frequently. Since the knowledge of mechanics is widely applicable for other fields too, the cultivation of this may be welcomed.

3.3 Observation System

3.3.1 General

The current observation system mainly comprises:

- hydrometeorological record inside Bangladesh obtained at selected gauging stations,
- hydrometeorological record outside Bangladesh transmitted from India,
- radar image obtained by BMD radar system, and
- satellite image received at FFWC and transmitted from SPARRSO.

The present situation of above items is mentioned below.

3.3.2 Number and Location of Gauging Stations in Bangladesh

As outlined in **Section 2.4**, an extensive network of water level and rainfall stations is currently operated by BWDB. However, data from the majority of sites are initially retained in the regions and forwarded to the central office in Dhaka only on a monthly (or longer) basis.

To satisfy requirements for the FFWS and also provide direct flood level information on a real-time basis, a network of manually observed hydrometeorological stations has been established and progressively expanded. According to the information provided by FFWC, the present network comprises:

- 91 water level gauging stations observed five times daily at three hourly intervals from 0600 to 1800 hours, and
- 56 rainfall gauging stations observed at 0900 hours daily defining rainfall over the previous 24 hours.

Their locations are shown on **Figure 3.3.1**.

It should be noted that the southeastern and sections of the south-western regions of the country are currently not incorporated into the analysis system operated by FFWS (refer to **Section 3.5**). Stations in this area are therefore not utilized in the current flood "forecasting" procedures but in the monitoring procedures. Notwithstanding, data from all sites are to be transmitted to FFWC around 0900 daily using either a wireless system or mobile/fixed telephones.

According to 'Guide to Hydrometeorological Practices' published by the World Meteorological Organization (WMO), the minimum densities of rainfall observation networks have been recommended for general hydrometeorological purposes:

a. For flat regions of temperate, Mediterranean, and tropical zones, 600 to 900 km^2 per station
b. For mountainous regions of temperate, Mediterranean, and tropical zones, 100 to 250 km^2 per station

c. For small mountainous islands with irregular precipitation, 25 km^2 per station
d. For arid and polar zones, 1,500 to 10,000 km^2 per station

As mentioned in **Section 2.4**, there are currently 269 rainfall gauging stations under the management of BWDB. Out of them, 56 stations are picked up for flood forecasting and warning purposes at present. When the total land area of Bangladesh (147,000 km^2) is simply divided by those numbers (269 and 56), the density of BWDB and FFWC networks are 546 km^2 and 2,625 km^2 per station, respectively.

Comparing to above WMO standard, the density of BWDB network meets the demand considering that Bangladesh is categorized within area 'a' of above climatologic/topographic classification. Although the FFWC network is not satisfactorily dense according to the WMO standard, the number of the rainfall gauging stations operated by FFWC is judged applicable in this Study for the following reasons:

- One of the main outputs of FFWS is flood water levels of the selected monitoring/forecasting points. This is dominated not only by precipitation over the country but also by precipitation in the upstream areas located outside Bangladesh, topographic information, evapotranspiration, inflow from the upstream areas and so on. Since there are a lot of uncertain elements between rainfall as an input and water level/discharge as an output, the increment of the number of rainfall gauging stations does not contribute for the drastic enhancement of the performance of existing FFWS.
- The point rainfall is also one of the important information items to be included in the FFWC outputs. The major cities and towns have been covered by the existing network as shown in **Figure 3.3.1**. Accurate aerial distribution of the rainfall is not so much important as the information to be disseminated promptly (of course it is very important as the basic hydromoteorological information to be accumulated/analyzed and is generated satisfactorily based on the dense BWDB network data).

Regarding the number of water level gauging stations, there are no such standards as that of rainfall gauging stations, because that should be decided basically according to the information to be obtained, the kind of planned project, and so on.

In current FFWS, 91 stations are selected out of 342 tidal/non-tidal water level gauging stations of BWDB. In this Study, the number of current real-time water level gauging stations (91) is judged acceptable for the following reasons:

- The points nearby major cities and towns have been covered by the present FFWC network as shown in **Figure 3.3.1**.
- The points with importance from hydrological/hydraulic aspects such as confluence or diverting point of large-scale rivers have already been covered.
- Major trans-nation points at the border between Bangladesh and India have been covered.
- Major points at the downstream end of the river system, which provide the

boundary conditions for the hydraulic model, have been covered by the existing FFWC network.

To complement the validity of the number of water level gauging stations, a preliminary analysis for the speculation of the relationship between the number of gauging stations and forecast accuracy was conducted.

FFWC's current forecasting model (Supermodel) is operated using the data of 23 base boundary stations and 27 internal boundary stations (refer to **Section 3.5**). Following trial calculations were conducted to assume the relationship between the number of internal boundary stations and forecast accuracy.

Case-1: Forecast simulation (24-, 48- and 72-hours) without internal boundary stations

Case-2: Forecast simulation (24-, 48- and 72-hours) with 3 internal boundary stations

Case-3: Forecast simulation (24-, 48- and 72-hours) with 27 internal boundary stations

The simulation was undertaken for the period of 2003 monsoon. In order to eliminate the influence of 'boundary estimation' on the forecast accuracy, the observed water levels were input at base boundary points. As the index of the forecast accuracy, the maximum value of mean absolute errors (MAEs) among 30 forecasting points was employed.

The result of the analysis is plotted in **Figure 3.3.2**. According to the graph shown, about 45 internal boundary stations are necessary to maintain maximum MAE within 20 cm for 24-hours forecast. It can therefore be assumed that totally 68 water level gauging stations (23 for base boundary and 45 for internal boundary) is necessary. At present, the coverage of the Supermodel is about 2/3 of the entire Bangladesh. Based on the rough estimation, 102 (= 68 x 3/2) water level gauging stations are necessary if it is simply considered that the forecasting model covers the entire Bangladesh territory.

Comparing to this figure, existing number of water level gauging stations of FFWC (91) is reasonable.

As a result, the location and number of both rainfall and water level gauging stations are confirmed acceptable in this Study.

3.3.3 Current Situation of Domestic Observation System

(1) General

Based on a list of hydrometeorological stations obtained from FFWC, an inventory survey was undertaken at each site on the course of this JICA Study to define location, existing condition of the structures, likely accuracy of observed data, method of data transmission, condition of associated instrumentation, and so on. This included a qualitative assessment of instrumentation and general site conditions (which could influence recording accuracy). A comprehensive set of site photographs was also obtained to assist in assessing the possibility of upgrading specific sites as part of a more comprehensive automatic telemetry network, as discussed below.

A summary of the results of the inventory survey is presented in **Table 3.3.1** and more detailed results are given in **ANNEX-I**.

(2) Manual Observation System

Overall, the following points should be noted:

a. Rainfall Gauging Stations

The majority of stations are fully operational and instrumentation is in good order. Daily rainfall totals are normally observed at around 0900 hours with data from 41 sites being transmitted regularly to FFWC at that time.

However, distance from the gauge to surrounding structures or vegetation is considered insufficient at approximately 50% of the sites. This may influence the accuracy of the associated rainfall data and those sites affected should be either relocated or adequate clearance provided.

b. Water Level Gauging Stations

The majority of sites are in good condition. The survey confirmed observations are made five times daily at three hourly intervals from 0600 to 1800 hours throughout the year at all except for 2 sites.

During the flood season, data are forwarded to FFWC at around 0900 hours daily by wireless or mobile phone/fixed telephone from some 74 stations. During the remainder of the year (dry season), information is sent by courier or post.

It was noted during field visits that only a single gauge plate is generally used at most sites (68 stations). This must be periodically moved to allow observations to continue throughout the year. BWDB indicated that it is not possible to install a series of gauges at these sites to cover the entire water level range. This is due to large variability in river thalweg (the river course can change substantially from year to year or from flood to flood) and general instability of the river channel and embankments. Although a permanent gauge would be preferable, the BWDB confirmed the gauge plate is resurveyed after each installation based on the local bench mark (BM).

However, the result of inventory survey reveals that the distance between bench mark or temporally bench mark (TBM) and manual gauge location is rather long in many stations subject to gauge shifting. Based on this, it is assumed that the gauge shifting (setting new gauge zero elevation) in many stations is conducted by comparison of water level value between old and new gauge plates. Although this method does not have any harmful effect on the observation accuracy if the operation is conducted carefully, periodical confirmation of gauge zero elevation based on BM or TBM is still necessary. In this context, it is recommended to put BM or TBM near gauge locations so that gauge shifting work can be done more effectively and precisely.

(3) Automatic Observation System (Non-telemetric Stations)

In addition to the manually observed network, those sites at which automatic rainfall gauges and water level recorders have previously been installed by BWDB plus the existing limited telemetry network were also surveyed as a part of inventory survey.

A general summary of the automatic stations and their current status is presented in **Table 3.3.1**. Their locations are shown on **Figure 3.3.3**. Based on the inventory survey, the following comments are made.

a. Rainfall Gauging Stations

All stations are of the tipping bucket recorder type. Of the 15 stations installed, only 5 remain operational. The main reasons for non-functioning of these stations are related to equipment failure (clocks, piping and so on). Lack of spare parts or expendables such as recording charts is also a concern to the operators.

b. Water Level Gauging Stations

All stations are installed with float-wells except for one site (Bandarban) that has a pressure transducer. Seven sites are installed with data loggers while the remainder has conventional chart recorders.

Of the 17 stations, only 5 were operational during the inventory survey. An additional 3 were stated by the gauge readers to be mechanically in good order but river levels were below their respective intakes. The stations therefore do not operate during the low flow season.

Primary reasons for failure of the remaining 9 stations include bank erosion or flood damage causing structural failure and/or siltation of the inlet pipes. At 10 stations, bridges either exist or are under construction. Gauges are, however, constructed on bridges at only 2 of these sites. Relocating the recorders at the other 8 locations should reduce possibilities of their being damaged during flooding.

Overall, the lack of sufficient operation and maintenance has resulted in the 4 of majority of automatic stations no longer functioning.

(4) Telemetric Observation System

Any recommendations for future expansion of a telemetry system must consider not just requirements for flood monitoring and forecasting but also past performance of the existing network and possibility of establishing stations that will remain operational in the longer term. A more detailed outline of the status of the existing telemetry network is therefore presented in **Table 3.3.2**.

Among the existing 14 telemetric stations, 5 stations were established in the mid-1980s in the north-east region of the country (comprising both automatic rainfall and water level recorders). Remaining 9 stations were installed in 1996, predominantly around Dhaka and at the international boundaries on the Padma and Jamuna Rivers. The locations of the stations are shown on **Figure 3.3.3**.

Of those stations installed in the initial programme in 1985, none continue to transmit data to the FFWC. The primary reason is related to failure of the data transmission system and associated equipment (see **Section 3.4**).

To date, information from the existing telemetry system has been utilized neither in flood forecasting nor in flood monitoring. The reasons given by FFWC are:

- data for a number of the stations are not available,
- accuracy of the telemetered data has not been verified, and
- there is no interface between the telemetered data and the analysis system.

(5) Discussions

A summary of the current status of all stations is presented below.

General Operational Status of Network

Station Type		Number of Stations *Surveyed*	Stations Operating		Stations Not Operating			
			Number	Poor Site *Conditions*	Number	Cause of Failure		
						Gauge Location	*Floods*	*Equipment*
Manual	R	67	64	32	3	0	0	3
	WL	88	87	3/68 (1)	1	0	0	1
Automatic	R	15	5	1	10	0	0	10
	WL	17	5	0	12	3	5	4
Telemetry	R	6	2	0	4	0	0	4 (2)
	WL	13	5	0	8	0	3	5 (2)

Notes: (1) 3 sites have obstructions near gauges, 68 stations have one gauge moved periodically.
(2) Due to failure/removal of recorder gauge and/or telecommunications equipment.

Manual Observation System

Overall, the existing manually operated hydrometeorological network provides a satisfactory coverage for use in the FFWS. The inventory survey indicated all stations incorporated in the flood warning system are generally in good condition apart from those problems related to:

- the need to periodically shift the gauge plate at most sites, and
- poor clearance of a significant number of rainfall gauges.

For the former, it is recognized that this cannot be avoided at many locations. Consideration should therefore be given to installing the gauges at any permanent structures that may exist at least at high water levels. This would involve installing gauge plates in the following manners:

- installing on existing embankments,

- extending inclined railings with gauge plates attached on embankment similar to the Rajshahi water level station, or
- transferring gauge plates to nearby bridges.

Automatic Observation System

The major problems are associated with operation of both the network of automatic stations plus the existing telemetry network. The majority of stations (both water level and rainfall) are in poor working condition with many not operating at all.

Ongoing operation and maintenance is therefore a major concern. Sufficient funding is essential if the existing network and any proposed expansion are to be maintained. For the automatic and telemetry water level stations, a number have also failed during large floods, highlighting the need to install stations at more permanent locations whenever possible. Finally, at a small number of sites river levels during the dry season fall below the intakes of the gauges. Although this should not affect recording during higher flows, low flow information, essential for water resource management, is not recorded.

Transmission of data from the manually operated network occurs daily during the flood season as required and reviews of the FFWC (and BWDB) database indicate the procedures implemented to verify the voracity of data at the FFWC ensures its general accuracy. Nonetheless, manual entry is time consuming and increases the possibilities of additional errors being made during this process. Digital transmission of manually observed data should therefore be considered with checking then being fully computerized.

3.3.4 Quality of the Data Stored in FFWC's Database

(1) General

According to FFWC staff, one of the major problems encountered to their operation is unreliability of water level data transmitted from the manual observatories. However, the extent of the quality of manually observed data has not been assessed by FFWC yet. Based on the hydrometeorological data collected by FFWC, the quality of the data was assessed. As indexes of this data quality, 1) percentage of missing data and 2) percentage of doubtful data were evaluated.

(2) Percentage of Missing Data

Missing data forces FFWC staff to make additional operations for the supplementation or inter-/extrapolation of it, and it may therefore cause the delay in forecasting analysis and warning dissemination.

According to the data stored in FFWC, the missing data occupies 16.2 % and 13.5 % of the total data required through monsoon season (May – October) and flood season (June – September), respectively. The summary of this assessment is tabulated below:

Percentage of Missing Data

Share of Missing Data in Total Number of Data Required	May – October	June – September
	Number of Observatories (Percentage)	Number of Observatories (Percentage)
50 % ~	6 (6.6 %)	5 (5.5 %)
40 % ~ 50 %	3 (3.3 %)	4 (4.4 %)
30 % ~ 40 %	3 (3.3 %)	2 (2.2 %)
20 % ~ 30 %	11 (12.1 %)	9 (9.9 %)
10 % ~ 20 %	12 (13.2 %)	6 (6.6 %)
~ 10 %	56 (61.5 %)	65 (71.4 %)
Total	91 (100.0 %)	91 (100.0 %)

As shown in the table, the number of observatories with percentage of missing data of less than 10 % is 56 for monsoon season and 65 for flood season.

As the causes of data missing, many factors are conceivable. According to FFWC, main factors are as follows:

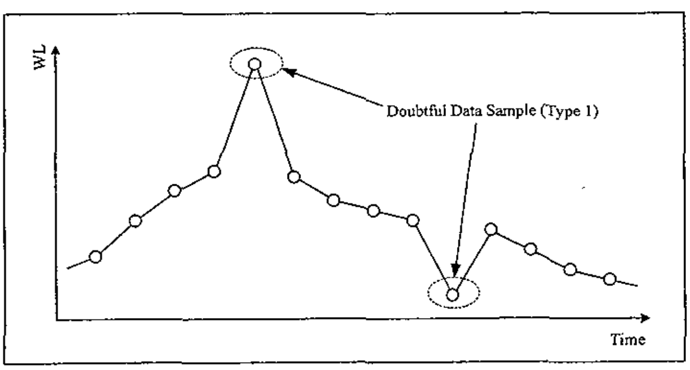
- Factors related to telecommunications such as interference, malfunction of wireless equipment etc.
- Factors related to human elements of gauge reader or wireless operator such as idleness, urgent business, sickness etc.
- Factors related to manual staff gauge such as being washed away, being robbed, being broken etc.
- Factors related to budget shortage for the employment of gauge reader or wireless operator.

(3) Percentage of Doubtful Data

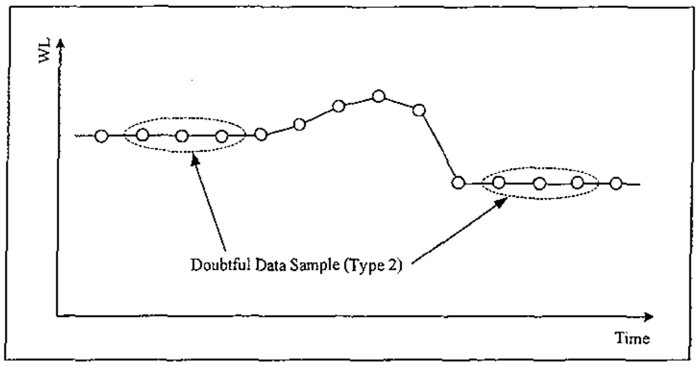
Needless to say, erroneous data sample lowers the value of entire data population. Moreover, since erroneous data may cause instability in hydraulic calculation using forecasting model and/or remarkable errors in forecasting result, it should be eliminated before running the model. The erroneous or doubtful data is eliminated or corrected by FFWC staff by manual procedure.

Following two types are considered as typical doubtful data sample:

- Type 1: Data sample whose value differs considerably from those around it.



- Type 2: Data sample whose value is exactly the same as those around it.



Among these two types of doubtful data sample, "type 1" may be caused by careless data input operation and this can be called as erroneous data sample. In terms of "type 2", although it may occur partially because of human element of field staff, it sometimes shows the fact of slowness or smallness of water level fluctuation especially in the monsoon (normal) flood area. This type of data sample therefore cannot always be considered as erroneous data.

Based on the data (May – October) available in FFWC database whose recording interval is 3 hours in principle, the share of above data samples is assessed for each observatory by means of manual procedure. The result is summarized in the table below. The table shows the percentage of the doubtful data sample by flood type and by requirement of current forecasting model. It should be noted that the data assessed by the Study Team is the ones which have already been checked and corrected, if necessary, by FFWC before.

Percentage of Doubtful Data Samples

Flood Type	Model Requirement	Total Number of Data Samples	Percentage of Type 1 Doubtful Data Samples (%)	Percentage of Type 2 Doubtful Data Samples (%)
Normal (Monsoon)	Required	155,118	0.016	9.5
	Not Required	85,726	0.024	12.6
Total of "Normal (Monsoon)"		*240,844*	*0.019*	*10.6*
Flash	Required	72,841	0.037	6.3
	Not Required	34,519	0.104	6.1
Total of "Flash"		*107,360*	*0.059*	*6.2*
Tidal	Required	15,358	0.026	0.0
	Not Required	21,997	0.068	0.4
Total of "Tidal"		*37,355*	*0.051*	*0.2*
Total of Observatories with Model Requirement		243,317	0.023	8.0
Total of Observatories without Model Requirement		142,242	0.051	9.1
Total of All Observatories		**385,559**	**0.033**	**8.4**
Maximum among the Observatories*			***0.302***	***23.5***

Note*: The shares shown in the marked row is the highest ones among the observatories.

From the above the following conclusions can be drawn:

- As a whole, the percentage of "type 1" doubtful data is small (about 33 for one lakh samples). This indicates such errors are readily observed and corrected by FFWC staff during the manual data checking procedure.
- Among flood types, the percentage of "type 1" doubtful data is remarkably small in those areas subject to monsoon flood compared to flash and tidal flood areas. Again such errors are readily identified for the monsoon flood area during preliminary data checking because of the relatively smooth changes in water level fluctuation.
- When comparing data for those stations required or not required for modeling, the percentage of "type 1" doubtful data for those stations required is less of that for those stations not required. It appears more careful checking is undertaken of data for those stations required for modeling.
- As a whole, the percentage of "type 2" doubtful data is large. This may be due to difficulties in identifying and confirming the data are actually in error, particularly for stations in monsoon flood areas.
- The percentage of "type 2" doubtful data is high for stations in flash flood areas. This may also indicate difficulties in identifying and confirming errors of this type for data recorded at stations in these areas.
- In tidal affected areas, the occurrence of "type 2" doubtful data is rare.
- Comparing percentages for those stations required for the modeling, the percentage of "type 2" doubtful data does not decrease much even if more careful data checking is conducted.

3.3.5 Hydrometeorological Record outside Bangladesh

(1) Efforts Made in Bangladesh Side

There is an agreement between Bangladesh and India which mentions hydrometeorological data exchange for flood forecasting and warning purposes. This was originally concluded in 1972 through the arrangement of the Joint Rivers Commission (JRC) in both Dhaka (Bangladesh) and New Delhi (India). At present, the data from 20 observatories located in India are transferred to Bangladesh through BMD's wireless communication system or point-to-point direct communication system (refer to **Section 2.2.4** and **Figure 2.4.19**).

As shown in **Figure 2.4.19**, all of the water level stations whose records are available in Bangladesh are located within 100 km from the international border. If the average current velocity of flood is considered as 1~2 m/sec, the duration of flood traveling for 100 km is assumed to be around 13~27 hours. Moreover, there is a regulation for the data transmission for 14 stations (except for 6 'point-to-point' stations) that;

- water level and discharge data are reported to Bangladesh side only if the water level reaches or exceeds the warning level set at 1 m below danger level, and
- rainfall data are reported to Bangladesh side only if the rainfall amount exceeds 50 mm/day.

Due to these limitations and regulations, sustainable use and incorporation of hydrometeorological data of Indian observatories in the FFWC's current system is not possible. To overcome this inconvenience, FFWC proposed the improvement of flood related data exchange to Indian side through JRC Bangladesh in 1996. In this 1996 proposal, Bangladesh side or FFWC offered;

- continuous data transfer during the monsoon season (May 15 – Oct. 15),
- data transfer from additional Indian observatories, and
- provision of river cross-section data of the Ganges, Brahmaputra, Teesta and Barak Rivers.

The outline of the 1996 proposal is illustrated in **Figure 3.3.4**.

However, the proposal has not been accepted by Indian side yet. Because the extent of the improvement of FFWS in Bangladesh obtained by this additional data was not explained to Indian side with enough persuasion.

Concerning the rainfall data in India, that is transferred to Bangladesh if the daily rainfall amount of certain station exceeds 50 mm as mentioned above. To overcome this inconvenience, FFWC now obtains 24-hour rainfall record at Indian observatories directly from the web site of India Meteorological Department (IMD). However, the Indian network does not include Cherrapunji, which is located at the south face of Megalaya Hilly Area (one of the major origins of flash flood in Bangladesh) and has the world record of maximum point rainfall amount not only for annual also monthly and 4-day and so on. It is vital for Bangladesh side to get rainfall data of such regions even they are located outside the country.

(2) Quality of the Data from India

Stage water level record at Farakka station is plotted together with that of Pankha station for the monsoon seasons of 1998 and 2002 in **Figure 3.3.5**. The distance between Farakka and Pankha is about 40 km along the Ganges River. It is observed that the water level data at Farakka is very limited (that was available only for about 10 days in 2002 monsoon season). This is due to the said regulation. It is also observed that there is no remarkable lag in the time of flood peak occurrence because Farakka station is too near from Pankha station.

Figure 3.3.6 shows the water level hydrographs at Goalpara, India and Noonkhawa, Bangladesh for the monsoon seasons of 1991 and 2000. The data at Goalpara of 1998 monsoon, which caused catastrophic flood damage, was not available from the FFWC database. The water level record at Goalpara is also limited due to said condition. Although the distance between Goalpara and Noonkhawa is about 100 km along the Brahmaputra river, no significant time lag in the flood peak occurrence is observed. Moreover, the recorded occurrence of the peak water level at Noonkhawa (downstream) in 1991 monsoon is earlier than that of Goalpara (upstream) for some 24 hours as shown in **Figure 3.3.6**. Though it is unclear what causes such a doubtful recording, this is one of the examples that shows the un-smoothness in data exchange between India and Bangladesh.

3.3.6 Radar and Satellite Image

Radar and satellite image are available at FFWC as supporting information for flood forecasting and warning activities. Although they are not directly utilized for flood forecasting analysis at present, that information is useful when FFWC makes some assumption or estimation on current and future rainfall amount or estimation of future boundary condition of hydraulic simulation model.

A terminal unit of computer system which is directly connected to BMD radar system is set in the computer room of FFWC. FFWC staff can monitor the radar image in the real-time basis. However, since the information available in FFWC is image data only, numerical analysis utilizing radar data cannot be done at present.

Regarding the satellite image, FFWC owns a unit of computer with function of reception and analysis of NOAA satellite information. A GMS image is also available from SPARRSO on-demand basis. FFWC therefore can monitor satellite image in the real-time basis. According to FFWC staff, these satellite images are useful not only for the estimation of future hydrometeorological condition but also for grasping the inundation phenomenon actually occurred.

3.4 Data Transmission System

3.4.1 Communication Network during Flood

During a flood, many kinds of data and information are transmitted to FFWC by telephone, mobile phone, fax, wireless radio, BMD data network (intranet network of Bangladesh Meteorological Department), internet, satellite, and telemeter.

After analysis by the FFWC, a flood bulletin is published and disseminated to relevant agencies by fax and E-mail (Refer to **Figure 3.4.1**).

A summary of information collected and disseminated by FFWC is presented in **Tables 3.4.1** and **3.4.2** respectively.

3.4.2 Communication System of FFWC

FFWC

Hydrological Data utilized by FFWC:

Hydrological data (water-level, rainfall, etc.) utilized by FFWC basically consist of wireless radio, telemeter, and post mail (refer to **Figure 3.4.2**).

Wireless Radio : In principle, the FFWS is to use real-time data collected through wireless radio observation stations.

Telemeter : Only in the event that the above data are not obtained, data (limited to a few stations) collected through the telemeter system are utilized. Under actual conditions, telemeter data are not used.

Post Mail : For the purpose of theoretical analysis, a wide range of data collected by post mail from various observation stations are utilized.

Forecast Timetable:

At FFWC, collected data are processed according to the following timetable.

Forecast Time Table

9:00	Transmitting through wireless radio the data that has been collected until 6:00 on the day.
9:00 – 10:30	Forecast analysis
10:30 – 12:00	Preparation of a statistical bulletin
12:00 – 15:00	Preparation of "Daily Flood Bulletin" and Flood Map
15:00	Dissemination of information

Utilizing the data collected at 9:00 am, a forecast is made for the following 24 and 48 hour time periods.

Attempted Interface between Telemeter System and FFWS

Data from the existing telemeter system are not currently used for FFWS. However, there has been one attempt to connect the two systems. The interface between the two networks was tried experimentally by creating an input interface (software) on the FFWS side and connecting the cable to both systems. However, it appears that the experiment ended in failure. The system engineer of the telemeter control system should have participated in the experiment.

Using data from the Telemeter Network System:

It appears that data from the Telemeter Network System has hardly been used. The reasons for this may be as follows.

- The current telemeter system was considered as a pilot project, consisting of 14 gauging stations only.
- There is no connection between the telemeter system and FFWS. It is considered to be difficult to connect two systems without a system engineer of telemeter control system.
- The volume of data coming from the 14 stations is considered not sufficient to increase the forecast accuracy and too little to modify the existing software program.
- The next project, to increase the number of stations and to connect the two systems, was considered to be implemented in succession.

Unified administration and sharing of data is necessary

FFWC has created a database of various data and information (including river cross-sections, river structures etc). FFWC has used the database for flood forecasting and warning analysis, while the BWDB Green Road office has used another database maintaining the original data for other purposes including water resources development plans, river morphology, etc. So there are two databases with almost the same contents resulting in duplication of data entry and maintenance at different locations. A system of unified administration and sharing of data is necessary.

Furthermore, BWDB's divisional offices at present have no means of accessing the FFWC or Green Road office database. Therefore, it is necessary to construct a network internal to the BWDB, inclusive of FFWC and BWDB's divisional offices, to allow unification and sharing of the existing database.

Governmental Emergency Communications Network is necessary

FFWC is currently connected to the BMD network and is thus able to access BMD's data provision server and utilize the meteorological data collected and prepared by the BWDB. This so-called Governmental Emergency Network, a kind of interagency network connecting BMB and various relevant agencies, provides a critical service in disseminating valuable meteorological information and supplying a hot line telephone. FFWC and BWDB need to effectively utilize the data available at various relevant agencies and connect via hot line telephone among various relevant agencies, as DMB does, by taking full advantage of the Governmental Emergency Network.

Wireless Communications Network Systems of FFWC

Basic Flow of Data Collection

Observation data collected at 91 water-level and 56 rainfall gauging stations is sent to Dhaka, the majority through HF short-wave radio transmissions. From the time of data collection to the data entry into the FFWS system, the following four steps are involved:

a. A gauge reader reads the gauge data at the gauging station and relays them to an operator at a radio station.
b. The operator at the radio station transmits the data to Dhaka through a transceiver with voice communication.
c. An operator in Dhaka rewrites the data received from the radio station.
d. The rewritten data is then input into the FFWS server by a FFWC staff member.

The fact that there are four staff members involved in processing the collected data seems to be the cause for possible dissemination of erroneous data or delay in data provision.

Data Collection and Transmission Schedule

The schedule for data collection and transmission varies from season to season.

The gauge data are observed daily at three hourly intervals from 0600 to 1800. They are transmitted to Dhaka weekly in the dry season and daily in the flood season.

At the important tidal gauging stations, hourly observations are taken.

Season		Observation	Data Transmission
Stations	Dry Season	Daily: 6:00, 9:00, 12:00, 15:00 and 18:00	Weekly on Saturday 9:00 – 12:00
	Flood Season	Previous Day: 9:00, 12:00 15:00 and 18:00 On the Day: 6:00	On the day: 9:00

Data Reception Method at Dhaka

In principle, a data transmission request is sent by Dhaka and in response, the station that receives the request is to send out the collected data. Since it is almost impossible to simultaneously receive and process collected data from almost 90 stations, these stations are divided into five different blocks and each block's transmission time is scheduled at ten-minute intervals to allow a process of "a transmission request and data transmission" to take place.

At the Dhaka reception station, there are two HF trans-receivers. Two operators are on duty to make the most effective use of these two trans-receivers. The data collection is carried out each morning from 9:00am. However, radio voice is noisy and it is rather difficult to process all data collected without error from almost 45 radio stations per operator.

Ability of Wireless radio operator, Accessibility to the radio station, Backup facilities

The radio operators have sufficient knowledge to use the wireless radio. But, their telecommunication ability on wireless radio is not high, thus technical maintenance seems to be lacking. For example, radio cable is reeled wastefully and thus causes radio noise. Also, batteries for the transceiver are not maintained resulting in power trouble and shortened battery life.

Accessibility for the operators is good because almost all are living near the radio station. But there is, however, no other backup staff for almost all radio stations.

Telemeter Network System

Network Configuration

The telemeter network system consists of 14 observation and 11 repeater stations equipped with VHF radio and a central control station in Dhaka. BTTB's repeater stations (one is a BRTA repeater station) are used as relay stations in the network. The data collected at each gauging station are transmitted to the BWDB's repeater equipment established in BTTB's repeater stations via VHF radio. The repeater stations then send the received data to Dhaka's central control station via BTTB's network through connection with BTTB's multiplex equipment (see **Figure 3.4.3**).

Survey Results:

The survey results indicate that Dhaka's central control station has received proper observatory data from only five telemeter gauging stations. The following factors seem to be the cause.

Lack of maintenance budget

At almost all gauging stations in the Moulvi Bazar region, the telemeter equipment experienced difficulties and was removed for replacement. Because the equipment was initially installed in 1985 and improved in 1995, spare parts needed for repairing the older equipment are not readily available and are hard to procure even in Japan.

BWDB cannot handle major maintenance activities such as replacing/upgrading equipment. Also damaged gauging stations have been left unrepaired.

The reliability and serviceability of transmission lines is low

BTTB and BRTA have not been effective in dealing with this situation. The defective lines have not been repaired and sometimes the connections between BWDB's repeater equipment and BTTB's multiplex equipment have been cut at the BTTB repeater stations.

Detailed situations for each station are discussed in **Table 3.4.3**.

Electric power source

Reliability of electric power is very low. There are power blackouts at least once a day, some lasting as long as 30 minutes.

Telemeter station:

Solar power is used for all the telemeter stations. Considering the hours of sunlight, the reliability of solar power is sufficient.

FFWC:

Power for important computers is provided through their own UPS (Uninterrupted Power Supply). A small generator is available during lengthy periods of power shortages.

There is a large CVCF (constant voltage constant frequency) system in the telemeter control room to provide reliable power to the telemeter control system only.

Operation and Maintenance System

Condition of operation and maintenance of Data Transmission System: Lack of maintenance budget and staff

C & I Division in Dhaka handles all aspects of management and maintenance of the wireless radio system and the telemeter system's observation, relay and control stations. The Division is staffed by one manager, one electrical engineer and two assistant engineers. It appears that an attempt is being made to carry out the basic tasks of compiling maintenance manuals and conducting routine maintenance. However, in addition to the lack of staffing, they do not even have a single vehicle. This limits their ability to fully carry out their duties.

Condition of operation and maintenance of electrical facility: technical level of electrical engineer is high but lack of electrical engineering resources

The electrical engineer was trained in Japan in connection with the installation of the telemeter system in 1995. Therefore, it is safe to assume that the skill level of the engineer is relatively high in that he is able to carry out various repair jobs for parts as well as a variety of maintenance tasks such as replacing a base panel by referencing the repair. But at almost all radio stations, operators do not have electrical ability. Thus there seems to be a lack of maintenance of the electric facility, for example lack of battery water and bad radio cabling.

Issues relevant to maintenance

The parts of the wireless radio system are easily obtainable and thus repair jobs can be carried out rather smoothly. However, some parts of the telemeter system, such as program chips, are not that easy to procure. In such a case, the necessary part is obtained by contacting the manufacturer.

Parts used in those telemeters installed in 1985 are no longer readily available on the market and there are not too many original manufacturers that can still supply them.

Looking into the future, in the event that a new network system is to be constructed, it is suggested that the availability of system parts on the market and the system's economic efficiency as well as the usage of the global standard as a base technology should be seriously taken into account. How long one can expect to procure necessary parts and equipment in the market is highly critical to deciding on the sort of system to be constructed.

3.5 Analysis System

3.5.1 Data/Information Incorporated in and Output from the Analysis System

As mentioned in above subsections, basic data/information assembled by FFWC on a "real-time basis" comprises:

- water level data at 91 gauging stations widely spread over Bangladesh,
- rainfall data at 56 gauging stations widely spread over Bangladesh,
- hydrometeorological data at 20 observatories located in India,
- BMD radar images, and
- NOAA and GMS satellite images.

It should be noted that the water level information in India is obtained only when the observed water level exceeds 1 m below danger level, while rainfall information is transmitted to Bangladesh only when the observation exceeds 50 mm/day.

In addition to the above real-time information, the following data/information are incorporated in the analysis model (Supermodel) as "base information":

- river (branch) network data in and around Bangladesh (topographic coordination of branch route),

- longitudinal and cross-section data of rivers (branches),
- dimensions of existing river structures whose effects on the hydraulic phenomena are not negligible,
- topographic information of flood plains (area-elevation relationship of each flood plain, referred to as 'flood cell'),
- evapotranspiration data,
- Digital Elevation Model (DEM) on which simulated flood inundation mapping is generated, and so on.

All of the above data/information apart from evapotranspiration do not have any fluctuation over the smaller time scale. Regarding evapotranspiration, although it may fluctuate widely on a daily or hourly basis, a fixed value such as 5 mm/day is applied in the modeling due to difficulty in measuring this parameter on a real-time basis.

As described in the next subsection, there are three kinds of activities covered by the analysis system, that is, 1) monitoring, 2) real-time simulation and 3) forecasting. Following table summarizes the main input/output information of those activities:

Main Input/Output Information of Analysis Activities

Activities	Input Data	Output Data	Remarks
Monitoring	- Observed Water Level - Observed Rainfall	- Observed Water Level - Observed Rainfall	Mathematical model is not employed.
Real-time Simulation	- Observed Water Level - Observed Rainfall - Branch Route - Structure's Dimension - Topographic Data - River Cross-section - Evapotranspiration	- Simulated Water Level - Simulated Discharge	Mathematical model is employed
Forecasting	- Observed Water Level - Observed Rainfall - Future Water Level - Future Rainfall - Branch Route - Structure's Dimension - Topographic Data - River Cross-section - Evapotranspiration	- Forecasted Water Level - Forecasted Discharge	Mathematical model is employed

Each activity is described in the succeeding subsections in detail.

3.5.2 Monitoring, Real-time Simulation and Forecasting

The activities undertaken in the analysis system during the wet season (May – October) can be roughly divided into three, i.e. 'Monitoring', 'Real-time Simulation' and 'Forecasting'. Monitoring is also conducted continuously in the dry season (November to April) on a weekly basis.

In the monitoring activity, as-recorded hydrometeorological data obtained from the field are presented in the bulletin or web page, after quality checking. Monitoring items include water levels and rainfall. Quality checking of water level information is undertaken mainly by comparing time series trends. Rainfall is checked by comparison with radar and satellite images or rainfall records of nearby stations. The checking processes are undertaken manually.

In real-time simulation, a hydrological and hydraulic approach together with a GIS technique is applied. This is based on MIKE11 modeling software developed by the Danish Hydraulic Institute (DHI). The outputs of this real-time simulation are hydraulically calculated water levels at defined points often where observed water level data are not available. In other words, interpolation of water level information along the river branches is made based on modeling using observed water level and rainfall data.

In the forecasting activity, the same software as utilized for real-time simulation is employed. Water level forecasting in the dry season (lowflow forecasting) is one of the outputs of the on-going DANIDA project (CSFFWSP), with this system now under preparation. The lowflow forecasting is therefore not included in current FFWC activities.

The above three activities can be merged into 2 components reflecting the required hydrological / hydraulic calculations. The 'monitoring' activity does not require such calculations, while 'real-time simulation' and 'forecasting' require rather complicated analyses. Monitoring, real-time simulation and forecasting activities are described in more detail in the following subsections.

3.5.3 Monitoring

As mentioned above, there are 91 water level and 56 rainfall gauging stations from which data are transferred to FFWC in real-time. Experts in FFWC check the quality by temporal plotting or comparison with data of nearby stations.

Regarding the water level data, current status (the water level at 0600 hours of the day) of each gauging station is monitored and displayed on the bulletin and web page together with the station's danger level in meter PWD. Rise or fall in water level from the previous day is also calculated and reported.

For rainfall data, the totals for the three previous 24 hour periods (as at 0900 hours daily) are presented for each station in the bulletin and web page. For the current month, cumulative rainfalls and historical average and maximum monthly rainfalls are also given.

In the dry season, data at 18 water level stations and 18 rainfall gauging stations are checked and reported in a weekly bulletin. The hydrometeorological information is not displayed in the FFWC web page during the dry season.

3.5.4 Real-time Simulation and Forecasting

Real-time simulation and forecasting activities are carried out by FFWC staff utilizing MIKE11 together with a GIS technique.

(1) Outline of Software for Real-time Simulation and Forecasting

The MIKE11 software package is applied for the current hydrological and hydraulic modeling. This package is further divided into a series of modules such as Hydrodynamic (HD), Structural Operation (SO), Rainfall-Runoff (RR), Flood Forecasting (FF) and so on.

For generation of the flood inundation map, MIKE11 GIS is employed. MIKE Flood Watch, operating under the Arcview environment, is utilized for preparation of the flood bulletin and updating of web contents. In the application of the MIKE11 model, this also acts as something like an Operating System (OS) for above applications.

Overall, the software and modules comprising the current FFWC analysis system are outlined below:

Software/Modules Incorporated in the Current FFWC Forecasting Analysis System

Software	Module	Developer	Purpose
MIKE11	Hydrodynamic (HD)	DHI	One-dimensional (1D) steady/unsteady flow calculation (hydraulic approach)
	Structural Operation (SO)	DHI	Calculation of the effect of river structures such as weir, culvert, pumping station, etc.
	Rainfall-Runoff (RR)	DHI	Rainfall-runoff calculation by hydrological approach
	Flood Forecasting (FF)	DHI	Forecasting of future hydrological condition (water level, discharge)
MIKE11 GIS	-	DHI	Generation of flood inundation map based on the calculation results of MIKE11
MIKE Flood Watch	-	DHI	Preparation of bulletin/web contents and application management

Figure 3.5.1 shows the typical work flow for the flood forecasting and warning procedure using the above software and modules. Short descriptions of the software and modules are given below.

i) MIKE11 Hydrodynamic Module (HD)

FFWC uses this module for quasi two-dimensional unsteady flow calculation. In this module, the hydraulic values (water level, discharge, etc.) at each temporal/spatial step are calculated by solving Saint Venant Equations, i.e. conservation of mass and conservation of momentum equations. Main information to be provided for this module is as follows:

- topographic coordinates (longitude (X) & latitude (Y)) of branch course,
- information of branch connection,
- cross-section data of each branch,
- hydraulic parameters (roughness coefficient, etc.),
- topographic information (Area-Elevation curve) of flood plains,
- boundary conditions (water level or discharge at upstream and downstream boundaries),
- spatial step (Δx) and time step (Δt) for the solution scheme of Saint Venant

Equations.

ii) MIKE11 Structural Operation Module (SO)

This module is applicable when the influence of a certain river structure on hydraulic phenomena is not negligible. The effect of most river structures such as weirs, culverts, bridges, pumping stations etc. can be simulated by this module. Main input is the physical dimensions (width, height, etc.) of the structures.

iii) MIKE11 Rainfall-Runoff Module (RR)

Three rainfall-runoff calculation methods area available in this RR module. These are 1) NAM model, 2) Unit Hydrograph method, and 3) SMAP model. Out of them, since SMAP model is applied mainly for long-term basin runoff simulation based on 10-day or monthly basis runoff, it is not suitable for real-time flood runoff simulation. FFWC selected NAM as the basin runoff simulation model for flood forecasting.

NAM, originally developed by Technical University of Denmark, is a lumped and conceptual basin runoff model, simulating the overland-, inter-, and base-flow components as a function of the moisture contents in four storages, i.e. surface, lower or root zone, ground water, and snow. This has a similar concept to the Tank Model, commonly used for both lowflow and flood runoff simulations in Japan, or Xinanjiang model, developed in China. The concept of the NAM model is illustrated in **Figure 3.5.2**.

As shown in **Figure 3.5.2**, there are many parameters to be set in the NAM model. Of these the following seven are important in estimating flood runoff from the objective drainage basins. They are constituent elements of the surface and root zone parameter sets:

- Maximum water content in surface storage (U_{max})
- Maximum water content in root zone storage (L_{max})
- Overland flow runoff coefficient (CQOF)
- Time constant for interflow (CKIF)
- Time constant for routing interflow and overland flow (CK_{12})
- Root zone threshold value for overland flow (TOF)
- Root zone threshold value for interflow (TIF)

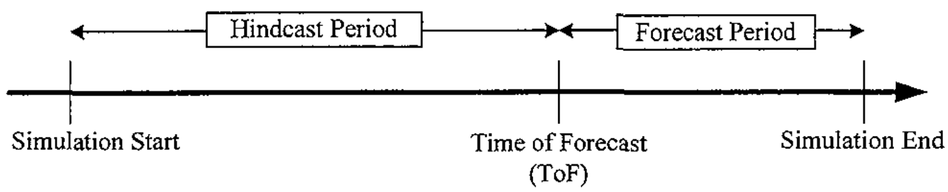
Usually, a certain area is divided into several sub-basins according to the topography, and each sub-basin has its own parameter set for runoff calculation. Main items to be input into NAM are rainfall and evapotranspiration. From these information upstream inflow or lateral inflow to the branch network model (HD module) are calculated.

iv) MIKE11 Flood Forecasting Module (FF)

This flood forecasting module employs several forecasting techniques. The main sequence for running this module is:

- Definition of basic flood forecasting parameters such as forecast length (period), accuracy and so on,
- Definition of boundary conditions in the forecast period (forecasted boundary conditions)
- Definition of forecast points
- Requirement for updating of hydrological values for improvement of forecast accuracy as outlined below. (The measured and simulated water levels or discharges are compared and analyzed in the hindcast period and the simulations corrected to minimize the discrepancy between the observations and model simulations.)

The time of forecast (ToF) is defined in relation to the hindcast and the forecast period as shown below.



Definition of ToF

It is easily understandable that the result of real-time simulation shows the water level information at ToF.

For the definition of future boundary water levels or discharges, typical operation of this FF module is to extrapolate water level or discharge of the hindcast period beyond the ToF or simply define based on local knowledge. For future rainfall forecasting, no method is incorporated in this module.

In defining forecasting points internally within the network, any grid (calculation) point can be selected for output.

One of the notable characteristics of this module is the method of hydrological value updating. "Discharge adjustment" is the typical method used in updating, and this is applied in the current analysis system in Bangladesh. After selecting points, referred to as "Internal Boundaries (IB)" at which observed water levels are available, at calculation points discharge adjustment is made as outlined in **Figure 3.5.3**.

The discharge adjustment is carried out to improve model accuracy in the hindcast period. This involves adding or subtracting a discharge (Q_{ADJ}) from the modeled discharge through the hindcast simulation to obtain a better 'fit' between the observed and simulated water levels at the internal boundaries. **Figure 3.5.4** shows the forecasting procedure at an internal boundary in relation to the availability of observed data (observation interval).

v) MIKE11 GIS

This tool is applied for generating flood inundation maps based on the results of the hydrodynamic calculation, namely HD output.

HD output is imported to this ArcView-based application (GIS software developed by ESRI, USA), and inundation maps are generated based on a comparison of calculated water level at each grid point and its associated elevation data.

Besides accurate HD output, accurate Digital Elevation Model (DEM) is necessary for generation of high quality flood inundation maps. DEM is grid based information of elevation. An area is divided into grids (meshes) in DEM, and an elevation value is assigned to each grid (mesh).

vi) MIKE Flood Watch

This ArcView-based module works as a management tool for the other simulation modules. It has functions of automatic checking of received hydrometeorological data, establishing the necessary database of verified data for the hydrological/hydraulic simulation system, extracting simulation/forecast results, and automatic generation of bulletins, graphs, web contents, etc.

(2) Description of Supermodel 2001

The modeling undertaken for the FFWS in Bangladesh is based on the applications outlined above. It is referred to as the Supermodel. As the MIKE11 modeling system has powerful flexibility for expansion of a modeling area, FFWC continues to expand and update the modeled area with the assistance of an on-going DANIDA project. The current analysis model is called 'Supermodel 2001 (SM2001)'. A description of SM2001 is given below.

The modeling network comprises:

- 272 channels defining major and larger secondary rivers within the country,
- 227 link channels defining the relatively complex interconnection of rivers plus major depression areas within the country, and
- a series of modeling weirs (38 nos.) and culverts (15 nos.) simulating the physical characteristics of major embankment overflows and flow transfers to flood plain areas.

The branch network of SM2001 is shown in **Figure 3.5.5**.

The model also incorporates approximately 1,100 river cross-sections based directly on the surveys undertaken by BWDB. These define the river channels and adjacent floodplain areas and include major river structures. The latter would typically include flood control embankments, roads and similar. Approximately 200 river cross-sections are resurveyed annually and about 900 sections are resurveyed every 2 or 3 years by BWDB. **Table 2.4.3** lists the river-cross sections surveyed by BWDB. In an attempt to maintain accuracy of the model input, those resurveyed sections are incorporated in the cross-section database of SM2001.

As noted in **Section 3.3**, basic hydrometeorological data are provided from a network of manually observed water level and rainfall stations within Bangladesh. The observed data are transferred on a daily basis, normally around 0900 to 1000 hours, by wireless or cell phone/telephone, to FFWC after which the information is reviewed for accuracy and consistency. Typically, for both water level and rainfall, this includes comparisons of data values with observations from nearby sites. For water levels, reviews of data trends are also undertaken.

The data are then entered manually into the computer and utilized to prepare flood forecasts at selected forecast points for both current period (ToF) (real-time simulation) plus the following 24, 48 and 72 hours (forecasting).

The SM2001 requires data for a total of 52 boundary water level gauging stations that effectively 'drive' the simulation (refer to **Figure 3.5.5**). Real-time water levels or associated discharges are available for 23 of these sites. These could be referred to as 'base' boundary stations. The other 29 boundary stations are currently set as constant discharge inputs (0.3, 2 or 10 m^3/sec) or their discharges are based on scaling flow from the most relevant nearby base station. Of the 'base' boundary stations, 5 define tidal levels and the remaining 18 define inflows from the major rivers flowing into the country or inflows/water levels at model boundaries within the country.

Additionally, water level data from 27 stations within the FFWC network located internally within the country are also used to improve model performance in real-time as 'Internal Boundaries (IB)' as shown in **Figure 3.5.5**.

Data from 37 rainfall gauging stations are used in conjunction with the NAM rainfall-runoff model to derive inflow flood hydrographs to the branch network model for the local catchments either wholly within the modeled area within Bangladesh or those smaller catchments originating in India. For this purpose, the modeled area has been divided into a total of 114 sub-catchments as seen in **Figure 3.5.6**. The areas of those sub-catchments vary from around 200 to 4,500 km^2 as presented in **Table 3.5.1**. Only 24 hour rainfall data are available from the rainfall gauging stations, as discussed in **Section 3.3**. It is also noted that data are not available to define rainfall depth or aerial variability for those portions of sub-catchments within India.

The basin average rainfall for each sub-catchment, based on a Thiessen-weighted average of the most relevant nearby stations from the 37 available, is assumed to be areally uniform. The temporal distribution within the 24-hour period is also assumed uniform.

(3) Real-time Simulation

Real-time information issued by the FFWC in the Daily Flood Bulletin is based directly on observations forwarded daily from the network of water levels stations outlined in **Section 3.3**. A total of 54 forecast points within the country are used for disseminating flood warnings although there is a plan to expand this to around 70 in the near future (there is information that the number of forecast points was expanded to 78 locations by the end of March 2003). Existing forecast points include selected boundary and internal boundary stations actually used in the modeling plus additional monitoring stations for which data are also received in real-time by the FFWC. These latter sites are located in areas currently not within the coverage area of the SM2001, such as stations in the south-eastern hill basin area, or at locations of special interest to authorities engaged in flood warning.

Currently, modeling is therefore not explicitly required to issue real-time flood level warnings. It is, however, required to 'fit' the model based on the most up-to-date river levels and inflows to provide accurate start-up conditions for forecasting. For modeling of real-time simulation, the following methodology is therefore applied:

i) The manually recorded water levels and rainfalls from the hydrometeorological network are communicated to the FFWC by around 10am. Their accuracy is checked and the data are manually entered into the computer.

ii) For those water level stations at the upstream boundaries of the river network (a number of which are located at the entry points of the three international rivers, the Padma, Jamuna and Meghna) or on rivers internally within the country, the water levels are generally converted to discharges although water levels are also input directly for several locations. For the former, this is based on available stage-discharge relationships for each site while for the latter the model derives discharges internally using the hydraulic characteristics of the local river reaches.

iii) For catchments within Bangladesh, the NAM rainfall-runoff model is applied using the available rainfall to derive a flood hydrograph. The model uses a 'warm-up' simulation period of seven days preceding the current day (ToF) to establish antecedent catchment conditions, that is it directly incorporates any preceding rainfall. This hydrograph provides the estimate of local sub-area inflow.

iv) The SM2001 is used to simulate the water surface profiles along the river network. Like the rainfall-runoff model, a 'start-up' period is also incorporated. Based on the previous seven days' data, water levels are computed for the ToF and compared with the observed data at each internal boundary station. If there are substantial differences, the discharges within the associated river reaches are modified until these observed and estimated levels are comparable (updating/discharge adjustment; see **Figure 3.5.3**). It is considered any initial differences in these levels reflect inaccuracies in the available river cross-sections, stage-discharge relationships (defining system inflows), and rainfall data used in estimating local catchment inflows within Bangladesh.

Therefore, the model simulates current flooding condition as defined by the available flood level data transmitted daily to the FFWC.

Based on information from FFWC and the results of the inventory survey, the existing manual water level and rainfall networks are operating adequately and data are currently received from all required stations on a daily basis at the appropriate time for use in real-time simulation. General accuracy of the data was also confirmed during analysis of water level data stored on the FFWC database for a number of the key stations in the network.

Minor problems were noted for only several of the sites analyzed. Although such errors were limited, they included erroneous data values, periods when only single water levels were recorded each day, or short periods of missing record.

Based on the results of real-time simulation (simulated water level at each calculation point, referred to as a 'h-point'), the flood inundation map of the modeled area is generated utilizing the GIS technique. Although the Digital Elevation Model (DEM), which defines the topography of the country, has a resolution of 300 x 300 m, this was generated using the topographic mapping developed in the 1960's. The DEM utilized for generation of inundation maps is shown in **Figure 3.5.7**. The current DEM therefore does not have sufficient accuracy due to both possible changes in ground elevation and a lack of information on the structures constructed in the country since that date. To address this problem, FFWC is now making efforts to gather topographic information and update the DEM.

(4) Forecasting

The procedure for forecasting is essentially the same as real-time simulation except when using the model in this mode *all boundary data must be estimated prior to the analyses*. This is undertaken by the FFWC. Also, no future water level data are available for the internal stations.

For water levels, recorded data for 'base' boundary stations are reviewed and extrapolated using observed trends as well as qualitatively taking into consideration any water level information from upstream areas such as stations in India. These are outlined in **Section 3.3**.

For rainfall, available satellite and radar information (available in real-time in the FFWC computer room) are also considered. This involves initially assessing rainfall patterns on a qualitative basis and then quantifying rainfall estimates for each site. The procedure necessarily relies on experience and a quantitative judgment.

FFWC is currently undertaking studies in an attempt to estimate future water levels for the boundary stations on the Padma and Jamuna Rivers. But as the lag times between the sites upstream in India at which water level data are available and the boundary stations are not longer than around 4 to 5 hours, any results will only be of limited used in estimating boundary forecasts.

Based on the results of the analyses the FFWC then includes in the Daily Flood Bulletin forecasts for selected stations located along the main rivers for the following 24 and 48 hours. This only occurs when the forecast levels exceed target levels for the stations. For the flash flood areas, the forecasts are only qualitative up to the beginning of July as it is felt the accuracy of the results from the modeling is insufficient to provide quantitative estimates. It was noted, however, that from the beginning of July, quantitative estimates were actually issued in the Bulletin even though the main period for flash flooding generally occurs from May to June.

(5) Time Requirements for Running Supermodel 2001

According to FFWC staff, it takes some 20 minutes for running the SM2001 for hydrological and hydraulic calculation, 20 minutes for exporting simulation results (water level at each 'h-point') to the GIS database, and 30 to 35 minutes to generate flood inundation maps of the entire area.

(6) Accuracy of Flood Forecast

As noted above, in the period of forecasting the boundary conditions are estimated and no data are available to define future water levels at the internal points. Therefore inaccuracies are likely in the forecasts. To obtain a better appreciation of the magnitude of such errors, the actual forecasts by FFWC for 2001, 2002 and 2003 (till around the end of August) were reviewed.

This involved computing errors in the 24, 48 and 72 hour estimates for a total of 31 forecast points. They included the internal boundary stations (used to adjust the model in real-time) and 4 monitoring stations not actually used in the flood modeling (similar to the analyses undertaken in 'Model Performance During 2001 Monsoon', SWMC, 2001). As the forecasts associated with 'base' stations are estimates adopted by the FFWC for model purposes, these sites do not represent inaccuracies in the modeling but rather inaccuracies in the estimation of boundary conditions prior to simulations. They were therefore not included in this assessment.

The errors in the forecasts for each station and forecast time were expressed in terms of an absolute error (AE). For each year the mean absolute error (MAE), maximum error and those AE's that exceeded a given percentage of time were computed. The AE and MAE are defined as:

$$AE = |x_i - y_i| \quad \text{and} \quad MAE = \sum \frac{|x_i - y_i|}{n}$$

where
AE = absolute error (m),
MAE = mean absolute error (m),
xi = observed water level (m),
y_i = forecast water level (m), and
n = number of days of forecasting at station.

The detailed results are listed in **ANNEX-VI**. A summary of the MAE's is presented in **Table 3.5.2** based on a grouping of stations according to their flooding characteristics, that is stations located in either monsoonal or flash flooding areas. The accuracies of the 24-, 48- and 72-hour forecasts for 2002 are roughly visualized in **Figures 3.5.8**, **3.5.9** and **3.5.10**, respectively. The results indicate:

i) forecasting accuracy at the stations is generally consistent from year to year,
ii) accuracy of forecasting reduces as forecast duration increases for both regions,
iii) forecasting accuracy is significantly higher in those areas subject to monsoonal flooding (MAE's less than around 0.20m), remaining good for durations up to 48 hours and only marginally less accurate at 72 hours, and
iv) forecasting accuracy for those areas subject to flash flooding is only average for the 24 hour duration and reduces further as the duration increases.

The inaccuracies in the input boundary estimates for 2002 and 2003 are presented in detail in **ANNEX-VI**. A summary is given in **Table 3.5.3**. These were based directly on the modeling results obtained from FFWC and highlight the increase in errors of the boundary estimates as forecast duration increases. They also indicate that the larger errors for those boundary stations in the flash flood regions. Also included are the maximum errors. These are significantly larger than the MAE's, particularly for those stations in the north-east and north-west flash flood regions.

To clarify possible reasons for the inaccuracies of the upstream boundaries, a more detailed analysis of the actual flood forecasts for 2001 and 2002 was undertaken. This involved extracting observed and estimated/forecast future water levels (at 24, 48 and 72 hour periods) for selected stations on the model boundaries and those forecast stations immediately downstream. These were located in regions subject to flash and monsoonal flooding and included:

- Pankha and Hardinge Bridge (Padma River, monsoonal flood region),
- Noonkhawa and Sirajganj (Jamuna River, monsoonal flood region),
- Monu Railway Bridge and Moulvi Bazar (north-east flash flood region),
- Sarighat and Sylhet (north-east flash flood region), and
- Panchagarh and Bhusirbandar (north-west flash flood region).

The upstream boundary stations, which are based on input by FFWC, are listed first.

The water level hydrographs for Pankha and Hardinge Bridge (monsoonal flood region) and Monu Railway Bridge and Moulvi Bazar (flash flood region) are shown on **Figures 3.5.11** and **3.5.12** for part of the flood season. They include observed water levels and 24, 48 and 72 hour forecasts.

For the boundary locations the following points were apparent.

a. Flash Flood Regions

A pattern of short duration, individual flood hydrographs is observed with relatively rapid increases and decreases in water level. Whenever a rise or fall in the observed hydrograph occurs, boundary estimates over the following days tend to lag the observed hydrograph (for all forecast durations).

The greater the rate of rise or fall, the greater the differences or errors of boundary estimation. When the rise or fall is more prolonged or more gradual, differences between the observed and estimated hydrographs reduce.

The same results were also apparent for those other stations analyzed that are located in flash flood regions.

b. Major Rivers Subject to Monsoonal Flooding

The variability in the observed flood hydrograph is less. Although the estimated boundary hydrographs again sometimes lag the observed record the differences, or errors in boundary estimation, are relatively small.

For those stations immediately downstream at which flood forecasts are made, the same patterns are also apparent for the concurrent periods. Although the general trend in the observed water level hydrograph is matched by the forecasts, flood peaks particularly for the 48 and 72 hour periods often lag the actual events by as much as two days. Those for the 24 hour forecasts are slightly more accurate. This suggests that errors occurring in the forecasting at the internal stations are to some extent a result of inaccuracies in estimation of the upstream boundary conditions.

The important point to note from this analysis is that accurate forecasts of water levels (in both timing and magnitude) are to some extent dependent on the accuracy of future boundary estimations. This is particularly the case for flash flood areas.

(7) Assessment of Actual Water Level Fluctuations

To better define the areas subject to flash flooding and monsoonal flooding, an analysis of the rates of change in river levels was undertaken by the Study Team using historic records for representative water level stations in Bangladesh. For each site, maximum increases in water levels for durations of 3 hours and 24 hours were calculated annually. The period of record analyzed was from 1996 to 2002. Only increases occurring around the peaks of the annual hydrograph were considered, these being more representative of water level changes during periods of flooding. The results based on the maximum increases at each site are shown on **Figures 2.4.8** and **2.4.9** for 3- and 24-hour durations, respectively.

A similar but more detailed analysis was subsequently undertaken for a number of stations specifically representative of flash flood and monsoonal regions. The periods of record analyzed were generally longer at around 20 years. Only those changes occurring when the flood hydrograph was within 1 m of the danger level were considered when defining the series of annual maximum values for each station. A summary of the results is presented in **Table 3.5.4**.

From **Figures 2.4.8** and **2.4.9**, the larger changes in river levels occur in those areas in the north-east and south-east of the country. Maximum changes can be as high as around 2 and 5 m over 3 and 24 hours, respectively (see **Table 3.5.4**).

Although the north-west region is also subject to flash flooding, rises are less marked. Along the Padma and Jamuna Rivers, changes are far smaller and over 3 hours do not exceed around 0.2 m while over 24 hours they are around 0.8 m. It should also be noted that the large increases for those stations located on or near the Bay of Bengal reflect tidal changes. This was confirmed from a close inspection of the actual data.

3.5.5 Problems Encountered by Analysis System

As outlined above, the current analysis system shows better performance for monsoonal flood forecasting. However, some problems are apparent in the current analysis system. These are summarized below:

- Input errors often occur due to the manually operated data encoding work.
- The data from the telemetry system installed in the 1980s and 1990s have not been effectively utilized due to the absence of a suitable interface system.
- The current system analyzes short cycle flood phenomena such as flash floods assuming an averaging of rainfall both areally over the catchments and temporally over the 24 hour periods even though calculations are based on 30 minute intervals.
- There is a model requirement that future hydrometeorological conditions of boundary stations and rainfall stations should be input for water level forecasting. Such information is estimated by the staff of FFWC based primarily on experience.
- The accuracy of the generated flood inundation maps is low due to outdated topographic information.
- The current system cannot accurately forecast more than 72 hours ahead even for the monsoonal areas because the hydrometeorological information received from India is limited.
- Because of the complexities of setting up and running the model, the required transfer of knowledge among experts requires a strong commitment from the FFWC to the continuing training of its staff.
- The operation manual of the Supermodel has not yet been prepared for the FFWC, although the software manuals for MIKE11 issued by DHI are available.

3.5.6 Conceivable Solutions

(1) Development of Automatic Data Input System

Installation of an automatic data input system can contribute to minimizing the likelihood of input error associated with manual operation. It is also effective in minimizing time currently required for manual data input. The direct transmission of observed hydrometeorological data in digital format meets this requirement, particularly as MIKE Flood Watch has a function for automatic data import.

(2) Updating of Topographic Information

The updating of topographic information is necessary for improvement in the accuracy of the generated flood inundation maps. Moreover, this will enhance the accuracy of hydraulic calculation because of improved definition of the floodplain topography.

(3) More Frequent Operation of Simulation Model

Additional operation of the SM2001 model could enable the FFWS to issue more accurate information on flood levels more frequently, an important consideration for the people and infrastructure especially in the flash flood regions. Considering the large difference in the time scale of the rise and recession of the flood hydrograph between monsoonal and flash flood areas, the development of an independent analysis system for flash flood regions may be preferable.

(4) Establishment of a Method for Accurate Boundary Forecast

The current forecasting procedure requires the input of future up- and downstream boundary conditions (water level or discharge).

a. Future Downstream Boundary Condition

In terms of future downstream boundary conditions, the existing tidal table is currently employed for their estimation with satisfactory results.

b. Future Upstream Boundary Condition

In terms of future upstream boundary condition, many attempts have been made for estimation based on the data available within Bangladesh. For example, a short and medium-term weather forecasting technique is being developed as part of the Climate Forecast Applications in Bangladesh (CFAB) project in conjunction with BWDB. If this proves successful, the CFAB model could provide discharge estimates for short (5 day) and medium term (20-25 day) timeframes for major rivers. These could then be applied for more accurate estimation of future upstream boundary conditions for monsoonal areas.

In addition to above study, efforts for the collection of relevant hydrometeorological data from India are currently being made by BWDB and JRC. The incorporation of data from stations upstream of model boundaries is the simple and most reliable way to enhance the accuracy of water level estimates at the international boundaries (entrance points to Bangladesh).

Considering the short lag time between rainfall and runoff, accurate monitoring of rainfall at short intervals over the flash flood area is necessary, although it must be remembered that catchments of many of the main rivers are located outside Bangladesh. According to the rainfall record within Bangladesh, rainfall and rainfall gradients in flash flood regions are high (see **Figure 2.4.1**) and there is large spatial variability (see **Figure 3.5.13** comparing daily rainfalls at Sylhet, Kanaighat and Sheola located in the north-east). Utilization of radar information is one of the solutions to define rainfall data not only within Bangladesh but also those parts of the catchments located outside Bangladesh where rivers flowing through flash flood areas originate.

(5) Staff Training and Preparation of Operation Manual

For sustainable operation of a sophisticated mathematical model such as the Supermodel, the smooth transfer of knowledge is necessary. Preparation of a detailed operation manual for the Supermodel to clarify the required daily routines to be followed is most useful. It is recommended that training programs are established according to this operation manual.

3.6 Warning Dissemination System

3.6.1 Present Condition

FFWC of BWDB is responsible for issuing flood warning. FFWC produces flood bulletins and flood warnings everyday during the monsoon period starting from April and ending in November. This product provides flood information to the organizations and policy makers and general people. FFWC circulates this message from the office of the Prime Minister down to the district level including the media (TV, Radio and Newspaper etc.), NGOs, and foreign mission & donors. The river situation, flood forecast and flood warnings are also available in the FFWC website, which is updated daily.

At present, flood warning is calculated in terms of water level of the rivers at 54 points. The warning says how high or low the water level is with respect to the danger level at each site.

It is noted that Danger level of a river is a level above which it is likely that the flood may cause damage to crops and homesteads. Danger level is defined for a particular measuring station for the area in its immediate vicinity. Danger level and flood severity as defined by BWDB are given below (Source: Daily Flood Bulletin, FFWC):

Danger level

Not embanked river	*Embanked river*
It is about annual average flood level.	It is fixed slightly below design flood level of the embankment.

Flood severity

Normal flood	When water level is up to 50 cm below danger level
Moderate flood	When water level is up to 50 cm above danger level
Severe flood	When water level is above 50 cm of danger level

In order to understand the current warning dissemination and response management and to develop appropriate dissemination and response procedures, pilot studies were conducted under the on-going DANIDA project for 3 flood vulnerable locations of the country. These included Sundarganj Upazilla in Gaibandha, Chouhali Upazilla in Sirajganj and Louhaganj Upazilla in Munshiganj.

According to the report of the pilot study (Development of People Oriented Flood Warning Dissemination Procedures, November, 2001), people never received flood warning in the past. People mostly knew about flood situation from public places like market, and neighbors and friends. Sometimes they also receive information through radio, television and newspapers. However, the information they receive through media is of a general type, not area specific. As a result, they cannot take action based on that information. On the other hand, the report finds that, the need for receiving advanced and appropriate flood warning had been rated very highly.

Similar information was also obtained by the Study Team through the field investigation, workshop, and awareness survey conducted under this Study. JICA Study Team conducted surveys in 15 locations throughout the country. The major findings are:

- No formal flood warning dissemination exists in rural areas.
- Local government administration and NGO should jointly work for warning dissemination.
- Village committee should be formed for warning dissemination.
- Awareness building is necessary.
- Farmers should get information on flood possibility.
- Local teachers and religious leaders should be involved.
- Means of dissemination are suggested as use of loud speakers, radio/TV, village meeting, newspaper, red flag, posters and leaflets.

The present flood warning dissemination procedure is given in the flow chart in **Figure 3.6.1**. FFWC is responsible to provide flood warning up to district level. However, in practice, FFWC provides flood warning to the district administration only when water level nears danger level. Below district administration, it is the responsibility of the local government institutions with indirect support from MDMR. Depending on the degree of disaster, the District Disaster Management Committee (DDMC) inform Upazilla Disaster Management Committees (UZDMC) by fax, phone and sometimes by police wireless. Though information is supposed to go to Union DMC from Upazilla DMC, in most cases, information does not properly reach the Union level. The major reason is that the communication between Upazilla and Union is not good in all cases. According to the Standing Orders of Disaster Management, the Union DMC is responsible to inform village people.

During the field investigation carried out by the Study Team in various districts, Upazilla and union in and around Sylhet, Rajshahi, Barisal, Faridpur, and Narayanganj, it was also found that although flood warnings are not received, there is good communication between district and Upazilla regarding the actual flood situation.

3.6.2 Problems Encountered

<u>*Lack of root level dissemination*</u>: Warning dissemination is yet to be satisfactory at the vulnerable communities. Though FFWC issues flood warning with 24 and 48 hour lead times, the flood information not always reaches to the ultimate users in time.

<u>*Short lead time*</u>: Various stakeholders mentioned that the present lead time is inadequate to take proper response action. It is also mentioned that 7 days lead time

for warning is considered useful, and a 5 day lead time is considered as required for proper response action.

Ambiguous warning message: The information provided in the present format is not easily understandable. The present flood information is given as the water level above the local danger level. Present danger level is marked only at selected places by the side of the major rivers and it is not possible to relate the danger level to inundation at certain inland places. Many local people do not have any idea where the local danger level bench is situated. Further, it is not possible to apprehend the water inundation at resident's place with such information.

Improper danger level: The present danger level fixation is rather old and it should be reviewed. In some cases, new embankments have been constructed since the last danger level fixation. In those cases, no flooding occurs even though there is a warning message.

Use of old topographic map: The topographic map used for flood forecasting is rather old. It is not possible to make accurate forecasts (depths of flooding) with this old map. Warning based on calculated inundation is different from the actual situation.

Accuracy of warning: Flood forecasting in the tidal region is often not accurate due to the tidal influence and cyclonic weather. Similarly, warning is not accurate for flash flood areas.

No specific warning for structures: Even BWDB does not routinely use flood warning for the operation of their own river structures. Other agencies operating river structures are also do not use flood forecasting specifically in their operation.

3.6.3 Conceivable Countermeasures

Proper root level warning dissemination: Improvement of flood warning dissemination will increase the benefit of FFWS even with the present flood warning accuracy.

As explained before, there is no fixed setup for warning dissemination below the Upazilla level. The major bottleneck is the information transfer from Upazilla to Union. One of the options is to have a wireless set at Union. However, to ensure proper maintenance of the wireless, it has to be purchased by the community. Another option is to send some messenger from Upazilla to convey the message to Union. Some incentive can be given to these messengers.

Another alternative can be conceived in line of Cyclone Preparedness Program (CPP). Under proposed Flood Preparedness Program (FPP), volunteers could be trained in each village to act as warning disseminator.

According to the report of the DANIDA supported pilot study (Development of People Oriented Flood Warning Dissemination Procedures, November, 2001), recommendations on warning dissemination are as follows:

- Flood type, timing, water level, expected duration should be included in warning
- Area to be inundated should be informed
- At least 5 days lead time is required
- Good reliability must be ensured
- Messages must be easily understandable, and
- Local dissemination mechanism must be enforced.

According to the same report, the following suggestions came out for the dissemination agent:

- At the union level, the Union Council Chairman and Members should be regarded as lead dissemination agents.
- Imam of the local mosque, teachers of local schools, and NGO workers should be entrusted with the main dissemination responsibility.
- Some viewed that paid staff should be employed for dissemination.
- Some viewed that the staff of BWDB should carry out the duty of warning dissemination.

The same Study also pointed out the means of information dissemination as suggested by the people. These are the use of loud speakers (mainly through mosques), drum beating, interpersonal communication, hoisting red flags and red light focusing.

Sufficient lead time: Study Team gathered the views of the people regarding sufficient lead time required to take response measures through discussion, awareness survey and consultative workshop. The general conclusion is that in future the lead time should be increased as much as possible. This lead time can be different based on the flood type. In flash flood area, at least 4 hours is required for evacuation. In other areas, at least 4 days is required from the agricultural and other damage reduction viewpoints. FFWC should issue flood warnings with a lead time that is maximum possible based on technological limitations.

Clear warning message: Area-wise flood forecasting should be developed. Instead of giving water level at major rivers, inundation maps should be issued. All important structures located in the particular area should be included in the map and response actions should be prepared.

Until there is a proper warning for the local area, it is possible to fix gauges in important places of the village and correlate these with the remote danger level. In this way, people will understand the meaning of the danger level-based warning.

Review of danger level: Danger levels should be reviewed periodically. IFWM of BUET made a study on the criteria of danger level fixation. That study should be consulted for next danger level review.

Preparation of new topographic map: To make proper flood warning, topographic mapping should be updated urgently. However, until that can be done, FFWC should at least give warning to Upazilla level even in general terms.

Accuracy of warning: Flood warning accuracy is important especially in tidal and flash flood areas. If people lose faith in the warning, proper evacuation could not be ensured.

Specific warning for structures: Warning should be provided for all river structures so that proper response action can be undertaken in case of emergency. Forecast of inundation to the major highways should be initiated right now. This will not only provide better countermeasures for flooding of roads and highways but also ensure better transportation planning.

3.7 Response System

3.7.1 Present Condition

The ultimate target of the flood forecasting and warning services is the response system, by which it would be possible to reduce damage during floods. There are various aspects of the response system shown below. Among these, the most important is to eliminate loss of human life.

Prevention items	*Response measures*
Human life loss	Evacuation
Livestock loss	Evacuation with livestock
Movable property damage	Evacuation with movable property
Immovable property damage	Preventive measures
Crop damage	Early harvesting, if possible
Fishery damage	Early catching or removal to safe place
River structure damage (embankment, pumping house, canal, gates, port, ferry terminal, bridge, etc.)	Respective preventive measures

Though it is mentioned in the Standing Orders on Disaster (1999) that the Disaster Management Committee (DMC) of District, Upazilla and Union level will assist in evacuation, it was found from the field investigation, workshops and awareness surveys conducted by the Study Team that no regular fixed systems for evacuation exist.

Because of the lack of security, people in general do not want to evacuate. In the cases of severe flooding in 1987, 1988 and 1998, the inundation periods were very long, more than one month at least. People do not want to evacuate for the entire period leaving their property. Except in the flash flood and tidal flood prone areas, flood waters rise very slowly, at around 20 to 30 cm per day. In the early stages of flooding, people make platforms within their house and start to live there. If flood waters increase further, many of them prefer to live on the roofs of their houses. Only in the extreme case, where flood water exceeds roof level, are they forced to evacuate. It was found that in all such cases people evacuated on their own.

When people are forced to evacuate, they mostly move to roads, embankments, nearby schools and other high rise structures. In cases of prolonged flooding, living standards of the people evacuated are generally miserable. There are severe shortages of food, medicine, drinking water and sanitation facilities.

The Study Team conducted surveys in 15 locations throughout the country. The major findings were:

- There is no organized and pre-planned evacuation
- There is lack of transport for evacuation and relief
- People do not want to evacuate leaving their house because of lack of security
- Security problem in the shelter, especially for women
- Insufficient food, medicine and safe water in shelters
- Poor food preparation and cooking arrangement in shelters
- Local teachers and religious leaders should be involved
- Village committees should be formed for evacuation management

At present there is no setup to move livestock. People arrange by themselves elevated places by putting earth for the livestock shelter.

There is no guideline for the people about prevention of damage to immovable property, agricultural crop and fisheries.

There is also no set policy to prevent damage of the river structure based on flood warning.

3.7.2 Problems Encountered

No formal evacuation system: The present setup for the evacuation system is seen as unsatisfactory. Though it is stated in the Standing Orders on Disaster (1999) that Union and Upazilla DMC will assist evacuation, it is not practiced.

No designated flood shelter: Although there are 1841 cyclone shelters designated (some of them specifically constructed as cyclone shelters), there are about 200 designated flood shelters. In times of emergency, people shelter on roads, embankments, schools and other high-rise facilities. Sometimes, district DMC and Upazilla DMC declare some facilities as evacuation shelters, but many times people just move to such places independently.

Lack of security: People do not want to evacuate because there is lack of security. This sometimes leads to loss of life.

Lack of transport: Since no formal evacuation system exists, there is also no plan for transportation for the people to move to shelters.

Low living condition in shelter: As there are no designated flood shelters, it is not always possible to ensure acceptable living conditions. Lack of food, medicine, drinking water and sanitation facilities causes diseases and health nuisance. This also discourages people from moving to shelters.

Lack of awareness: People are not motivated to make quick response.

No shelter for livestock: Livestock is an important asset of rural Bangladesh. Loss of livestock also indirectly hampers agriculture as cows are mainly used with ploughs.

However, there is no setup for sheltering of livestock at present.

No guideline to prevent property damage: There is no guideline for people regarding prevention of damage to immovable property, agricultural crops and fisheries.

No response guideline for river structures: At present, there is no set policy to prevent damage to river structures based on flood warning.

3.7.3 Conceivable Countermeasures

Establishment of formal evacuation system: A formal evacuation system should be established where Upazilla DMC will be the supervisor and Union DMC will be the executor. Local NGOs should be involved in the process. Volunteers should be trained, in a similar manner to CPP, to assist in the evacuation process.

Designation of flood shelter: Upazilla DMC should nominate some structures as flood evacuation centers. In case no such places exist, new shelters should be constructed similar to cyclone shelters. These could be used as schools in normal times.

Proper security measures: Upazilla DMC should arrange proper security during the period people are evacuated. Volunteers drawn from the flood affected people can patrol the area under supervision of Upazilla DMC.

Arrangement of transportations: The Upazilla DMC should prepare to arrange proper transportation during the time of emergency.

Ensure proper living condition in the shelters: Once the shelter is designated, it is possible to plan properly to ensure acceptable living conditions can be provided. Upazilla DMC will fix and inform District DMC about the route of relief movement to the shelter. There should be prior planning for drinking water and sanitation facilities in the shelters.

Awareness building: People must be motivated to take prompt response action. Orientation courses, small meetings and inter personal contact are the most effective modes of awareness building. Flood drills are also required for improved evacuation, as practiced by the Cyclone Preparedness Program (CPP).

Shelter for livestock: There should be some arrangements for livestock shelter.

Guideline to prevent property damage: There should be proper area specific guidelines to prevent flood damage prepared by District DMC. District DMC should periodically issue response measures based on warning information. In this regard, District DMC should work closely with Directorate of Agricultural Extension (DAE) and Fisheries Department.

Guideline for river structures: There should be proper facility specific guidelines prepared by respective agencies.

BWDB should start integrating flood forecasting with flood management for its important projects such as Megna Dhanogoda, Chandpur Irrigation, Pabna Irrigation, important projects such as Megna Dhanogoda, Chandpur Irrigation, Pabna Irrigation, Ganga Kapotak, NNIP, DND, CPP, etc. In the polder area, warning should be utilized for increased pumping in an anticipated flood water rise.

All agencies that maintain river structures like Roads and Highways Department (RHD), Railway, Local Government Engineering Department (LGED), Department of Public Health Engineering (DPHE), Bangladesh Inland Water Transport Corporation (BIWTC), Port Authorities, Bangladesh Agricultural Development Agency (BADC), and Local Government Institutions, etc. need to have their own action plan fully integrated with the flood warning.

3.8 Organizational and Institutional Matters

3.8.1 Current Situation of Flood Forecasting Sector

(1) Institutional Analysis of Flood Forecasting Sector

Many organizations are related with the flood forecasting sector besides FFWC or BWDB. A holistic institutional analysis is made to grasp the sector situation.

A matrix is prepared showing each institution's relation in policy making, laws and regulations, strategic planning, implementation, monitoring & information management, awareness raising, education, research & training, and resource mobilization. The Matrix is shown in **Table 3.8.1**.

(2) On-going Relevant Projects

Consolidation and Strengthening of Flood Forecasting and Warning Services (CSFFWS): This is an ongoing DANIDA assisted project with a total cost of around 4.5 million US$. The project period is from 2000 to 2004. The following key activities have been identified under this project:

- Capacity building
- Flood Forecasting Model update and expansion of forecast areas
- Upgrade of computer hardware and software
- Forecast of rainfall over catchments within Bangladesh
- Forecast of rainfall over upper catchments outside Bangladesh
- Further development of dissemination services
- Institutional development
- Real time data transmission system
- Low flow forecasting
- Technology transfer

Water Sector Improvement Project (WSIP), Water Management Improvement Project (WMIP): A World Bank preparation mission concerning this project was conducted in July 1999. The project is still in the process of negotiation. The main focus of WSIP will be reorientation of BWDB's role in the water sector by divesting small water sector schemes to Water Management Associations (WMA) and to enable it to effectively manage larger schemes which would remain under BWDB's jurisdiction. Thus, WSIP will be more concerned with operational aspects of water schemes. The World Bank preparation mission commented in July 1999 that the restructuring process has not adequately addressed the need for establishing a corporate management framework and further pointed to earlier indications made by IDA that the 1998 reorganization has not fully met the needs of improving organizational performance and decentralized management (Institutional Report No. 1, CSFFWS, DHI, March, 2001).

The name of this project is now changed to Water Management Improvement Project (WMIP) and this is taking over the entire scope of the WSIP. A report titled "Preparation Study" was published in June 2003 and WB appraisal will take place in December 2003. According to the "Preparation Study", there are two major focus points in the proposed project, institutional development of BWDB and rationalization of existing schemes. Preliminarily, implementation is expected to start from July 2004 and planned to be completed within 6 years with an estimated cost of 100 million US$.

Comprehensive Disaster Management Program (CDMP): This is a multi donor financed up-coming project coordinated by UNDP. It is a five year project to be started in 2003 with an estimated project cost of 14.5 million US$. Despite its title, the CDMP is, in fact, concerned primarily with institutional and organizational aspects, not major physical works. The components of the Phase I of the Project are as follows (Program Support Document for CDMP, UNDP, November, 2002):

1. Capacity Building
    a. Program, Policy, and Partnership Development Unit (PPPDU)
    b. Professional skilling of MDMR and key implementing agency staff
2. Partnership Development
    a. Advocacy program
    b. Training for national and sub-national officials of Government, NGO and private sector
3. Community Empowerment
    a. Program gap analysis for strategic partnerships
    b. Community risk reduction program
    c. Local disaster risk reduction fund
4. Research Information Management
    a. Urban risk research –earthquake emergency response
    b. Establishing an integrated approach to climate change risk management at national and local levels
5. Response Management
    a. Establish Disaster Management Information Center (DMIC) and strengthening information systems

It is to be noted that there is no item regarding flood warning dissemination and response is included in Phase I.

Others:

1. Environment Monitoring Information Network (EMIN) Project
   - Donor: Canada International Development Agency (CIDA)
   - Objectives: 1) To improve communication among Government and Non-government and other stakeholders for flood and erosion monitoring, 2) To improve good governance among stakeholders, and 3) To improve timely flood and disaster information to the stakeholders
   - Duration: 2003 - 2005
2. Community-based Flood Information System (CFIS) Project
   - Donor: the United States Agency for International Development (USAID)
   - Objective: To develop methodology to generate flood map in the floodplain and to develop system to reduce vulnerability at the community level using flood forecasting information issued by FFWC
   - Objective Area: Daulatpur and Nagarpur area
   - Duration: 2003 - 2007
3. Climate Forecast Application in Bangladesh (CFAB) Project
   - Donor: the United States Agency for International Development (USAID)
   - Objectives: 1) To increase lead time utilizing climate and oceanographic data, and 2) To develop and implement application of long, medium and short term forecast
   - Duration: 2003 - 2004

(3) Donor Activities in Flood Forecasting Sector

A large number of donors are actively supporting the sector. These include multilateral agencies such as World Bank, Asian Development Bank and Islamic Development bank; bilateral agencies from Japan, UK, Canada, Germany, Denmark, and Netherlands; and UN agencies like UNDP. There is a committee on the water sector under the Local Consultative Group (LCG) for coordination of the donor side in this sector. This committee sits regularly to review the sector activity, progress of donor assisted projects, and future donor strategy.

(4) Trans-boundary Information Acquisition and Application

Since 93% of the catchments of the major rivers of Bangladesh lie outside Bangladesh, trans-boundary information gathering is extremely important for proper flood prediction. The Joint Rivers Commission (JRC) is responsible for dealing with co-riparian countries on information acquisition. In the present system, Indian data are coming to FFWC through JRC and BMD.

According to FFWC, Bangladesh receives information of 10 water level stations only when the water level is less than 1 m below the danger level. Data from four stations are received via BMD and six are reported directly by wireless to FFWC stations for ongoing transmission. Also information from 26 rainfall stations is provided to Bangladesh, only when the observed rainfall exceeds 50 mm/day.

However, this information is not used in the FFWC model. According to the Joint Rivers Commission (JRC), because of this, it is rather difficult on their part to request information from India for information from more stations.

(5) Disaster Management

Disaster management includes cyclone protection, flood proofing, erosion control, drought management, in addition to the wider and more general requirements for disaster preparedness and post-disaster relief. Ministry of Disaster Management and Relief (MDMR) is the responsible ministry for this and implements the activities through two line agencies, namely, Disaster Management Bureau (DMB), and Directorate of Relief and Rehabilitation, one center namely, Emergency Operation Center (EOC), Local Government Institutions like District, Upazilla and Union Councils, and NGOs like Red Cross. There is an Inter-Ministerial Disaster Management Coordination Committee headed by the Minister of MDMR, and a National Disaster Management Council chaired by the Prime Minister.

Disaster management activities in Bangladesh date back three decades. The Cyclone Preparedness Program (CPP) was initiated after the 1970 cyclone. Standing Orders for Floods and for Cyclones were issued in 1984 and 1985, respectively, supplemented by Emergency Standing Orders in 1996. In 1999, revised Standing Orders on Disaster were issued. As a result, the country now has a highly effective Cyclone Preparedness Program. A Comprehensive Disaster Management Program (CDMP) is currently being prepared with UNDP assistance, details of which are explained above. Disaster awareness is now included in national school curriculums from grade 5 to grade 12.

The DMB plays a central role in disaster preparedness. Created in 1994, DMB provides services such as awareness raising, collecting, preserving and disseminating management and geographical information and damage assessment. It is also responsible for managing disaster in all stages (pre, during and post). DMB carries out its responsibility through disaster management committees at Union (headed by Union Council Chairman), Upazilla (headed by Upazilla Executive Officer), and District Level (headed by Deputy Commissioner). DMB is also preparing the Local Disaster Action Plan (LDAP). Together with the Cyclone Preparedness Program (CPP), DMB has already provided training to 35,000 volunteers, who are the principal workforce for cyclone warning dissemination and evacuation.

Directorate of Relief and Rehabilitation is a post-disaster management body. Based on the local demand, it allocates relief money and materials to the local authorities.

The EOC is the control room for the disaster. This acts as a focal point within the MDMR for all types of disasters. It operates 8 AM to 8 PM in normal time and 24 hours in a disaster situation. EOC has wireless communication with all 64 district administrations. In addition, there are wireless communications with 95 coastal stations for cyclone management. In normal time, information from these 159 places comes to EOC at least twice a day; while in disaster time, communication with these stations is continuous. Basically, two types of information come to EOC, damage information and relief requirements. EOC compiles the damage information for each district by several categories like agricultural damage, loss of life, livestock loss, homestead loss and loss of various infrastructures. For the relief requirement information, EOC passes it to the Directorate of Relief. Also, EOC receives information from Directorate of Relief on actual relief disbursement. Based on this information, EOC maintains a relief situation database for each district showing various categories like money, food, clothes, etc.

(6) Role of Local Government in Flood Situation

At present, the Local Government Institutions (LGIs) are relatively weak. They are largely dependent on the Department of Public Health Engineering (DPHE) and Local Government Engineering Department (LGED) to undertake their works program. Generally, decisions on projects to be taken up are made centrally. Funding and recruitment are also centrally controlled. Another major weakness of the LGIs is that they are allowed to handle small amounts of funds. There are also severe technical limitations on part of LGIs.

In the context of the flood, LGIs are responsible for flood warning dissemination and evacuation. Because of their weak institutional strength, it is not always possible for them to deliver the required service.

(7) Role of NGOs in Flood Situation

Local, national and international NGOs provide goods and services to the community. In some sectors, like micro-credit, non-formal education, primary health care and income generation activities, the NGOs of Bangladesh are internationally recognized for their success. NGOs are increasingly influencing public opinion on various issues namely land reform, gender equality, education, water supply and sanitation, environment and water management. NGOs are also involved with advocacy for the underprivileged groups.

Because of their intense interaction with the people, the NGOs are in an advantageous position. Some of the NGOs are banking on this and embarking into specialized fields. Some of the NGOs are already engaged in the flood related sectors in different ways. These include mainly post flood response, flood proofing livelihood, and recently, warning dissemination, evacuation, and flood awareness building.

(8) Information Management and Research and Development

The National Water Policy emphasizes research and information management. The Policy also assigns responsibility to WARPO for development of a central database and management information system that would consolidate information from various agencies in the water sector. NWMP also recommends that WARPO should receive and archive copies of all water sector reports including digital formats.

The National Water Resources Database (NWRD) has been setup in WARPO with support from CEGIS and IWM. The primary activity of NWRD is to meet the demand of water resource planners for a consolidated and reliable data bank. At present, NWRD has more than 300 data layers in several main groups like base data, surface water, groundwater, soil and agriculture, fisheries, forest, socio-economic, meteorological, environment and images.

Research in the water sector needs to be focused on areas that directly contribute to improved performance of the sector. The National Water Policy specifically identifies areas where further study is required to allow decisions of strategic importance to be made. These include water and land management, agricultural research, flood control and management issues, sociological issues (like interference with water structures), waste reduction, efficient water use, and conjunctive water use.

This research should involve public and private research institutions and universities. The Institute of Water and Flood Management (IWFM) of Bangladesh University of Engineering and Technology (BUET) is one of the leading research bodies in this sector.

IWFM was established in 1974 within BUET to conduct basic research, carry out human development, and provide advisory services on flood and water management. The Institute has carried out about 100 research projects in the areas of hydrology, morphology, river mechanics, coastal hydraulics, groundwater, agriculture, water management and environment. Major relevant researches by IWFM includes:

- Investigation of the Mechanism of Flash Floods (JICA, 1997)
- Selection of Probability Distribution Function for Flood Frequency Analysis in Bangladesh (UNDP, 1995)
- Study on Revision of Danger Level (UNDP, 1995)

3.8.2 Problems on Institutional Matter

(1) Institutional Weakness of BWDB

<u>Centralized administration of BWDB</u>: BWDB is a top down centralized agency. Field offices of BWDB are responsible for only operation and maintenance of the existing facilities. Planning and design activities are carried out centrally. Projects are implemented by project offices. Because of this, there is a lack of coordination among various units of BWDB at field level. Hydrology field levels staff cannot utilize properly the logistics of the O&M wing. To reduce cost, hydrology should share various logistic facilities including cars with the O&M offices.

<u>Centralized administration of Hydrology</u>: The Hydrology service is also a centralized unit. The field offices of Hydrology just collect the data. Data entry, validation, compilation, storage and flood forecasting is done centrally. As a result, it is not

always possible to take the regional context into account. Since there are no field staff of C&I division, every time there is a problem with the data transmission, staff of C&I have to go to the field from Dhaka.

Organizational setup of Hydrology: In the present organization of Hydrology service (**Figure 2.8.3**), all field observations are done by three data collection circles. After that data are transferred to PFFC for processing by the three respective branches. However, PFFC also includes FFWC and an electro-mechanical division. As a result, PFFC has various different types of work responsibility.

Inadequate O&M budget: According to the Annual Report of BWDB 2000-2001, actual O&M budget allocation is significantly less than the requirement. The comparison is shown below:

Unit: Million Taka

Year	OM fund available	BWDB's Projection for fund
1995-1996	2,677.62	5,029.37
1996-1997	2,619.87	4,300.22
1997-1998	2,188.37	4,073.15
1998-1999	2,408.09	4,249.60
1999-2000	2,944.45	4,563.98
2000-2001	3,133.43	4,369.03
2001-2002	2,886.00	4,063.33

Source: Annual Report, BWDB, 2001-2002

In 2001-2002, the O&M fund available is only about two-third of the requirement.

Weak accountability: Accountability of the staff is rather weak. Because of this, full utilization of human resources cannot be assured.

Poor monitoring system: There is no set monitoring guideline in BWDB. Monitoring is done in discrete ways. Also, a feedback system is non-existent.

(2) Operation and Maintenance

No formal operational procedure: In most cases, it was found that there is no set operational manual for the operation of specific facilities of BWDB. Further, no ledger book is kept for each facility. Also, there is no permanent inspection and monitoring schedule. It was found by the Study Team that many items of equipment and ancillary facilities have been stolen from various facilities.

Untimely budget allocation: It is reported that it takes sometimes 3 to 6 months to receive the allocated budget by the circle and division office. This creates problem in proper operation and maintenance.

Poor water levy collection: As explained in **Section 2.8.4**, water levy collection is extremely poor.

Vacancies in key positions: BWDB faces a paradoxical situation in that while it has a sizeable staff surplus, it suffers from acute shortage of professional staff. As at 30 June, 2001, there were 200 vacant technical posts. (Annual Report, BWDB, 2001-2002).

Insufficient logistic support: Logistics required for proper operation and maintenance are lacking.

(3) Information Management

Lack of integrated data management: Though information on various projects of BWDB is maintained in a scattered way, there is no central integrated database. Difficult retrieval of project information not only makes the planning process difficult but also hampers operation and maintenance work. However, the office of the Chief Engineer is now preparing a database for all projects.

Old topographic mapping: The present Digital Elevation Model (DEM) is based on rather old topographic information. Because of this, accurate area-wise flood forecasting is not possible.

(4) Skill Development

Staff Training: At present, there are training facilities of BWDB and staff receive training. From time to time, staff also go abroad to receive training. However, most of these are demand driven. There is no set rule and no provision of continuing education.

Merit based promotion: In most cases, the promotions of BWDB staff are based on seniority. For better efficiency, merit based promotion must be introduced.

Quick rotation: Usually, the staff of BWDB is rotated every few years. This is not always conducive to skill development, especially for hydrology services.

Lack of incentives: There is no overtime allowance for BWDB officers. There is an allowance for research, design and planning staff. However, staff of FFWC do not get any incentive though they must put in long hours during emergency situations.

Applied research: The river network of Bangladesh is complex. Many of the physical phenomena like erosion, siltation, flash flood and river course change are not well understood. Some research is carried out by IWM, CEGIS, and IWFM of BUET. More research is needed to understand these phenomena so that proper steps can be taken.

Lack of multi-disciplinary staffing: Interaction of the water sector with so many other sectors, especially with the social sectors requires multi-disciplinary staff.

(5) Inadequate Warning Dissemination and Response

Weak Local Government Institutions: Because of the weak local government institutions, they cannot carryout their stipulated duties of flood warning dissemination and evacuation.

No setup like CPP: Cyclone Preparedness Program (CPP) is functioning very well. However, there is no such setup for flood management.

No warning and response for river structures: At present, there is no specific warning dissemination for river structures operated by BWDB and other agencies.

Subsequently, there is no response system incorporating the flood warning.

(6) Planning Issues

FFWS in NWMP: The National Water Management Plan will become an umbrella plan for the water resources sector after its approval. Although there are some indicative directions for FFWS in the NWMP, there are no specific targets and execution course.

Program-based approach of NWMP: NWMP adopted a program-based approach. As a result, specific intentions and schemes are not underlined. A separate study should be undertaken for each sub-sector to identify the schemes.

No up-to-date water balance study: For comprehensive water sector planning, detailed water balance is essential. However, no up-to-date detailed water balance study is available.

FFWS in CDMP: A new project, the Comprehensive Disaster Management Program (CDMP), has been started in 2003 with UNDP support. However, FFWS is not well defined in this program.

No land use policy: Until now, there is no nationwide land use policy. Absence of this may lead to unplanned development, which in turn, would create increased flood and water logging hazards.

No water code: A national water code is under preparation. Without clear water rights and water allocation, it is difficult to develop proper water resources development plans.

(7) Management of Trans-boundary River Issues

Insufficient Indian data: For both accuracy and lead time improvement, information on water level and rainfall in the international rivers upstream of Bangladesh is extremely important. At present, the quality of data obtained from India is insufficient. Water level information is given to Bangladesh only when it is near the danger level. All the water level information given to Bangladesh is from stations close to the borders, which carry less importance than that of further upstream sites. Also there is no information shared on the river cross-sections. These lead to difficulties in flood forecasting.

No direct application of Indian Data: It is difficult to incorporate the limited data that FFWC now receives from India. However, use of this information in the model could provide improved forecasting, which in turn, would help JRC to negotiate its receipt from India.

Lack of proper water sharing treaty: There are many trans-boundary rivers in Bangladesh coming from India. In some cases, India has constructed dams and barrages in the upstream reaches of these rivers. Lack of a proper water sharing treaty with India sometimes causes uneven water distribution.

There was an agreement signed on Ganges water sharing at Farakka Barrage in 1996. The principal point of that treaty is that during the dry period, Bangladesh will get at least 50% of the total flow available. However, the treaty failed to address the wet season water sharing.

For the other rivers, like Teesta and Monu, no agreement is reached yet.

(8) Limited Participation of NGOs and Private Sector

Private sector participation: It is widely recognized that the public sector can no longer be, nor should be, the provider of all infrastructure and services. There are practical advantages in an increased role of the private sector. Infrastructure will be often provided more speedily. Increased efficiency associated with innovation, management expertise and incentives will reduce risks and time and cost overruns. However, since flood management and especially flood warning services is a sensitive sector, it is possible to entrust only part of the services with the private sector.

Participation of NGOs: Achievements of NGOs in Bangladesh are considered as a success story. Involvement of NGOs in CPP has also proved to be effective. At present, no such role is defined for NGOs in flood disaster management.

3.8.3 Conceivable Countermeasures

(1) Institutional Strengthening of BWDB

Decentralized administration of BWDB: For efficient functioning, better coordination and cost reduction, regional offices should have more authority. Some regional offices can be established that can carry out planning, designing and hydrology related activities. As mentioned in the earlier section, World Bank and IDA are also advocating decentralization of BWDB.

Decentralized administration of Hydrology: For better field level coordination and consideration of local context, regional offices of Hydrology service can be established. In addition to data collection, compilation, and relevant maintenance, these offices can also provide regional flood warning. Comparative merit of the centralized and decentralized administration of Hydrology service in respect to FFWS service is given in **Table 3.8.2**.

Organizational setup of Hydrology: PFFC should be reorganized based on the work responsibility. Since C&I division is the single electro-mechanical division of Hydrology, it should function independently of PFFC. Similarly, the work of FFWC is different from the other processing branches and therefore, it should function separately. All supporting activities required for flood forecasting should be brought under FFWC.

Adequate O&M budget: Provision should be made for greater budget allocation for the operation and maintenance of BWDB facilities. As mentioned in the table in **Section 2.8**, O&M budget allocation to BWDB in 2001-2002, it is only around two third of the requirement. Without extra funding available, it would not be sustainable to introduce a telemeter system in FFWS.

Strong accountability: Proper accountability should be ensured for better working efficiency. Performance based rewarding system should be introduced.

Adequate monitoring system: Proper guideline for monitoring should be established. A strong feedback mechanism should be introduced. Institutional review should also be done every 5 years.

(2) Operation and Maintenance

Formal operational procedure: There must be an operational manual. A ledger book must be maintained for each facility. This ledger book will record the entire history of the facility and also the inspection and monitoring schedule.

Timely budget allocation: Timely release of funding at the beginning of the financial year is important for appropriate operation and maintenance.

Water levy collection: A working procedure should be practiced to collect water levies. Field operation offices should be allowed to retain that money to utilize for maintenance. Water user associations should be organized to improve the levy collection.

Filling vacancies in key positions: Vacancies in key technical positions will harm proper functioning. The posts should be filled urgently. If it is not possible due to government regulations, steps should be taken to fill the post temporarily or relocate surplus staff.

Sufficient logistic support: Sufficient logistic support is required for accurate operation and maintenance. To reduce the cost, sharing of facilities among various units is recommended.

(3) Information Management

Integrated data management: The Office of the Chief Engineer, O&M is now preparing a database for all projects. It must be completed as soon as possible. Also, all future new projects and changes in existing structures must be included in the database immediately. This should be available to all concerned planning officials.

New topographic information: A new Digital Elevation Model (DEM) must be prepared with present topographic information. With this, accurate area-wise flood forecasting will be possible.

(4) Skill Development

Staff Training: Set rules should be established for regular and periodic staff training including continuing education.

Merit based promotion: For better efficiency, merit based promotion must be introduced.

Appropriate rotation: Staff rotation should be planned appropriately, especially for the top management of Hydrology.

Proper incentive: Incentive mechanisms should be introduced for increasing motivation of the staff, especially for the staff of FFWC.

Applied research: More applied research is needed to understand the complex physical phenomena of the river network of Bangladesh in the fields of erosion, siltation, flash floods and river course changes.

Multi-disciplinary staffing: Multi-disciplinary staffing is important for the flood management field to incorporate social approaches.

(5) Inadequate Warning Dissemination and Response

Strong Local Government Institutions: The main responsibility of flood warning dissemination and evacuation lies with local institutions. To carry this out, there must be strong set ups within the local government institutions. In these, BWDB should have a monitoring function. There should also be feedback systems.

CPP-like setup: The Cyclone Preparedness Program (CPP) is functioning very well. A similar setup is required for flood response. Under the proposed Flood Cyclone Preparedness Program (FPP), volunteers should be trained, who would carry out warning dissemination and assist in evacuation.

Proper warning and response for river structures: All river structures are beneficiaries of flood forecasting services. Warnings should be specifically made for the structures and there should be an operation guideline incorporating response based on flood warnings.

(6) Planning Issues

FFWS in NWMP: There should be overall target and implementation strategies for FFWS in NWMP.

Scheme identification from NWMP: NMWP provides a program-based approach. Sub-sector studies should be undertaken to identify specific schemes in the light of NWMP.

Updating water balance study: A nationwide water balance study should be updated periodically. This will help comprehensive water sector planning.

FFWS in CDMP: In the up-coming UNDP-financed Comprehensive Disaster Management Program (CDMP), FFWS should be defined clearly.

Land use policy: A national land use policy is to be prepared for coordinated development planning.

Water code: A national water code is urgently required to coordinate water sector development planning.

(7) Management of Trans-boundary River Issues

Insufficient Indian data: For both accuracy and lead time improvement, information of water levels and rainfall in the upstream reaches of the major rivers is extremely important. Steps should be taken to get all relevant information from India such as, continuous water levels of all major rivers upstream to Patna (Ganges) and Dibrugarh (Brahmaputra), and cross-sections of all major rivers at least up to Patna. This will help improve flood forecasting.

Use of currently available Indian data: Currently available Indian data should be used in the model to show the importance of such data. This will help JRC to negotiate with India for additional information.

Proper water sharing treaty with India: Water sharing treaties of all major international rivers should be concluded as early as possible. An international body similar to the Mekong Committee can be established to deal with these issues.

(8) Increased Private Sector and NGO Participation

Private sector participation: Since the flood forecasting and warning services are a sensitive sector, only part of the services can be handed over to the private sector. Part of data acquisition, data transmission, and warning dissemination can be effectively handed over to the private sector for better results. In the case of data processing, the on-going DANIDA project recommends that IWM will periodically update the model. This kind of involvement along with technical input from competent consultants is encouraged. Present utilization of the private sector in data transmission can be further increased. In the case of warning dissemination, private printed and electronic media is already doing a good amount of work. This can be made more rigorous. Part of data collection can also be handed over to the private sector. For example, gauge readers may be appointed on a contract basis to increase their accountability.

Participation of NGOs: Achievements of NGOs in Bangladesh are considered a success story. Involvement of NGOs in flood warning dissemination, evacuation and awareness building will bring better service delivery.