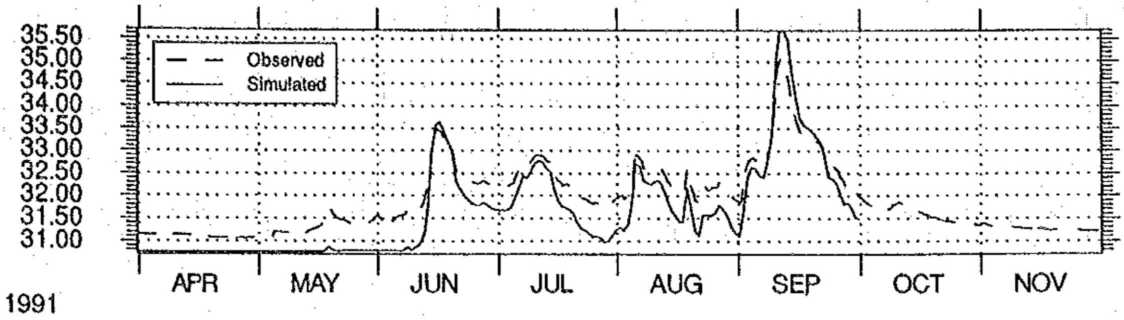


Figure 11.4 Jafarganj (wl)

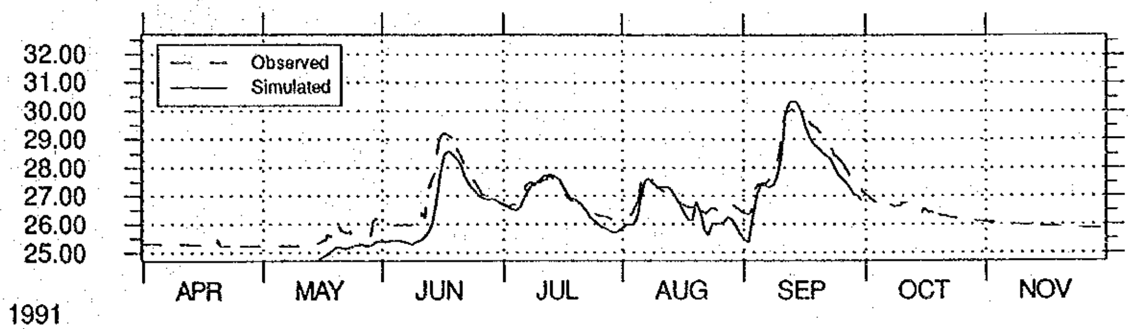


Figure 11.5 Islampur (wl)

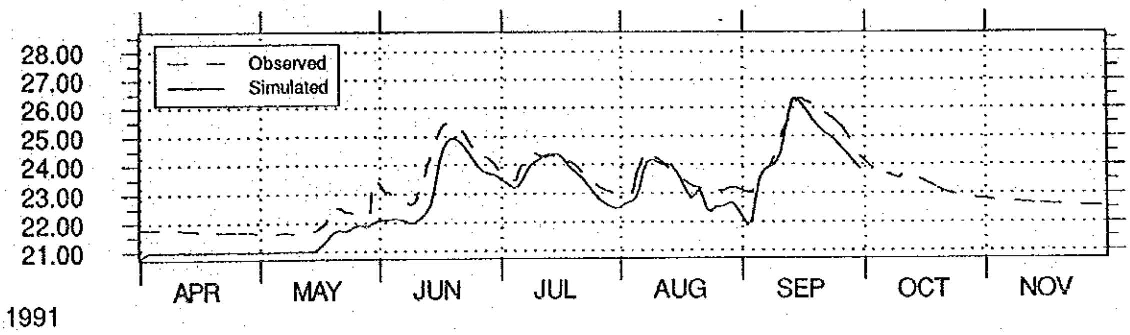


Figure 11.6 Mirjapur (wl)

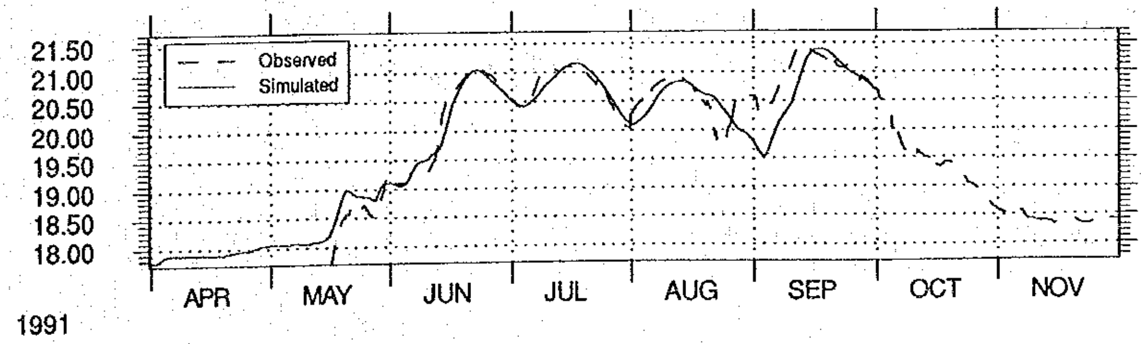


Figure 11.7 Galbandha (wl)

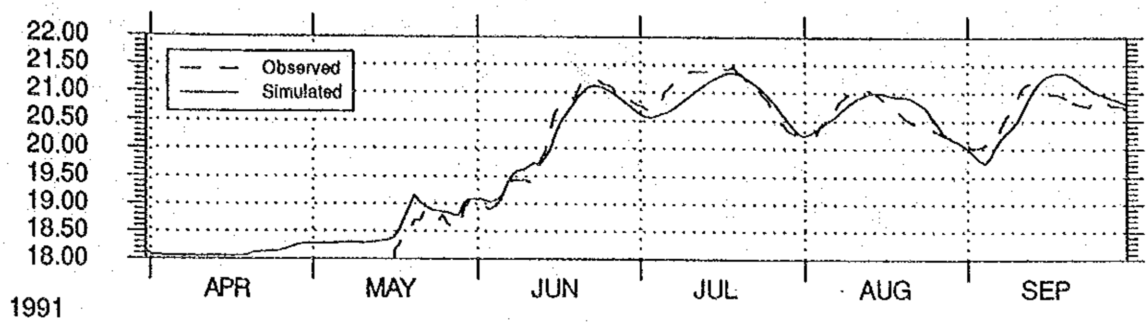


Figure 11.8 Manas c/s (wl)

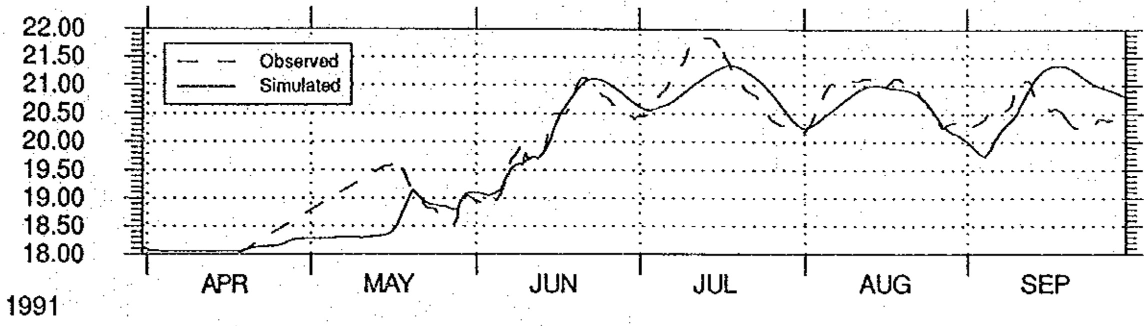


Figure 11.9 Manas c/s v Man-Riv (wl)

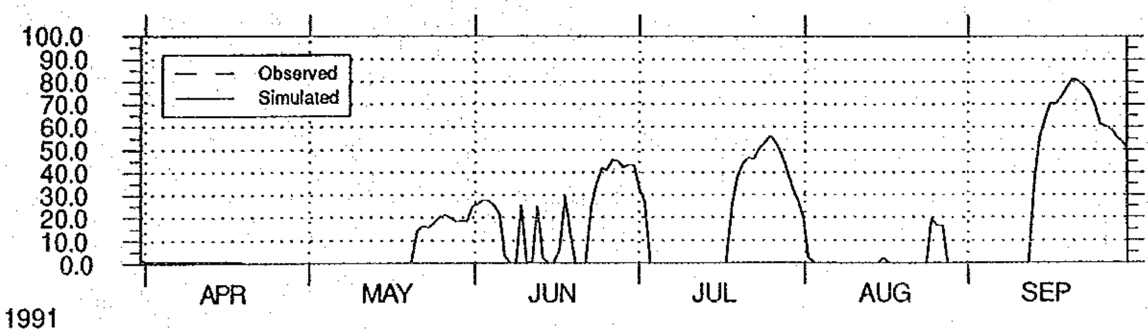


Figure 11.10 Manas (q)

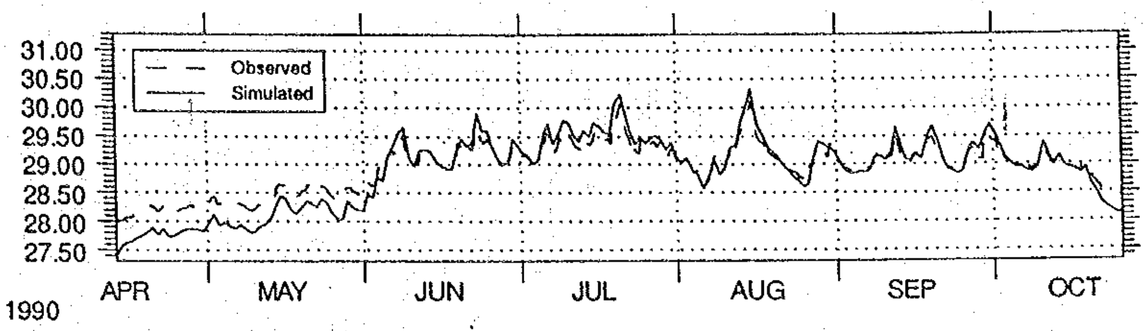


Figure 11.11 Kaunia (wl)

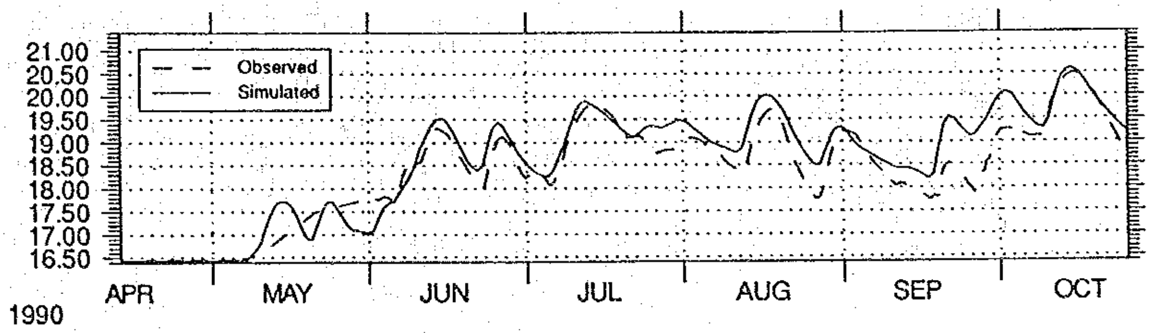


Figure 11.12 Chakrahimpur (wl)

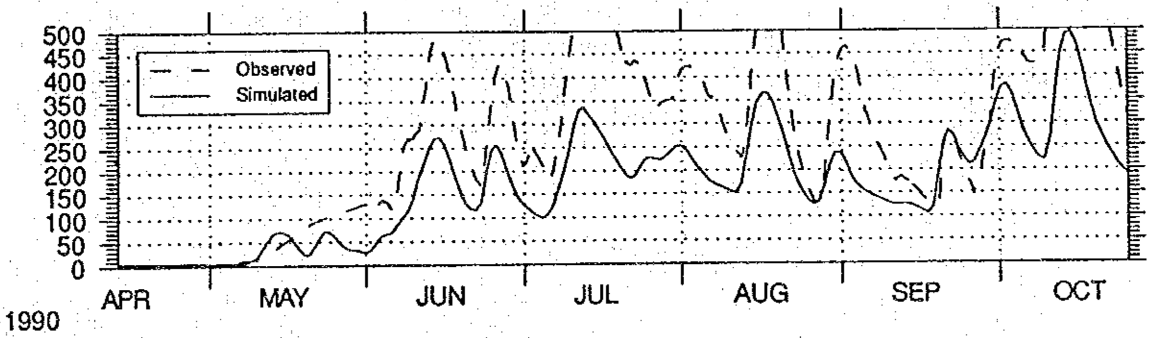


Figure 11.13 Chakrahimpur (q)

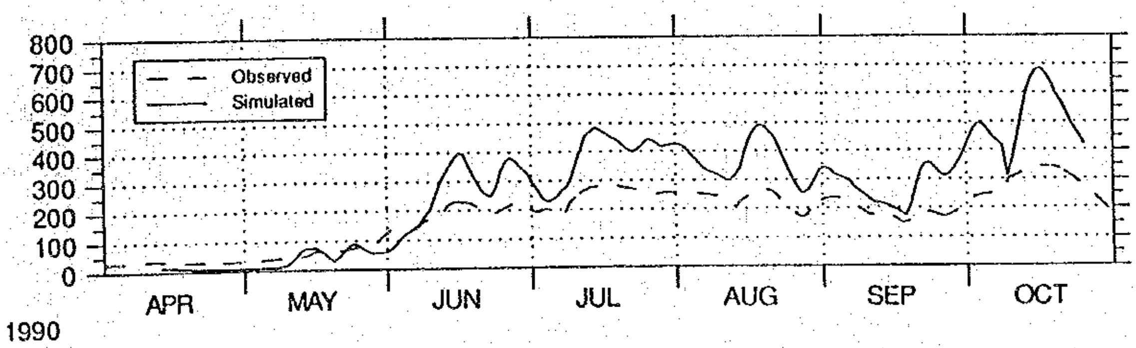
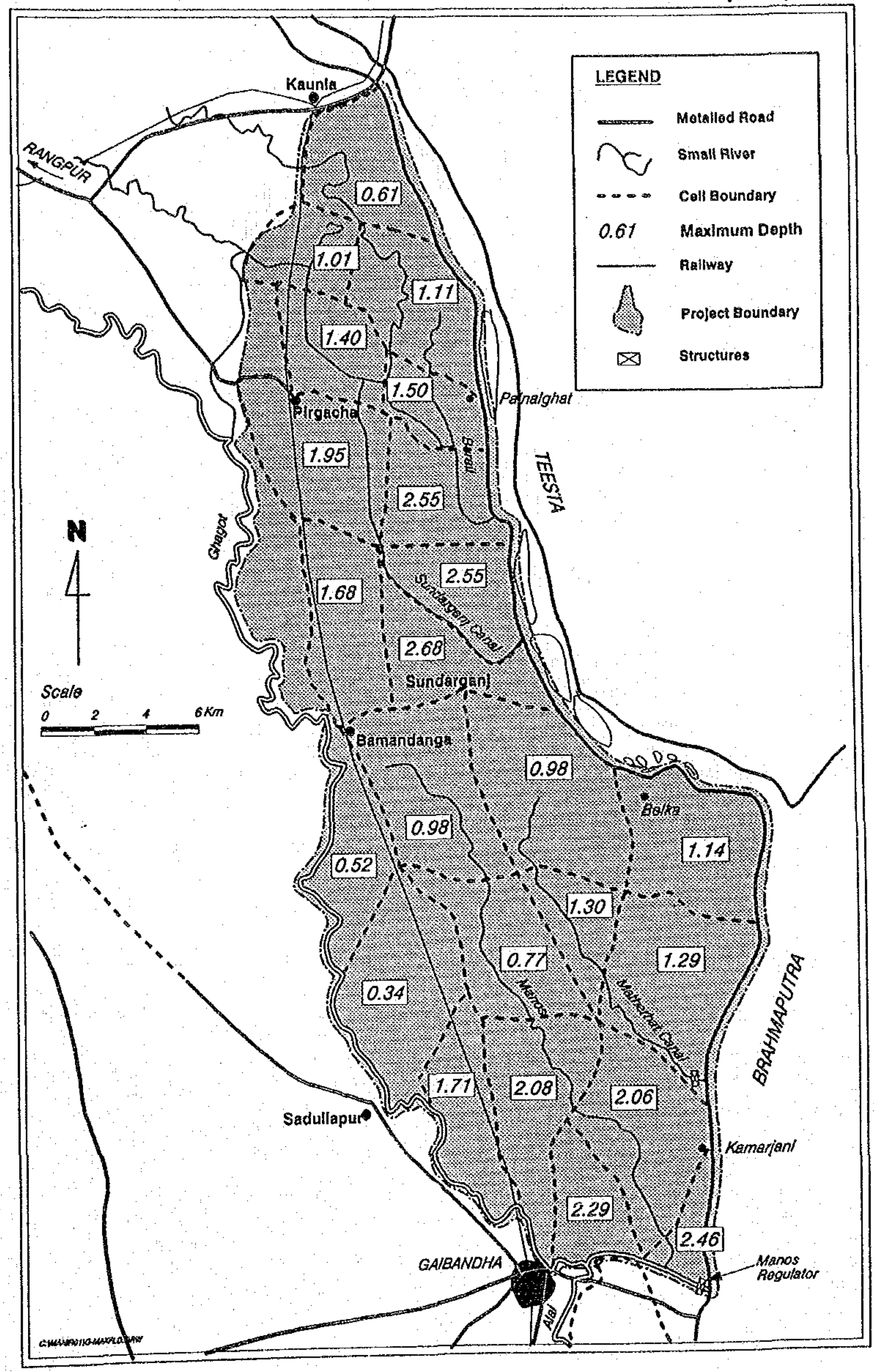


Figure 11.14 Mohimaganj (q)

Figure 11.15

Maximum Flood Depth (1991)



CHAPTER 12

GAIBANDHA WITHOUT PROJECT SIMULATION

12.1 Description

12.1.1 General

Once the Gaibanda Improvement Project (GIP) model had been calibrated and validated a 25 year Without Project simulation was carried out. This assumed that the BRE was sealed and that no breaching or public cuts took place along the BRE. This is a only slight variation from the present situation as it is known that public cuts take place a short distance upstream of the Manas regulator. This area is cut to facilitate rapid drainage from the area due to the insufficient capacity of the Manas regulator.

This simulation was for a 25 year period and used the hydrological data from 1965 to 1989. The objective of the model was to produce data on water level and discharge variations over a period of 25 hydrological years with the BRE sealed. This information would form the baseline data for investigating the impact of developments proposed as part of the NWRS.

The objective was not to simulated observed water level and discharge variations over the 25 year period from 1965 to 1989.

12.1.2 Boundary conditions

In order to carry out a 25 year model simulations 25 years of hydrological data are required at the boundaries. This information was not available at all boundary stations. At discharge boundaries where water level, but not discharge data, was available for the required duration rating equations were used to generate the required hydrological information. Where necessary, NAM inputs were used at minor channel boundaries and also as rainfall-runoff inputs to the internal cells. At all boundary stations consistency checking and some infilling was carried out to obtain a complete dataset.

At the downstream water level boundaries on the Brahmaputra the results of FAP-25 Run 6 were used to provide the 25 year time series of water levels.

12.2 Results of Without Project simulation

Water levels

Hydrological analysis was carried out on the 25 year time series of water levels at key points within the GIP area. The results of the Without Project simulation were analysed on a 10 day basis to give minimum, mean and maximum water levels for each decade. In addition, return period water levels were calculated for 2, 5, 10, 20, 50 and 100 years. These were used as baseline information on which to assess the impacts of proposed developments.

Figure 12.1 shows a longitudinal profile of maximum levels along the Ghagot river for 1987, which was approximately a 1:20 year event in the GIP area. This demonstrates clearly the problems which are associated with the Manas regulator. Levels in the Ghagot exceed those in the Brahmaputra due to drainage congestion at the regulator site. The capacity of the regulator is insufficient and a

backing-up of drainage waters occurs at the upstream face of the regulator. This is why the BRE is cut just upstream of the regulator; to give additional drainage relief to this area.

The figure also shows the joint backwater influence of the regulator and high levels in the Brahmaputra.

Discharges

The maximum discharges, simulated in the Without Project run during 1987, in the main drainage channels of the GIP area are shown in Figure 12.2. Also shown in this figure area the magnitude of the spills from the Ghagot and through the breaches in the Teesta right embankment.

Spills on the right bank of the Ghagot travel through minor channels (Akhira and Naleya) or as overland flow through a depressed area in to the Middle Karatoya basin. It is estimated that some 300m^3/s is transferred from the Ghagot to the Karatoya basin.

There is also spilling on the left bank of the Ghagot, 150m^3/s, which directly enters the project area. Another major contributor to flows within the project area is the large breach in the TRE downstream of Kaunia, over 400m^3/s.

Downstream of Gaibanda much of the Ghagot flow passes down the Alai Nadi; the remaining flow passes through the Manas regulator to the Brahmaputra, when external levels allow. The Alai Nadi flows southwards joining the Karatoya a short distance upstream of Mohimaganj.

Despite the complex internal network of roads and minor embankments, the prominent flow in the internal drainage channels of the GIP area is from north to south; this means that the water which spills through the breaches in the Teesta right embankment eventually reaches the Manas basin in the south of the GIP area. It is this southern area of the GIP that suffers greatest from drainage congestion due to the backwater influence from the Brahmaputra. As shown in Chapter 11 it is in this area that the deepest and most prolonged flooding occurs.

Flood Phases

As described in Chapter 11 the internal area of the Gaibanda Improvement Project was divided into 22 flood cells for modelling purposes. In addition the floodplain area at the tail of the Ghagot river was attached to the river cross-section.

Area/elevation curves, together with the five year return period water levels calculated from the 25 year Without Project simulation, were used to calculate the flood phases for each of these 23 areas. The results of this analysis is presented in Figure 12.3 and Figure 12.4. Figure 12.3 shows the percentage of F0+F1 land for each of the cells. This method of representation was used since as far as agricultural productivity is concerned the percentage of F0+F1 land is critical.

Throughout most of the GIP area almost all of the land falls into the F0+F1 category. The area for which this is not true is in the south-east which suffers from drainage congestion due to high water levels in the Brahmaputra and insufficient sizing of the present Manas regulator; in this part of the GIP area less than 50 % of the land falls into the F0+F1 category.

The impact of spillage through breaches in the TRE can be seen in the cells adjacent to the Teesta river. The percentage of F0+F1 land is lower here than in the remaining parts of the Northern Compartment of the GIP. Even in these areas, there is more than 90 % F0+F1 land indicating that