People's Republic of Bangladesh
Ministry of Irrigation, Water Development and Flood Control

Flood Plan Coordination Organisation

Southwest Area Water Resources Management Project

United Nations Development Programme
(BGD/88/038)

Asian Development Bank
(TA No 1498-BAN)

FAP 4

FINAL REPORT

BN-112
A-151(2)

Executive Summary

August 1993

Sir William Halcrow & Partners Ltd.

in association with
Danish Hydraulic Institute
Engineering & Planning Consultants Ltd.
Sthapati Sangshad Limited

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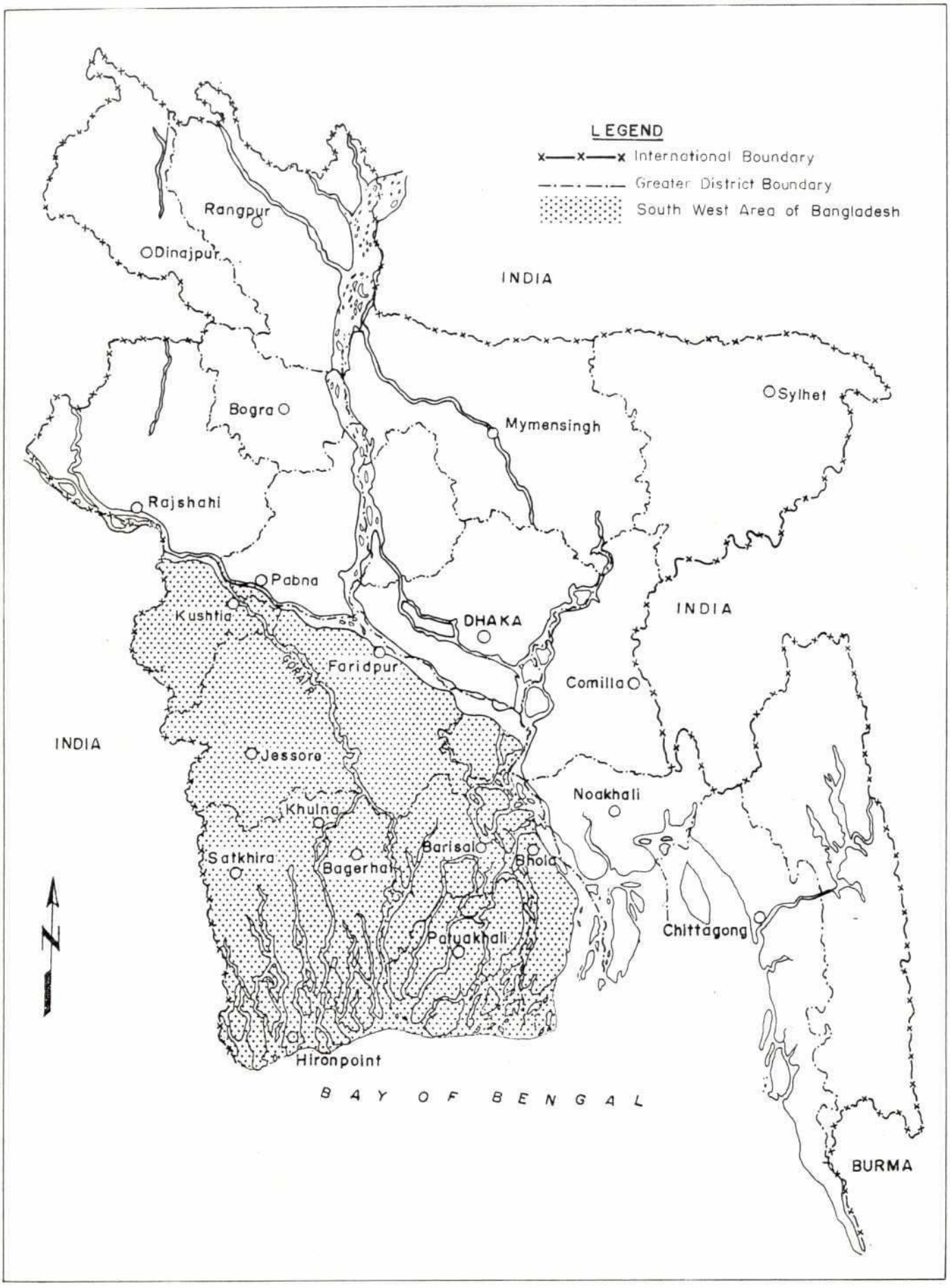
Figure 1.1



South West Area Location Map

SOUTHWEST AREA WATER RESOURCES MANAGEMENT PROJECT (FAP-4)

FINAL REPORT

EXECUTIVE SUMMARY

S1 Introduction

The Southwest Area Water Resources Management Project is a component of the Flood Action Plan which was instituted in response to the disastrous floods in 1987 and 1988. The Project known as FAP-4, is jointly financed by the United Nations Development Programme (UNDP) and Asian Development Bank (ADB) with ADB acting as the executive agency. The Project commenced in October 1991 and with 19 months duration was completed at the end of May 1993.

The main objective of the study is to assist the Government in formulating a comprehensive regional water resources development and management plan for the Southwest Area (SWA). In formulating the regional water resources management plan the study would identify a number of short, medium and long-term water resources management projects.

In preparing the water resources management plan full account has been taken of the Government's policy for water resources development contained in the Fourth Five Year Plan (1990-1995), the National Water Plan and the policies of the Flood Action Plan (FAP) as embodied in the Eleven Guiding Principles.

The Final Report, submitted after the completion of the study, contains the Regional Water Resources Management Plan, the results of the hydraulic and morphological studies, pre-feasibility of the Gorai Augmentation Project and seven other schemes including Chenchuri Beel Rehabilitation Project.

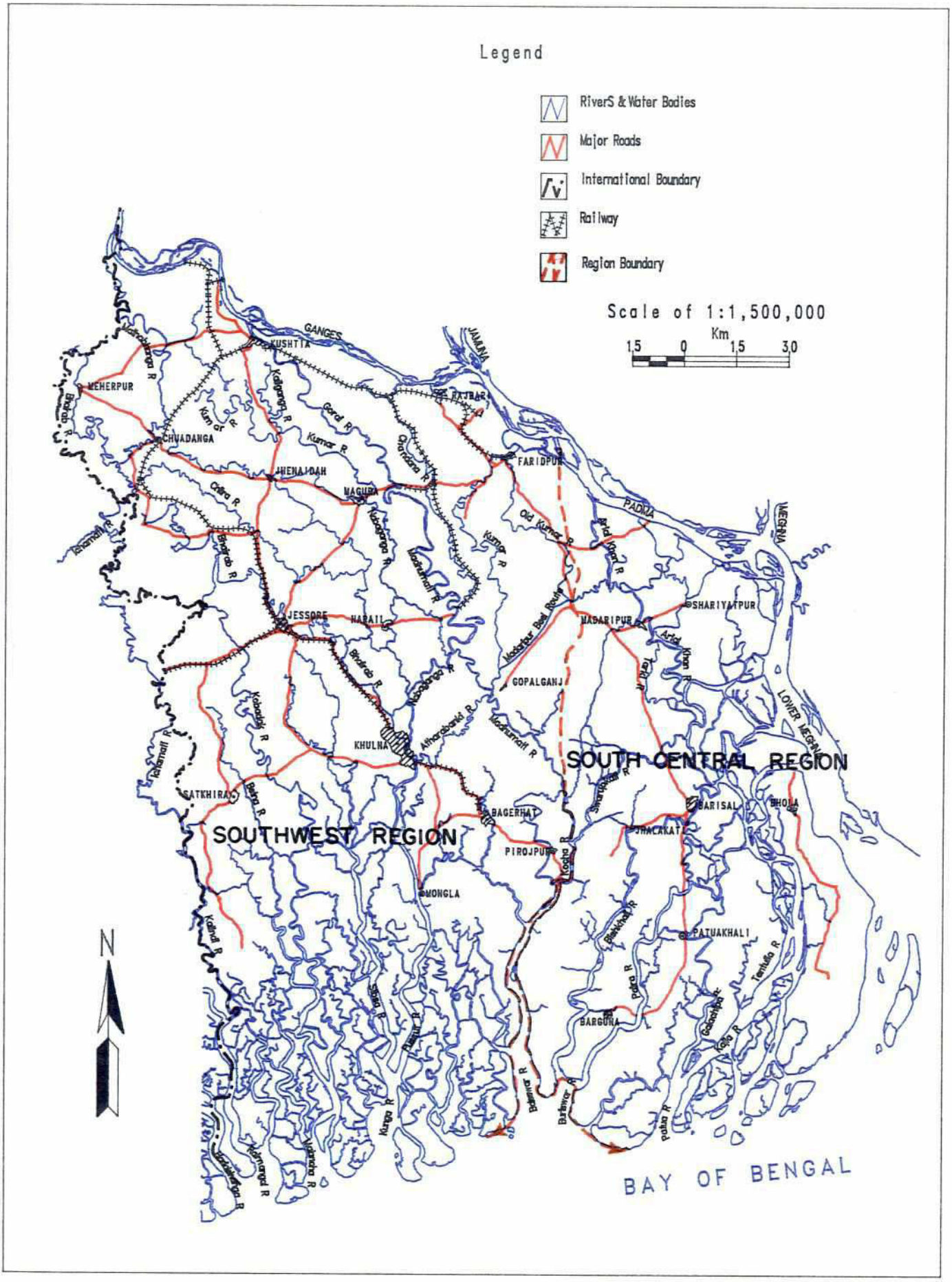
The Report is presented in 13 Volumes. Volume 1, the Main Report is presented in three parts: Part I contains the Regional Plan, in Part II the Water Resources Management Options are discussed and in Part III the other related policy options are given. Results of the hydraulic, morphological studies and other sector studies including the pre-feasibility studies and supporting annexes are presented in Volumes 2 to 13.

S2 Regional Overview

The Southwest Area (SWA) comprises the Southwest and South Central Regions (Figure S1) which together have a gross area of about 40,450 km². The SWA is bounded by the three major rivers (Ganges, Padma and Lower Meghna), the Indian border and the Bay of Bengal. The Gorai, the principal regional river which supplies the Southwest Region (SWR) is a spill river from the Ganges and in recent years has been totally dry during the dry season due largely to diminution of flows in the Ganges and accumulation of sediment at the Gorai mouth. The South Central Region (SCR) has relatively an abundance of water throughout the year.

The population of the Area is just over 26 million which is currently estimated to be growing at the rate of 1.89% a year. Agriculture is the most important economic activity of the Area and currently a total of 2.5 m ha net are cultivated of which 1.1 m ha are provided with some measure of flood control and drainage and about 0.64m ha are irrigated. On average nearly 12 percent of land is subjected to flooding each year and 22% is regularly inundated to depths of 90cm (F2) or greater.

Figure S1



Southwest Area

More than 70 percent of the population is living in conditions of absolute poverty. Whilst in some areas at present small food energy surpluses exist both Regions are overall in deficit. Without actions now to improve conditions, the situation will be dramatically worse in 25 years time (Figure S2).

Forecasts of the Area's population show that it will increase from the present 26.1 million to 30.8 million by the year 2000 and to nearly 35 million by 2010. Even if the population of farming households remains unaltered at 76% the effect on the farming community will be drastic. To retain the same amount of land for each farming household the proportion of landless households (including fishermen) would have to increase from about 25% in 1991 to 36% in 2000 and 43% in year 2010.

The land use has undergone changes in the past 15 - 20 years reflecting trends in agricultural production. At a national level the production of all crops except pulses has increased albeit at levels less than the population has risen. The overriding trend is the decrease in the area of HYV aus, b. aman and jute and increases in areas of HYV aman, HYV boro. It is almost certain that without further intervention, crop production will not keep pace with the continued increase in population. The expansion of the area under boro cannot produce sufficient rice for the population and further FCD will be needed to lessen the risks to the aman rice crop and provide further substantial increases in production.

Capture fishery catch has been falling in recent years and the expansion of agriculture by FCD schemes will only accelerate this fall in production. Although culture fisheries has expanded it cannot be reasonably considered to replace the shortfall. Shrimp farming has expanded in areas south of Khulna but the yields are still low. If the present trend continues the yields will further go down due to shortage of post-larvae which are threatened by off-shore trawled catch.

Forestry resources are declining and unless measures are taken to arrest this situation, it will continue to fall. In the Sundarbans the reduction in upland flows is thought to have contributed to the decline of commercial timber and coupled with over-felling the disappearance of certain species of timber in the near future is a distinct possibility.

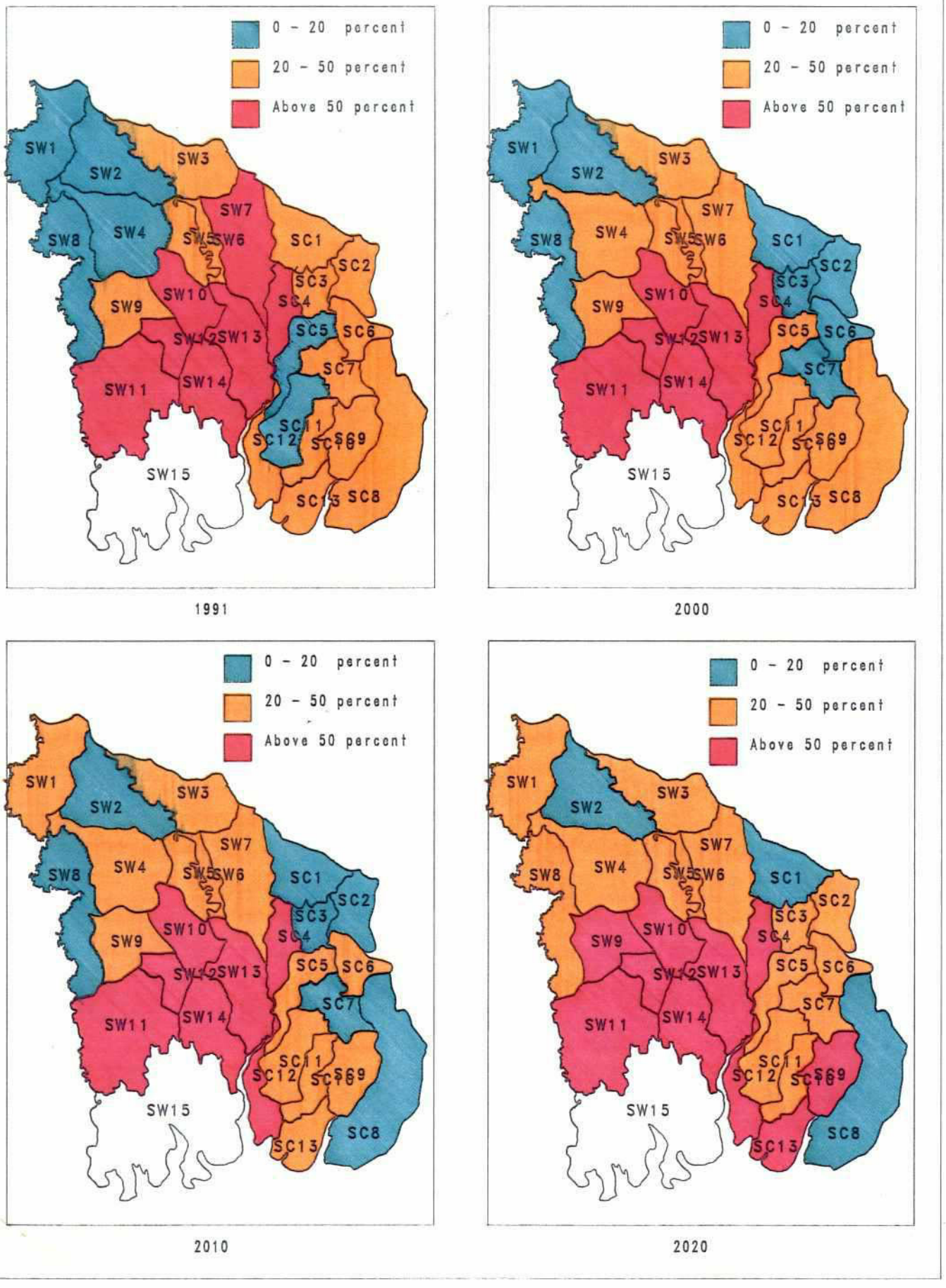
Nutritional standards are expected to fall with growing unemployment and under-employment. This in turn will affect public health by a general lowering of the disease resistance of individuals.

As land holdings decrease in size rural employment opportunities will fall. Without increased investment in rural development including water resources management the pressures on resources can only lead to wider food and fuel energy deficits. This coupled with an increase in the already high proportion of the population with limited means of support, will lead to adverse social and cultural changes placing an increasing strain on the SWA and national economies.

The major source of domestic and industrial water supplies in the SWA is groundwater. Though the quality of water is good in the northern areas salinity is a problem faced by areas around Khulna and further south. The industries located around Khulna use surface water for their use, also suffer from increase in salinity in rivers during the driest months. Given the large population of Khulna and with the expansion of industries, groundwater cannot meet the demands for both potable and industrial water supplies and surface water sources will become a necessity.

The SWA is presently facing a trend of general degradation in a predominantly agricultural area. The reduction in dry season flows through the Ganges distributaries to the SWR is the most serious threat to the region. As a result of this threat there would be difficulty in providing and extending surface water irrigation to the existing schemes in the area.

Figure S2



Food Energy Shortage (Devlopement Without Augmentation)

Groundwater development alone will not provide for the water supply and irrigation needs and has its limitations.

The northward movement of the saline wedge and increased sedimentation would further restrict areas for agricultural expansion. If sedimentation rates increase, which will undoubtedly do if the present situation continues, at the northern end of the Sundarbans there will be degradation of the forest as flushing regimes will be lost.

The Gorai spill flows are likely to continue to vary widely as the upstream abstraction increases and the Ganges alters the position and orientation of its low flow channel(s). Both wet and dry season flows in the Gorai and other right bank distributaries will diminish. Deterioration of the Gorai off-take mouth will continue with the underlying trend to its permanent abandonment as a Ganges spill channel. Conversion of the Gorai to an inland river will occur sometime in future, unless actions are taken to prevent this. The reduction in spill flows, especially from the Ganges, will increase the penetration of saline water into the Area and, in the long term, to siltation in the smaller tidal rivers.

Major overbank spill presently occurs mainly from the Padma, Lower Meghna and the Arial Khan. High water levels in inland rivers cause drainage congestion in most areas, south of Khulna. Since the 1987 and 1988 floods certain flood control measures along the Ganges and the Padma right banks have been implemented but there are still gaps in the embankments. Without closing these gaps and improving the internal drainage, the Area will continue to suffer from flooding and inundation.

The rivers in the coastal region show a continuing process of siltation progressing generally from the NW toward the SE and the polders show a deteriorating trend in the same direction. The southwestern coastal zone is in a state of transition from an active developing delta to a semi-moribund delta. Saline intrusion has increased due to tidal penetrations and reduction in freshwater flows. Any further reduction in freshwater flows will increase the penetration of saline water into the area and in the long term, to siltation of the smaller rivers. Primary navigation routes within the Area have been deteriorating. The possibility of future sea level rise poses a threat to the long term viability of maintaining effective gravity drainage system in some areas.

S3 Water Management Issues and Needs

The major water management issues in the SWA are:

- acute shortages in the Southwest Region of surface water resources in the dry season
- widespread flooding, primarily from the Ganges/Padma and Lower Meghna
- drainage congestion, primarily in the coastal polder areas but also in inland areas where natural drainage is inadequate
- salinity intrusion from the coast.

To these may be added concerns about siltation, the availability and management of the groundwater resources and grave concerns of the sustainability of a number of important rivers. Declining capture fisheries is also a major concern. Deterioration of the Sundarbans due to diminution of fresh water flows from the north and the deterioration of quality of freshwater to Khulna are also causing concern.

The acute shortages of surface water in the SWR in the dry season is caused by reduced flows in the Ganges since the construction of the Farakka Barrage in India. In addition, the natural and progressive deteriorating cycles of dry season flows in the Gorai have been made worse. Morphological studies indicate that at sometime in the future the Gorai as a major spill river from the Ganges will go into irreversible decline unless steps are taken to prevent this. The timing of such a decline however is very difficult to predict.

Whilst loss of dry season flows in the Gorai would have relatively small impacts, as it will not be worse than the present situation, the loss of wet season discharges could have major impacts on the hydrology, environment and ecology of the Region with catastrophic consequences to the Area. The environmental degradation itself will be of gigantic proportions.

The needs of the SWA are many and diverse. They relate principally to the underlying social needs. These needs are bounded by the recognition that development should proceed in an environmentally sustainable manner, which includes acceptance of resource limitations as well as giving importance to ensuring a reasonable quality of life to all the inhabitants now and for future generations.

Whilst for Bangladesh and SWA in particular, water management is self evidentally a central issue, it is not the only issue. This Report, which is primarily directed at the opportunities in water sector endeavours to address those other issues which directly or indirectly impact upon the choices for water management options.

In the context above the key elements to the development of the Area as a whole are increases in agricultural and aquacultural productivity as a manner which increases and equitably distributes rural wealth; provision of secure rural and urban water supplies; improve the general standard of health and hygiene; reduction in loss of life and property caused by flooding and cyclones; maintenance of an adequate transportation network; promotion of forestry as both a source of fuel as well as for other uses and strengthening the institutional capability of the public and private sector to plan, implement and operate the activity in a constructive and coordinated manner that takes full account of the people's views.

S4 Development Choices

The main water management development options that have been identified to address these key issues are as follows:

- Securing the Gorai mouth as a priority measure and progressive augmentation of the surface water resources of the Southwest Region to meet future demands both for agriculture and control of salinity intrusion

- Development of irrigation within the area through exploitation of both surface and groundwater resources to the extent that may be permitted with or without augmentation

- Strengthening and extension of embankments protecting the Area from the main boundary rivers and provision of upgraded and new flood control and drainage facilities where appropriate within the Area

- Improvement of drainage within the coastal polders for which a range of alternative measures have been investigated from which a policy focussed on a controlled transition to tidal equilibrium is preferred

- Measures to support the largely private sector development of groundwater and improved monitoring and assessment of groundwater utilisation and resource assessment, measures to encourage and/or enforce the institution of a buffer zone to control saline intrusion and measures to mitigate against adverse effects of groundwater development on potable supplies

- Strengthening overall of management and monitoring capabilities related to water resource development and usage.

Within the context above, choices exist between different land uses. As an example, in the northern parts of the Area, the highest value land generally, in order of magnitude, would be, social forestry, culture fisheries and irrigated agriculture, whereas in the southern parts, in the saline areas shrimp farming is currently and potentially more valuable than any form of agriculture. Trade-offs between differing land uses are therefore necessary to arrive at a development plan which is in line with the broad policies of the Government and the needs of the people.

Accompanying the principal measures outlined above are a range of ongoing and proposed interventions in sectors directly related to water management. These include: strengthening of the agricultural sector with emphasis on crop diversification, better input and credit supply, research, extension and marketing; expansion of fisheries production through growth of culture fish ponds; arrest the decline of capture fisheries and restocking of beels; support for the forestry sector to encourage the growth of homestead groves (social forestry), to manage the Sundarbans as a complete ecosystem; expanding the industries sector, particularly in Khulna and Kushtia areas.

S5 Development Options

The water resource development options are focussed primarily on facilitating growth of agriculture production and attain equitable distribution of incomes in the context of a socially and environmentally sound approach.

Flood control and drainage (FCD) without corresponding irrigation development would result in only a marginal benefit to the area. However, the value of FCD without an irrigation component depends on how badly an area is presently inundated and what improvements in internal management could be achieved through compartmentalisation.

At present the main line of defence against flooding is the Ganges right embankment which stretches from close to the Indian border down to beyond Faridpur. This embankment requires only minor works to bring it up to an acceptable standard. Beyond this the embankment is only partially complete along the Padma. With only moderate investment it can be extended to the Arial Khan and with further extension along the Arial Khan would immediately reduce the areas within the SWA as a whole the high risk of flooding by some 30 percent. To the east of the Arial Khan, a poorly constructed embankment is in existence which again could be upgraded relatively simply. Further development of embankments along the Lower Meghna right bank are risky and not recommended before the impacts of left bank and upstream works are assessed.

Three basic options have been considered to address the problems of drainage congestion in the coastal polder areas.

- 'Do-Nothing' option

- Controlled transition to tidal equilibrium by progressively intervening in deteriorated or deteriorating polders

- Create a non-tidal coastal zone by construction of tidal barriers/closures.

The preferred option is controlled transition to tidal equilibrium as this is the least disruptive and early returns to investment can be expected. The 'do nothing' option, although not dependent on upland freshwater flows and does not involve any large capital investments it does not address the problems of continuing deterioration of the area and therefore the needs of the people. Moreover it will take a very long time for the tidal equilibrium to attain. The creation of tidal barriers will result in a massive investment covering over 50-60 years and benefits cannot be achieved before it is fully completed. The ecological and environmental impacts of this can be enormous.

The solution proposed is to identify sustainable rivers and to re-organise the polders and their internal drainage so that they outfall to these sustainable rivers.

The shortages of surface water resources in the dry season to the SWR can theoretically be alleviated by groundwater. However since privatisation of the groundwater development in 1985 there has been a rapid growth in the number of shallow and deep tubewells and there is only limited potential for further groundwater development. This is confined to the north east of the area. In areas just south of Khulna there is a problem of salinity and the need to maintain a buffer zone between the saline and fresh water zones has been recognised and therefore caution must be exercised in any large scale exploitation. Overall groundwater alone will not meet the long term needs of irrigation of the Area.

Surface water by augmentation of flows from the boundary rivers is another option. The principal choices are from the Ganges and from the Padma. The latter is more reliable in the dry season but levels are such that only a small area can be commanded. Out of the distributaries of the Ganges, Gorai provides the best option in the short to medium term. As noted earlier, the Gorai is on the decline and it is predicted that it will sometime in the near future go into irreversible decline detaching from the Ganges and becoming an inland river just as the Bhairab, the Mathabanga and the Chandana did in the past.

The loss of dry season flows to the Gorai would have relatively small impacts, as it will not be worse than the present situation. The losing of wet season flows, on the other hand, will have, apart from the obvious impact on agriculture (almost the entire SWR depends on the Gorai during the wet season) impacts on fisheries, navigation, forestry, groundwater, salinity and siltation. The saline front, which is now kept south by the flows from the Gorai during the wet season, will move northwards even during the wet season.

The 'zero flow' scenario in the Gorai was simulated and the results show that the wet season salinity levels increases dramatically and the highest increase was found to be during the month of September (about 140% increase). The effect of this on the following dry season was also simulated and found that it has a detrimental effect. This indicates that the salinity front will probably stay permanently northwards making the water supply to the whole of the area south of Jessore unsuitable for agriculture and drinking purposes. In the long term this will also affect the quality of groundwater.

The damage to the fisheries although cannot be quantified at this stage, will lead to substantial reductions in the inland open water capture fishery and the salinity ingression will affect the sweet water species.

The impacts on the forestry sector will be less than obvious but the lack of upland flow and consequent depletion of soil moisture and the increase of salinity will have severe consequences on Sundarbans which is the principal supplier of commercial timber. Natural regeneration of mangrove forests will remarkably retard while 'top-dying' of the commercially attractive Sundri trees might become more pronounced and widespread.

Inland navigation will be another hard hit sector where communication will suffer severely if the upland flows are reduced. As most of the SWA depends entirely on the river transport this will have social, economic and ecological consequences resulting in hardship and eventual migration of the population from these areas.

The drawback with abstraction from the Ganges is the unreliability of flows due to upstream abstractions. In the period since 1989 corresponding to expiry of the Agreement with India over releases from Farakka, the mean and 80% dependable flows in the Ganges have been reduced to 576 and 517 cumec respectively. This may be contrasted with the mean and 80% dependable flows for the driest month between 1978 and 1988 of 1063 and 663 cumec respectively. However in the last two years the flow has been declining even further with the minimum flow recorded on 30 March 1993 (261 cumec).

Analyses undertaken indicate that a peak dry season abstraction from the Ganges of approximately 100 m^3/s taken by the G-K project and a further commitment to 100 m^3/s minimum flow to meet downstream requirements in the Ganges leaves only a very small amount for extraction through the Gorai. However at present the levels in the Ganges are low for any abstraction by the G-K pumps in the driest months and in the absence of any control in the Ganges, this should be available for abstraction through the Gorai.

Whilst augmentation of the Gorai as described above offers a worthwhile and necessary investment and addresses the immediate risks associated with closure of the Gorai mouth, at a regional level the impact on agriculture is relatively small. To maximise opportunities for long term development it is necessary to both control water levels in the Ganges to maximise abstraction capability and to provide storage within the water resource system. Together with groundwater development, FCD and surface irrigation schemes, the Ganges Barrage facilitates food security throughout the Southwest and South Central Regions with the exception of areas to the south of Khulna and in the lower portions of the South Central Region where salinity limits the potential for irrigated agriculture. The Barrage gives the opportunity to expand irrigated agriculture further and with current level of flows about 660,000 ha could be benefitted. If, however, there is no restriction to the dry season flows then over 1.0 million ha could be brought under irrigation.

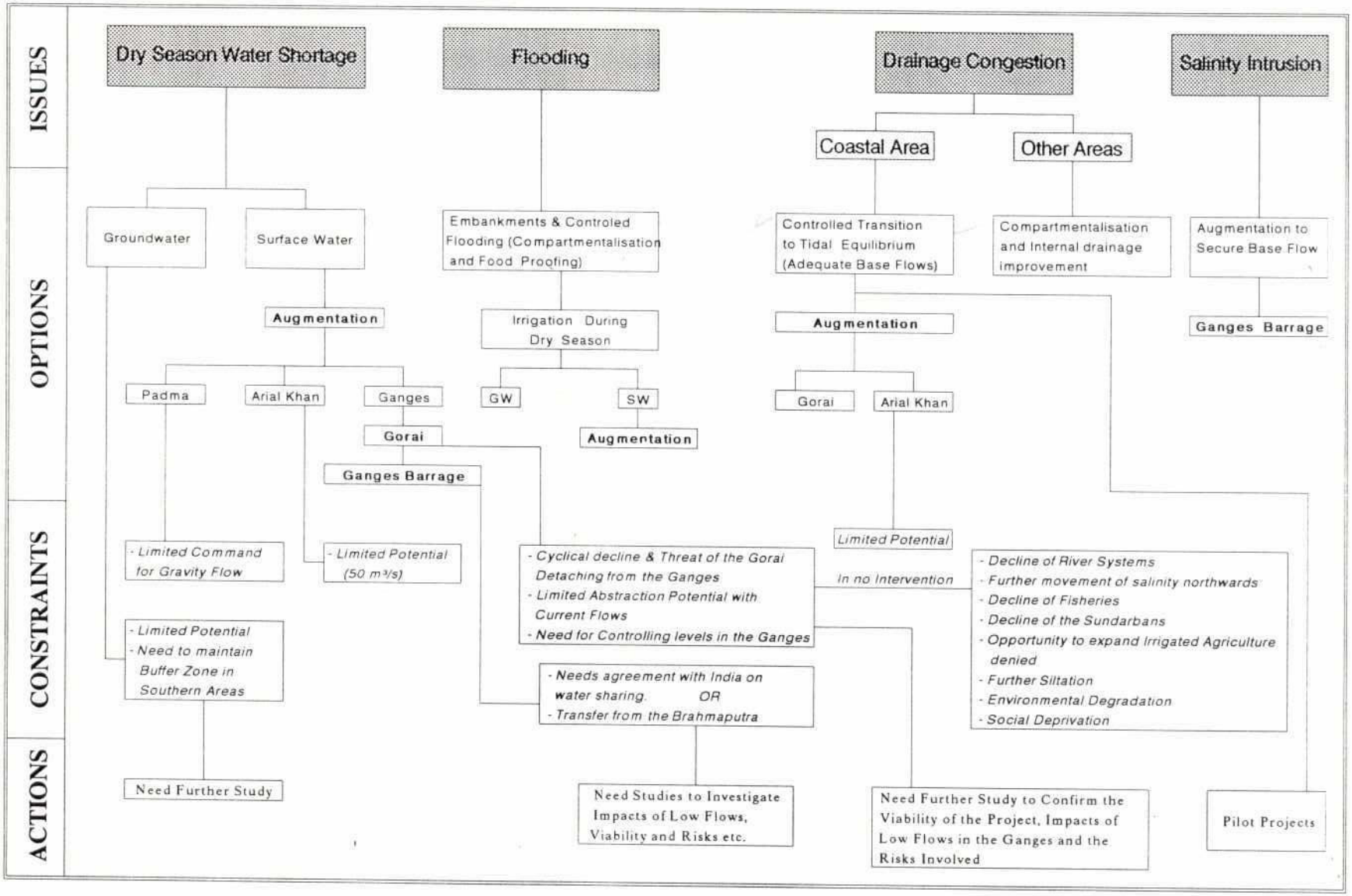
Salinity control could be effected by augmentation of flows by securing the base flows in the Gorai. The Barrage offers the opportunity to allocate about 150 m^3/s, the minimum required for any significant movement of the saline front southwards. The Barrage also has other advantages. It will reduce the pumping head required at the G-K intake thereby securing the supply during the critical months in the dry season.

The viability of the Ganges Barrage is however dependent on the adequacy of dry season releases downstream of Farakka. Establishment of a new agreement over the sharing of Ganges flows is therefore essential. Alternatively, augmentation of the Ganges flows by other means needs consideration. In order the risks associated with the augmentation and the impact of the Ganges low flows can be quantified further study should be initiated as a matter of priority. Preliminary studies for the Gorai Augmentation Project indicate that it is viable but sensitive to flows in the Ganges. In order to study the impact of different flows on the viability and to assess the impacts of the 'do nothing' option, further studies are needed urgently.

The Arial Khan-MB Route identified at an early stage as an alternative means of augmenting surface water resources in the SWR has its main disadvantages in that the degree of augmentation is limited to about 50 m^3/s by the head available and the difficulty in securing a stable intake. This option is therefore not considered further.

Pumping from the Ganges has also been considered at the initial stages. Although this scheme has relatively small capital cost, has a very high maintenance cost and with the

MAIN ISSUES AND OPTIONS



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Main Issues and Options

Figure S3

experience and performance of other pumping schemes in the country (notably the G-K Project) has not been taken further.

Figure S3 gives diagrammatically the main issues and options for water resource development in the SWA.

S6 Linkages

The development options proposed for the various issues appear to be independent but there are linkages between them. The main linkage of the proposal is the Gorai Augmentation Project on which many of the other development options are either dependant upon or the viability will be enhanced by the project. The strategy for the coastal embankment project in improving the drainage congestion, particularly to the Khulna, Satkhira and Bagerhat areas, depends on adequate upland flows. If this is not reasonably guaranteed then the strategy proposed will likely to fail. The pilot projects proposed will enable the impacts of augmentation on the coastal polders and on the Sundarbans to be studied before a full scale implementation programme is embarked. One of the strategies for ensuring good quality water supply for Khulna also depends on the Gorai Augmentation Project. In the long term, if adequate flows are guaranteed in the Ganges, the strategy for pushing the saline wedge southwards also depends on the augmentation of dry season flows through the Gorai with secure base flows.

The viability and economic benefits of a number of projects identified will enhance by the Gorai Augmentation Project while others benefit from the Ganges/Padma R.B. embankment project.

Some of the schemes proposed depend on the reduction of flood flows during the wet season and therefore on the Gorai Intake structure.

The long term sustainability of the beel areas and the Sundarbans is also linked to the upland flows and therefore to the Gorai Augmentation Project.

Groundwater, being connected to surface water, has linkage with discharges into the SWA through spill rivers from the boundary rivers, notably from the Ganges and therefore maintaining wet and dry season flows in the Gorai is fundamental to the long term sustainability of the groundwater resource.

Fisheries and navigation have also linkages to maintaining adequate water supply in the rivers.

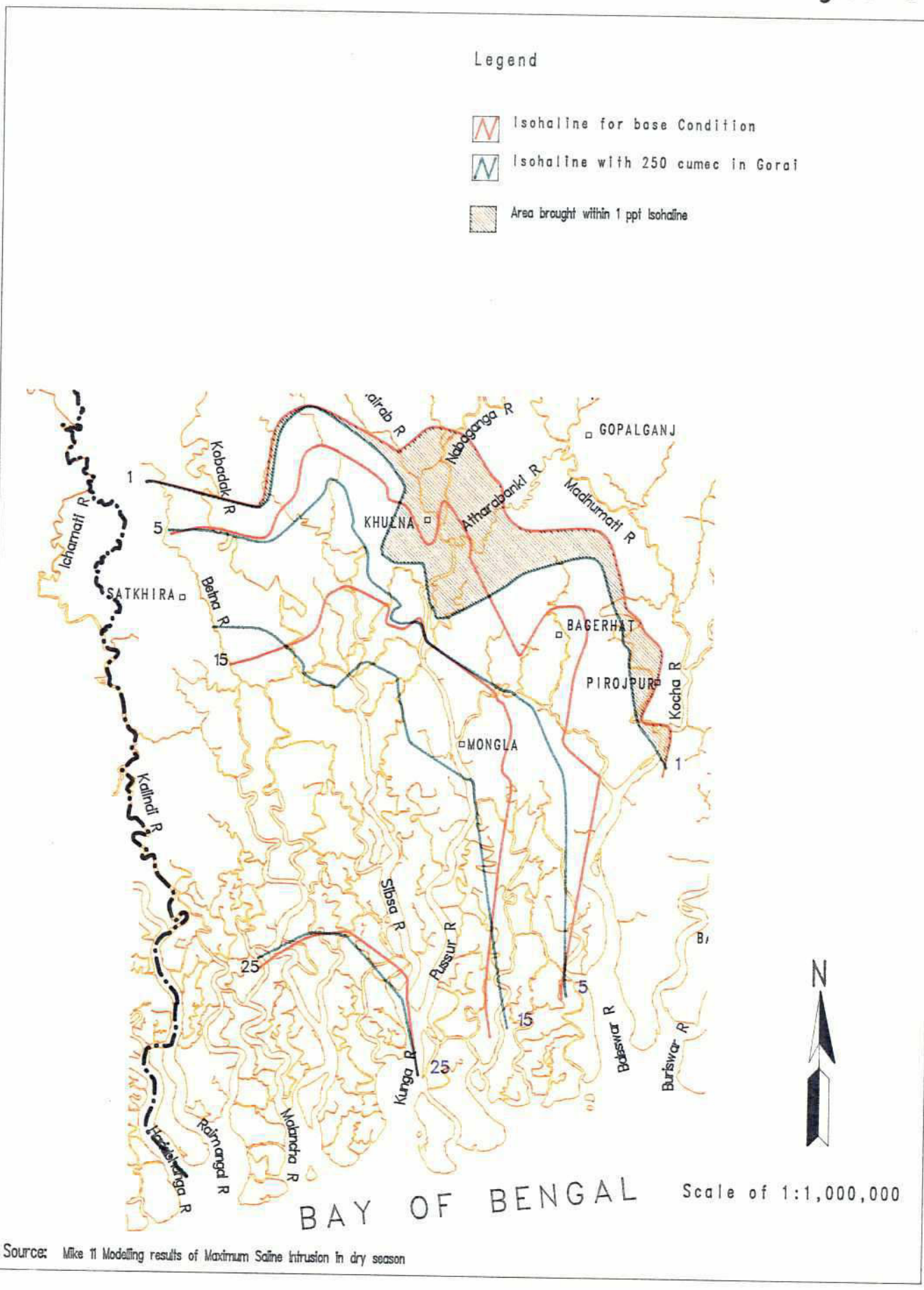
Although the Gorai Augmentation Project is independent of the Ganges Barrage Project clearly there are benefits from it. If a decision is taken to proceed with the Barrage before the Phase II of the Gorai Augmentation Project is implemented then the work required for Phase II is minimal as no additional dredging is required. Ganges Barrage also offers the opportunity to expand irrigated agriculture in the SWA and provides adequate flows for pushing the salinity front further south (Figure S4). By maintaining adequate flows in the Gorai in the dry season will undoubtedly benefit the hydrological regime of the rivers and the Sundarbans, fisheries and navigation sectors will all be benefitted.

The linkages are shown diagrammatically in Figure S5.

S7 Strategy

As discussed earlier, the underlying policies within the water resources management plan are to address the perceived socio-economic and environmental needs of the growing

Figure S4



Source: Mike 11 Modelling results of Maximum Saline Intrusion in dry season

Change in Saline Front with 250 Cumec in Gorai

Linkages of Development Options

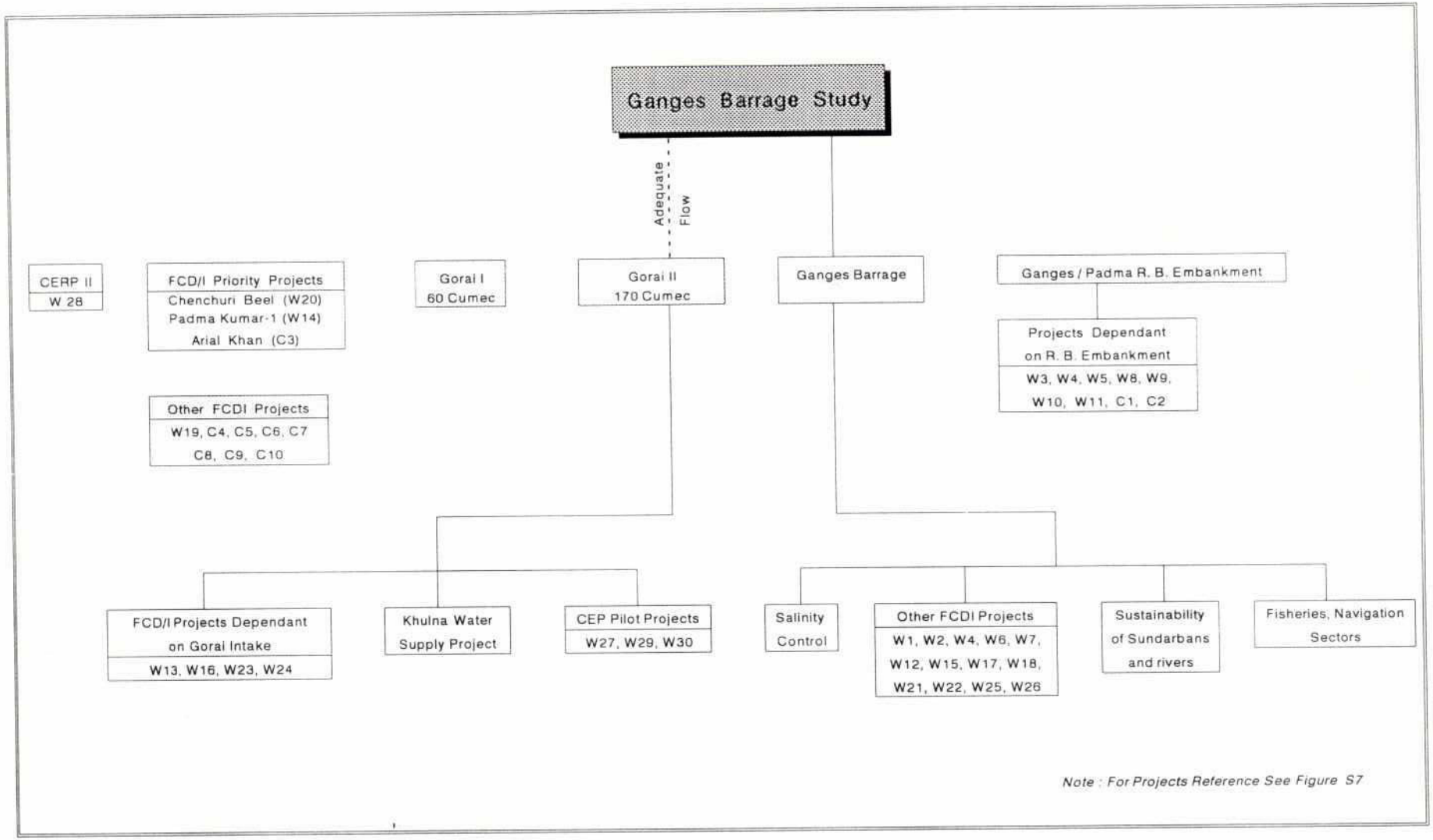


Figure S5

population of the Area within the context of the changing resource setting and within the framework of Government's policies and objectives. This leads to recognition that the land and water resources of the Area should be developed efficiently to promote the continued growth of agriculture as a prime source of food, employment and income. To ensure a balanced approach and to minimise the negative impacts on different sections of the community, fisheries and forestry should be promoted in parallel to agriculture. Where appropriate within the Area, these activities may be given precedence over agriculture if comparative advantages exist and especially where agricultural alone is seen to be unable to meet the people's needs.

To sustain the growing population, a fundamental policy has to be to give priority to the provision of potable domestic water supplies and to industrial water requirements on the reasonable assumption that the latter represents the highest value of water use other than domestic supplies.

Given the scarcity of resources the prudent use of groundwater should continue to be encouraged and it is recommended that with certain provisos the impetus for this development should be left with private sector. The provisos are ensuring the means by which to mitigate against greater draw-downs affecting hand operated shallow tubewell supplies for domestic use and institution of a buffer zone to protect against northwards movement of saline groundwater. The current trend that wherever possible potable supplies should be drawn from groundwater is also to be encouraged.

A further fundamental aspect of the strategy is recognition that the surface water resources of Area are inadequate to meet long term needs and that augmentation is a necessity. From the studies made, water resource development and augmentation in particular will not meet all the Area's needs and it is fully recognised that throughout the Area and more so in certain parts, parallel social programmes will be required to promote income generation and social equitability.

The principal features of the proposed strategy fall into the following general categories:

- Structural water resource development interventions
- Non-structural and institutional measures
- Parallel development in related sectors

Structural Water Resource Development Interventions

The structural water resource development measures proposed and their phasing are directed at achieving best returns on investment in the shortest period of time given a reasonable investment schedule. The measures relate to activities within the period to 2020. The measures fall into the categories of:

- Augmentation of surface water resources
- Development of surface water irrigation schemes
- Rehabilitation and/or construction of new flood control and drainage schemes
- Maintenance of river channels

For the Southwest Region the main interventions relate to the two main issues of FCD/I development and of rehabilitation of the coastal polder area. The strategy for irrigation development hinges on securing the Gorai intake and augmentation of dry season flows initially and the phased introduction of low lift pump schemes in a sequence determined by the construction of transfer canals from the Gorai. The Gorai Augmentation Project has two main phases. The first involves abstraction of a dry season minimum flow of 60 cumec which would provide sufficient water to develop approximately 60,000 ha within the Gorai corridor on both the left and right banks by the year 2005. The intake structure, by capping

wet season flows, would also bring immediate benefits to flood control and drainage improvement to the areas draining into the Gorai. The second phase is conditional on whether a final decision has been taken to proceed with the Ganges Barrage by that time. If this is the case then there is no need to undertake further capital dredging of the Gorai, since the Barrage will provide sufficient head through the intake structure. This, together with reduced maintenance dredging requirements would represent a significant reduction in costs associated with the Gorai as well as mitigation of environmental impacts arising from continued long term dredging. If the decision is not taken then to complete the Gorai Augmentation Project, additional capital dredging would be required to facilitate further irrigation development.

Within the Southwest Region the development of FCDI would be phased taking account of the above, the anticipated growth of groundwater irrigation and the viability of rehabilitating or constructing new flood control and drainage schemes. Development of flood control and drainage of the areas affected by the Ganges - Padma and Arial Khan Rivers are seen as key measures as a consequence of this. FCD schemes would be based on the philosophy of controlled flooding in order to minimise disruption to existing water management practices and to capture fisheries generally. Attention would be given in the design of all FCD schemes to preserving existing beels and baors by either excluding them from the protected areas or by ensuring that inflows are possible in a manner which least hinders the normal migrations of fish.

Surface water irrigation would be based on the development generally of low level channels serving privately financed LLPs and local area development.

It is proposed that to meet future requirements a Barrage is built on the Ganges, subject to detailed study of its feasibility. Studies of the Barrage should proceed without delay in order that a final decision to build can be made within the next five years. In the meantime, the Gorai Augmentation Project should proceed immediately to full feasibility study.

The preliminary analyses undertaken indicate that for allocation of flows specifically for salinity control in the Khulna area is not prudent until the Ganges Barrage is constructed.

In the South Central Region the proposed strategy is to complete the Ganges - Padma and Arial Khan embanking to enable controlled flooding, to not proceed with embanking the Lower Meghna within the next 50 - 100 years and to develop FCDI schemes where resources and conditions are favourable.

In the coastal zone, the proposed strategy in the long term is to progressively improve drainage conditions in different areas as and when such measures become viable as a result of deterioration. Such interventions overall will be in the context of allowing the coastal zone to move towards a new tidally dominated equilibrium, and individually the interventions will have to take account of the effects they will cause in both a regional and local perspective. The interventions proposed include dredging of those rivers considered sustainable in the long term, the creation of macro-polders to promote their sustainability, improvements to drainage outfall structures to increase drainability and to internal water management. Recognition is given to the long term consequences of sea level rises and land subsidence and acknowledgement made of the probability, that resort may be made in the future to pumped drainage as a more viable alternative to improvement of gravity drainage systems.

In the short to medium terms, priority areas and outline measures to relieve drainage congestion have been identified and recommendations made to undertake pilot schemes in two areas and further studies at a third.

Non-structural and Institutional Measures

Non-structural measures proposed for the Area includes provision for flood proofing and flood preparedness in those areas where flood protection does or will not exist, accompanied by a system for flood warning. Within the coastal area cyclone protection shelters and refuges are planned to supplement existing facilities together with continued support for the expansion of coastal plantations.

The strategy proposed for the Southwest Area requires a high degree of multisectoral coordination, a strong overall management team and technically sound implementation. However, considering the experience of the performance of FCD/I schemes in the past, the need for proper planning, design and operation and maintenance of the development proposed cannot be stressed enough. People's participation at stages of planning, design and implementation is therefore an essential part of the planning processes. Coordination and interaction between different agencies and the beneficiaries will be the key to the success.

At the local level it is anticipated that the impetus for irrigation development will increasingly be borne by the private sector. The National Minor Irrigation Development Project (NMIDP) under the Ministry of Agriculture represents a major step forward in this respect. NMIDP will provide support to LLP schemes in the SWA in the form of technical guidance, credit and monitoring.

Operation and maintenance of the various works is expected to be the responsibility of the owners and through people's participation the level to which this can be achieved could be identified. Preliminary recommendations have been given on the results of the study undertaken to a part of the Chenchuri Beel Project. In order to reduce the burden of the Government in shouldering the O & M costs, the need for cost recovery measures are emphasised and will be studied in detail in the next phases of implementation. However, the experience so far and the low rate of recovering costs in existing projects calls for innovate approach.

The development programme as proposed involves investment of a scale, probably never experienced in Bangladesh. BWDB which takes the traditional role of the executing agency, needs considerable institutional strengthening to enable to implement and monitor the progress and eventual successful completion of the development programmes.

Parallel Development in Related Sectors

Most of the water resource developments are targeted primarily at the agriculture sector and this sector would clearly benefit the most. The policy objectives set in the Fourth Five Year Plan target food self-sufficiency, crop diversification and general increases in productivity. The expansion of minor irrigation is a cornerstone of the agricultural strategy and the proposals in this Report are substantially in accord with this. Other areas where investments are required are input supplies, research and extension, marketing, area development and targeted programmes.

The forecast achievements of food security indicates that with development of the Ganges Barrage and related works, food surpluses will be achieved in most of the areas directly affected. Nevertheless by 2020 average deficits of 25% and 30% in the Southwest and South Central Regions can still be expected. In order to make up these shortages other sectors, notably industries, should be developed. However the present problem of water quality should be addressed first.

The fisheries sector is also intimately linked with water resources development. Government policies place emphasis on productivity increases, employment generation,

improvements to the well being of fishing communities and increasing exports. Capture fisheries in the SWA have shown a marked decline attributed to a variety of reasons, including the loss of flood plains for spawning and growth arising from FCD projects. Whilst generally of low productivity, capture fisheries are nevertheless important, especially to the rural poor and landless. The expansion of FCD anticipated in the SWA will further depress capture fisheries despite the mitigating measures that can be introduced to the engineering designs. The possible improvements to culture fin and shrimp production can go a long way to offset these losses in terms of tonnages but such measures need to be accompanied by generation of employment opportunities for the disadvantage capture fishermen.

The studies undertaken indicate that the least developed areas by 2020 will be the coastal areas for which in general irrigated agriculture is not feasible, but for which shrimp or shrimp plus rice farming is more appropriate. The experiments in Polder 20 demonstrate that many of the social and technical problems can be overcome with prudent planning based on local participation and cooperation and this should be replicated in other areas.

Government policy in the forestry sector centres upon rehabilitation of existing national forests, expansion wherever possible of the area under trees including better integration with farm land, adoption of wood conserving techniques, creation of employment opportunities and general environmental improvements. Increasing emphasis is being given to social forestry (homestead groves) as recognition of this important resource grows. In general the water resource management options as described have a positive impact in so far as with new embankments and greater opportunities exist for social forestry. A particular concern however is that during the course of construction the substantial likely increase in demand for brick will consume substantial stocks of timber. Though wood burning for brick firing is illegal the practice is still widespread. The possible impacts on the Sundarbans, as previously noted, are a further cause for concern and mitigatory measures such as encouraging to use coal for brick firing need to be considered.

The proposed strategy for the Sundarbans is that the area should be managed as a complete eco-system with due account taken of the multisectoral benefits obtainable. It is proposed that whilst studies continue to enable a clear understanding of the complex inter-relationships within the area, no specific measures should be taken to significantly alter the quality and quantity of surface water flows entering the area. The on-going The Sundarbans Integrated Development Project funded by UNDP/FAO may provide some understanding of this complex eco-system but monitoring and baseline data collection should continue.

The considerable importance of river transport is acknowledged within the overall strategy for the Area, as is the value of Mongla Port as a major transportation hub. The measures proposed for the Area do not conflict with any of the established major routes serving the Area, and generally favour the situation for Mongla Port. Many of these structures and closures proposed will interfere with the passage of country boats. Due account will have to be taken in designing these structures to allow for locks or boat lifts to minimise these negative impacts. Similarly, where appropriate adequate provision for fish passes would be required.

S8 Regional Water Resources Management Plan

Figure S6 gives a summary of the Regional Plan and Figure S7 provides a location plan. The components of the plan have been divided into structural and non-structural water management measures and developments in parallel sectors. The structural measures are considered in two parts reflecting what can be achieved with and without the use of Ganges waters.

There are clearly some development measures which can proceed immediately and others are contingent upon the reliable flow in the Ganges. Whilst it is very difficult, with the

Figure S6

Southwest Area Water Resources Development Plan
Summary

28-Apr-93

Project	Short Term	Medium Term	Long Term
From	1993	2001	2011
To	2000	2010	2020

Southwest Region

Gorai Augmentation Project :
- *Intake and river works*
- *Diversion and Transfer Works*
- *Area development **

Ganges Barrage :
- *Barrage*
- *Transfer Link 3*
- *Transfer Links 4, 5, 6 and 8*
- *Transfer Links 1 and 2*
- *Area development **

Coastal Zone :
- *Satkhira Project*
- *Khulna (south) Project*
- *CERP 2*
- *Bagherat Project*
- *Further programmes*
- *Cyclone Protection*
- *Monitoring coastal zone*

Other FCD(I) Projects * :
- *Khoksa Scheme, Phase 1*
- *Madhukhali – Baliakandi Rehabilitation*
- *Chenchuri Beel Rehabilitation, Phase 1*
- *Padma – Kumar, Phase 1.1*
- *Sakunia Beel Drainage Scheme*
- *Baramanikdi Project*
- *Narail Project, Phase 1*
- *Tarail Pachuria Project, Phase 1*

South Central Region

Ganges – Padma Right Bank * :
- *Embankment construction*
- *Sadarpur Scheme*
- *Palong Padma Scheme*
- *Arial Khan – Bisarkandi Scheme*

Lower Meghna Right Bank :
- *River Study*
- *Flood proofing*

General Development * :
- *Tarki – Gourndi – Bamrail Scheme*
- *Swarupkhati Scheme*
- *Ramsil Kafulbari Project*
- *Barisal Irrigation Project*
- *Bhola Irrigation, Phase 2*
- *Bhelumia – Bheduria Scheme*
- *Bishkhali Scheme*
- *Polder Rehabilitation Schemes*
- *Monitoring coastal zone*

* *Area Development includes FCD/I Projects dependent on the Ganges flow and includes compartmentalisation measures where appropriate*

Legend :
- *Study and design*
- *Study and Pilot Schemes*
- *Construction*

available data to place a reliable figure on the minimum flows that will be available during the dry season in the Ganges, it should be possible to evaluate the impacts of different flows on the viability of these schemes. Some preliminary indications are given in this Report but more detailed studies are necessary to evaluate these risks properly.

The Plan recommends development in the short term of the following projects which can proceed independently of Ganges flows.

Southwest Region

- Khoksa Scheme, Phase I	Ref W3
- Madhukhali - Baliakandi Rehabilitation	Ref W8
- Chenchuri Beel Rehabilitation, Phase I	Ref W20
- Padma - Kumar, Phase I	Ref W14
- Sakunia Beel Drainage Scheme	Ref W9
- Baramanikdi Project	Ref W10
- Narail Project Phase I	Ref W19
- Tarail Pachuria Project, Phase I	Ref W25, W24
- Satkhira Area Drainage Relief	Ref W27
- Khulna Area Drainage Relief	Ref W29
- CERP II	Ref W28
- Bagherhat Area Drainage Relief	Ref W30

South Central Region

- Completion of the Ganges-Padma Right Embankment	
- Sadarpur Scheme	Ref C1
- Palong - Padma Scheme	Ref C2
- Arial Khan - Bisharkandi Scheme	Ref C3
- Tarki - Gourndi - Barnal Scheme	Ref C4
- Ramsil Kafulbari Project	Ref C5
- Barisal Irrigation Project	Ref C7
- Bhola Irrigation Project, Phase 2	Ref C9
- Polder Rehabilitation Schemes	

These are not grouped in any order of priority.

Other projects in the two Regions that could proceed are recommended as medium term projects, since at evaluation they appear to offer a viable but less attractive return on investment than those listed above.

Southwest Region

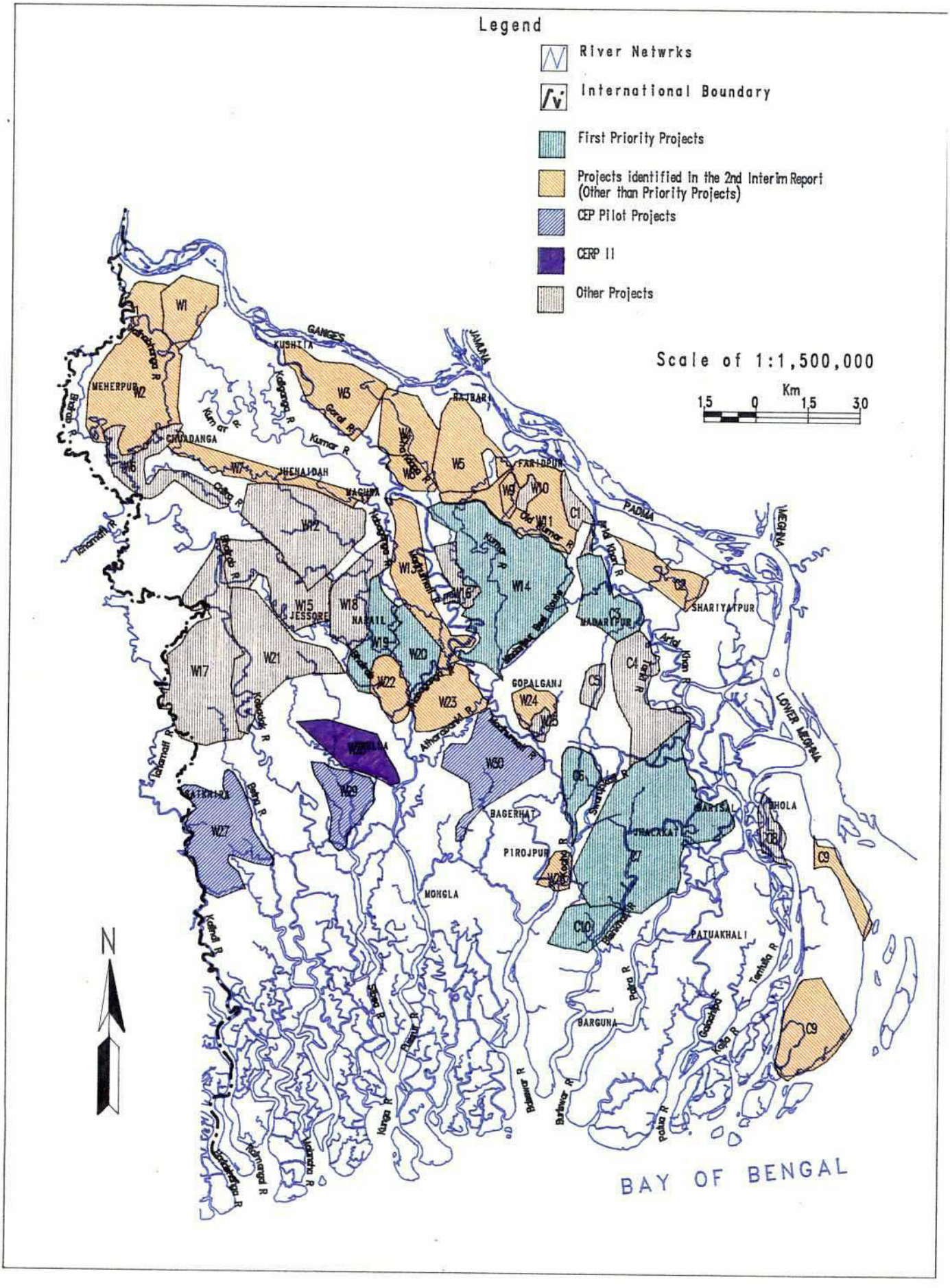
- Drainage improvement in the G-K area	
- Padma Kumar, Phase 2	Ref W11

South Central Region

- Swarupkhati Scheme	Ref C6
- Bhelumia-Bheduria Scheme	Ref C8
- Bishkhali Scheme	Ref C10

On the assumption that a reliable flow in the Ganges by Agreement or by other internal development can be established then the following are recommended for the Southwest Region.

Figure S7



Development Plan

Short Term:

Gorai Augmentation Scheme, Phase 1

- Salikha Scheme Phase I	Ref W18
- Madhumati-Nabaganga Rehabilitation, Phase I	Ref W13
- Chenchuri Beel Scheme, Phase 2	Ref W20
- Alfadanga-Boalmari Phase I	Ref W16
- Barnal-Salimpur-Kolabashukhali, Phase I	Ref W23
- Pirojpur Project, Phase I	Ref W26

Medium Term:

- Ganges Barrage includes Links 3-6 and 8	
- G-K Extension, Phase I	Ref W7
- Chandana Scheme	Ref W4
- Rajbari Scheme, Phase I	Ref W5
- Salikha Scheme, Phase 2	Ref W18
- Jhenaidah Scheme	Ref W12
- Kaliganj Scheme	Ref W15
- Alfadanga-Boalmari, Phase 2	Ref W16
- Betna Irrigation Project	Ref W17
- Harihar-Kobadak Irrigation Project	Ref W21
- Singia-Nebugati Project	Ref W22
- Barnal-Salimpur-Kolabashukhali, Phase 2	Ref W23
- Tarail Pachuria Project, Phase 2	Ref W24
- Pirojpur Project, Phase 2	Ref W26

Long Term:

- Hisni - Mathabanga Transfer	
- Transfer Channel Links 1 and 2	
- Hisni Scheme	Ref W2
- G-K Extension Phase 2	Ref W1
- Mathabanga - Upper Bhairab Scheme	Ref W6
- Madhumati-Nabaganga, Phase 2	Ref W13
- Padma-Kumar, Phase 1 Extension	Ref W14
- Padma-Kumar, Phase 2 Extension	Ref W11
- Barnal - Salimpur - Kolabashukhali, Phase	Ref W23

The recommended non-structural measures within the Plan which should be carried out in parallel with the structural measures are:

- Flood proofing in areas expected to remain vulnerable within the medium to long term

- Continuation of the Cyclone Protection Project

- Study of the possible impacts of flood protection works at Chandpur on the long term alignment of the Lower Meghna and how this may affect the South Central Region, notably the right bank spill rivers

- Institution of a temporary buffer zone against further groundwater development in an east-west line to the north of Khulna combined with upgraded groundwater monitoring and resource evaluation and assessment of rural water supply needs

- Support to the private sector for the long term efficient development of minor irrigation

- Institutional support and training in project planning, coordination, implementation and operation and maintenance.

This Report has identified that in parallel with the structural water resources management measures the following programmes should be taken up:

- General development within the agricultural sector including extension, training, credit and input supplies and marketing

- Support and development of social forestry as a key element within the forestry sector

- Support and development of culture fisheries

- Support and mitigative actions to preserve capture fisheries

- Development of artisanal shrimp and shrimp/rice culture in appropriate areas together with the development of hatcheries

- Social programmes including income generating projects targeted especially at low income groups and groups such as those involved in capture fisheries.

The key aspects to the implementation programme are as follows:

(i) Priority should be given to a feasibility study of the Gorai Augmentation Project with early implementation of the first phase

(ii) Priority should be attached to a regional pre-feasibility to 'investment' of the Ganges Barrage and related components such that a decision can be taken as soon as possible on whether or not to proceed with the Barrage or a second phase of the Gorai Augmentation Project

(iii) Priority should be attached to instituting more detailed studies and pilot schemes of drainage congestion relief works at Satkhira, Khulna and, following a pre-feasibility study, at Bagherhat

(iv) Priority should be attached to the study of the Lower Meghna river and its possible impact on the right bank spills to the South Central Region.

Each of the above are in some way related to events external to the development programme. The Gorai study anticipates the risk of early disconnection from Ganges. The Ganges Barrage study should proceed so that decisions can be taken with regard to the second phase of the Gorai Augmentation Project. The drainage schemes in the coastal area should not be delayed in the face of a rapidly deteriorating without-project situation. Finally, the Lower Meghna study should proceed in order to assess the risks that may or may not be inherent in the strategy for the development of its left bank.

All of the other interventions proposed may be progressed at any time, subject only to whether they are linked to the augmentation project or not. The proposed scheduling of these projects is based on the assessment of their relative returns on investment and the social and environmental benefits that will result.

Whilst the order in which these projects are implemented is a question of preference and availability of funds, the overall importance of proceeding with development programme as a whole is considerable in the face of the rising population and demands and the expected continued deterioration of the resource base.

An economic evaluation was carried out for the Plan as proposed with full development with the Ganges Barrage. The analysis indicate that the programme will achieve an overall Economic Internal Rate of Return (EIRR) of 19.8% with a net present value (NPV) at a discount rate of 12% of Tk 14309 M.

A preliminary economic analysis was also undertaken for the progressive development of the Area and the results are summarised below:

Summary of Economic Analysis for Progressive Development of SWA

Phase	Dry Season Flow required through the Gorai (m^3/s)	Area benefitted (ha)	EIRR
With Gorai Augmentation only	170	165,000	15.6%
With Ganges Barrage (current flows)	660	663,000	19.8%
With Ganges Barrage (unlimited flows)	1010	1,070,000	17.0%

The results, though approximate at this level of study, clearly indicate that the proposals are worth considering further and feasibility studies should be initiated to assess the viability in more detail.

S9 Impacts

An initial Social Impact Assessment and Initial Environmental Evaluation (IEE) have been carried out for the proposed Plan. The proposed water management measures have both positive and negative impacts.

The benefits of surface water augmentation schemes would mainly be to the agricultural sector, through increased crop productivity, cropping intensity, and a greater distribution of agricultural income. The overwhelming majority of farmers, it is predicted, will switch to HYV cultivation, as a result of the additional water availability in the rivers and canals in the dry season. Surface water augmentation, depending upon its volume, will reclaim certain portions of land area already affected by salinity.

The Gorai Augmentation Project will have many positive impacts mainly benefitting the farmer communities and generally increasing the food security in the region. The Project is also expected to generate rural income during and after construction and therefore beneficial to the whole community. There are, however, some negative impacts particularly to the fishing communities. Capture fishery is likely to suffer from further declines. Whilst culture fisheries, which will be encouraged as part of the project will go someway in

mitigating these negative impacts it cannot replace it. In designing structures this will be taken into account and 'fish friendly' structures will be incorporated wherever posible in the project design. People's views and the experience of other FAP programmes in this sector, notably FAP17 will be taken into consideration during the design.

Land acquisition for canals and structures, estimated at about 3% of the project area will undoubtedly cause one of the greatest disbenefit. Timely resettlement planning with people's participation and adequate compensation with prompt payment will lessen the impact.

Although there will be negative impacts, they are controllable and mitigatory measures will be proposed during detailed feasibility study stage. The consequences of the Gorai closure on the Area is well described in earlier sections and the catastrophic impacts will be avoided by the augmentation measures proposed under the plan. Further studies, however are needed to confirm and quantify these impacts and a full EIA is recommended under the Feasibility Studies.

The proposed development of FCD schemes comprises embankments along unprotected boundary rivers, controlled flooding and drainage and compartmentalisation of the area using existing rural road networks. Embankments will provide rural transport, improved communication, security from flooding and in some instances accommodation. The expansion of FCD/I schemes will undoubtedly increase agriculture and increased incomes to all sections of the community. This will inturn lead to better diets, food security and improved health of the population.

The recommended strategy for the coastal zone will have generally neutral or marginally positive impacts. The pilot projects proposed in the Satkhira, Bagerhat and Khulna areas will be helpful in identifying the impacts of these proposed measures on other polders and on the Sundarbans. Augmentation measures also will have positive impacts on the Sundarbans in maintaining the fresh flows during the dry season thus preserving the conditions existed before the Farakka Barrage was built. However, data collection and monitoring must go on to maintain the eco-system. Separate study to determine the dynamics of the wetlands eco-system of the mangrove mosaic with specific reference to determining the interactions between the hydrology, water chemistry, sedimentation and the mangrove community structures, is therefore recommended to be initiated.

For better management, data collection and monitoring activities, strengthening of the Department of the Environment and other institutions concerned with the environment are recognised and recommendations given.

S10 Recommendations

The Plan as given in Figure S6 is structured into several phases. Within the short-term plan, clearly there are components which need immediate action. The Gorai Augmentation Project is one of the priority projects which is recommended to proceed as a matter of urgency. The pre-feasibility study undertaken as part of the present study, has shown the project to be feasible economically and technically, but more importantly highlights the negative impacts of not doing anything with catastrophic consequences. Detailed feasibility study is therefore recommended to be commenced as soon as possible. The pre-feasibility study, however, is based on the current dry season flows for computing agriculture benefits and during the feasibility study stage the risks related to basing the project on the existing rate of flows should be studied and if possible, quantified. Indirect benefits such as increased salinity in the wet season if the project does not proceed will also be considered.

Parallel with this there are other FCD/I developments which could be implemented and benefits realised in the short term. There are several such schemes identified of which the following schemes are recommended for implementation in the first instance. These schemes were selected on the basis of their superior B/C Ratio, impacts on environment and the relative social benefits (eg: distribution of income).

(a) Chenchuri Beel FCD Rehabilitation Project
(b) Padma Kumar FCD/I Project
(c) Arial Khan FCD/I Project

In the Coastal zone three pilot schemes have been recommended for early implementation and these should be taken up as soon as possible. Out of the three, two schemes have been recommended for feasibility studies, which are :

- Khulna macro polder (Polders 17/1-2, 26, 18/19, 20 & 29)
- Satkhira polders (Polders 1, 2, 3)

The other scheme, Bagerhat Polder Drainage Scheme should be studied to pre-feasibility level in the first instance.

CERP II which includes Polder 25 (Beel Dakatia) is programmed in the short term and its implementation is recommended as soon as detailed designs including Environmental and Social Impact Assessment surveys are completed.

The Study has concluded that for further expansion by irrigated agriculture beyond year 2000 and for maintaining the present morphology of the rivers and for salinity and environmental control, further augmentation of surface water by a Ganges Barrage is required. In order that a decision can be taken to implement this Project, detailed investigation and studies should be undertaken as a matter of priority. The viability of the Ganges Barrage which depends on the dry season flows in the Ganges will also needs to be assessed during the initial study stage.

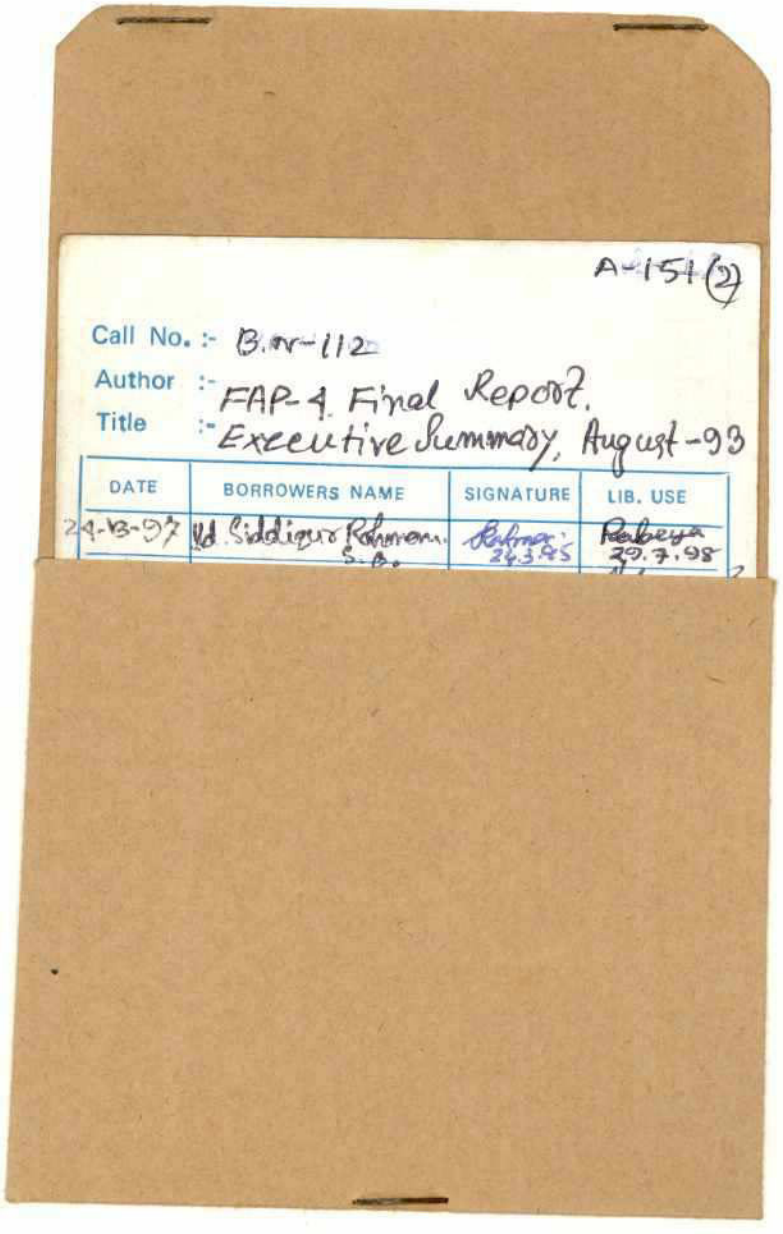
In order that priority developments in the Plan can proceed further detailed feasibility studies should be undertaken for all those projects recommended.

In parallel with the above, other programmes need to be undertaken in certain other sectors. These include:

- Institutional Development and Training Support
- Improved Operation and Maintenance and Cost Recovery
- Assessment of groundwater recharge potential
- Strengthening of groundwater monitoring and resource assessment
- Support for Minor Irrigation development
- Rural and Urban water supply programmes
- Initiating and continuation of monitoring of the Sundarbans
- Flood Proofing study and implementation
- Continuation of cyclone protection project

It is further recommended that this Water Resources Management Plan be reviewed every five years and be subjected to a full re-evaluation every 10 years.

Lack of reliable data was highlighted as one of the drawbacks in the study and programmes should be initiated to collect baseline data on river discharges, water quality, agriculture, fisheries, forestry (Sundarbans) and environmental sectors.



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