PART-II FORMULATION OF FFWS

CHAPTER 4 FRAMEWORK PLAN OF FFWS

4.1 Needs of Flood Forecasting and Warning Services

4.1.1 Objects of FFWS

Disaster management, including that associated with flooding, is a responsibility of the Government of Bangladesh and is aimed at minimizing loss of human life, property and other economic assets.

To achieve this, the GOB, in conjunction with foreign donor agencies, has in the past implemented a large number of flood control projects along major waterways including the Padma, Jamuna and Meghna Rivers. Nowadays, such structural measures are recognized as extremely expensive, not always economically feasible and take much time to implement. Thus, small-scale structural measures such as construction of Polders and flood proofing and non-structural measures are now often seen as more practical and economic. Flood forecasting and warning is a non-structural measure that, as mentioned in the previous Chapter, is one of the essential supporting measures for flood mitigation in the country. Recognized in the FAP project, the GOB has now implemented FFWS nationwide.

The FFWS provides information on flood forecasting and warning to the population with the aim of mitigating flood damage through the following measures:

(1) Evacuation and/or Flood Cooping Operation for the People

The FFWS provides advanced warning to the population of an impending flood indicating its likely magnitude and lead time, that is time allowance between people receiving information and the occurrence of the forecast flood level. This provides the opportunity for evacuation of those likely to be affected to nominated safer areas where appropriate preparations for their safety have been made. Measures can also be implemented to permit the transfer of movable assets to such areas or even to higher levels within existing residences. Without such information, it is not possible for people to evacuate either themselves or property safely. Lead time required for evacuation to ensure safety of human life may be 3-4 hours at the shortest.

(2) Operation of River Structures

There are many river-related structures in Bangladesh. With the provision of adequate flood warnings these could be operated with a greater degree of safety. As outlined in **Section 2.5.4**, the JICA Study Team undertook a questionnaire survey of O&M and Hydrology Divisional and Sub-divisional Offices of BWDB on the necessity of a FFWS. Although the number of respondents to this questionnaire was limited, the majority supported its necessity and noted that operation of river structures during periods of flooding may not be possible without it. Lead time for emergency operation for river structures was estimated to be around 12-24 hours. It is considered an essential component of the O&M for river structures and appurtenant facilities.

(3) Operation of Transportation System

There are a number of important bridge crossings plus many river navigation facilities in Bangladesh. FFWS is very important and essential for safe operation of those transportation facilities. At present, some officials indicated the current FFWS should be improved in terms of its reliability and accuracy. Some operators for river navigation stated that they operate their own FFWS, as the current FFWS of the BWDB is not sufficiently reliable. In order to eliminate unnecessary economic disturbance due to traffic congestion during flooding, a FFWS would contribute to more efficient traffic control. In such cases, comprehensive management among the agencies concerned is essential.

(4) Earlier Harvesting of Crops

There are many Polders in Bangladesh. Typically harvesting occurs at the end of the dry season or beginning of the flood season and polder embankments should be safe at least until its completion. If floods occur earlier than normal, farmers will generally want to harvest earlier. Based on information from local people during the Study, the necessary lead time required for flood warning should be more than 4-5 days. A FFWS would be most beneficial to farmers in making such decisions on early harvesting.

(5) Social and Economic Activities

Flood can result in major disturbances to social and economic activities. Orderly management should be undertaken by the government based on the FFWS. An inter-agency information system connecting all agencies concerned should also be established for more effective use of warnings from the FFWS.

All the above requirement of FFWS will be taken into account in the planning of FFWS including project evaluation.

4.1.2 Objective Areas of FFWS

As discussed in the previous Chapter, extremely low elevations and ground slopes throughout Bangladesh result in much of the country being affected by flooding.

Although only very limited information defining flood damage is generally available for most years, more detailed records were collated by the authorities following the recent major flood in 1998. This included details on flooded areas, number of affected people and flood damage in monetary terms. This information was used in the current study to identify the objective area for the FFWS as outlined below.

Administratively, Bangladesh consists of 6 Divisions and 64 Districts (Zilla). During the 1998 flood, 52 Districts suffered some level of flood damage while the remaining 12 Districts reported none (Report of Management Information & Monitoring (MIM) Division, DMB).

The 12 Districts suffering no flood damage were as follows.

Division	District
Barisal	3 Districts of Barguna, Jhalokhali, and Patualhali
Chittagong	1 District of Khagrachart
Khulna	5 Districts of Jessor, Jhenaidah, Khulna, Merrerpur, and Satkhira
Rajshahi	3 Districts of Dinajpur, Panchaghar, and Thakurgaon

All 12 Districts except Khagrachart in Chittagong Division are located in the western regions of Bangladesh. This would suggest these regions may be less prone to flood damage. One possible reason may be comparatively lower rainfall intensities when compared to those of other regions. However, Dinajpur O&M Division has implemented several flood control works suggesting that this area does in fact suffer from flooding. Three (3) Districts in Barisal Division also reported no flood damage. However, based on information and comments of participants during the Workshop at Barisal conducted by the JICA Study Team it was concluded that flood control including FFWS is essential to mitigate flood damage in this area.

A victim ratio (VR), defined as the number of victims divided by population (at District level), was calculated based on flood damage information for the 1998 flood. The highest VR was 91% in Madarpur District in Dhaka Division followed by Shariatpur in Dhaka. The number of Districts having a VR exceeding 30% totaled 19 while 48 Districts had a VR exceeding 10%. A summary of VR based on the six Divisions in Bangladesh is given below.

Victim Ratio by Division

Division	Population	Affected people	Victim ratio (%)
Barisal	8,101,435	1,346,961	16.6
Chittagong	23,999,345	6,707,746	17.9
Dhaka	38,677,876	14,663,311	37.9
Khulna	14,468,819	1,143,101	7.9
Rajshahi	29,992,855	5,639,178	18.8
Sylhet	7,899,816	1,286,048	16.3

Based on the above observations of reported flood damage and victim ratios for the 1998 flood, the Study Team concluded that there were no significant differences in the likelihood of flood damage between the various Divisions and Districts. Therefore, it was concluded that the entire country of Bangladesh should be considered as the objective area for a FFWS. The Framework Plan for the FFWS outlined in this Study therefore focused on the entire nation with the Feasibility Study component being conducted on the selected optimum plan.

4.1.3 Delineation of Flood Types

It is widely recognized that there are four flood types in Bangladesh, namely 1) monsoon flood, 2) flash flood, 3) tidal surge and 4) local inundation. Local inundation can be considered as a part of monsoon flood.

Although there is no quantitative demarcation of Bangladesh according to flood types, maps showing such areal divisions are available from different sources. Based on these and hydrometeorological data available in BWDB and FFWC, a delineation map of flood types was generated for framework planning as shown in **Figure 4.1.1**.

4.1.4 Required Accuracy of Flood Forecast

In the current flood forecasting and warning services provided by FFWC, the information disseminated includes 1) observed water level, 2) observed rainfall and 3) forecast water level for the following 24 and 48 hour time periods.

The error (required accuracy) of the 24-hour forecast, defined as the difference between observed and forecast water levels, should not exceed:

- 20cm when the change in water level over the 24 hour period is less than 1m or
- 20% of the change in water level over the 24 hour period if this exceeds 1m.

If the error of the forecast water level is maintained within these limits, this will ensure useful and reliable information can be disseminated to recipients.

Monsoon Flood

The accuracy of the current forecasting model is relatively high in the monsoon flood area. The mean absolute error between observed and forecast water levels is less than 20 cm at the majority of forecasting points within the monsoon flood area even for the 72 hour forecast (see **Table 3.5.1**). The maximum absolute errors for most stations do not, however, meet the required forecast accuracy possibly due to input errors in boundary conditions that have estimated before commencing the forecast simulations.

Flash Flood

In the flash flood affected regions, since the time difference between the occurrences of causal (heavy) rainfall and resulting flood is small (often only several hours), accurate and reliable forecasting for areas subject to flash floods is still difficult within the current framework of the observation and analysis system. Therefore FFWC does not issue any forecasting information for stations in flash flood areas.

However, as mentioned **Section 4.1.5** below, some information of future conditions is still necessary in flash flood regions. Such information, which could include current water level and current rainfall intensity over the upstream drainage areas, is still useful for decision-making regarding the need to evacuate and so on. Rough estimates of current rainfall or cloud intensity can be monitored through the BMD radar or NOAA satellite images. The frequent provision to local authorities of observed hydrometric data (water level and rainfall) and knowledge obtained from radar or satellite images is essential.

Tidal Surge

Tidal surge is also recognized as one of the most severe flood disasters in Bangladesh.

The quantitative forecast of water level rising due to tidal surge is not covered by the analysis system in FFWC. The behavior of tidal surge depends strongly on the characteristics of cyclones or atmospheric depressions, and also on topographic characteristics of the objective areas. Although the quantitative forecasting of tidal surge has been widely studied throughout the world, it is still under examination.

Since it is premature to make quantitative forecasts of tidal surge in Bangladesh, the response activities or their decision-making should be done based on the storm warning issued by BMD.

4.1.5 Required and Possible Lead Time

Lead Time

Lead time may be defined as the difference between the time when the warning message is reached people and the time when the flood phenomenon occurs at the objective place.

Required Lead Time

Based on the result of the "Survey on Evacuation Condition and Awareness of Flood Victims", PCM workshops, and interview surveys of O&M staff of BWDB conducted in the early part of the Study, necessary times for the response activity were established as follows:

Necessary Time by Response Activities

Response Activity	Necessary Time for Completion of Activity
Evacuation with minimum necessary belonging	4 hours
Protection of river structure from flood damage	12 hours
Early harvesting of crops	4 ~ 5 days

Possible Lead Time

As shown in the table above, if the flood warning can reach inhabitants 4 to 5 days before, it may provide considerable use for almost all response activities. However, the available or possible lead time differs throughout the country according to the local hydrometeorological conditions.

To assess the available lead times by region, a trial analysis was conducted. In this analysis, the minimum time required for the water level to rise from an elevation 1m below danger level to danger level was calculated at all FFWC stations based on the available historical water level record. This is referred to as the available time for preparedness and provides an indicative measure of the times for people to initiate response actions once the water level reaches 1m below danger level. Comparing the available time with the necessary time indicates those regions of the country that may be more critical in terms of being able to initiate responses.

Figure 4.1.2 shows the minimum available time for preparedness based on the historical records. The area with an available time for preparedness of less than 4 hours is located mainly in the international border area of northeastern and southeastern Bangladesh. It also can be observed that at least 24 hours are available for initiation of response activities over the majority of Bangladesh.

Based on the required lead time from the viewpoint of the recipients of flood warning, target lead time provided by FFWS is considered as 4 days for monsoon flood area and 4 hours for flash flood area. To achieve this target, the acquisition of the hydrometeorological information in the upstream basin area, particularly in India, is essential.

4.1.6 Basic Conditions for Formulation of Framework Plan

(1) Objects to be protected by FFWS

a) Human lives (to minimize the death of people)
b) Movable assets in homestead (to protect household assets)
c) Agricultural product (to make early harvesting possible)
d) Infrastructures (emergency operation of river structures, traffic control)
e) Social and economic activities

(2) Objective areas of FFWS

a) Entire area of Bangladesh
b) Priority study for implementation will be conducted after feasibility study

(3) Social and economic condition as a target year of framework plan

a) Present socio-economic condition to be adopted for the formulation of framework plan
b) Future socio-economic condition including population, GDP, etc will not be considered.

4.2 Component Alternative Development Plan

4.2.1 General

The problems associated with the current FFWS in Bangladesh were extracted and analyzed by components (observation, data transmission, analysis, warning dissemination, and response systems) in the previous Chapter. Based on the findings on the existing FFWS, alternative improvement plans were developed and are outlined below.

The component alternatives were developed considering that they formed an overall combined alternative framework plan. The combined alternative framework plans were largely divided as follows:

1) manual observation system, telemeter system, or combined system of manyal observation and telemeter
2) central control system or regional control system

4.2.2 Observation System

(1) General

The existing observation network is currently considered to meet the required coverage for use in the FFWS as mentioned in **Section 3.3**. A number of steps should, however, be implemented to improve the accuracy of the data (both rainfall and water level). These include:

- ensuring all rainfall gauges have adequate clearance from nearby structures or vegetation, and
- installing permanent gauge plates at the higher flow levels at those water level stations with permanent embankments or structures.

In addition, expansion of the existing telemetry network is proposed. This will provide accurate real-time monitoring particularly in those areas subject to flash flooding, where substantial water level changes can occur within 3 to 6 hours. It will also allow more accurate future forecasting in these areas for up to around 24 hours in advance using the flood forecasting analysis model.

For easy understanding of the following descriptions, the alternatives derived from this observation system are listed at first as follows:

1) Retention of present manual observation system (only data communication system will be improved),
2) Installation of automatic water level and rainfall gauging equipment with telemetric system at all of existing FFWC observatories (91 water level and 56 rainfall gauging stations)
3) Installation of automatic water level and rainfall gauging equipment with telemetric system at proposed 23 observatories (data communication system will be improved for remaining manually operated observatories), and

In view of reliability, accuracy and consistency of observation, it is clear that option 2) is most preferable provided this large number of automatic gauges is properly maintained. Option 3) defined the case that the number of automatic gauges is reduced with automatic gauges being installed only at locations important from the viewpoints of model requirement and flood characteristics etc. Although there is no improvement in the reliability, accuracy and consistency of observation in option 1), possible errors that could have previously occurred during the data transmission and manual data entry stages would be reduced.

The process of the selection of the 23 stations mentioned in option 3) above is described in detail below.

(2) Criteria for Selection of Telemetric Stations

Four (4) criteria were considered for the selection of the proposed telemetry network as follows:

1) Flood Characteristics [Criteria 1]

In principle, the accurate observation of all flood types recognized in Bangladesh, i.e. i) monsoon flood, ii) flash flood, iii) tidal surge, and iv) local inundation, should be achieved by the hydrometeorological network of FFWC. Given the difference in rates of rise/fall in water levels in those areas subject to different flood characteristics the required observation intervals will also vary. The telemetric system is more useful in those areas subject to short-term floods such as flash flood or tidal surge.

2) Highly Developed Area/City [Criteria 2]

More accurate and frequent monitoring of flood phenomena is necessary in more highly developed areas or areas with larger population due to their greater economic and social importance.

3) Model Requirement [Criteria 3]

Current flood level analyses/forecasts in FFWC are determined using a hydrological and hydraulic software package developed by DHI. Since this analysis system has been judged as suitable for application in the FFWS in Bangladesh (as mentioned in the previous chapter), it is practical that the telemetric stations be selected according to model requirements.

Critical information for model operation included upstream and downstream boundary water levels and rainfall data. The latter are, however, of minimal importance in accurately defining flood levels. The stations to be selected using this criteria were therefore determined according to those stations necessary to adequately define water level boundaries for the hydraulic model.

4) Strategic Point in View of Hydrology [Criteria 4]

Confluence or divergence points of a river network are often recognized as strategic points from the hydrological viewpoint. Although a large number of junctions occur in the river network of Bangladesh (see **Location Map: Rivers of Bangladesh**), a prioritization was applied.

Screening of the various FFWC gauging stations was conducted based on the above criteria. This involved initially screening each station according to the various criteria with a subsequent final selection based on eliminating all except one station if a number were located in close proximity. The detailed process is explained below.

(3) First Screening of the Stations to be Telemetered

The first screening was carried out based on the total score assigned for the stations using the above four criteria. The scores to be assigned are presented below:

[Criteria 1 (Flood Characteristics)]

In order to assess the flood characteristics, the calculation results of maximum water level change in 3 hours were utilized (see **Figure 2.4.8**).

Criteria 1: Flood Characteristics

Item (Maximum Water Level Increase in 3 Hours)	Score to be Assigned
200 cm ~ (Non-tidal Effect)	5
150 cm ~ 200 cm (Non-tidal Effect)	4
100 cm ~ 150 cm (Non-tidal Effect), or Station subject to Tidal Effect	3
50 cm ~ 100 cm (Non-tidal Effect)	2
~ 50 cm (Non-tidal Effect)	1

[Criteria 2 (Highly Developed City/Area)]

The extent of development in an area was assessed based on the population density in 2001 of the district in which the gauging station was located (see **Figure 2.2.2**).

Criteria 2: Highly Developed City/Area

Item	Score to be Assigned
Division Capital	6
Population Density (1,501 persons/ km^2 ~)	5
Population Density (1,001 ~ 1,500 persons/ km^2)	4
Population Density (751 ~ 1,000 persons/ km^2)	3
Population Density (501 ~ 750 persons/ km^2)	2
Population Density (~ 500 persons/km^2)	1

[Criteria 3 (Model Requirement)]

Those sites coinciding with 'base' boundary stations for the Supermodel 2001 and where associated streamflows during flooding were relatively large, were more important in the hydraulic modeling. Considering that a hydraulic approach is applied in the Supermodel 2001, acquisition of data at boundary points ('base' boundary stations) contributes to improvements in accuracy of model performance.

The following items were considered in assessing the importance of the station with regard to the current model.

Criteria 3: Model Requirement

Item	Score to be Assigned
Base Boundary Station Located at International Border	5
Boundary Station Located within Bangladesh	4
Internal Boundary Station	3
Others	0

[Criteria 4 (Hydrological Strategic Point)]

Usually, strategic hydrologic points are defined at locations whose data contribute to improved forecasting accuracy for target areas. In this Study, the target area extends over the whole of Bangladesh. On this basis, the evaluation items outlined below were adopted:

Criteria 4: Hydrological Strategic Point

Item	Score to be Assigned
Stations Located at International Boundary at Large Rivers	5
Stations Located at International Boundary at Medium Rivers	4
Stations Located at International Boundary at Small Rivers, or Confluence/Diverging Point of Large Rivers	3
Confluence/Diverging Point of Large and Medium/Small Rivers, or River Mouth	2
Others	1

Notes: 1) Large rivers are the Jamuna, Padma, and Meghna rivers.
2) Medium rivers are the Barak, the Kushiyara, the Surma, the Old Brahmaputra, the Dharala, the Teesta, the Gorai, and the Madhumari.
3) Other rivers are categorized in small rivers.

Scores were assigned for each FFWC gauging station by criteria. First screening of the importance of the gauging stations was carried out by the comparison of total score of the stations.

The scores assigned for each station by criteria are presented in **Table 4.2.1** together with total scores.

As the first screening, thirty three (33) stations with total score of 10 or more were taken up. According to the FFWC staff, they have an idea that the existing flood analysis model is to be operated automatically using the hydrometric data transferred through telemetric system in near future. To meet this intension, the threshold score was set at 10, because almost all of the important stations in view of model operation clear this score.

The stations passed the first screening are summarized below:

Stations Passed the First Screening

Sl.No.	Station Name	ID*	Sl.No.	Station Name	ID*	Sl.No.	Station Name	ID*
1	Kurigram	1	12	Khulna	61	23	Laurergarh	80
2	Dalia	2	13	Kanaighat	63	24	Panchapukuria	83
3	Noonkhawa	5	14	Sylhet	64	25	Sadarghat	95
4	Sirajganj	9	15	Amalshid/Zakiganj	66	26	Daulatkhan	97
5	Dhaka	15	16	Monu Rly. Bridge	68	27	Patharghata	98
6	Narayanganj	16	17	Durgapur	71	28	Mongla	99
7	Mirpur	17	18	Bhairab Bazar	72	29	Rayenda	100
8	Tongi	18	19	Comilla	73	30	Dasmina	101
9	Pachagarh	24	20	Sarighat	75	31	Chatlaghat	105
10	Pankha	26	21	Jalia Jhanjail	77	32	Jibanpur	106
11	Hariharpara	52	22	Nakugaon	78	33	Kangsanagar	107

Note*: IDs of the stations coincide with those on **Figure 3.3.1**.

(4) Second Screening of the Stations to be Telemetered

The first screening was conducted based directly on a ranking of the stations. To ensure stations were also adequately distributed and not located too close, a second screening was therefore carried out based on station proximity.

Through this second screening, a further 10 gauging stations were eliminated as outlined below:

Stations Eliminated through the Second Screening

Station (ID)	Reason	Station (ID)	Reason
Narayanganj (16)	Merged with Dhaka (15)	Sylhet (94)	Merged with Amalshid (66)
Mirpur (17)	- ditto -	Jalia Jhanjail (77)	Merged with Nakugaon (78)
Tongi (18)	- ditto -	Monu Rly. Br. (68)	Merged with Chatlaghat (105)
Hariharpara (52)	- ditto -	Jibanpur (106)	Merged with Comilla (73)
Khulna (61)	Merged with Mongla (99)	Kangsnagar (107)	- ditto -

Note*: IDs of the stations coincide with those on **Figure 3.3.1**.

(5) Proposed Telemetric Network

Based on this analysis, it was proposed that a telemetric network including 23 stations be established as one of the component alternatives for the observation system. Automatic water level gauges would be installed at each.

Proposed Telemetric Observatory

Sl.No.	Station Name	Sl.No.	Station Name	Sl.No.	Station Name
1	Panchagarh	9	Laurergarh	17	Mongla
2	Dalia	10	Sarighat	18	Rayenda
3	Noonkhawa	11	Kanaighat	19	Patharghata
4	Kurigram	12	Amalshid	20	Dasmina
5	Sirajganj	13	Chatlaghat	21	Daulatkhan
6	Pankha	14	Bhairab Bazar	22	Panchapukuria
7	Nakuagaon	15	Comilla	23	Chittagong (Sadarghat)
8	Durgapur	16	Dhaka (Mill Barak)		

The location of these telemetric stations is presented in **Figure 4.2.1**. In addition, the characteristics of the catchments of proposed telemetry stations are described in **Table 4.2.2**. They are predominantly located on the boundaries of the existing Supermodel river network. Two, Chittagong (Sadarghat) and Panchapukuria, are also situated in the south-eastern region and will be used for both real-time flood level monitoring and modeling of this area in the future by the FFWC.

According to the finding about analysis system mentioned in **Section 3.5**, most of possible errors in simulated water levels, which are due to poor rainfall data, poor topographic data etc., are forcibly fit by means of 'discharge adjustment' technique. This means that the importance of the accuracy of rainfall observation is relatively small comparing to that of water level observation as long as such a technique is applied. However, it should be noted that the physical (theoretical) background of discharge adjustment is very weak and this operation may not be necessary in the ideal situation. In order to strengthen the physical background, rainfall observation in shorter interval is also important especially in the flash flood areas and affected area of local inundation (rainfed flood). Installation of automatic rainfall gauge together with automatic water level gauge is therefore proposed.

Based on field visits and the inventory survey of the observation network, the automatic stations can be constructed on existing permanent structures (bridges, spur dikes, wharves and so on) at most of the locations. Several locations have no permanent structures but automatic stations have been successfully installed and operated for a number of years. At the remaining sites, available information from BWDB personnel indicates no major problems should be anticipated either during construction or under future operation.

4.2.3 Data Transmission System

(1) Needs to be Met by the Communications Network

Establishment of a unified administration and data disseminating structure: Such a network system must allow for the unified management of river-related data and its prompt dissemination to relevant authorities. This will enable such agencies and the general public to accurately comprehend incoming data and thus carry out effective preventative actions without confusion.

Use of data as shared resource: Data collected, stored and processed must be managed in a unified manner with a system that allows effective sharing of such data among all relevant divisions.

Diversification of data for dissemination: The content of data disseminating to relevant agencies and public may not necessarily be identical. It is necessary to differentiate the data provided to each in terms of its level of detail and urgency depending upon the targeted audience.

Improvement of Network Reliability: Disaster prevention data needs to be communicated accurately, reliably and in timely manner. Therefore, data communication networks connected to relevant agencies must ensure that the transmission speed and lines are technologically reliable.

(2) Existing Problems

As explained in **Chapter 3**, the following items are found as major problems in the existing FFWS and telemeter system.

Existing FFWS

- Error or delay in data transmission of manually observed data seems to be caused by human factors.
- Data transmission from the gauging sites to FFWC in Dhaka is based on wireless telephone with voice communication in case of manual gauging stations. This implies possible errors in observations, listening and rewriting.
- Some delay in dissemination of disaster prevention information to relevant

agencies and the public occurs because the dissemination only occurs after collection/transfer to the Central office and subsequent analysis.

Existing Telemeter System

- There is a lack of proper maintenance of the existing telemeter system (due to budget constraints, staffing, maintenance, institutions, etc.).
- Telemeter gauging stations (numbering 14) never been utilized for flood forecasting due to flood damage, sediment accumulation, scouring of structures, and unavailability of spare parts.
- The service and reliability of BTTB and BRTA are poor.

(3) Data Transmission Alternative Plan

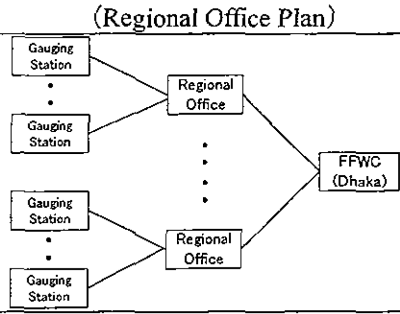
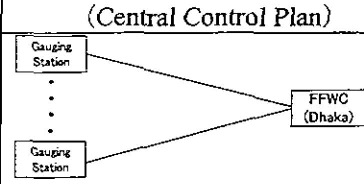
1) Regional Office Plan

Outline of the Plan

Two types of setup for data transmission system can be considered, such as a "Centralized system (Central control Plan)" and a "Distributed system (Regional office Plan)".

The "Centralized system" is suitable for initial development stages of a project or for a small-scale system. It is easy to establish the institution and functions for a Centralized System, however, quick actions and responses are more difficult (refer to **Figure 4.2.2**).

The "Distributed system" is suitable for a large-scale system to act quickly and efficiently. However, it is necessary to develop operational and management capabilities and clear definition of the decision authority and responsibility is needed (refer to **Figure 4.2.3**).

	Distributed system (Regional Office Plan)	Centralized system (Central Control Plan)
Model		
Merit	Quick action at the Regional office for the local condition.	Central control Unified administration of information and technology

The effect of "Regional Office Plan"

- Activation of local community for flood disaster prevention
- Dissemination of information in consideration of local area
- Quick response for flood fighting in consideration of local condition

Condition for installation of "Regional Office Plan"

- Collection of information (observation and other necessary information) to the Regional office
- Clarification of decision authority and responsibility of Regional office.

Central office function in case of "Regional Office Plan"

- Collection of nationwide information
- Nationwide management and analysis
- Distribution of information to mass media and relevant organizations

2) Telemeter System Plan

Outline of the Plan

To address data collection errors and delays, a telemeter system will be effective as reliable rainfall and water level data will be automatically (and continuously) collected every 10 minutes.

However, in addition to facility establishment costs, continuous maintenance costs will be required. Therefore, only the minimum number of telemeter stations should be considered.

	Existing System(manual system)	Telemeter System
Model	1: A gauge reader observes the data (Staff gauge and rainfall quantity) and relays it to a Radio operator at a Radio Station. 2: The operator at the Radio Station transmits the data to Dhaka through a transceiver. 3: An operator in Dhaka processes the data received from the Radio Station. 4: The collected data is then entered into the FFWS server by a FFWC staff member.	1: Water-level and rainfall quantity is sensed and transmitted automatically. 2: Transmitted data are collected and entered into the data server automatically.
Merit	If a river changes section, the location of the staff gauge can be moved. Low cost of OM	Continues and detail observation can be realized with high reliability

Effect of Telemeter system

For flood disaster action: Particularly effective for flash flood areas to assist in disseminating early warnings and forecasting.

For river management: Observation during night and observation of remote gauging stations are possible. This will also reduce the required number of staff.

For river control planning: River control planning and improving the river model are possible by using the more detailed data.

Condition for installation of telemeter system

- Provision of adequate O&M system (budget +staffing+ organization)
- Development of data entry interface for both telemeter and manual data

3) Digital Communication for Manual Observation Plan

Outline of the Plan

The telemeter system will be installed only at the required gauging stations (as outlined above). For the FFWS, all other gauging stations currently operated by FFWC will continue to be manually observed. To ensure data errors and delays in data input to the analysis system (database) are minimized, an automatic input system will be required. Where mobile phone transmission can be used at the gauging station, the observed data can be transferred and input automatically into the server. Where this is not possible, the observed data can be transmitted through existing radio stations using HF wireless radio communication with the data again automatically input into the data server.

	Mobile data communication	Wireless radio data communication
Model	1: The gauge reader observes the data at the gauging station. And the gauge reader transmits the observed data by mobile phone using the data sending function. 2: Transmitted data is automatically input in the data server. 3: The analyzing system can use the observed data from data server whenever it requires.	1: The gauge reader observes the data at the gauging station. The gauge reader reads to a Radio operator at a Radio Station. 2: The operator input the observed data into the computer connected with Digital wireless radio at the Radio Station. 3: Transmitted data is automatically inputted in the data server. 4: The Analyzing system can use the observed data from data server whenever it requires.
Merit	Automatically input into the data server. The prevention of the wrong input. Reducing staff Low cost of O&M	Automatically input into the data server. The prevention of the wrong input

Condition for installation of digital communication

- The fulfillment of the OM system (budget + staffing + organization)
- Introduction of data entry interface for both telemeter and digital communication

(4) Optimum Telecommunication Plan

An optimum telecommunication method was selected for the FFWS system with the adopted system differing based on its location, that is from the gauging station to regional office (selected first) and regional to central office. The telecommunication method selected for dissemination of warnings to Union or NGO was undertaken as part of the Feasibility Study and is discussed in **Chapter 7**.

1) From the gauging station

Selection basis for the alternative plan

At the gauging station, electric power reliability is very low. As a result it was decided to use solar power for which overall power consumption must be minimized. Space constraints at the stations also required that the size of the equipment also be minimized.

The selected alternative plans included:

a) VHF (refer to **Figure 4.2.4**)

b) BTTB public network (refer to **Figure 4.2.5**)

c) Mobile network (refer to **Figure 4.2.6**)

d) INMALSAT (refer to **Figure 4.2.7**)

Criteria for selection of optimum plan

Criteria for selecting an optimum communication plan were based on the following.

a) Reliability

- BWDB's own network has greater reliability than that of a private company.
- In case of emergency, the communication quality of a private company's network is not necessarily guaranteed due to communication congestion. This raises the possibility of sometimes failing to transmit data from gauging stations.

b) Low power consumption

- In rural areas where gauging stations will typically be installed, reliability of commercial power is generally low.
- Conversely, solar power is an effective option for power supply.
- Equipment with low power consumption is therefore required in the gauging station.

c) Small sized equipment

- In order to minimize gauging station dimensions, the installed equipment must be compact.

d) Less O/M requirement

- In case of equipment malfunction, BWDB staff must repair immediately.
- It is therefore desirable for BWDB staff to use equipment with which they are familiar and have used.
- It takes considerable time and cost to acquire O&M of new equipment.

Evaluation and Conclusion

The most important criteria for collecting data from the gauging stations is reliability of communication. Therefore, VHF radio should be selected even if the costs are greater. An added advantage is BWDB staff's familiarity with the equipment.

The BTTB public network, Mobile network and INMALSAT, being private company networks, are less reliable. In addition, the annual cost of INMALSAT is too expensive when compared with the other plans.

2) From Regional Office to FFWC

Selection basis for the alternative plan

From the Regional office to FFWC, various types of data transfer are important including not only observed data but also database information and voice communication. At both the Regional and central (FFWC) offices sufficient space plus a reliable electricity supply are also available, hence various alternative plans are possible including:

a) Digital HF (refer to **Figure 4.2.8**)
b) BWDB's Microwave (refer to **Figure 4.2.9**)
c) VSAT (refer to **Figure 4.2.10**)
d) GRAMEEN Network (refer to **Figure 4.2.11**)
e) BTTB Public Network (refer to **Figure 4.2.12**)
f) BTTB Lease line (refer to **Figure 4.2.13**)

Criteria for selection of optimum plan

Criteria for selecting an optimum communication plan include the following:

a) Reliability

- BWDB's own network has greater reliability than that of a private company.
- In case of emergency, communication quality of a private company's network is not necessarily guaranteed due to communication congestion. This raises the possibility of sometimes failing to transmit data from gauging stations.
- Since quick action for the flood fighting is important, the reliability of telecommunication system should be ensured especially for the central control system.

b) Transmitting speed and capacity

- At the Regional office, it is necessary to have sufficient transmission speed and capacity to forward all collated data from telemeter stations to the FFWC.
- Not only data but also voice transmission should available.

c) Less O&M requirement

- In case of equipment malfunction, BWDB staff must repair immediately.
- It is therefore desirable for BWDB staff to use equipment with which they are familiar and have used.
- It takes considerable time and cost to acquire O&M of new equipment.

d) Less repeater station

- If the number of repeater station is increased, installation costs rise.

- It is preferable that no repeater stations are required.

Evaluation

The most important criteria are reliability of communication and capability of ensuring O&M.

VSAT, GRAMEEN network and BTTB lease line are possibly less reliable during periods of significant congestion. BWDB's microwave is reliable. However, BWDB staff have only limited O&M experience and its installation is expensive.

The Digital HF radio network is BWDB's own network, but communication is less reliable because of fluctuations in radio propagation quality. However, BWDB staff are familiar with the equipment (conditional on propagation quality fluctuations) and there is an existing and good O&M system in place.

The BTTB public network is not optimum for main communication networks. It is, however, used for public communication and with low annual operating costs is considered appropriate as a backup communication network.

Conclusion

In case of the regional control system, the sureness of telecommunication between the central and regional offices is less important than that in case of the central control system, because the regional offices can execute almost all of emergency actions without communicating with the central office. For this reason, digital HF radio is optimum and feasible for communications between the Regional office and Central office. To complement the weak point of digital HF, the BTTB public network was adopted as a backup particularly as it is comparatively reliable in the regional areas.

Contrarily, surer telecommunication system between the regional and central offices may be necessary in case of the central controlled system considering that the central office should conduct emergency activities for local community. To meet this requirement, BWDB's own microwave network was considered for the central control system. Also, digital HF with BTTB public line is proposed as optional plan although its reliability is not high. Because, microwave network is not easy to make proper operation and maintenance generally.

4.2.4 Analysis System

As mentioned in **Section 3.5**, the flood forecasting model implemented by the FFWC performs well within available resources. Since the adoption of an alternative flood forecasting analysis model is not practical, nor indeed necessary, recommendations outlined below are associated with the present system.

(1) Improvement Provided by the Installation of Telemetry System

Flood warnings are currently issued by the FFWC defining both real-time and forecast water levels at selected locations within the country.

The former are based on the network of manually observed water level stations installed and operated by the BWDB. The limited automatic telemetry network comprising a total of 14 water level and/or rainfall stations, installed initially in the mid-1980s and expanded in 1996, is not utilized at all in this process. Only 5 stations remained fully operational as of September, 2003.

Flood forecasting is based on the use of a simulation program installed at the FFWC. Flood levels are forecast for future 24, 48 and 72 hour intervals although actual forecasts are only issued by the FFWC up to 48 hours in advance. To improve the adequacy of the forecasting, particularly in those areas of the country subject to flash flooding, it is proposed that the automatic telemetry network be upgraded and expanded as outlined in **Section 4.2.2**.

To assess the likely benefits of the upgrading, a quantitative assessment of the level of improvement in the accuracy of the flood forecasting system was undertaken during the second stage of the project in Bangladesh. This included evaluating the following conditions:

(i) maintaining the existing network with improvements to ensure accuracy of the data collection and transmission system,

(ii) establishing the telemetry network at all water level stations currently used in the Supermodel, and

(iii) establishing the more limited telemetry network as outlined in **Section 4.2.2.**

To complement the availability of continuous (hourly) water level data from the automatic stations, it is recommended that the simulation model be operated more frequently. For this purpose use of regional models in conjunction with the Supermodel is recommended.

This will require interface programs to be developed to integrate data between the Supermodel and regional model(s), integrate both manually observed records and data from the telemetry stations into the models and to enable the transfer of data between the two systems. Assessment of associated data trends for forecasting of boundary conditions will also be required.

(2) Improvement to be Undertaken by the Inter-agency Basis

As mentioned in **Section 3.5**, the major obstacles for accurate flood forecasting with longer lead time are:

- limitations in existing topographic information, and
- inaccuracy of boundary estimates for flood forecasting.

These problems cannot be solved by installation of a dense telemetry system in Bangladesh or by applying an alternative forecasting system. To overcome these fundamental obstacles, the following recommendations are made:

a) Topographic Information

The source of the current digital evaluation model (DEM at 300 x 300m) is 1:50,000 topographic mapping generated in the 1960's. To account for changes in infrastructure development in the intervening period, the FFWC is making efforts to update the DEM as site specific information becomes available. The topographic surveys should also incorporate the revised national benchmarks recently resurveyed to update existing 1:50,000 and 1:250,000 topographic maps.

b) Future Boundary Estimation

In order to more accurately estimate future boundary conditions, there are many activities/studies ongoing in Bangladesh. These activities are roughly divided into the following approaches:

- Physical Approach (Hydrological / Hydraulic Approach)

  Future boundary conditions estimated using observed hydrometeorological information for sites outside Bangladesh by means of hydrological/hydraulic simulation models for example water level correlations, use of radar for estimation of rainfall etc.
- Statistical Approach

  Future boundary conditions are estimated based on statistical approaches using historical hydrometeorological records, for example 'Neural Networks' or 'Artificial Intelligence'.
- Qualitative Approach

  Future boundary conditions are estimated by qualitatively interpreting available hydrometeorological information, such as water levels at Indian stations with those on the international borders, radar and satellite images now received in the FFWC control room etc.

Given the lack of hydrometeorological data from India available to the FFWC and limited development of more sophisticated physical methods such as estimation of rainfall using radar images or the statistical approaches listed above, the FFWC is at present only able to consider the qualitative approach.

Nonetheless, in the future the hydrological/hydraulic approach is considered to be the most suitable and the following recommendations are therefore made:

- Ongoing efforts should be made for the collection of hydrometeorological data outside Bangladesh, especially in India.
- Quantitative estimation of rainfall outside Bangladesh utilizing existing information of meteorological radar, especially in the Meghalaya mountainous area to the north-east where much of the flash flooding originates, is important.
- Regardless of the availability of Indian data, the limitation of current flood forecasting results should be clarified and clearly stated to the local

population.

4.2.5 Warning Dissemination System

(1) Inhabitants

There already exists documented procedure for flood warning dissemination for inhabitants as mentioned in the Standing Orders for Disaster, 1999, and mostly it is working fine till the Upazilla level. However, the dissemination link between Upazilla to Union is not properly working. The proposed alternative is "Current procedure with major up-gradation in the lower tiers together with feedback".

In this alternative, the following aspects should be included:

- Flood warning bulletin issued by FFWC must reach to all district administration
- Local BWDB staff who is a member of District Disaster Management Committee (DMC), should help interpreting the warning message
- Local BWDB staff will monitor the dissemination process in the lower tiers
- Introduction of reward / punishment for the Upazilla level responsible officer to inform Union DMC
- Involvement of local NGO in the Upazilla and Union DMC
- Arrangement of wireless or mobile phone at Union by participatory contribution
- Introduction of feedback system, for example, once the Union DMC receives information; there should be some mechanism to confirm that to Upazilla DMC
- Training of volunteers in the village level similar to CPP

(2) River Structures

BWDB operations various river structures like embankments, polders, pumping stations, irrigation intakes, irrigation canals, etc. Unfortunately, there are no fixed guidelines on routine dissemination of flood warning for all BWDB field operation office. Also, there is no system to incorporate flood warning in the operation of the various river structures maintained by Roads and Highways (RHD), Bangladesh Inland Water Transport Authority (BIWTA), Bangladesh Inland Water Transport Corporation (BIWTC), Bangladesh Agricultural Development Corporation (BADC), etc. Structures maintained by these agencies include bridges, ferry terminals, ports, irrigation canals, pumping stations, etc. The proposed alternative is "all river structure operation must receive flood forecasting".

In this alternative, the following aspects should be included:

- Flood warning will be provided to the central O&M office of BWDB, which in turn will inform all field operation office,
- For major structures, flood warning will be given directly to the project operation office,
- After receiving flood warning, BWDB divisional office will also inform field operation offices,
- Flood warning will be provided to all relevant agencies and respective agencies

will inform their field operation office, and

- For major facilities, like port, bridges and major ferry terminals, flood warning will be given directly to the field operation offices.

4.2.6 Response System

(1) Evacuation

There is no fixed setup for appropriate flood evacuation. However, a well-developed system is operating for cyclone warning under CPP. An effective flood evacuation system should be initiated in order to achieve similar benefits with flood warning. DMCs at various levels should take responsibility with overall supervision by Disaster Management Bureau (DMB).

In this proposal, the following aspects should be included:

- Actual responsibility of evacuation should lie with Union DMC,
- Volunteers should be trained to a similar level as those in the CPP to assist in the evacuation process,
- Upazilla DMC should earmark evacuation centers and transportation, and
- Upazilla DMC should arrange security for evacuated dwellings.

(2) Other Non-structural Response

There is no response management for other non-structural measures such as harvesting, and fish cultivation. A proper response system would reduce the property damage caused by flooding.

In this proposal, the following aspects should be included:

- A response management guideline should be prepared by DMB,
- District DMC should issue response measures for agriculture and fisheries taking into consideration of the flood warning,
- District DMC will work closely with the relevant agencies like Directorate of Agriculture Extension (DAE) and Fisheries Department, and
- Union DMC should inform the people and monitor the response undertaken.

(3) Response for the River Structures

Even BWDB now does not use flood forecasting in their operation of water structures. Other agencies operating other river structures also do not incorporate flood forecasting in their operation. A proper response will ensure smooth operation and safety of the structures.

In this proposal, the following aspects should be included:

- A response management guideline should be prepared by all concerned agencies including BWDB,
- The Operation and Maintenance office of each agency should issue response measures for river structures taking into consideration of the flood warning,
- Field operation offices of each agency should undertake proper response measures

as stipulated in the guideline, and

- District level offices of the concerned agencies should monitor the action taken by the field offices.

4.3 ***Institutional Alternatives***

4.3.1 General

As explained in the **Section 2.8**, the present institutional setup has serious bottleneck to deliver desired services in relation to flood forecasting. To overcome those, 3 alternatives can be considered. These are,

- Current Organization with some major improvement
- Establishment of regional offices of Hydrology Service, and
- Establishment of regional offices of BWDB

4.3.2 Organizational Alternatives

(1) Current Organization with Some Major Improvement

At present, there are 3 data collection circles for surface water, groundwater and morphology. They are only collecting the data. After collection, they send those to PFFC circle. In PFFC circle, there are 3 processing branches for those 3 circles.

The FFWC is one branch of PFFC. For flood forecasting, FFWC uses water level and rainfall data of only some stations out of total hydrology stations. Real time data transmission from these stations are again done by another branch of PFFC named C&I division. However, C&I division is also responsible for maintaining all electro-mechanical instrument of entire Hydrology.

For smooth operation of hydrology in general and flood forecasting in particular, improvement is proposed as shown in the **Figure 4.3.1**. In this proposal, the present mandate of PFFC is divided based on similar work nature. Newly proposed Processing Division will be placed directly under the Hydrology service and will consist of present 3 processing branches, Index and publication branch, and Management and services branch. Because of its strategic location, it will be easy for this division to coordinate with 3 data collection circles. A new circle will be Flood Hydrology Circle. There will be 3 divisions under this circle. Present FFWC will become Forecasting division with a mandate of flood forecasting, model update, model validation and low flow forecasting. Part of present C&I will become Data Transmission division and a new division will be created named data collection division by transferring some personnel from the Surface water hydrology circle. Part of the C&I division will become Instrumentation division placed directly under Hydrology Service, and will be responsible for maintaining electro-mechanical equipment of the 3 data collection circles.

Mandate of the Flood Hydrology Circle (FHC) will be:

- Collect all observation data

- Transmit the data to regional office
- Run the super model
- Issue flood forecast with local context
- Mandated to be a member of national disaster management committee
- Monitor the warning dissemination process
- Help in the evacuation and other response management
- Make dry season monitoring

(2) Establishment of Regional Offices of Hydrology Service

FFWC is now working at central level. In some instances, it is not possible for FFWC to interact with the local context. To overcome this problem, establishment of regional offices of Hydrology Service is proposed as an alternative.

In this alternative, in addition to the re-organization of Hydrology service centrally as explained in alternative 1, regional offices of Hydrology service will be established. Under the regional Hydrology Service, the organization will be similar to that of the central. The mandate of the regional FHC will be as follows:

- Collection of all observation data
- Transmission of data to regional office
- Operation of the regional flood forecasting model
- Issue of flood forecasts with local context
- A mandate to be a member of regional disaster management committee
- Monitoring of the warning dissemination process
- Assisting in the evacuation and other response management
- Undertaking dry season monitoring on a regional basis

Before full operation, the regional FHC will test run the regional models for at least 2 years. During this interim period, the supermodel will continue operation. Once the regional models function accurately, the supermodel can be operated for monitoring of the entire country.

(3) Establishment of Regional Offices of BWDB

The coordination among different sections of BWDB is not always satisfactory especially at field level. Planning and design are done centrally, major implementation is done by specific project offices and O&M are done by O&M field offices. Furthermore, hydrology field offices work separately from the field offices of O&M. This results in problems with coordination.

In this alternative, there will be a number of BWDB decentralized regional offices headed by a regional director. The office will be responsible for all activities such as planning, design, implementation, operation and maintenance, and hydrology including flood forecasting. The mandate and activity of the FHC under the regional BWDB will be the same as in Alternative 2.

4.4 Combined Alternatives and Selection of Optimum Framework Plan

4.4.1 Candidate Alternatives

(1) Basic Problems Encountering in the Present FFWS

Prior to the assessment of the conceivable alternatives, the basic problems which must be addressed include the following.

a) Insufficient information from India

Bangladesh is located at the confluence of the three International Rivers, the Ganges, Brahmaputra and Meghna. Therefore, hydrological conditions in Bangladesh are largely dependent on hydrometeorological conditions in India. Without hydrological data from India, floods in Bangladesh cannot be forecast more accurately than at present. Hydrological information currently received from India is limited and considered insufficient.

Conceivable solutions to overcome this basic problem are i) Rainfall forecasting using satellite images, ii) Concluding bilateral or regional agreements on hydrological information exchange among all countries and iii) Rainfall forecasting using radar.

Among the above, application of satellite imagery is premature as the technology for rainfall prediction is only now being developed and will take more time for practical application. The second conceivable solution has been seriously addressed by the GOB. However, it is taking considerable time to reach agreement on data exchange. The GOB is now intending to introduce a rainfall-radar system covering some areas in India as well as the entire area of Bangladesh, although a schedule for its installation is not fixed yet.

When realized, all conceivable solutions will contribute to upgrading the accuracy of flood forecasting. In this Study, however, alternative plans will be conceived under existing conditions and those that can be addressed internally within Bangladesh.

b) Insufficient Operation and Maintenance

It must again be emphasized that the present operation and maintenance of the flood forecasting and warning system is very weak in view of the following:

- The existing telemeter system has never been used for flood forecasting. In this regard, the following should be confirmed:
  - Necessity of telemeter gauging stations
  - Recognition by staff working in FFWC and other related offices of the importance and necessity of the FFWS.

  If this necessity is recognized, possible countermeasures by all means regardless of shortage of budget, manpower, equipment, etc should be employed.

- Currently, only 5 telemeter gauging stations (of the original 14 installed) are operational. There are a number of reasons as outlined in **Chapter 3**, including gauges being washed out and/or silted up, unavailability of spare parts, etc. The question then is whether to "just abandon or reactivate either at the same location or an alternative site" with replacement only occurring if really necessary.
- There is no ledger sheet recording the history of operation and maintenance of FFWS facilities. The operation and maintenance may not be conducted properly without ledger sheet. Ledger sheets of telemeter equipment also provide some form of control on availability of spare parts.
- It is difficult to ensure that gauge reader(s) observe water level and rainfall on time as mandated. Reviews of historic records sometimes indicated possible doubtful data. The divisional office should take necessary actions in such cases by monitoring the gauge readers in order to ensure observations are undertaken as scheduled.
- Some equipment rooms of gauging stations are not properly maintained suggesting periodic maintenance is not undertaken.
- Orderly operation and maintenance are a basic requirement for equipment included in a sophisticated telemeter system.

c) More accurate forecast with longer lead-time for flood forecast

At present, BWDB defines the lead time for flood forecasting as 24-, 48- and 72-hours. According to BWDB, the accuracy of 24 hours forecast is about 98%, while 48 hrs and 72 hrs forecasts are considerably less accurate but still good. During the Workshops conducted by the JICA Study Team the participants, of which the majority were farmers, indicated a need for flood forecasting with a longer lead time (more than 4 days) to allow early harvesting of agricultural crops. This would not be possible without more information from India.

Flash floods result in serious damage especially in the north-eastern area (around Sylhet). The GOB has a specific intention to develop a FFWS in this area although the possible lead time may only be a few hours even with the installation of a telemeter system.

Conceivable solutions are i) flood forecasting with a telemeter system combined with rainfall forecasts using radar to reduce time for forecasting and ii) regional forecast operation to reduce time. Furthermore, the authorities and people should be informed of the accuracy of the forecast with respect to lead time and its technical limitations so they can properly judge the necessary actions to be undertaken. In a flash flood river, the forecast lead time will be limited (4-5 hours only). Therefore, the FFWS should clearly define possible forecast lead time by region. These alternative solutions have been taken into account in this JICA Study.

(2) Combined Alternatives

Possible combined alternatives are presented below together with a summary of the present condition, problems and conceivable solutions by component.

a) Observation System

Present condition and problems:

- Combined operation of manual and telemeter observations has occurred in the present system.
- However, telemeter data are not used for flood forecasting, since the network is not well maintained and combined operation of manual and telemeter data does not occur as the latter are not interfaced to the analysis system.
- Some telemeter gauges are not operational because of physical damage, unavailability of spare parts, and so on.

Conceivable solutions

- An all manual observation system or all telemeter system will be considered.
- In addition, a combined system will be evaluated with telemeter stations installed at sites considered important from the viewpoints of modeling (defining boundary conditions) and their long-term sustainability.
- An appropriate digital communication system should be considered for manual observation.
- Conceived alternatives were defined as 1) All manual observation system, 2) All telemetry system and 3) Combined system with manual and telemeter stations.

b) Data Transmission System

Present condition and problems:

- A voice communication system by means of wireless telephone is generally adopted at present
- Transmission difficulties may have occurred resulting in failure to forward data to the FFWC
- Public telephone lines are not always reliable

Conceivable solutions:

- Automatic data transmission will be considered for the telemeter system.
- Digital communication will be considered for the manual gauging system

c) Analysis System

Present condition and problems:

- The MIKE 11 computer program is used. This is a multifunctional hydrological and hydraulic analysis model suitable for the purpose given the hydraulic conditions in the country.
- For the hydrological and hydraulic calculations, the boundary conditions for

each river system are required. These are critical to the accuracy of water level estimation within the country. For forecasting, boundary conditions are estimated. The water level data from the more upstream gauging stations on the Ganges, Brahmaputra and Meghna Rivers in India are required to better estimate these boundary conditions and so improve flood forecasting. This is related to item a) above.

- Only limited river structures are incorporated in the model (in principle, river channel embankments and only some river structures)
- Differences between observed and estimated water levels at forecast points within the country are reduced using a discharge adjustment technique within the model. These differences reflect the lack of updated topographic maps to more accurately estimate overflows to the floodplain areas.
- Hazard maps produced in the modeling may be inaccurate due to use of outdated topographic information and no data on existing infrastructure etc.

Conceivable solutions:

- The hydrological and hydraulic analysis model, MIKE 11, will be maintained for ongoing application.
- The input data such as topography, river structures etc. will be upgraded / updated.
- Accuracy of hazard mapping will be improved by applying updated and more detailed topographic maps and information.

d) Warning Dissemination System

Present condition and problems:

- Warning messages are not adequate; they indicate only danger level and rises/falls in water level, etc.
- Warning messages are not clearly understood by the public.
- FFWC is responsible for disseminating the warning messages to selected agencies and the media.
- The messages do not formally reach the public.
- The above deficiencies reflect insufficient institutional arrangements and/or insufficient communication equipment available to the public.

Conceivable solutions:

- More detailed and clearer messages to be provided.
- Regional information should be integrated with the forecast activities.
- Regional forecast centers are to be established so that regional offices can participate in the evacuation activities, acting as information centers.
- Taking the above into account, a regional forecast center system will be considered as one of the combined alternatives.
- Thus, the candidate alternatives are I) Centralized operation system and II) Regionalized operation system
- Methods of communication at local level should be considered.

- Establishment of regional flood forecast centers will be considered.
- Active participation in evacuation activities as a member of the local disaster management committee in charge of information dissemination.
- Thus the conceivable alternatives are the same as the above, that is centralized operation system and regionalized operation system.

e) Response System

Present condition and problems:

- Response system operation is the responsibility of BDMB and the local administration, not FFWC.
- Although evacuation needs timely information on flood forecasting and real-time hydrological conditions, warning messages do not always reach the public.
- Rules and regulations exist with mandates for BDMB and Disaster Management Committees have been established at each tier of Government (district, union, etc.). However, it appears that these are not functioning well.

Conceivable solutions:

- Establishment of regional flood forecasting center is to be considered.
- If a regional flood forecasting center is established, it is to be a member of flood disaster management committee.
- Thus the conceivable alternatives are the same as in item d) above.

As implied from the above discussion on present condition, problems encountered and conceivable solution, the basis of the combined alternatives is I-Observation system and II-Institutional arrangement (central and / or regional operation systems). The conceivable combined alternatives are given below.

Alternative 1:	**Centralized Control System (FFWC central office as same as current organization with some improvement)**
Alternative 1-1:	All manual observation system
Alternative 1-2:	All telemeter system
Alternative 1-3:	Combined system of manual and telemeter system
Alternative 2:	**Regionalized Control System (Regional office under BWDB or under Chief Engineer, Hydrology)**
Alternative 2-1:	All manual observation system
Alternative 2-2:	All telemeter system
Alternative 2-3:	Combined system of manual and telemeter system

In terms of the communication method between the center and region, "Microwave" and "Digital HF with back up of BTTB public line" were selected for Alternative 1 and 2, respectively. However, since the microwave has difficulty in the operation and maintenance, "Digital HF with back up of BTTB public line" for Alternative 1 was also included in the comparative study as Alternative 1'.

4.4.2 Institutional Arrangement

The organization of BWDB is highly segregated. Because of the top-down chain of command, and in spite of implementing work with similar objectives, cooperation among various divisions is not always smooth. Therefore, work congestions occur between related divisions negatively affecting their operations.

The basic administrative role should be "to build the base for livelihood and production and secure the national safety". Administration has a duty to mutually cooperate to realize works beneficial to the nation.

FFWS will never become effective simply by installed additional equipment. The organization should be modified to eliminate the biggest problem associated with the FFWS, that is that flood forecasting and warning is not reaching the public.

1) Decentralization

The basic policy of the Bangladesh Government is decentralization and efficient manpower utilization. The decentralization approach selected as one of the conceivable alternatives in **Section 4.4.1** fully complies with the basic Government policy.

As discussed in **Section 4.4.1**, to overcome the present institutional constraints it is necessary to modify the FFWS to a decentralized operation. To achieve that two approaches can be considered: a) Regional office of BWDB and b) Regional office of Hydrology Service. When the overall picture of river and water resources management is considered, it would be better to merge O&M and Hydrology Divisions. The subsequent unification of the regional river management would provide an effective and efficient river management system to oversee planning, design, as well as maintenance. However, given the closed and top-down organization existing in BWDB the merging of O&M and Hydrology Divisions would be very time consuming. Therefore, the Study Team proposes that regional offices be set up for Hydrology Division.

2) Smooth Operation of Hydrology Service

For smooth operation of hydrology in general and flood forecasting in particular, improvement is proposed as shown in **Figure 4.3.1**. In this proposal, the present mandate of PFFC is divided based on similar work nature. The newly proposed Processing Division will be placed directly under the Hydrology service and will consist of present three processing branches, Index and publication branch, and Management and services branch. Because of its strategic location, it will be simple for this division to coordinate with the three data collection circles.

There will be three divisions under this circle. The existing FFWC will become the Forecasting division with a mandate of flood forecasting, model updating and model validation. Part of the existing C&I will become Data Transmission division and a new division, Data Collection division, created by transferring some personnel from the Surface water hydrology circle. Part of the C&I division will become Instrumentation division placed directly under Hydrology Service, and will be responsible for maintaining electro-mechanical equipment of the three data collection circles.

In this proposal, it is considered that common organizations such as Instrumentation Division and Processing Division should be placed directly under Hydrology Service for effective and efficient organizational setup.

Although changing an organizational structure is delicate and difficult, a strong willingness that these changes be implemented will be necessary to ensure the future FFWS works effectively.

4.4.3 Comparative Study of Combined Alternatives

Each combined alternative is aimed at improving the existing FFWS. In this section, a technical evaluation of each combined alternative is presented on the basis that each will provide the same level of effectiveness. An evaluation is also presented in terms of organization and cost-effectiveness. This provides an estimate of required investment for service improvement when evaluated from the socio-economic viewpoint.

(1) Technical Evaluation

Criteria for Selection of the Optimum Plan

In order to compare alternative proposals, the technical aspects for each alternative plan were considered in terms of a) Sureness, b) Accuracy, c) Timeliness, and d) Official. These are defined below.

a) Sureness

The FFWS should be highly reliable. The flood warning message must be forwarded with sureness. Warning messages must be disseminated to all concerned under any weather conditions. That is, a reliability of more than 99% should be ensured.

b) Accuracy

Needless to say, the higher the accuracy of the flood forecast the more accurate the warnings provided by the FFWS. However, higher accuracy will only be achieved with higher costs. The JICA Study Team assumed the acceptable error (required accuracy) of the 24-hour forecast, defined as the difference between observed and forecast water levels, should not exceed:

- 20cm when the change in water level over the 24 hour period is less than 1m or
- 20% of the change in water level over the 24 hour period if this exceeds 1m.

c) Timeliness

All components of the forecasting procedure undertaken by the FFWS shall occur as quickly as possible to enable dissemination of the warning message to the various beneficiaries within a certain designated time, such as 4 hours for evacuation of people, 12 hours for preventative works for protection of river structures and 4 days for farmers to allow harvesting.

d) Official-ness

The Government is responsible for disseminating flood warnings. If flood damage occurs due to incorrect flood warnings, the Government shall compensate for such damage. Therefore, flood forecasting and dissemination of flood warning messages may not be conducted by private entities or those without the necessary responsibility. Flood forecasts must be official.

Evaluation

a) Sureness

<u>Selection of suitable observation sites for disaster management</u>

The observation of water levels of rivers at borders of the country and also those located internally is important to accurately define existing river conditions. Only with this information can appropriate disaster management response be initiated. In particular, timely observation and provision of this information are required for flash flood or tidal surge areas and the selection of suitable observation sites in these regions is important.

<u>Sureness in dissemination of information</u>

Sureness of information dissemination is dependent on provision of secure lines of communication to union, the responsible agency for evacuation. In addition, secure communication is also essential with other supporting organizations such as NGOs. For wide-ranging transmission of information to the general public, alarms or emergency public broadcast announcements with loudspeaker would also be effective.

In the case of regional control, information is directly disseminated from the Regional office and staff must act to guarantee its sureness.

For central control where FFWC collects, analyzes and distributes information, it is necessary to have not just central staff in charge of regional communications but also local field personnel (and office) to guarantee sureness of dissemination. In addition, long distance and hot line telephones between FFWC and field office would be essential.

<u>Sureness in collected information</u>

Sureness in collection of information from observatories is dependent on continuous observation and a reliable communication system for transmission of data.

The telemeter circuit is a reliable means of communication guaranteeing transmission even during emergencies (e.g. natural disasters) when public lines are less reliable. It is of course at times such as these that transmission is essential. It is also preferable that the telemeter stations be fixed to structures such as a bridge or a stable dyke. Due to continuous river fluctuation of many rivers in Bangladesh, this is sometimes not possible and stable structures must be constructed at significant cost.

Manual gauge observation, to be comparable to the telemeter recording requires continuous hourly observation by multiple gauge readers. A shelter would therefore be necessary at most gauge stations for continuous recording throughout the night.

b) Accuracy

To improve the accuracy of flood forecasts, observations must be both free of error and also recorded at suitable locations for use in the hydraulic modeling applied in the FFWS.

Accurate observation

Manual observations raise the possibility of reading errors, temporal errors (incorrect time of reading) and communication errors. Approaches to reduce these effects include a double check system using several observers and mobile telephones with a direct data input function. However, automatic recording (and transmission) based on a telemeter system eliminates such errors and the larger the number of such stations installed the higher the observation accuracy of the overall network.

Observation at suitable locations

To improve model accuracy, hydraulic conditions at model boundaries under existing and future conditions must be better defined. For existing conditions, installation of telemeter gauging stations at important boundary locations (defining model boundary conditions) will assist. Upstream data from India are also extremely important for definition of existing and future boundary estimates. But at present such information is generally not available for the most relevant stations from India to be used in this estimation or is not continuously transferred.

c) Timeliness

Lead time required for warning will be unique to the local situation due to its dependence on local flood characteristics. In the flash flood areas where the available lead time is relatively short, continuous telemeter observation and transmission of information could be used to increase the number of times the flood forecasting model is operated and thus improve forecast accuracy at least in the short term. In addition, the improved estimation of water levels/discharges at the upstream boundaries (borders of the country) through acquisition of information from India is important in increasing the accuracy of flood warnings and available lead time in the flash flood areas.

While the regionally-controlled system only requires a circuit to gauging station to regional office, the centrally-controlled system requires a circuit from the gauging station to central office.

In the central system, even if information is obtained, responses to local disaster management are likely to be longer and a 'hotline' between central and field staff is necessary for timely response.

Also the regional office is likely to have a greater appreciation of local conditions. Warning preparation and dissemination activities can therefore be implemented more effectively by the regional offices.

d) Official-ness

For a flood forecasting and warning system to benefit the overall public, it must contribute to the wider disaster management and evacuation procedures of the population. Thus, information must be certain of reaching those affected and must be clearly understood.

A very important aspect of the FFWS is allocating official responsibility to the offices and agencies involved in implementing the various activities. While announcing FFWC information widely through public broadcasting or newspapers can be effective, information distributed through the official network should be adapted to ensure full understanding at a local level. During emergencies, conditions also tend to change continuously at this level and a centralized system would find it more difficult to cope or provide accurate and relevant information. For this reason, regional staff would also be required to remain and act in the local areas.

Countermeasures Necessary for Effective FFWS

Central Control Plan (Alternative 1)

	Alternative 1-1 Telemeter = 0 Manual = All	Alternative 1-2 Telemeter = All Manual = 0	Alternative 1-3 Telemeter = 23 Manual = Rest
Sureness	(Manual Station) Doubling of gauge readers for 23 gauging stations Automatic entry system with Mobile phone	(Telemeter Station) Stable and extensive structures	(Telemeter Station) Stable and extensive structures (Manual Station) Automatic entry system with Mobile phone
Accuracy	(Manual Station) Double check of reading data for 23 gauging stations Check program for mis-typing		(Manual Station) Check program for mis-typing
Timeliness	(Manual Station) Hourly reading for 23 gauging stations		
	Timely dissemination and activity with field Hot line from Central office to O&M division, Union and other related organization Enough staffs in central office in charge of region		
Official-ness	Confirmation of response activity and Collecting local situation and information by O&M division		

Regional Control Plan (Alternative 2)

	Alternative 2-1 Telemeter =0 Manual = All	Alternative 2-2 Telemeter =All Manual = 0	Alternative 2-3 Telemeter = 23 Manual = Rest
Sureness	(Manual Station) Doubling of gauge readers for 23 telemeter stations Automatic entry system with Mobile phone	(Telemeter Station) Stable and extensive structures	(Telemeter Station) Stable and extensive structures (Manual Station) Automatic entry system with Mobile phone
Accuracy	(Manual Station) Double check of reading data for 23 gauging stations Check program for mis-typing		(Manual Station) Check program for mis-typing
Timeliness	(Manual Station) Hourly reading for 23 gauging station		

(2) Institutional Evaluation

Sureness of information provided is dependant on coordination with the union, which is responsible for evacuation, and with other supporting organizations such as NGOs. Furthermore, it is also important to join in the local disaster management committee to effectively use the provided information and participate in the flood management and evacuation activities.

Whether the FFWS system becomes a true official system depends on how effectively the information provided by it can function for the public's disaster management activities. As the union is responsible for the local residents' disaster management activities, the important key is how effectively the FFWS information can be used in these activities by the Regional office.

For an effective FFWS, data collection and transmission are very important. In the central system, maintenance is time consuming, which may prove fatal during times of emergency. Conversely, maintenance is more efficient from the regional office.

Comparative merits of the centralized and decentralized administration of Hydrology service with respect to FFWS service are given in **Table 3.8.2**.

(3) Cost Evaluation

The technical evaluation clarified the required improvements necessary in the various alternatives to produce similar levels of effectiveness in an improved FFWS. The associated investment costs and operation and maintenance costs for implementing these countermeasures are outlined and compared below.

In case of central control system, Alternative 1 includes the utilization of BWDB's exclusive microwave network for the communication between the regional and central offices. In addition to this, an Alternative 1', in which digital HF with BTTB public line to be utilized for the communication between the regional and central offices, is considered.

In case of regional control system, digital HF with BTTB public line is proposed.

Investment Cost

Condition of evaluation for investment cost

a) Facilities

Central Control Office:	Dhaka
Regional Office:	4 Regional office and Dhaka (with Central Office)
Manual or Telemeter Stations:	108 locations

b) Equipment

Main Server:	National information database from all observatories including both Telemeter and Manual
Regional Server:	Regional information database from gauging stations including both Telemeter and Manual
Supermodel System:	Nationwide flood warning system covering three major rivers
Regional Model System:	Local flood warning system for the regional scale
Monitor:	Terminal for supervising operations
Repeater Equipment:	Radio relay station

Telemeter Equipment:	Equipment of Telemeter observatory Station
Mobile Phone:	Mobile phone for digital data transmission from manual gauging station
Digital HF set:	Digital HF set for digital data transmission from manual gauging station (where mobile phone cannot be utilized)
Warning Equipment:	Point to point Warning Equipment for dissemination (32 sets at each flash flood area)

Data transmission Equipment between the Regional and Central Offices:

Alternative 1: Microwave Equipment
(13 repeater stations)
Alternatives 1' and 2: Digital HF with BTTB line

Conclusion of Comparative Study

Investment cost estimates for each alternative plan are indicated as follows. Detailed breakdown is presented in **Table 4.4.1**.

Investment Cost of Central Control Plan (Alternative 1, with Microwave)

Alternative		1-1	1-2	1-3
Number of Telemeter Stations		0	108	23
Number of Manual Stations		108	0	85
Number of Equipment (unit: Nos.)				
Central Office	Main Server	1	1	1
	Super Model System	1	1	1
	Regional Server	5	5	5
	Regional Model System	5	5	5
Repeater Station			81	27
Telemeter Station			108	23
Manual Station	Mobile Phone	54		43
	HF digital	54		42
Warning Equipment		32	32	32
Investment Cost (unit: Million Taka)				
	Direct installation	951	1,904	1,225
	Administration	10	19	12
	Engineering	143	286	184
	Training	6	12	8
	Contingency	47	118	66
Total Investment Cost (Million Taka)		***1,156***	***2,339***	***1,495***

Investment Cost of Central Control Plan (Alternative 1', without Microwave)

Alternative		1'-1	1'-2	1'-3
	Direct installation	566	1,521	840
	Administration	6	15	8
	Engineering	85	228	126
	Training	4	9	5
	Contingency	26	98	46
Total Investment Cost (Million Taka)		***686***	***1,871***	***1,026***

Investment Cost of Regional Control Plan (Alternative 2)

Alternative		2-1	2-2	2-3
Number of Telemeter Stations		0	108	23
Number of Manual Stations		108	0	85
Number of Equipment (unit: Nos.)				
Central Office	Main Server	1	1	1
	Super Model System	1	1	1
Regional Office	Regional Server	5	5	5
	Regional Model System	5	5	5
Repeater Station			81	27
Telemeter Station			108	23
Manual Station	Mobile Phone	54		43
	HF digital	54		42
Warning Equipment		32	32	32
Investment Cost (unit: Million Taka)				
	Direct installation	646	1,600	925
	Administration	6	16	9
	Engineering	97	240	139
	Training	4	10	6
	Contingency	31	103	51
Total Investment Cost (Million Taka)		***785***	***1,968***	***1,130***

The investment cost of central control plan with microwave (Alternative 1) becomes much higher than the regional control plan (Alternative 2). Moreover, even when comparing the costs for the central control plan without microwave (Alternative 1') and regional control plan (Alternative 2), the differences are not large though Alternative 1' showed lower investment cost.

On the other hand, comparison of alternative plans with different numbers of telemeters indicates that the "all manual" plan is the least expensive, followed by the plan with 23 telemeters. The "all telemeter" plan is very costly.

Operation & Maintenance Cost

The operation and maintenance cost was calculated based on staffing and electricity/communication and depreciation costs for equipment.

Condition of evaluation for investment cost

a) Staffing

[Basic Concept]

For the regional and central control plans for FFWS, after examining the existing FFWC and C&I staffing, the numbers of staff were determined by considering various tasks at each Flood Hydrology (FH) office including analysis, editing/provision of information, communication equipment maintenance, observatory maintenance, driving, and administration.

[Gauge Reader]

One gauge reader was assumed to be permanently stationed to perform manual observations and take the reading every hour (in line with the data available from the telemeter stations). For this reason, 3 gauge readers will work in rotating 8 hour shifts.

As explained in **Section 4.2,** 23 observation points were considered necessary for the combined alternative. For reliable observation data from these stations, there should be two gauge readers working concurrently. This would ensure continuous and accurate observations with a very high reliability.

[Central Control FFWS]

Even when the central control system is adopted, provision of water level information, flood warning information and so on locally and to promote local activities through the regional disaster management committee are still important. As a result, regional staff was considered necessary in each regional office for the local disaster management activities while dissemination coordinators were required in the central control office of the FFWC for the regional areas.

[Staff Salaries]

Standard salaries were set as follows:

Staff Salary Set for Cost Estimate

Position	Salary
Superintending Engineer (SE)	Tk. 20,000 x 14 (man-year)
Executive Engineer (XEN)	Tk. 17,000 x 14 (man-year)
Sub-divisional Engineer (SDE)	Tk. 15,000 x 14 (man-year)
Assistant Engineer (AE)	Tk. 10,000 x 14 (man-year)
Technical Staff	Tk. 6,500 x 14 (man-year)
Support Staff	Tk. 6,000 x 14 (man-year)
Gauge Reader	Tk. 5,000 x 14 (man-year)

b) Repair and maintenance cost

It is estimated annual repair and maintenance costs will be 0.5% of total telemeter equipment cost, 10.0% of total computer equipment cost, 2.0% of total civil construction cost and 5.0% of existing gauging station cost.

c) Other O&M costs

Other O&M costs included transportation costs for business trips, communication costs for daily data transmission and warning dissemination, electricity costs for offices and other incidental costs.

d) Depreciation cost for equipment

It is estimated annual depreciation cost will be 10% for equipment, 20% for computers and 3.3 % for the structure.

Conclusion of Comparative Study

Annual O&M costs estimated for each alternative plan are indicated below. Detailed breakdown is shown in **Tables 4.4.2** and **4.4.3**.

Annual O&M Cost for Central Control Plan (Alternative 1, with Microwave)

Alternative		1-1	1-2	1-3
Number of Telemeter Stations		0	108	23
Number of Manual Stations		108	0	85
Number of Staff	SE	1	1	1
	XEN	3	3	3
	SDE	9	9	9
	AE	14	21	17
	Technical Staff	39	88	45
	Support Staff	35	61	40
	Gauge Reader	223	21.6	90
	Total	324	204.6	205
O&M Cost (Million Taka)	Staffing	26.9	20.5	19.0
	Repair, Maintenance	43.3	47.6	46.4
	other O&Ms	15.0	17.1	15.7
	Sub Total	85.2	85.1	81.1
Depreciation Cost (Million Taka)		140.4	279.3	181.0
Total Annual O&M Cost (Million Taka)		***225.6***	***364.4***	***262.1***

Annual O&M Cost for Central Control Plan (Alternative 1', without Microwave)

Alternative		1-1'	1-2'	1-3'
O&M Cost (Million Taka)	Staffing	26.9	20.5	19.0
	Repair, Maintenance	21.9	26.2	25.0
	other O&Ms	18.4	20.5	19.1
	Sub Total	67.3	67.2	63.1
Depreciation Cost (Million Taka)		83.4	222.5	124.0
Total Annual O&M Cost (Million Taka)		***150.7***	***289.7***	***187.2***

Annual O&M Cost for Regional Control Plan (Alternative 2)

Alternative		2-1	2-2	2-3
Number of Telemeter Stations		0	108	23
Number of Manual Stations		108	0	85
Number of Staff	SE	1	1	1
	XEN	8	8	8
	SDE	17	17	17
	AE	17	17	17
	Technical Staff	46	96	51
	Support Staff	42	67	47
	Gauge Reader	223	21.6	90
	Total	354	227.6	231
O&M Cost (Million Taka)	Staffing	31.5	24.0	23.0
	Repair, Maintenance	24.0	28.3	27.1
	other O&Ms	15.2	16.5	15.5
	Sub Total	70.7	68.8	65.6
Depreciation Cost (Million Taka)		95.4	234.3	136.8
Total Annual O&M Cost (Million Taka)		***166.1***	***303.1***	***202.4***

When comparing the costs for Alternative 1 and 2, the annual O&M costs for

Alternative 1 are considerably high. This is due to the additional repair and maintenance costs for the microwave equipment.

However, when comparing the costs for Alternative 1' and 2, the results indicate the annual O&M costs of the central control system are less than those of the regional control system. This is due to the additional maintenance and operational costs of the regional facilities for the latter system.

Economic Evaluation

Expected Effect of FFWS

According to **Section 2.6**, annual average flood damage is estimated to be 12,161 Million Taka. In this assessment, the effect of all countermeasures such as FFWS, flood proofing, rescue and so on were assumed to be from 5% to 10% of annual average flood damage. The reductions due specifically to the FFWS were estimated to be 10% of these countermeasure effects, that is 0.5% to1% of annual average flood damage. The estimated amount of damage avoided through implementing the FFWS was therefore estimated to range from 61 to 122 Million Taka.

Cost of Alternative Plans

Among the alternative plans considered, the maximum costs were calculated as:

- investment cost for equipment = 2,339 million Taka (Alternative 1-2)
- annual O&M cost (excluding dep.)= 85.2 million Taka (Alternative 1-1)

Evaluation

When comparing the annual O&M costs and expected annual effects of the FFWS for the various alternatives the latter are larger, indicating that the currently planned equipment investment is within the appropriate boundary.

4.4.4 Selection of Optimal Plan

Based on the results of the comparative study presented in **Sections 4.4.2** and **4.4.3**, Alternative 2-3 was selected as the optimum plan by the Study Team based on the following factors:

(1) Institutional Aspect

One important issue for the FFWS is that information issued must reach the end beneficiaries. To achieve this, establishment of regional Hydrology offices and participation in the local disaster management committee and local disaster management activities are suggested. In terms of the institutional option, the Study Team proposes the Regional Control system for Hydrology Services (Alternative 2, see **Figure 4.4.1**).

(2) Technical Comparison on Sureness

In case of the regional control system, the sureness of telecommunication between the central and regional offices is less important than that in case of the central control system, because the regional offices can execute almost all of emergency actions without communicating with the central office.

Contrarily, surer telecommunication system between the regional and central offices may be necessary in case of the central controlled system considering that the central office should conduce emergency activities for local community. To meet this requirement, BWDB's own microwave network was considered for the central control system.

(3) Cost Comparison

The Study Team proposed two alternatives concerning the institutional matters and each alternative had three technical alternatives for data collection and transmission. The comparison of both investment and O&M costs was made among the alternatives.

Cost comparison in view of institution (Central vs. Regional)

As a result, the central system (Alternative 1') showed a little lower cost than the regional system (Alternative 2) both in the investment and O&M costs. However, in case of the central system with exclusive microwave network (Alternative 1), both investment and O&M costs became higher than those of the regional system. This shows that the costs (investment and O&M) of the central control system are higher than those of the regional control system if the reliability and effectiveness of FFWS to be secured in the competitive levels both in the central and regional systems.

The Study Team concluded that the regional control system is more preferable.

Cost comparison in view of data collection and transmission

In terms of the investment cost, the all manual system showed the lowest. However, in terms of the O&M cost, the combined (telemeter and manual) system showed the lowest (without considering the depreciation).

For the all telemeter system, the high cost reflects the impact of the expensive structures required to install the telemeter stations. These are indispensable in Bangladesh due to the often high and rapid fluctuations in water levels in the rivers. For the all manual system, the need to provide duplication of gauge readers (to ensure the same effectiveness in data observation and transmission as in the telemeter system) results in increased personnel costs.

It is also clear that in the case of a manual system, accurate water level measurement during the night would be difficult while for an all telemeter system O&M costs are high.

It is therefore proposed that a combined system including both telemeter and manually observed stations be adopted.

4.5 Operation and Maintenance

4.5.1 Organization

The "Operation" and "Maintenance" (O&M) tasks based on the selected optimum plan for the FFWS are categorized in **Table 4.5.1**. This FFWS organization basically consists of a central FFWC system in Dhaka complemented with a network of regional FFWC centers. The associated organizations include existing Surface Water Division and River Morphology Division as well as a newly proposed Instrumentation Division and Processing Division.

(1) Surface Water (Regional)

The proposed optimum plan suggests that Surface Water Division's gauge readers will conduct the reading as currently occurs. In case of the automatic reading with the telemeter, occasional staff gauge reading will also be required for supplemental purposes. In principle, the required number of gauge readers should therefore remain unchanged from the current number. In addition, Surface Water Division will also continue the discharge measurement program and collection and posting of observed data.

(2) River Morphology Division (Regional)

This division will continue its existing program of river cross-section measurement.

(3) Regional FFWC

Each Regional FFWS office will be the base for their respective Data Collection Division, Data Transmission Division and Forecasting Division.

1) Data Collection Division will be responsible for the maintenance of observatories and collection of data. It will also be in charge of repairing sensors and buildings, setting the staff gauges and measuring staff gauge levels.
2) Data Transmission Division will be responsible for maintenance of automatic gauges, telemeter system, communication system and system equipment. It will also undertake HF radio transmission when required.
3) Forecasting Division will provide forecasting and warning at the regional level. It will also undertake river monitoring utilizing local model analysis, provide information for local disaster management agencies via fax and e-mail, and participate in disaster management activities with the local disaster management committee. In addition, it will undertake any modification of Analysis Model software and Hazard Maps and manage and maintain computer system software.

(4) Central FFWC

Central FFWC will also comprise Data Collection Division, Data Transmission Division and Forecasting Division.

1) Data Collection Division will be responsible for the maintenance of observatories

and collection of data and regular collation of information forwarded from regional offices.

2) Data Transmission Division will be responsible for maintenance of all electronic equipment including communication system and system equipment. It will also undertake HF radio transmission when required.
3) Forecasting Division will provide forecasting and warning at the national level. It will also conduct river monitoring utilizing the Supermodel analysis and provide information to central government agencies, broadcast stations and newspapers via fax and e-mail. In addition, it will undertake any modification of the Analysis Model (Supermodel) and Hazard Maps and manage and maintain computer system software.

(5) C&I Division

This will succeed the Equipment Manufacture and Maintenance Division of C&I, currently located in Dhaka at Green Road. It will undertake calibration of discharge measurement instruments and manufacture staff gauges for water level observation and rainfall gauges.

(6) Processing Division

It is proposed that this agency will manage the process of transferring the recorded data into the system database and distribute it to necessary agencies. It will also process and transfer all data received from the field via mail including river cross-sections and discharge measurement information. Such information will be used, for example, in any updating of the analysis model.

4.5.2 Staffing

Considering the existing structure of BWDB, staffing needs to be deployed so that the proposed organization can function efficiently and effectively. In particular, the regional FFWC must provide support to local disaster management activities as a member of the local disaster management committee. It also should be capable of undertake the hydraulic analysis based on recorded data accurately and quickly. This will ensure speedy and appropriate decisions by the relevant agencies. This will require that the regional centers be staffed with managers capable of making decisions and engineers with technical knowledge to support disaster management. The proposed staffing schedule for both central and regional centers is presented in **Table 4.5.2**.

Currently, FFWC has executive engineers (XEN) with appropriate decision-making skills who manage the existing organization. Executive engineers (XEN level) with similar capabilities are required to manage regional and central offices of FFWC. Moreover, under XEN management, an appropriate number of assistant engineers and staff are required to ensure the three proposed Divisions within each center are fully functional.

4.5.3 Legal Arrangement

Laws and regulations defining the roles and rights of those involved in river management do not currently exist but are now under consideration. The proposed FFWC system requires participation of the regional center in local disaster management activities as a member of the local disaster management committee. In order to extend such FHC activities, its roles and responsibilities need to be defined by law.

CHAPTER 5 INTERNATIONAL RIVERS

5.1 Constraints on River Management in Bangladesh

As described in **Chapter 2**, Bangladesh is situated in the deltaic part of South Asia through which three major rivers, the Ganges, the Jamuna (or Brahmaputra as called in India) and the Meghna and their tributaries and distributions flow from outside the country into the Bay of Bengal. Only seven percent of surface waters originate within the country. Effective river management in Bangladesh, therefore, depends significantly on river management in upstream countries, particularly India and Nepal.

In relation to the scope of the FFWS study, it is critical for Bangladesh to obtain flood related data from India and Nepal and incorporate them into the modeling system to enable flood forecasting with longer lead time and improved accuracy. While there is an agreement between India and Bangladesh for the former to transmit water level, discharge and rainfall data from certain stations to the latter, the coverage of the agreement needs to be expanded to include data from upstream stations and to guarantee continuous data transmission regardless of whether water levels have reached warning stages or not, as the current agreement provides. With regard to floods, the operation of gates of barrages in India is said to be causing sudden floods in some parts of Bangladesh, though exact details are often not known and there seem to be, in some case, allegations based on misunderstanding.

Other phenomena and activities in upstream areas affect flows and quality of rivers and other related aspects in Bangladesh as well. It is well known that with the Farakka Barrage on the Ganges which started operations in 1975, the supply of surface water in the river during the dry season was reduced, which resulted in falls in groundwater levels, increases in sediment and changing bed profile of the river, and increases in salinity in both surface water and groundwater, though more studies may have to be carried out to determine the exact extent of the contributions of the Farakka Barrage to these phenomena. It is also reported that land erosions occurring in Nepal are causing the sediment increase in the river bed in Bangladesh. Pollution of river waters is another emerging problem which is beyond the control of Bangladesh if it originates in upstream areas. These changes in the Ganges have been impacting on navigation, fisheries, agriculture, forestry, industrial activities as well as environment and ecology.

In 2002, the Government of India declared a plan to link 37 rivers in India through more than 600 miles of canal digging and reservoir building, which will divert up to one-third of the flow of the Brahmaputra and other rivers to southern Indian rivers. It is reported that the aim is to provide 173 billion cubic meters of water a year, supplying millions of people in the states of Uttar Pradesh and Karnataka, irrigating 135,000 square miles of farmland and producing 34,000MW of hydroelectricity. The plan was envisaged by the National Water Development Agency (NWDA). The project, if implemented, will significantly reduce the water flow to Bangladesh. According to government scientists in Bangladesh, even a 10% to 20% reduction in the water flow to the country could dry out great areas for much of the year, which will cause devastating impacts on the economy and livelihood of the people as more than 80% of 20 million farmers in the country grow rice, relaying on water flowing through India.[1]

In addition to the agreement on the flood related data transfer, which was made at the level of Joint Rivers Commission (JRC), Bangladesh and India have the Ganges Water Treaty signed in 1996, that provides formulas for water allocations during the lean season. Under this Treaty, there is an agreement to "conclude water sharing Treaties/Agreements with regard to other common rivers" guided by "the principles of equity, fairness and no harm to either party." Talks to materialize the agreements on other rivers, however, are making little progress. Beyond this provision and a general framework that established JRC in 1972, there is no specific legal framework between Bangladesh and India to govern and facilitate efforts to manage international rivers in a manner to take into account interests of each other and to ensure equitable and reasonable uses of waters throughout a river basin.

Agreements with co-riparian, upstream countries, particularly with India, are vital for Bangladesh in order to undertake effective river management. The National Water Policy of the Government of Bangladesh approved in 1999 fully recognizes this need and articulates that the government will "endeavor to enter into agreements with co-riparian countries for sharing the waters of international rivers, data exchange, resource planning and long-term management of water resources under normal and emergency conditions of flood, drought and water pollution."[2] The policy is in line with the principles embodied in the international customary law such as the Helsinki Rules of 1966 and the UN Convention of 1997, which require the states sharing the same watercourse to develop and use the watercourse taking into account the interest of other watercourse states concerned and taking all appropriate measures to prevent causing significant harm to other watercourse states.[3]

It must be noted here that the ultimate objective is to achieve integrated river basin management without regard to national borders, including such aspects as water use, flood control, water quality, river environment and watershed management, with a view toward optimizing and ensuring equitable distortion of economic, social and environmental benefits as well as costs in the entire river basin.

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[1] The Guardian, 23 July 2003. The Daily Star, 14 August 2003 and subsequent issues. The Bangladesh Foreign Ministry lodged an official protest against the India's water diversion plan to the Indian High Commissioner in Bangladesh on 13 August 2003. It is reported that Indian environmentalists and the eastern states of West Bengal and Assam, who may lose water to the western states are opposed to this plan. The estimated project cost is around $200 billion and many are questioning its feasibility.

[2] Ministry of Water Resources, National Water Policy, pp. 4-5.

[3] Articles 5, 6, and 7, United Nations Convention on the Law of the Non-navigational Uses of International Watercourses (adopted by the UN General Assembly in May 1997).

5.2 Problems on International Rivers

5.2.1 International Rivers in Bangladesh

Bangladesh shares 56 rivers with India. The major ones are the Ganges, the Jamuna (Brahmaputra), and the Megna. In addition, there are seven medium sized rivers, namely, Teesta, Dharla, and Dudhkumar in the northwest, and Manu, Khowai and Gumti and Muhuri in the east. A list of the 56 rivers plus three rivers that the country shares with Myanmar and their locations are found in **Figure 2.4.20**. Bangladesh faces dams, barrages, or other water diversion facilities upstream on a total of at least 30 of these rivers.[4]

5.2.2 Problems in the Ganges Dependent Areas

General problems that Bangladesh have been experiencing with regard to international rivers, due to their very existence and due to lack of appropriate frameworks to manage them, are as described in **Section 5.1** above. This section will focus on problems having been encountered in the areas dependent on the flows of the Ganges. The consequences of the Farakka diversions during 1976 and 1977 were first reported in pamphlets prepared the Indian and Bangladesh governments prepared for the negotiations at the UN.[5] A detailed study to identify impacts during the same period was carried out jointly by the Government of Bangladesh and International Engineering Company Ltd. (IECO), a San Francisco-based firm, with the financial assistance of the World Bank.[6]

More recently, A. Nishat identified effects of the reduction of the Ganges flows caused by the construction of the Farakka barrage based on the data from 1976 to 1992.[7] Key findings are summarized below.

(1) Surface Water

The reduction in the Ganges flow during the dry season (January - May) started with the operation of the Farakka barrage in 1975. For example, the average flow measured at the Hardinge Bridge during 21-30 April, one of the leanest periods, was 1,977m^3/sec during 1934-1973. This was reduced to 1,528m^3/sec in 1975, 996m^3/sec in 1976, and 1,158m^3/sec in 1977. With the conclusion of the 1977 Ganges Treaty, the discharge was restored to the level of around 1,000 – 2,000m^3/sec during 1978-1988. With the

[4] International Farakka Committee, Inc. (NY, USA), 2003, National Documentation on the Problems of Arsenic and Farakka, pp.59-60.

[5] Ministry of External Affairs, Government of India, The Farakka Barrage, 1976, and Government of Bangladesh, White Paper on the Ganges Water Dispute, 1976.

[6] These three documents were reviewed in Ben Crow, Sharing the Ganges: The Politics and Technology of River Development, Dhaka, University Press Limited, 1997, pp124-158.

[7] A. Nishat, Impacts on Bangladesh of the Ganges Water Disputes, Asian International Waters: From Ganges-Brahmaputra to Mekong, ed. Asit K. Biswas and Tsuyoshi Hashimoto, Oxford University Press, 1996 (Japanese translation published in 1999). A. Nishat, Water Resources in Bangladesh, Sustainable development of the Ganges-Brahmaputra-Meghna basins, ed. Asit K. Biswas and Juha I. Uitto, United Nations University Press, 2001.

expiration of the water-sharing agreement in 1988, the discharge was dramatically reduced to 729m^3/sec (1989), 1,009m^3/sec (1990), 873m^3/sec (1991), and 457m^3/sec (1992). Among its distributaries, the Gorai plays an important role as it passes through the southwestern part of the country, supplying water for irrigation and industries and also for pushing back salinity and keeping an overall environmental balance.

(2) Groundwater

Since 1976, a fall in groundwater of about three meters has been identified in most of 374 wells used for observation along both banks of the Ganges, the Mohananda, and the Gorai-Modhumati from the pre-diversion normal level. The fall in groundwater level is greatest in the districts of Rajshahi and Pabna, followed by Kushtia and Jessore. The fall was not restored during the period of the water-sharing agreement, once the groundwater surface gradient had been reversed. Also, the quality of groundwater has also deteriorated. 64 observation points installed in the southwestern region recorded higher TDS (Total Dissolved Solids) figures in 1986 and 1987 compared with previous years, ranging from 147 to 3,2000 ppm. TDS of more than 1,000 ppm cannot be used for domestic, agricultural or industrial uses.

(3) River Morphology

A study of the longitudinal bed profile of the Ganges for the years 1974 and 1989 from its confluence with the Brahmaputra to the Indo-Bangladesh border and a study of changes at several cross-sections between the years 1974 and 1991 revealed the fact that the bed of the Ganges had silted up substantially in the recent past. This is increasing the chances for causing floods during the monsoon season.

(4) Salinity

Reduction in the dry season Ganges flows raised the salinity of the Khulna area from 380 micro-mhos/cm during the pre-diversion period (1974) to about 29,500 micro-mhos/cm in April 1992. The salinity front of 500 micro-mhos/cm moved through the Passur estuary from 145 km to about 219 km inland after the diversion. This has resulted in increased soil salinity, leading to drop damage and yield reduction. The salinity has also been affecting industry, fisheries, forestry, and power generation. It also has short and long-term impacts on health, mortality and the eco-system as a whole.

On the Ganges as well as other common rivers, BWDB regularly collects data on water level, discharge, sedimentation, groundwater, salinity, among others. These data were analyzed and reported regularly particularly in the form of a yearbook during the 1980s, but the activities have been abandoned since then due to staff and budget shortages. The basic tasks of regular observation, monitoring and analyses must be reactivated as part of domestic efforts for international river management. Given the current environment where the information and data available from India are limited,