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COMMUNITY FLOOD INFORMATION SYSTEM (CFIS)

FINAL REPORT

JUNE 2008

This publication was produced for review by the United States Agency for International Development. It was prepared by Riverside Technology, inc (RTi), the Center for Environmental and Geographic Information Services (CEGIS) and the Bangladesh Disaster Preparedness Center (BDPC).

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Office of U.S. Foreign Disaster Assistance (OFDA)
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Community Flood Information System (CFIS)

Final Report

May 2008

Prepared by:

Riverside Technology, inc.

CEGIS Center for Geographical Information Services

BDPC Bangladesh Disaster Preparedness Center

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BDPC disseminated flood information and warnings to affected communities, and provided training on interpreting and using the flood information to prepare for and mitigate impacts of flooding. The CFIS project director from BDPC was Muhammad Saidur Rahman and the project specialists included Moloy Chaki, M. Kamran Jacob, Nasir Uddin Ahmad, Md. Abdus Samad, and Suman Kanti Das.

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Acronyms

ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Center
BARC	Bangladesh Agriculture Research Center
BBS	Bangladesh Bureau of Statistics
BDPC	Bangladesh Disaster Preparedness Centre
BIWTA	Bangladesh Inland Water Transport Authority
BMD	Bangladesh Meteorological Department
BWDB	Bangladesh Water Development Board
CDMP	Comprehensive Disaster Management Programme
CEGIS	Center for Environmental and Geographic Information Services
CFAN	Climate Forecast Applications Network
CFIS	Community-based Flood Information System
CIDA	Canadian International Development Agency
CSFFWS	Consolidation and Strengthening of Flood Forecasting and Warning Services
DAE	Department of Agriculture Extension
DANIDA	Danish International Development Agency
DEM	Digital Elevation Model
DGPS	Differential Global Positioning System
DHI	Danish Hydraulic Institute
DMB	Disaster Management Bureau
DMCs	Disaster Management Committees
DMIC	Disaster Management Information Centre
EGIS	Environment and Geographic Information System Support Project for Water Sector Planning
EMIN	Environmental Monitoring Information Network
FAP	Flood Action Plan
FFWC	Flood Forecasting and Warning Centre
GBM	Ganges, Brahmaputra, and Meghna (Rivers)
GeoSFM	Geospatial Stream Flow Model
GIS	Geographic Information System
GMS	Geostationary Meteorological Satellite
GPS	Global Positioning System
GTS	Global Telecommunication System
ICT	Information and Communications Technology
ICTDG	Information and Communications Technology Development Group
IMDMCC	Inter-Ministerial Disaster Management Coordination Committee
IRS	India Remote Sensing
ISESCO	Islamic Education Scientific and Cultural Organization
ISPAN	Irrigation Support Project for Asia and the Near East
IWM	Institute of Water Modeling
JICA	Japan International Cooperation Agency
JRC	Joint River Commission
MoDMR	Ministry of Disaster Management and Relief
MPO	Master Plan Organization
NASA	National Aeronautics and Space Administration

NDMAC	National Disaster Management Advisory Committee
NDMC	National Disaster Management Council
NGO	Non-Government Organization
NOAA	National Oceanic and Atmospheric Administration
NWRD	National Water Resources Database
OFDA	Office of US Foreign Disaster Assistance
PWD	Public Works Department
RTi	Riverside Technology, inc.
SAR	Synthetic Aperture Radar
SMS	Short message service
SPARRSO	Space Research and Remote Sensing Organization, Bangladesh
SRDI	Soil Research and Development Institute
SWC	Storm Warning Centre
TDC	Thana Disaster Committee
UDC	Union Disaster Committee
UDMCs	Union Disaster Management Committees
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
USGS	United States Geological Survey
UzDMC	*Upazila* Disaster Management Committee
VFMC	Village Flood Management Committee
WARPO	Water Resources Planning Organization
WB	World Bank
WFP	World Food Programme
WMO	World Meteorological Organization
WV	World Vision

Summary

The Ganges, Brahmaputra, and Meghna (GBM) river systems in India and Bangladesh are some of the most flood-prone river systems in the world. Excessive floods present serious risks to the millions of people living in the floodplain areas. In a normal year an estimated 25 percent of Bangladesh is flooded, whereas, in an excessive flood year an estimated 65 percent of the country is flooded. Despite constant and pervasive flooding, Bangladesh does not have an effective system for providing useful flood forecasts or other flood warning information at the community level. The present system of government-issued flood warnings is presented in both a context and a format that are neither understood nor usable by the floodplain inhabitants.

The overall goal of this project was to reduce vulnerability to damage due to flooding in the floodplains of Bangladesh. This was accomplished by providing useful, timely, and understandable flood information at the community level in a study area. Farmers, fishers, and other floodplain dwellers strongly expressed their need for forecasts and related information during periods of potentially disastrous floods to enable them to take early action to mitigate against damage and loss of property. Also, field investigations indicated that floodplain communities would benefit from forecasts during unusually low floods and even during the "normal" flood to support daily decisions on managing their livelihoods and their resources. The present river-based system for monitoring and forecasting floods is inadequate for floodplain communities where rural inhabitants reside and maintain their livelihood. Furthermore, the government-issued flood warnings are presented in a context and format that is not understood or usable by the communities and floodplain inhabitants.

For communities and inhabitants to benefit from flood forecasts, the information must be timely and in a format that is understandable and useful. This project fully recognized the technical challenges of creating reliable local level forecasts, and the equal, if not greater, challenge of communicating the information to local communities. This project, entitled "Vulnerability and Risk Reduction Through a Community-Based System for Flood Monitoring and Forecasting" is known in short as the *Community Flood Information System*, or CFIS. The CFIS project was designed as a pilot operational system to produce accurate and timely information on current and forecasted flood conditions for a floodplain study area. The project was split into three main components:

- ***Pilot Operational System*:** An operational pilot system was developed to produce daily flood monitoring and forecast maps for use at the community level. The pilot system was designed to operate during the 2004-2007 flood seasons, providing the project with a range of hydrological conditions (wet and dry years) for analysis and evaluation.
- ***Flood Mitigation*:** Flood information was provided to the local government and communities in the study area to help them to mitigate potential impacts of flooding. Cooperation and partnerships with other organizations were sought to leverage resources and broaden dissemination and flood mitigation activities.
- ***Replication*:** In addition to the operating system and flood mitigation, the final two years of the project sought methods and sources for extension and replication of the CFIS in other flood-prone areas of the country.

The CFIS project and related activities have made great progress over the past decade to forecast floods beyond the main rivers and to disseminate information to stakeholders beyond the national agencies. The main achievements and success of the CFIS project are described below:

Needs assessment: Over a two-year period, CFIS conducted detailed assessments to understand the complex needs of communities and local government for flood information, the format and content required for effectively communicating the information, and the training and awareness building that would be needed for stakeholders to fully understand and use the information to reduce losses from floods. In addition, CFIS project proponents participated in several other related assessments funded under projects of the Bangladesh Government, Asian Development Bank (ADB), Canadian International Development Agency (CIDA), United Nations Development Programme (UNDP), and others.

WATSURF: CFIS developed an innovative system for efficient and accurate floodplain modeling, along with an automated dissemination module. Flood forecasts are created for the study area as a digital map, allowing automated distribution of site-specific forecasts for any location. The 48-hour forecasts are accurate, with average error of 15 cm. In addition, WATSURF automatically creates inundation and flood-depth maps that can be used for risk and vulnerability assessments, for flood loss and damage estimates, and for targeting areas for relief and reconstruction activities.

Dissemination: CFIS explored a number of techniques for disseminating flood information to communities and local governments. Most successful in 2007 was automated SMS text messaging with multiple pathways to local governments, to key opinion leaders—such as school teachers, imams and shopkeepers—and directly to vulnerable households. Recipients had previously agreed to, and succeeded in, passing on warnings to their neighbors and wider community, and a network of flag sites, bulletin boards, and awareness raising exercises reinforced this effort.

Cellular telephone technology: With over 35 million subscribers in Bangladesh in 2007, mobile telephones are transforming communications in the rural, flood-prone areas. This created an important opportunity for low-cost, reliable, and deeply penetrating dissemination of flood forecasts to vulnerable communities. In the beginning of the CFIS project there were very few telephones in the project area; over half the project area had no telephones at all. By 2007, the entire area was fully covered by cellular networks from multiple, competing private companies. In every village, there are shopkeepers, boat owners, and schoolteachers that now own and use cell phones. Even some rickshaw pullers carry phones and lease the phone time out to their customers.

Public-private partnerships: The opportunity for partnerships is growing rapidly, particularly in using technology for development. All three cellular telephone companies approached by CFIS were interested in supporting the project with low- or no-cost dissemination of flood forecasts via SMS as an area of corporate social responsibility. CFIS secured an agreement with Banglalink, the second largest mobile company, for transmitting flood forecasts via SMS for both the 2007 and 2008 flood seasons at no cost. This pilot arrangement is the first known in Bangladesh to use mobile phone technology to disseminate early warning messages; such arrangements will be critically important as effective, low-cost methods for operational early warning for floods and other hazards.

Engaging the government and other stakeholders: As a pilot project, some elements of CFIS operated outside the established government disaster management system, in part because the established government system does not work well. CFIS created information that currently does not exist (flood forecasts in the densely populated and high-risk floodplains) and disseminated information using both established pathways (within the government system) as well as more direct, efficient pathways down to the household level. During the course of CFIS and via the project's relationship with EMIN, the project raised the awareness of all relevant government agencies about the need for accurate local flood information that can be clearly communicated to affected stakeholders.

Chapter 1
Introduction and Background

1.1 Introduction

This final report concludes the findings and experience for the project "Vulnerability and Risk Reduction Through a Community-Based System for Flood Monitoring and Forecasting," or the Community Flood Information System (CFIS) in short. The project was prepared in response to the April 24, 2002, annual program statement *"Enhanced Disaster Preparedness in South Asia: Through Community-Based and Regional Approaches"* of the U.S. Agency for International Development (USAID), Bureau for Humanitarian Response, Office of U.S. Foreign Disaster Assistance (OFDA).

Riverside Technology, inc. (RTi), the Center for Environmental and Geographic Information Services (CEGIS), and the Bangladesh Disaster Preparedness Centre (BDPC) conducted the project that was initiated in October 2002 and completed in March 2008.

1.2 Bangladesh Floods

Excessive floods in the Ganges, Brahmaputra, and Meghna (GBM) river systems in India and Bangladesh present serious risk to the millions of people living in the floodplains, but much of the same population also relies on the floodplain and its annual "normal" flood for agriculture and fisheries-based regional economies. In a normal year, an estimated 25 percent of Bangladesh is flooded, but in an excessive flood year, such as 1998, an estimated 65 percent of the country is flooded (FFWC, 1998). Despite pervasive flooding, Bangladesh does not have an effective system for providing useful flood forecasts or other flood information at the community level.

As described further in ***Chapter 2***, there are four main types of flooding in Bangladesh: 1) coastal storm surge flooding; 2) flash flooding; 3) monsoon floods associated with the rise of major river systems; and, 4) floods from high intensity rainfall in the monsoon season (WARPO, 1999). The CFIS project is concerned with flood information about the latter two types of floods and the longer duration flash floods in the northeast of the country. These types of floods cover most of the floodplains of Bangladesh with the exception of the coastal regions that are prone to cyclone storm surges, as discussed further in ***Chapter 2*** (***Figure 2.1***).

Due to the flat relief of Bangladesh, a small increase in water level above riverbanks can cause extensive inundation. Affected areas of different return period floods are presented in ***Table 1.1***. The difference in peak water levels between the 2- and 20-year return periods is about two-meters, with a one-meter difference between the 20- and 100-year return periods.

Table 1.1: Area of Bangladesh affected by floods of different return periods

Return period (years)	2	5	10	20	50	100	500
Area affected (% of the area of Bangladesh)	20	30	37	43	52	60	70

Source: (Shajahan, 1998)

The economic and other damage due to floods is increasing in Bangladesh (Rogers et al., 1989) due to a number of factors. First, the population of the country, at about 150 million as of July 2007, is growing at an annual rate of nearly 1.5 percent (BBS, 2001), while the amount of cultivated land remains nearly constant (Ahmad, 2001). Thus, the increase in the number of people and the amount and type of infrastructure directly occupying the floodplain is increasing Bangladesh's vulnerability to flooding. These activities also reduce the floodplain water storage capacity and exacerbate the potential for flood damage (WARPO, 1999). Superimposed on increasing population and infrastructure developments within Bangladesh's boundaries, and on recent trends in flood extent and damage, the effects of climate change are likely to further complicate the flood situation with a consequent increase in flood risk.

1.3 Rationale and Project Goal

The overall goal of this project was to reduce vulnerability to damage due to flooding in the floodplains of Bangladesh. This was accomplished by providing useful, timely, and understandable flood information at the community level in the selected study area. Farmers, fishers, and other floodplain dwellers strongly expressed their need for forecasts and related information during periods of potentially disastrous floods to enable them to take early action against damage and loss of property. In addition, field investigations indicated that floodplain communities would benefit from forecasts during unusually low floods and even during the normal flood to support daily decisions on managing their livelihoods and their resources (RTi and EGIS, 2000). The present river-based system for monitoring and forecasting floods is inadequate for floodplain communities (WARPO, 1999; FFWC, 1999). Furthermore, the government-issued flood warnings are presented in a context and format that is not understood or usable by the communities and floodplain inhabitants (BDPC, 2002).

An earlier study conducted by RTi and EGIS systematically identified users, requirements, and capabilities for accessing, processing, and using information for Bangladesh flood management (RTi and EGIS, 2000). In addition, the need for flood forecasts and flood information at community level is widely recognized by other studies -- for example ADB (2006), WARPO (1999), FFWC (1999), FFWC (2002), UNDP (2001), and MDMR (2000) – including the need for understandable, local-level forecasts (BDPC, 2002) as well as historic information on flood frequency and current monitoring information. However, comprehensive flood inundation/risk maps are essentially non-existent. Consistent monitoring and data collection on flood extent, depth, and duration, which is at the base of any information provision, is substantially lacking, both for supporting flood management in general and for disaster management in particular (Martin, et al., 1996). Similarly, damage functions are not well defined as deviations from normal floods. In addition to these data collection and processing constraints, the available information is not effectively disseminated and potential users are not aware of how to get the information (EGIS and RTi, 2000).

The Bangladesh Flood Forecasting and Warning Centre (FFWC) receives data on water level and rainfall from a number of stations throughout the country and provides forecasted water levels with 48-hour lead times for 52 point locations on the major rivers of Bangladesh and their primary distributaries. This is indeed a useful system that forecasts with a mean absolute error of about 10 cm at a 48-hour lead-time. The system is less reliable in the coastal zones and near the border (ADB, 2006). Additionally, the FFWC forecasts and related monitoring information of the Bangladesh Water Development Board (BWDB) are river-based systems, relevant for the main rivers and their distributaries, but do not provide forecasts or other information for the floodplains and communities most affected by riverine floods. Furthermore, the forecasts are presented in a context and format that is not understood or usable by the communities and floodplain inhabitants (BDPC, 2002). Addressing these two limitations was a goal of this project.

For communities and inhabitants to benefit from flood forecasts, the information must be timely and in a format that is understandable and useful. Several government projects and NGO activities are addressing the need for disseminating reliable flood forecasts to Bangladesh floodplain communities. Among others, the NGOs CARE and World Vision are implementing community-based flood mitigation programs. The FFWC has conducted pilot projects in different flood-prone areas to improve the dissemination of flood forecasting and warning messages to local level governments, NGOs, and to local communities (FFWC, 2002). This CFIS project fully recognized the technical challenges of creating reliable local level forecasts, and the equal, if not greater, challenge of communicating the information to local communities (FFWC, 2002; BDPC, 2002).

1.4 Target Community Profile

Broadly defined, the targeted at-risk communities are rural villages and inhabitants of towns and small cities in the floodplain areas of Bangladesh. This encompasses the full range of rural Bangladesh according to age, gender, and ethnicity. Flood-vulnerable areas of Bangladesh cover more than 50 percent of the country and include a population in the tens of millions. The affected area and number of floods varies by year, but in an extreme year impacts nearly all residents of the floodplains. For example, a report on the extreme flood of 1998 estimates that two-thirds of the country was inundated and that more than 20 million urban and rural people were directly affected (CARE Bangladesh, 1999). Millions of people were displaced from their houses and were without adequate food or shelter for a period of up to three months. Ten years prior, and with a magnitude similar to the 1998 flood, the 1988 flood displaced an estimated 45 million people and more than 2,000 died (Haque and Zaman, 1993). The disruption caused by these flooding disasters is long lasting, especially for the most vulnerable and poorest disaster victims. Within the general flood-vulnerable population, the CFIS project specifically targeted two unions in a flood vulnerable region of the country.

1.5 Project Approach

The CFIS project was designed as a pilot operational system, producing accurate and timely information on current and forecasted flood conditions for a floodplain study area. The project had three main components.

- ***Pilot Operational System*****:** An operational pilot system was developed to produce daily flood monitoring and forecast maps for use at the community level. The pilot system was designed to operate during the 2004-2007 flood seasons, providing the project with a range of hydrological conditions (wet and dry years) for analysis and evaluation. The overall concept and information flows in this, the most important of the components, is shown in ***Figure 1.1***.
- ***Flood Mitigation*****:** Flood information was provided to the local government and communities in the study area to mitigate potential impacts of flooding. Cooperation and partnerships with other organizations were sought to leverage resources and broaden dissemination and flood mitigation activities. The project coordinated with a number of projects/organizations, particularly the CIDA-funded Environmental Monitoring Information Network (EMIN) project.
- ***Replication*****:** In addition to the operating system and flood mitigation, the final two years of the project sought methods and sources for extension and replication of the CFIS distributed flood forecasting and monitoring system in other flood-prone areas of the country.

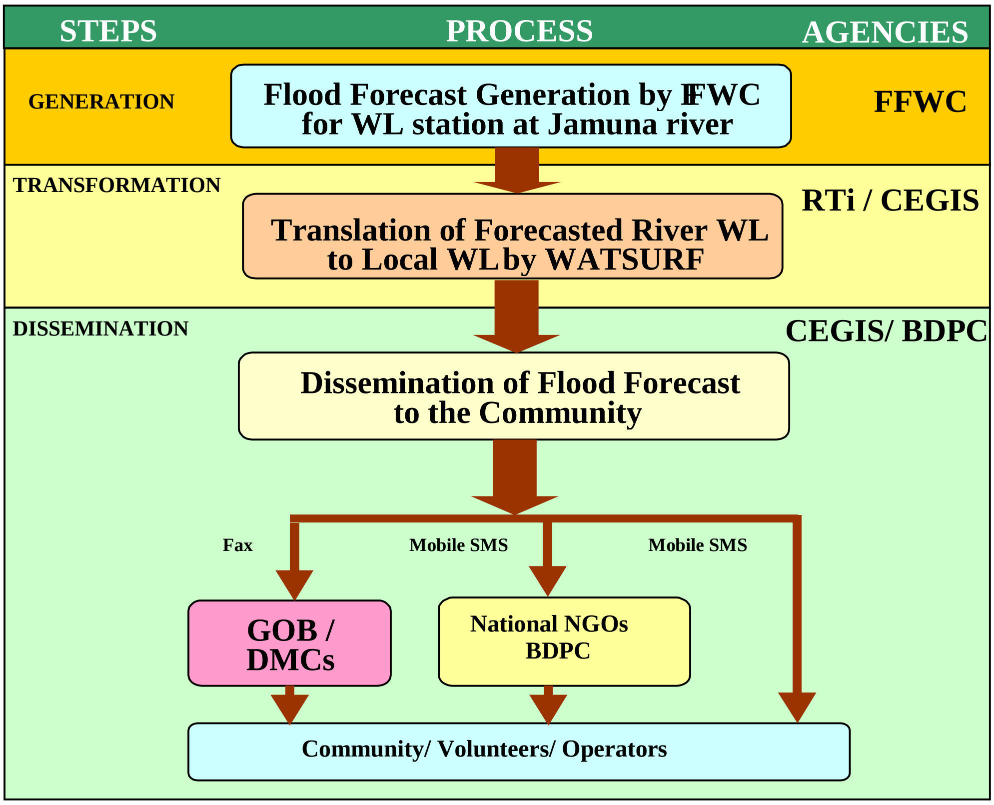

Figure 1.1: Overview of Flood Forecast Dissemination under CFIS Project

Critical to the CFIS project design were tasks to increase the sustainability and effectiveness of the CFIS project. The needs of the communities and the local government institutions for flood monitoring, forecasting, and warning dissemination were assessed under the CFIS project using a number of different participatory tools and methods with active participation of the communities. Special efforts were made to coordinate with local government programs and institutions to increase exposure and ownership.

1.6 Specific Challenges and Opportunities

Delivering useful, accurate, and timely flood information to the inhabitants of the floodplains in Bangladesh is an unprecedented and complex task. Two of the more notable challenges were:

- ***Uncertainty of flood events*:** The nature of flooding in the study area could not be predicted in advance; it is difficult to test a flood warning system without significant flooding. This is because the floodplain inhabitants are less interested in the forecast during normal to low flood years and some of the modeling tools are not applicable during low flood periods. During the CFIS implementation period, flood seasons 2004 and 2007 were unusually large floods, and 2005 and 2006 were unusually low floods. It was only in 2007 that all aspects of the CFIS system functioned well under a substantial flood, thus limiting adaptation of the system prior to the close of the project.
- ***Dynamic Floodplain*:** The Bangladesh floodplains are complex and dynamic. Due to sedimentation and degradation, the river and channel systems change their paths and alter the floodplain hydrology. It is very difficult and costly to monitor the ever-changing river systems in Bangladesh.

1.7 Partner Profiles and Responsibilities

Collectively, the project team has extensive experience working with community, national, regional and international organizations for flood and other hazard mitigation. Comprised of both Bangladesh national and U.S. experts, the team had a unique balance of the required technical and management skills, in addition to expertise in community development. The team's three organizations are briefly described below.

Riverside Technology, inc. (RTi) is a water resources engineering and consulting firm based in the United States and specializes in analysis and decision support systems for integrated water resources management. RTi's capabilities include real-time flood forecast system development and implementation; reservoir simulation and optimization; hydrologic and hydraulic modeling; automated hydro-meteorological data collection, and monitoring network design and implementation; data communications; and database management systems. RTi has worked on a wide spectrum of surface and ground water projects and has extensive experience in strengthening and developing water institutions at multiple levels, building linkages between water institutions and water users. RTi has assisted communities in developing flood forecasting and warning systems and has extensive international experience, including projects throughout the United States; in South, Southeast, and Central Asia; Latin America; Africa; and the Middle East.

Center for Environmental and Geographic Information Services (CEGIS) is a public trust established by the government of Bangladesh with the secretary of the Ministry of Water Resources as the chairperson of the Board of Trustees. As one of Bangladesh's premier scientifically independent centers of excellence, CEGIS' mission is to support the management of natural resources for sustainable socio-economic development using integrated environmental analysis, integrated water resources management, GIS, remote sensing, and information technology. The major strength of CEGIS is its multidisciplinary group of highly qualified scientists and technical professionals (e.g., fisheries, economics, agriculture, sociology, GIS, remote sensing, hydrology, database, programming, ecology, biology, river morphology, engineering, ground water, soil science, etc.) who bring a wide range of skills to the organization and are able to study and manage both technical and institutional water related issues in an integrated manner. CEGIS has extensive experience understanding and providing management tools for the complex river systems and floodplains of Bangladesh.

The Bangladesh Disaster Preparedness Centre (BDPC) is a non-governmental organization solely engaged in disaster management programs, including research, strategy formulation and project implementation, training; development of media materials and publications, post-disaster response planning and intervention, monitoring and evaluation, and advocacy. Most of BDPC's programs are involved with disaster preparedness that enhances the capacity of people at family and community levels, and with post-disaster relief and rehabilitation operations. A few of the many related projects of BDPC include: a USAID-supported disaster management handbook for Bangladesh; UNDP-funded strengthened flood warning and preparedness systems at national and local levels; a public awareness strategy for a flood-proofing pilot project formulated for CARE-Bangladesh; over 100 training courses conducted on disaster management for more than 250 NGOs working in cyclone and flood-prone areas, with emphasis on public awareness and response; and a DANIDA-funded pilot project for people-oriented flood warning dissemination procedures for the FFWC.

1.8 Links with EMIN Project

The Environmental Management Information Network (EMIN) project began during the second year of CFIS project. The CIDA-funded EMIN project contracted CEGIS as its local partner to support the Water Resources Planning Organization (WARPO). EMIN was an information network for facilitating planning and management of water and land resources as related to flood and erosion monitoring among national stakeholders and relevant agencies. EMIN also generated and disseminated flood information at the local level. During the inception phase of EMIN, it was decided to develop its flood applications and dissemination methods in the same area as CFIS. The two projects had similar objectives and deliberately cooperated with many aspects of the respective projects for economy of resources and efficiency. Some of the notable areas of cooperation that were led by EMIN and were particularly beneficial to CFIS included:

- Joint design of innovative methodologies for dissemination of flood information to local governments and communities in the study area particularly using the flag system, bulletin boards, and SMS messages.
- EMIN-led national seminars, training, and workshops where CFIS presented its project goals and accomplishments. This area was perhaps of most benefit to CFIS because it enabled recognition and dialogue on all aspects of CFIS, but the costs were borne mostly by the EMIN.
- Provision of Synthetic Aperture Radar (SAR) satellite imagery and processing at national and local level to validate flood extent maps produced by the CFIS program WATSURF.
- Development of a comprehensive system to enable the flow and use of information across Bangladesh government agencies for connecting the national level with local government and users in the project area, including local NGOs.
- Hardware purchased by EMIN that was used to advance the CFIS project, including mobile phone set, computer server, fax machine, and a boat. Mobile phone sets purchased under EMIN were especially useful for hydrological monitoring and data communication for validation of WATSURF generated results.

Areas of cooperation that were led or provided by CFIS that were particularly useful to EMIN included:

- Development of a GIS database of the study area, including digital elevation model and other resource information.
- Design, development, and operation of the WATSURF model that provided flood forecasts, inundation maps, and related information for use in the CFIS and EMIN study areas.
- Installation and maintenance of the floodplain gauge network in the study area for validation of the WATSURF model for provision of flood forecasts and related information to local government and communities.

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Chapter 2
State of Flood Forecasting and Monitoring in Floodplains

2.1 Water Resources System in Bangladesh

Water resources play a dominant role in the development of Bangladesh either directly or through various life supporting systems such as fish resources, mangrove forests, and terrestrial ecosystems. The water resources system is vital to national production, providing goods and services to satisfy human needs and for the upkeep of the ecosystem.

The water resource system, comprised of water with sediment and dissolved substances, is contained and controlled by natural landforms and man-made infrastructure, and is mainly composed of a) an inter-linked system of rivers, canals, etc; b) active floodplains, including *beels* (floodplain depressions that hold water year round or seasonally); and *haors* (seasonally deeply flooded basins in the northeast of Bangladesh); c) lakes and man-made ponds; d) ground water aquifers; and e) inter-tidal lands. The main components responsible for shaping and setting the periods of water flow in the system are described below.

2.1.1 River Systems

Over 200 rivers crisscross the land of Bangladesh, forming a complex and ever changing pattern from north to south. Most of these rivers are either the tributaries or distributaries to three rivers: the Ganges, Brahmaputra-Jamuna, and Meghna. These rivers dominate the hydrology of the country; but originate outside Bangladesh, carrying enormous volumes of water and sediment into the country. These rivers and their distributaries are mainly responsible for the floods, droughts, erosion, sedimentation, and salinity intrusion that occur in the country. The hydro-morphological characteristics and mean monthly flow of the Ganges-Brahmaputra-Meghna system are presented in ***Table 2.1***.

Table 2.1: Principal hydro-morphological characteristics of the Ganges, Brahmaputra, and Meghna Rivers

Parameters	Ganges	Brahmaputra	Meghna
Catchment area (sq. km.)	1,090,000	573,500	77,000
River length (km)	2,200	2,900	900
Mean annual rainfall within catchment (mm)	1,200	1,900	4,900
Average discharge (m3/sec)	11,300	20,200	4,600
Annual sediment transport (million tons/year)	548	590	13
Average width in Bangladesh (km)	5	11	1
Average depth in Bangladesh (m)	4.5	5	4.7
Bed slope in Bangladesh (in X / 10,000)	5	7	2
Planform	Point – bar meandering	Braided	Meandering canal form

Source: Barua, 1994 and Delft, 1996

The durations of peak water level exceeding the danger level in the 1998 floods were 55, 22, and 52 days for the Jamuna at Bahadurabad, the Ganges at Rajshahi and the Meghna at Bhairab Bazar, respectively. The average discharge of the Brahmaputra River is roughly 1.8 times and 4.4 times more than that of the Ganges and Meghna rivers, respectively. An example hydrograph for 2001-2005 for the Jamuna River is shown in ***Figure 2.1***.

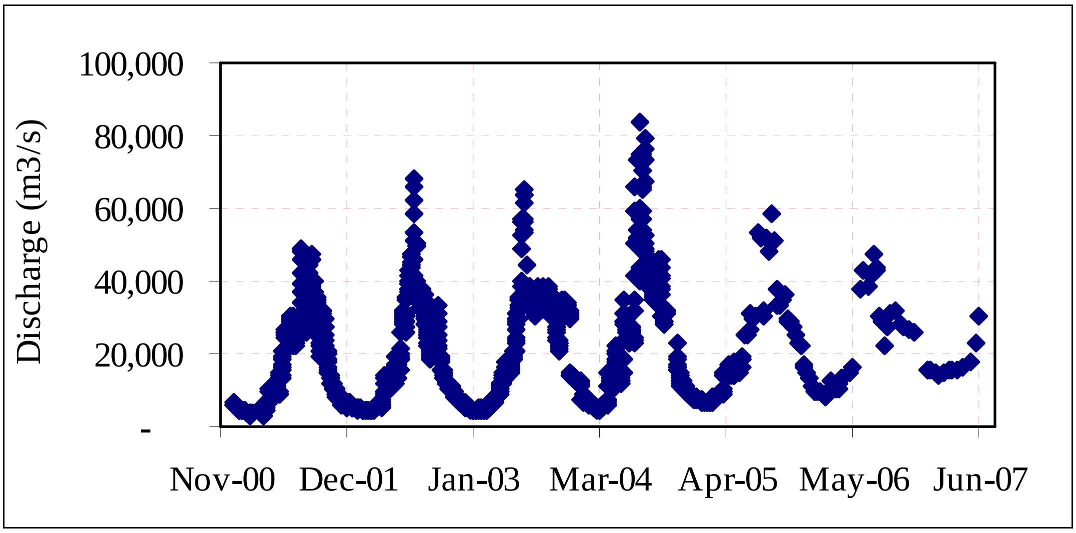


Figure 2.1: Discharge of the Jamuna River at Bahadurabad station for the period Nov. 2000 to June 2007

2.1.2 Floodplains

Floodplains serve as flood storage in the monsoon season and contribute water to the soil and ground water aquifers to support the ecosystem and maintain habitats. In the absence of floodplain storage and corresponding sedimentation, siltation may occur in the river system itself. Another function of the floodplains is the augmentation of post-monsoon river flows through the gradual release of stored floodwaters. Floodplains provide spawning grounds for many fish species. At the onset of the monsoon the floodplains are inundated, triggering migration and breeding for fish species that spend the dry season in *beels*, while later many juvenile fish move into the inundated floodplains to feed.

Non-active floodplains (young and old floodplains) are comprised of *haors* located in the northeast region, similar large floodplain *beels* in the southern part of the northwest region and central areas of the southwest region, as well as oxbow lakes (the abandoned reaches of meandering rivers known as *baors*, mostly located in the southwest and south-central regions). Bangladesh has more than 16,000 sq. km. of such wetlands (including lakes, ponds, rivers, and estuaries), which comprise approximately 11 percent of the country (ISESCO, 1997). Long term and short term drainage of *haors, baors,* and *beels* for irrigation, cultivation, and fishing purposes is a common practice all over the country, and creates a great impact on aquatic habitats, fisheries, and migratory birds.

The water resource system performs multiple functions to attenuate and regulate floods, such as retaining water as storage, assimilating and diluting waste, and carrying sediment (EGIS, 2000). The flood attenuation and regulation function refers to the capacity of the water resource system to alleviate river floods through storage of peak river discharges in the floodplain. This capacity is affected by the construction of flood protection works and other infrastructure such as roads and highways, and by the siltation of the channels in the drainage network. Many socioeconomic activities, as well as the ecosystem, depend on the regulatory capacity of the system during the monsoon and post monsoon periods.

The water management strategy of Bangladesh considers three types of flooding: a) river floods caused by bank overflow and local rainfall that causes flooding as drainage is impeded by high water levels in the rivers; (b) flash floods in the foothill areas due to intensive rainfall in the watersheds; and (c) tidal floods caused by tidal and storm surges in the coastal areas during cyclones, and corresponding tidal waves and storm set-up (see ***Table 2.2***). There are different perceptions of floods for different activities in the floodplains. Excessive flood causes damage to agriculture, property, and infrastructure, while “normal inundation” is beneficial as it brings sediment into the floodplains, improves soil fertility, flushes stagnant water with a positive impact on public health conditions, facilitates fish migration, and recharges ground water aquifers (ISESCO, 1997; World Bank, 1998). In fact, it is difficult to define “good” and “bad” floods meaningfully. An example of this concept is illustrated in ***Table 2.2***.

Table 2.2: Examples of main impacts of flood dynamics on floodplain users

Use category	Specific use	Pre-floods earlier	Peaks higher	Peaks longer duration	Post-floods later
Agriculture	Aman rice				−
	Boro rice	−			
Fisheries	Open water catch	+	+	+	+
	Aquaculture / ponds		−		
Population	Safety/ protection		−	−	
	Public health	+	−	−	+
Communication	Navigation		−	−	
Public facilities and private assets	Road and highways		−	−	
	Private settlements		−	−	
Ecosystem	Homestead vegetation		−	−	−
	Wetlands	+	+	+	
Off-season effects	Recharge of aquifers	+			+
	Retention of soil moisture	+			+
	Reduction in salt water intrusion	+			+

Source: RTi and EGIS, 2000 ("+" shows generally positive impact and "-" shows generally negative impact).

The Master Plan Organization (MPO) developed a flood depth classification for purposes of agricultural water management planning from a soil/agriculture reconnaissance survey made by the Soil Research and Development Institute (SRDI). The five flood phases/land types are: 1) F0: 0-30 cm, 2) F1: 30-90 cm, 3) F2: 90-180 cm, 4) F3: 180-300 cm, and 5) F4: over 300 cm, based on a three-day maximum flood depth calculation, theoretically with an exceedance return probability of one in 2.5 years (MPO, 1987).

Several parameters have been identified that characterize the flood cycle in relation to main floodplain users (RTi & EGIS, 2000).

- *Pre-flood levels.* Floods can be early or late; early floods are critical for *Boro* harvest.
- *Peak levels.* These are important regarding damage to infrastructure and settlements.
- *Duration.* The duration of peak floods can be important for households (public health) and fisheries; and in terms of causing damage to perennial vegetation as fruit trees.
- *Post-flood levels.* Flood recessions can be early or delayed; late floods have serious consequences for transplanting *Aman* rice.

These concepts can be used to map flood conditions by year, using the flood categories that first reflect floodplain usage. Together with overlay maps on land use and land cover, flood vulnerability can be derived showing the sensitivity to early floods and high peaks. ***Table 2.2*** shows an example of the main impacts of flood dynamics on floodplain users.

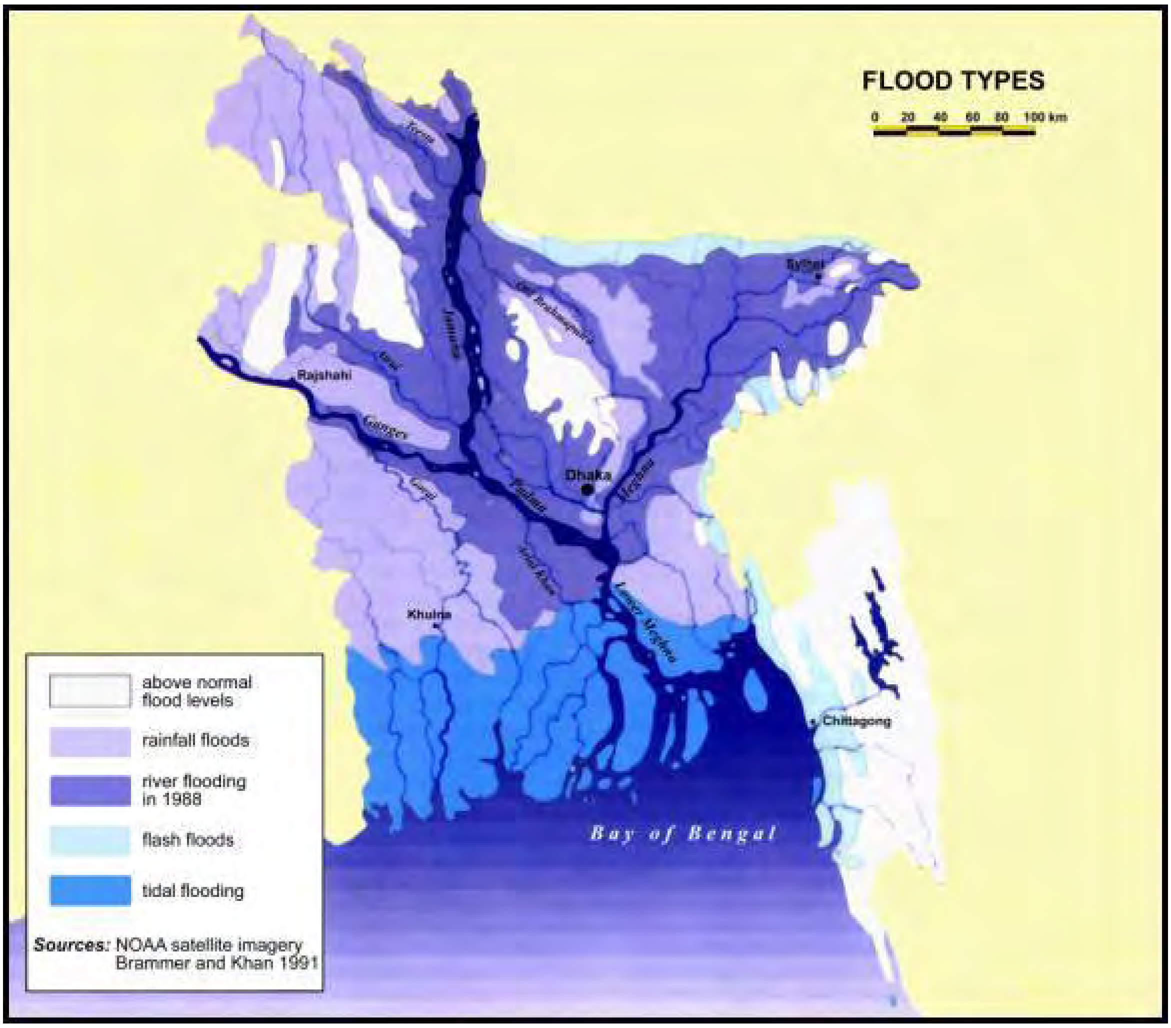


Figure 2.2: Flood Types in Bangladesh

2.2 Flood Disaster Concepts

Floods have severe impacts on the Bangladesh population, particularly on rural people. For example, the "flood of the century" in 1998 covered more than two-thirds of Bangladesh, causing a loss of 2.04 million tons of rice, an amount equal to 10.5 percent of the target total production in 1998/99. The flood also threatened the health and lives of millions through food shortages caused by crop failure, loss of purchasing power, and the spread of water-borne diseases. The rural poor lost their cattle, poultry, and vegetable fields due to the disaster. The daily laborers were hard hit as well, with little or no opportunity for work left in the wake of the disaster.

Recent severe floods in Bangladesh were in the years 1987, 1988, 1998, 2004, and 2007. The substantial damages caused by these floods are presented in ***Table 2.3***.

Table 2.3: Flood Damages in Bangladesh

<table>
<tr><th colspan="2">Item</th><th>1987[6]</th><th>1988[1]</th><th>1998[1]</th><th>2004[2]</th><th>2007[3]</th></tr>
<tr><td colspan="2">No. of districts</td><td>N/A</td><td>53</td><td>52</td><td>39</td><td>46</td></tr>
<tr><td colspan="2">No. of upazila</td><td>N/A</td><td>N/A</td><td>314</td><td>266</td><td>263</td></tr>
<tr><td colspan="2">Area flooded (sq km)[4]</td><td>57,491</td><td>77,700</td><td>84,000</td><td>34,583</td><td>44,000 [5]</td></tr>
<tr><td colspan="2">Affected people [4]</td><td>30 million</td><td>45 million</td><td>30 million</td><td>36 million</td><td>14 million</td></tr>
<tr><td colspan="2">Fully affected crops/ rice production loss</td><td>3.5 mill. ton</td><td>4.93 mill. ton</td><td>1.57 mill. ton</td><td>1.61 mill. ton</td><td>0.89 mill. acres</td></tr>
<tr><td colspan="2">No. of deaths</td><td>1,657</td><td>2,379</td><td>1,050</td><td>747</td><td>1,092</td></tr>
<tr><td colspan="2">No. of dead livestock</td><td>64,700</td><td>172,000</td><td>10,969</td><td>15,143</td><td>1,459</td></tr>
<tr><td rowspan="2">Affected road (km)</td><td>Fully</td><td rowspan="2">16,500</td><td>3,000</td><td rowspan="2">15,000</td><td>14,271</td><td>3,705</td></tr>
<tr><td>Partially</td><td>6,500</td><td>45,528</td><td>27,828</td></tr>
<tr><td rowspan="2">Affected embankment (km)</td><td>Fully</td><td rowspan="2">1,279</td><td rowspan="2">1,990</td><td rowspan="2">2,000</td><td rowspan="2">3,158</td><td>88</td></tr>
<tr><td>Partially</td><td>1,008</td></tr>
</table>

Note: N/A indicates that data could not be made available.

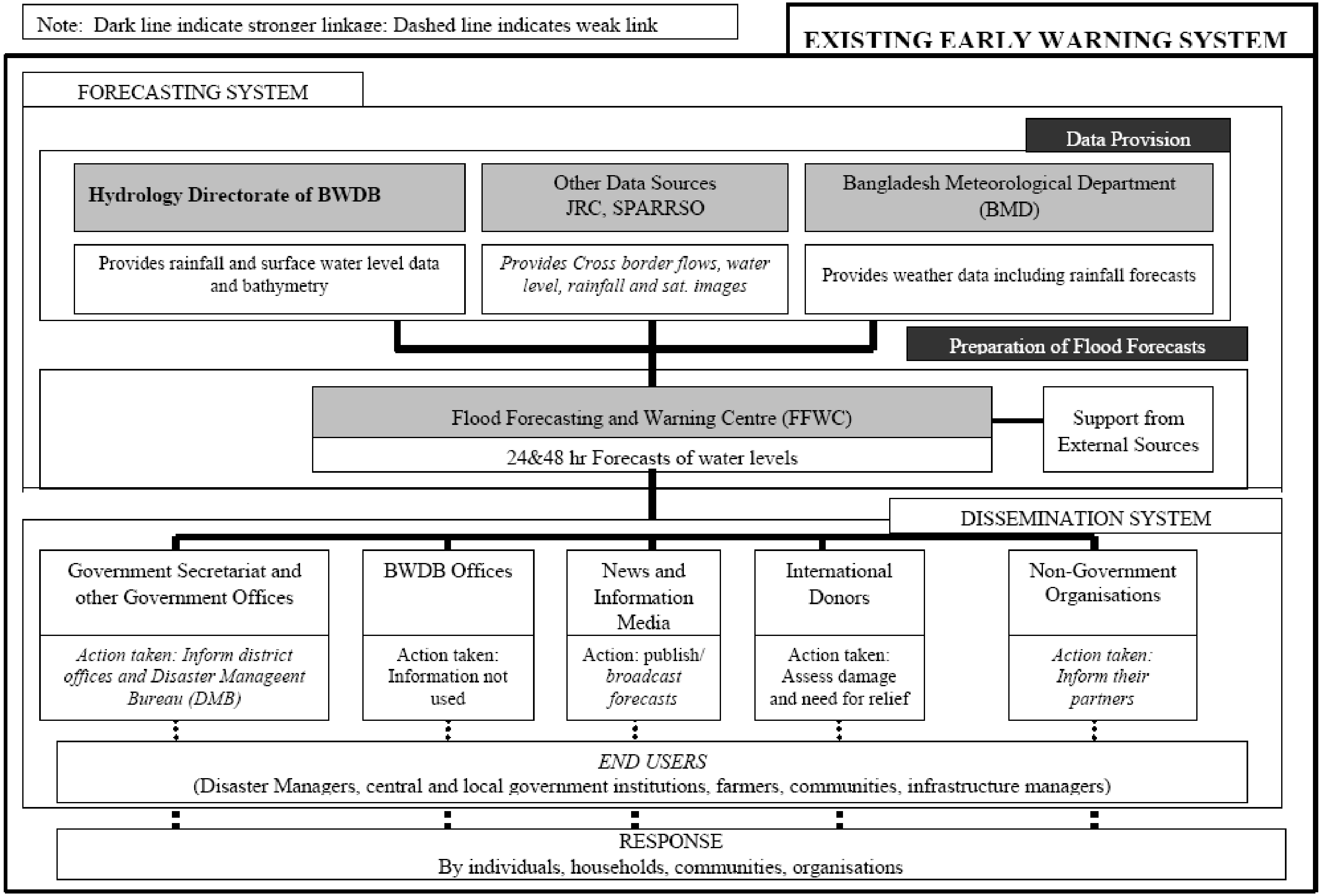
Source: 1. Manual for community-based flood management: Bangladesh; 2. Rahman 2006; 3.Flood and Weather Situation report of DMIC, DMB on 1 October 2007. 4 Islam 2000. 5. CEGIS, 2007, Brammer 2004.

2.3 Forecasting

Flood forecasts serve many purposes in support of planning and flood management, and in reducing losses by affected people. In Bangladesh, forecasts for flood management are related to forecasts of water levels or discharges in the river system. However, even though there has been great success in forecasting water levels in the river system of Bangladesh, there has been little progress in operational flood forecasting in the floodplain.

Three different time scales are relevant for flood management: 1) short-term for about –one to three days, 2) medium-term for about –four to 15 days, and 3) long-term up to seasonal prediction (RTi and EGIS 2000, and FFWC 2002). The uncertainty of the forecast increases with an increase in lead-time, but longer leads offer greater potential for the affected stakeholders to adapt and minimize losses. The Flood Forecasting and Warning Centre (FFWC) of the Bangladesh Water Development Board (BWDB) is responsible for the forecasting of floods and dissemination of flood warning. So far, FFWC is able to forecast only on a short-term scale, approximately two to three days.

The data, forecasting and dissemination components of the Bangladesh early warning system are shown in ***Figure 2.3***. Several organizations provide data for the FFWC system, including the BWDB and the Bangladesh Meteorological Department (BMD). Additional data sources include SPARRSO and Joint Rivers Commission (JRC). FFWC disseminates warning information to a number of government offices, the news media, and non-governmental organizations. Nonetheless, the warning information rarely reaches the inhabitants of the floodplains (ADB, 2006).



(Source: Early Warning System Study, ADB, 2006)

Figure 2.3: Existing Early Warning System

2.3.1 Flood Forecasting and Warning Center (FFWC)

The BWDB Act of 2000 stipulates that FFWC, established in 1972, should conduct flood and drought forecasting and warning. The center has direct communication with BMD and SPARRSO and coordinates its activities with the Disaster Management Bureau (DMB). It has access to all available data in BWDB. FFWC has a real-time data collection network of 56 rainfall stations and 86 stream gauges all over the country (ADB, 2006).

Since 1995, the Danish Hydraulic Institute (DHI) in collaboration with the Institute of Water Modeling (IWM) has provided technical support to FFWC to develop hydrological and hydrodynamic models to simulate and predict floods in the river networks of Bangladesh. Funded by DANIDA and other bi-lateral donors, FFWC is equipped with modern electronic equipment. It downloads satellite images (NOAA 12 and 14) through automatic picture transmission receiving stations. In addition, it receives observed and forecasted water level and rainfall data from India at certain times under an agreement between the two countries.

At present, FFWC makes short-term (one to three days) forecasts, with the developed model at 52 locations as shown in ***Figure 2.4***, covering most of the riverine flood prone areas of the country. Although FFWC has a model for medium-term (four to15 days) forecasting, it does not have operational tools for forecasting the flood levels at the country's boundary. No model is available for long-term forecasting. FFWC has a capacity for dissemination at the national level through its website, email, fax, and telephone and at the *upazila* level via BWDB field offices. However, at the union level, dissemination arrangements are weak and there is no dissemination at the local level. The FFWC daily activity flow chart is shown in ***Figure 2.5***.

The four main activities of FFWC are data collection, preparation, output/prediction, and dissemination.

- <u>Data collection.</u> Hydrological data is received from the field networks of BWDB. From April to September, water level data is collected five times daily from 86 stations, while rainfall information is collected once a day. Data is also collected from the automatic telemetry system operating in four stations around the capital city of Dhaka. Limited data on water level and rainfall forecasts are received from Indian stations through the teleprinter link of the Bangladesh Meteorological Department (BMD).
- <u>Preparation.</u> Estimates of the rise/fall of river water levels and rainfall in the catchments beyond the national boundaries are inputs for computer models. To estimate the rainfall situation, imagery from the NOAA satellite at FFWC, and from the Geostationary Meteorological Satellite (GMS) at SPARRSO are collected and used along with water level forecast and surface charts with pressure isoline from BMD.

  The collected data are fed into the computer database and checked. The trend of the hydrograph extrapolated up to the period of forecast from the levels of the previous few days, the response characteristics of the rivers, the effect of rainfall on water level, and the data related to water level and forecast received from India are all considered as the basis for the preparation of flood forecasts.

- <u>Output /Prediction.</u> After preparation, the model is run for 30 to 40 minutes to calculate the forecasts. These forecasts are used in flood bulletins and for the preparation of flood warning messages.

  During the monsoon period, FFWC runs daily flood bulletins, special as well as monthly and annual flood reports, and conducts flood mapping. During the dry period, it conducts weekly and regional flood monitoring, and produces out a dry season bulletin. ***Figure 2.6*** shows the outputs of FFWC.

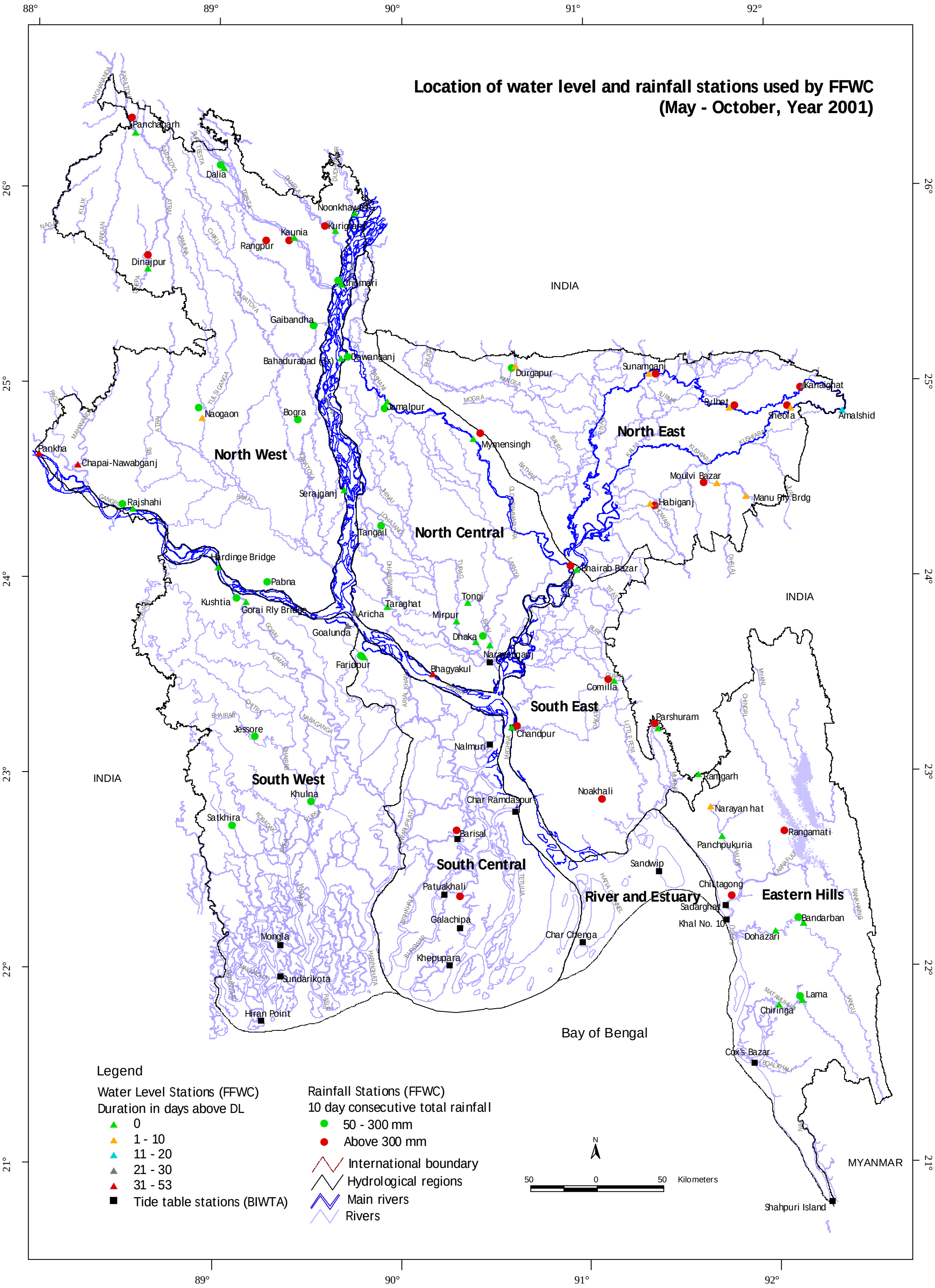
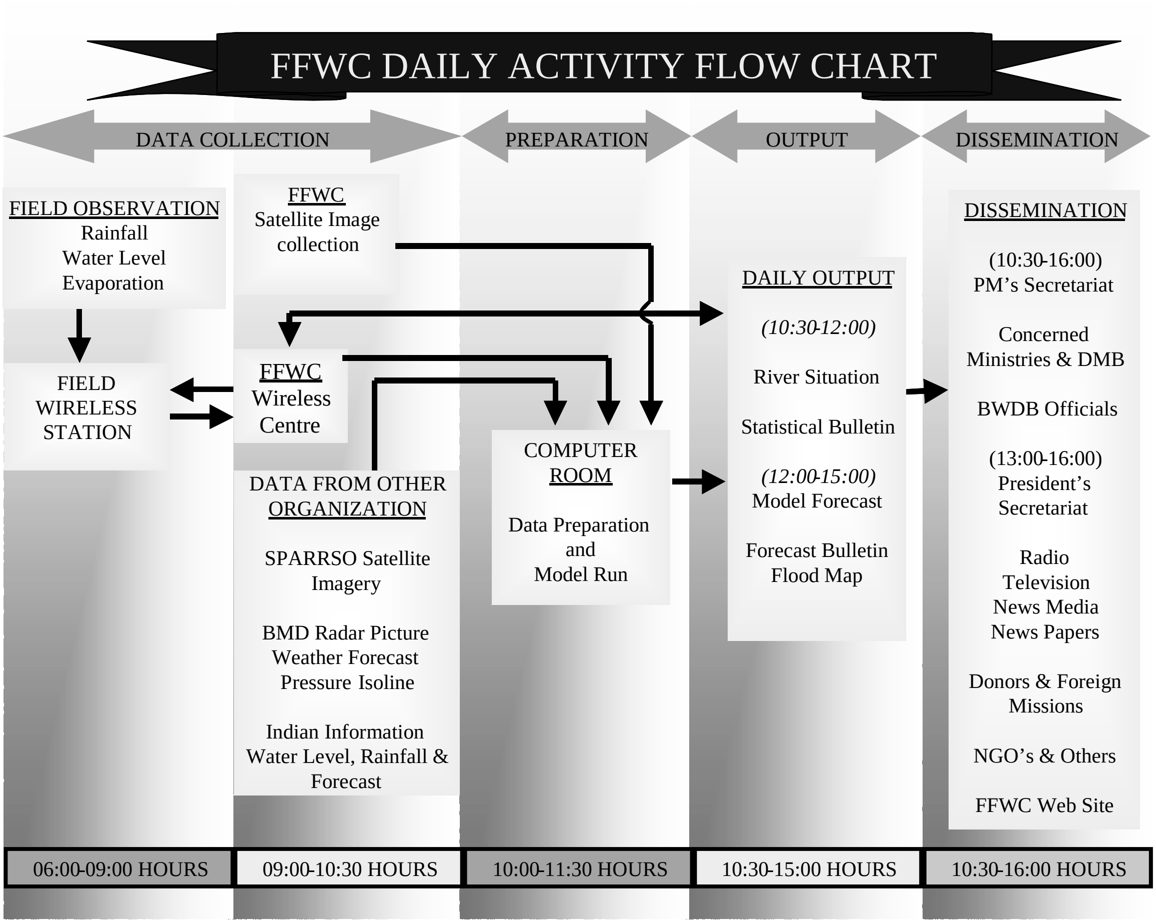


Figure 2.4: Location of rainfall and water level forecast stations used by FFWC (check year 2001)



(Source: FFWC/BWDB)

Figure 2.5: FFWC daily activity flow chart

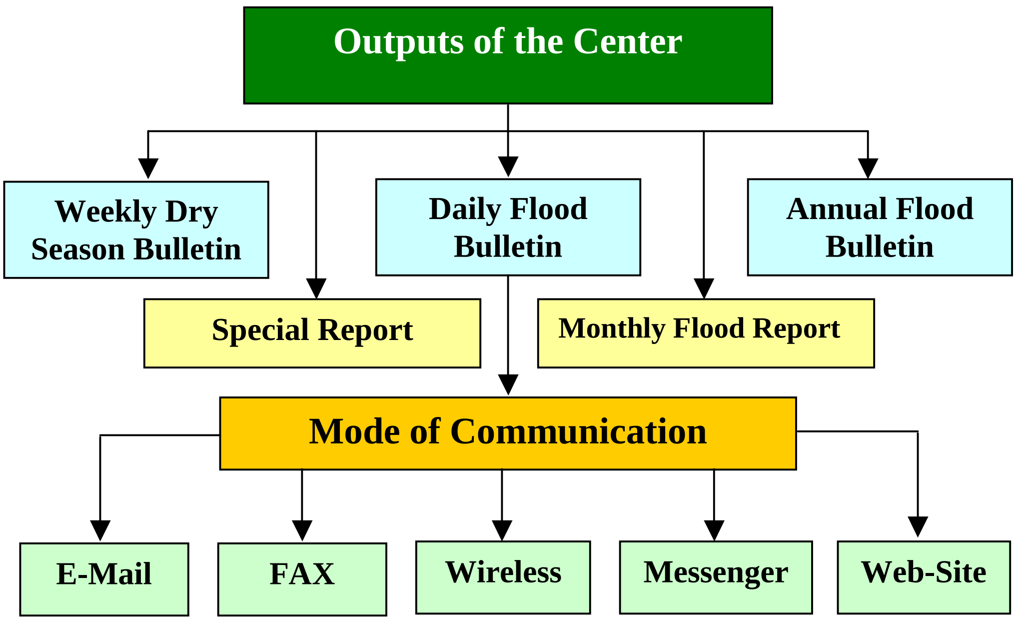


Figure 2.6: Outputs from FFWC

- Dissemination. The flood forecast bulletins and the flood warnings are disseminated to over 100 listed recipients. They include all the concerned offices of the government of Bangladesh (from the office of the President, Prime Minister, and Ministry of Disaster Management and Relief down to the deputy commissioners of each District), electronic and print media, selected foreign missions located in Dhaka, and some bi-lateral donors, as well as national and international

NGOs. ***Figure 2.7*** shows the dissemination flow from FFWC and ***Table 2.4*** shows the product dissemination routes. Email and Internet routes have been developed in the Consolidation and Strengthening of Flood Forecast and Warning Services (CSFFWS) project, and are taking over somewhat from the traditional methods of hard copy and fax. Both mediums lend themselves to mass distribution of warning messages and, hence, are very cost effective.

As per the standing order issued by the Ministry of Disaster Management and Relief, the responsibility of disseminating flood warnings down to the local level lies with Disaster Management Committees at the district and upazila levels.

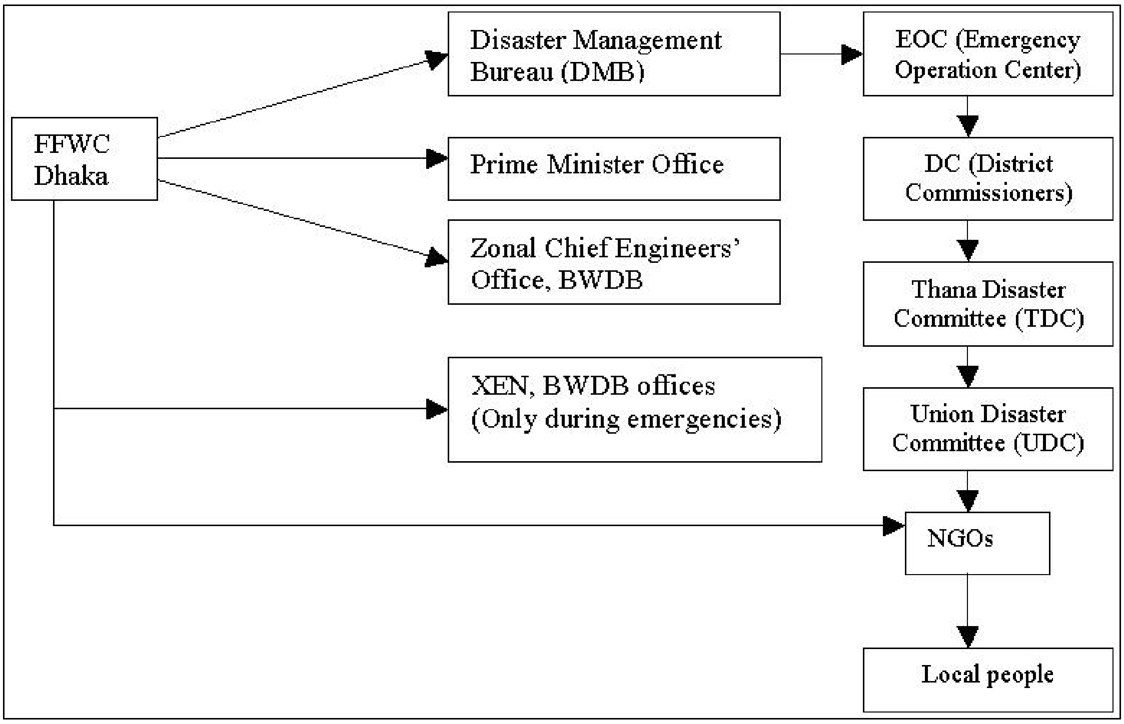


Figure 2.7: Dissemination from FFWC

Table 2.4: Flood Warning Product Dissemination Routes

Dissemination Medium	FFWC Product	Recipient Group
Hard copy (hand delivered), Fax and Email	Bulletins	Prime Minister's office, government ministries, BWDB officials, government organizations
Fax or Email only	Bulletins	NGO's, embassies, international donor and aid organizations, news media
Internet	Bulletins, plots, flood map, *upazila* status	General public, international

The FFWC website is located at http://www.ffwc.gov.bd. The web site is comprehensive and provides bulletins and water level plots. The ability to interact with the site and its various products is one of the strengths of this dissemination medium.

2.4 Monitoring

Monitoring flood and flood disaster management is the responsibility of various government organizations, such as BWDB, BMD, BIWTA, SPARRSO, and others along with technical support organizations such as CEGIS and IWM. A number of government projects, typically with donor funding, have supported capacity development activities or are supporting monitoring activities under area-specific projects.

2.4.1 Bangladesh Water Development Board (BWBD) Monitoring

BWDB has the most extensive national-level data collection and monitoring network. Four hydrology divisions are responsible for collecting all hydro-meteorological data for the country. Collected data are sent to a central division for processing and archiving in a computer database. The archive contains records dating back to the establishment of the collection system in 1959, with some dating even further back to the 1930s. ***Table 2.5*** shows the flood-related monitoring stations maintained by BWDB, some of which are used in the forecasting model of FFWC, particularly the auto gauges.

Table 2.5: Hydro-meteorological monitoring of the BWDB

Variables	Number of stations			Manual gauge	Auto-gauge
	Total	Non-tidal	Tidal		
Discharge	147	133	14	135	12
Water level	480	292	188	458	22
Rainfall	292			269	23
Evaporation	50			49	1

Source: NWRD, WARPO 2005

Water levels for non-tidal stations are read three-hourly with five readings a day; water levels for tidal stations are read hourly. The rainfall data are collected daily. Discharge for 108 locations (of which three are in tidal and the remaining in non-tidal rivers) is collected either fortnightly or monthly. The survey division of BWDB is responsible for surveying river cross sections in some 47 rivers at time intervals of once a year, once in two years, and once in three years (***Table 2.6***). In addition to these national-level monitoring and surveys, the local operations and maintenance divisions of BWDB also measure water levels, discharges, and river cross sections for specific projects. BWDB monitors embankment breaches through field observations, but does not have the capacity to fully monitor the effect of breaches.

Table 2.6: River cross sections monitored by BWDB

Frequency	No. of Rivers	No. of X-Sections	Remarks
Once/year	6	174	Total 1050 cross sections measured in 47 rivers
Once/2 years	36	757	
Once/3 years	5	119	

Source: BWDB

2.4.2 Bangladesh Meteorological Department (BMD) Observations

The Bangladesh Meteorological Department (BMD) was established from the Pakistan Meteorological Department after the liberation of Bangladesh in 1971. The BMD is the authorized government organization for all meteorological activities in the country. It maintains a network of surface and upper air observatories, radar and satellite stations, agro-meteorological observatories, geomagnetic and seismological observatories and meteorological telecommunication system. The Department has its headquarters in Dhaka with two regional centers: the Storm Warning Centre (SWC) in Dhaka and the Meteorological and Geo-Physical Centre (M&GC) in Chittagong.

The annual calendar of BMD includes forecasts of various ranges issued by SWC around the clock for the public, mariners, and farmers. Ten-day, monthly, and three-month forecasts are issued for the agriculture sector. Apart from this, forecasts for the movements of VIPs or other persons or organizations also are issued by SWC on request. The meteorological offices for different airports issue aviation forecasts.

BMD monitors meteorological conditions with 46 automatic gauges: 34 for rainfall and 12 for evaporation (NWRD, WARPO, 2005). In addition, radar stations operate at four coastal locations: Dhaka, Rangpur, Cox's Bazar, and Khepupara. The imagery is displayed via a dedicated communication line with FFWC. These radar stations transmit cloud information at intervals of two to three minutes and cover a circular area of a 300-km radius. BMD also has a downlink for receiving and processing NOAA polar orbiting satellite imagery and geostationary GMS images; furthermore, it has been working to establish a link with the Indian geo-stationary satellite. In addition to the radar data, BMD provides synoptic NOAA-12 and NOAA-14 pictures to FFWC.

Under an agreement with India, BMD receives on-line upstream observed and forecasted water levels at Farakka on the Ganges River, Goalpara/Dhubri on the Brahmaputra River, Silchar on the Barak River, and Domohoni on the Teesta River. Observed rainfall and other meteorological data are received at BMD through the global telecommunication system (GTS), and are then transmitted to FFWC through a teleprinter link. Data transmission from India is limited, and is only provided whenever water levels are within 50 cm of danger level and when rainfall exceeds 50 mm (DHI, 2000).

2.4.3 Monitoring with Satellite Imagery

Bangladesh does not operate any earth observing satellites, but with the rapid increase in the number and types of satellites, Bangladesh is developing a substantial capacity for processing and applying images. Since the 1980s, SPARRSO has been applying various satellite technologies and has investigated applications for flood monitoring, dry season water bodies and fish habitat, land use, and land cover. In the 1990s, CEGIS and its predecessor projects, EGIS, and FAP 16 and 19, joined with research and development activities in similar applications.

Satellite radar images are little affected by cloud cover during the monsoon season and thus have high potential for application in flood monitoring. The first use of space-based radar for flood monitoring in Bangladesh was an experimental application of SAR-C radar imagery by NASA and SPARRSO in the 1980s (Imhoff et al., 1987). This was followed by a number of applications research projects, the first being supported by the imagery from the first radar satellite, ERS-1 (FAP 19, 1995; Martin et al., 1996; EGIS, 1998). Since 1998, EGIS has continued with a number of additional applications-oriented development projects using satellite SAR as the basis for monitoring flood extent during the monsoon season. One such project was the operation of a portable SAR ground station, implemented jointly with SPARRSO. In addition to the overall experience that EGIS and SPARRSO gained in these exercises, specific knowledge was gained as to the nature of available information, the SAR data acquisition and processing requirements, and analytical techniques.

An example of the capability for applying new technologies in Bangladesh is EGIS' use of SAR satellite images during the 1998 flood. Much of the damage sustained by many areas of the country from the 1998 flood was due to the prolonged nature of the flood that began during July that year. The cumulative effect of the duration and successive flood peaks caused extensive loss of life and property. The necessity for an effective flood mapping and monitoring system to assist in managing flood disasters was recognized by many organizations. EGIS drew on its experience with the SAR satellite data that began in 1993. The key to EGIS' 1998 efforts was the acquisition of SAR images in near real time, provided to EGIS via the Internet. These satellite images, acquired by the Canadian satellite RADARSAT, were processed by EGIS and integrated with ancillary spatial information using its GIS and image processing facilities. Following this analysis, map products, statistics, and reports on flood extent, affected population, and crop damage were produced for the government, donors, and relief organizations. (EGIS, 1999; Hasan et al., 1998).

After recession of the 1998 flood, SPARRSO used a multi-temporal SAR image data set to examine flood conditions at a regional scale, and to assess post-flood agricultural characteristics.

2.5 Institutional Arrangements

In Bangladesh, a number of national and local level agencies are involved in generating and disseminating flood-related information. However, there still exists the need for more comprehensive and adequate information to be produced and delivered at the right time to the people and agencies needing the information. The agencies currently operating in flood monitoring, prediction, and mitigation are both national and local.

At the national level, FFWC is responsible for producing forecast related information and for disseminating it to national and local level agencies. FFWC receives information from other organizations such as BWDB, BMD, SPARRSO, and WMO. The forecast information is distributed first to the prime minister's secretariat, then to the president's secretariat. By the end of each day, FFWC disseminates the forecast information through fax, radio, television, and their website to other relevant agencies at the national and local levels.

The relevant local level organizations can be divided into three tiers. At the topmost tier are the district level offices of organizations including BWDB, DMB, BMD, BIWTA, LGED, BARC, DAE, and the office of the deputy commission. The responsibility of the district level offices is to disseminate the forecast information and to take part in post-flood relief activities. DMB assumes responsibility for disseminating flood information with assistance from other organizations. There is little dissemination of monitoring or base information through these institutions.

At the next tier is the *upazila* administration, including *upazila* staff of LGED and local NGOs. Dissemination of flood information as well as activities relating to flood preparedness and post-flood relief and rehabilitation at this level are carried out under the leadership of the *Upazila Nirbahi* officer. The NGOs play a role in disseminating information to vulnerable people through their own networks.

The bottom tier of local level organizations are the union *parishads* (local government comprising of elected councils with a chairman and 12 ward members) that have an important role in the dissemination process. Local NGOs and other local level organizations also have an important role to play at this level.

In August 1999, the Disaster Management Bureau, Ministry of Food and Disaster Management of the Government of Bangladesh prepared standing orders on disaster. These standing orders clearly identify and distribute the roles and responsibilities of different organizations. The purposes of the standing orders are:

1. To reduce the loss of life and property.
2. To alleviate the suffering of people affected by natural disasters.
3. To provide guidelines to different departments at the national, divisional, district, *upazila* and union level government, and non-government agencies for actions to be taken at different stages of a disaster, e.g., before, during, and after the disaster.
4. To clearly spell out what is to be done, when and by whom, at different stages of the disaster.

2.5.1 Role of Agencies

The standing orders on disaster states that the following council and committees will be responsible for policy formulation and coordination of disaster management at the national level:

- National Disaster Management Council (NDMC)
- Inter-Ministerial Disaster Management Coordination Committee (IMDMCC)
- National Disaster Management Advisory Committee (NDMAC)

The NDMC headed by the Prime Minister, and IMDMCC, chaired by the minister-in-charge of the Ministry of Food and Disaster Management, are to ensure coordination regarding disaster management activities at the national level. Coordination at the field level is to be carried out by respective district, *upazila*, and union disaster management committees headed by the deputy commissioner, the UNO, and the chairman of the union *parishad* respectively. The institutional arrangement for disaster management is shown in ***Figure 2.8***.

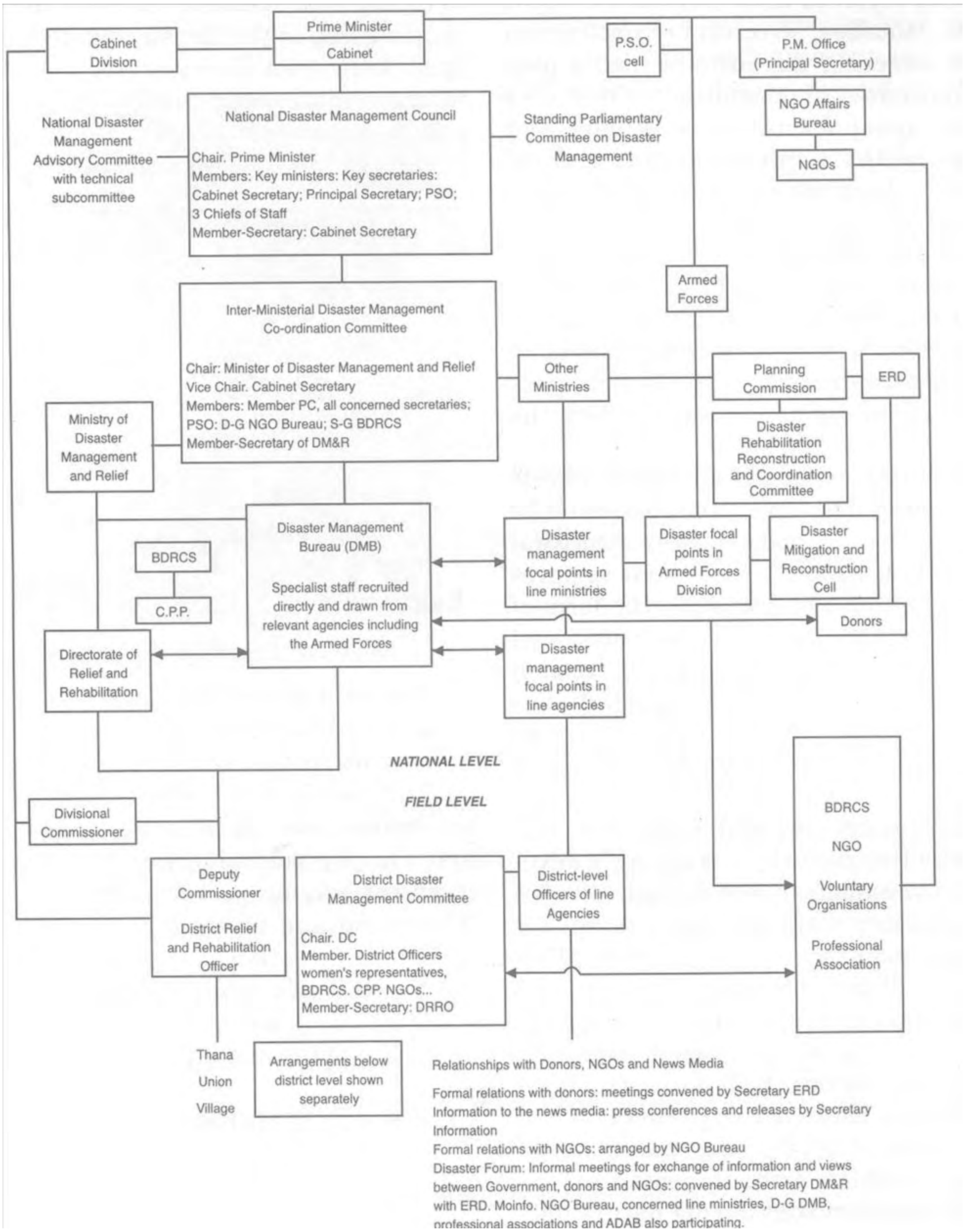


Figure 2.8: Institutional arrangement for disaster management in Bangladesh (Rahman, 2006)

According to the Standing Orders, 23 ministries are closely involved with disaster management, including the ministries of: Disaster Management and Relief; Water Resources; Information, Health and Family Welfare; Food, Agriculture; Fisheries and Livestock; Civil Aviation and Tourism; Defense, Home Affairs; Communications; Shipping; Housing and Public Works; Social Welfare; Local Government Rural Development and Cooperatives; Foreign Affairs; Finance; Industries; Education; Commerce; Post and Telecommunication; Power Energy and Mineral Resources; and Environment and Forests. Each ministry has its own action plans and responsibilities regarding disaster management. The standing order also describes the duties of other ministries as well. The roles of the key agencies closely related to flood management are summarized in ***Appendix 2***.

Notably the Disaster Management Bureau is to "establish and coordinate all activities related to flood forecasting and warning dissemination". BWDB is to "ensure an efficient flood forecasting and warning system." "On government orders, Bangladesh *Betar* would, especially at the stage of pre-disaster period, alert the people, motivate them, and inform them about the disaster position and their duties in this respect". The mass communication department is to "keep the people of the disaster prone areas informed through different publicity media about their duties at these stages," and the meteorological department is to "ensure full time effectiveness of the quickest channel of communication for disseminating weather warnings to all concerned".

2.5.2 Disaster Management Committees

According to the standing orders on disaster, disaster management committees should be constituted at union, *upazila*, district, city, corporation, and *pourasava* levels. These committees are generally comprised of a chairman, a number of members, and a member-secretary. The union, *upazila*, and district levels are relevant to the CFIS project and their responsibilities are detailed in ***Appendix 2***. Notably the union disaster management committees to "take steps for quickest and most effective publicity of forecasts/warnings relating to cyclone and floods, and also informs people about their responsibilities of saving lives and properties from disaster," and is responsible for "arrangement for rehearsals or drills on the dissemination of warning signals/forecasts, evacuation, rescue and primary relief operations." In addition, the district disaster management committee is responsible "to disseminate forecasts and warnings of disaster, and to make the people conscious about them," while the *upazila* disaster management committee seems to lack a significant role in flood warnings.

2.6 Expected Information Flows (Proposed ADB System)

A recent early warning system study (ADB, 2006) proposed a Flood Early Warning System (EWS) Enhancement Program. The development objective of the program is to reduce the risk for agriculture, infrastructure, and rural and urban populations, particularly poor and disadvantaged households, of loss or damage from floods by improving flood preparedness. Under this study, availability of existing data and resources, institutional set-up, and requirements for improvement of the existing EWS were analyzed.

The present flood EWS is limited in resources and institutional set-up. To overcome the limitations, the EWS study proposed a new framework under the Flood EWS Enhancement Program (***Figure 2.9***). This framework divides the process into data provision, preparation of flood forecasts, and dissemination system. The roles and responsibilities of institutions involved in each part are defined in the framework to ensure sustainable linkage of information and resource sharing.

The data provision segment comprises rainfall, water level, river cross section, weather, and cross border flows to be provided by BWDB, BMD, SPARRSO, JRC, and others. It is recommended that FFWC prepare a forecast of water levels as well as trend and duration. The final segment of the information flow is the dissemination system that involves the Disaster Management Information Centre (DMIC), key government offices, BWDB, infrastructure managers, and end users including disaster managers, central and local government institutions, farmers, and communities. In this segment of the process, the information should be disseminated to end users and their responses collected. One of the important features of this proposed system is to enable feed back mechanisms or demand-driven assessment of the system.

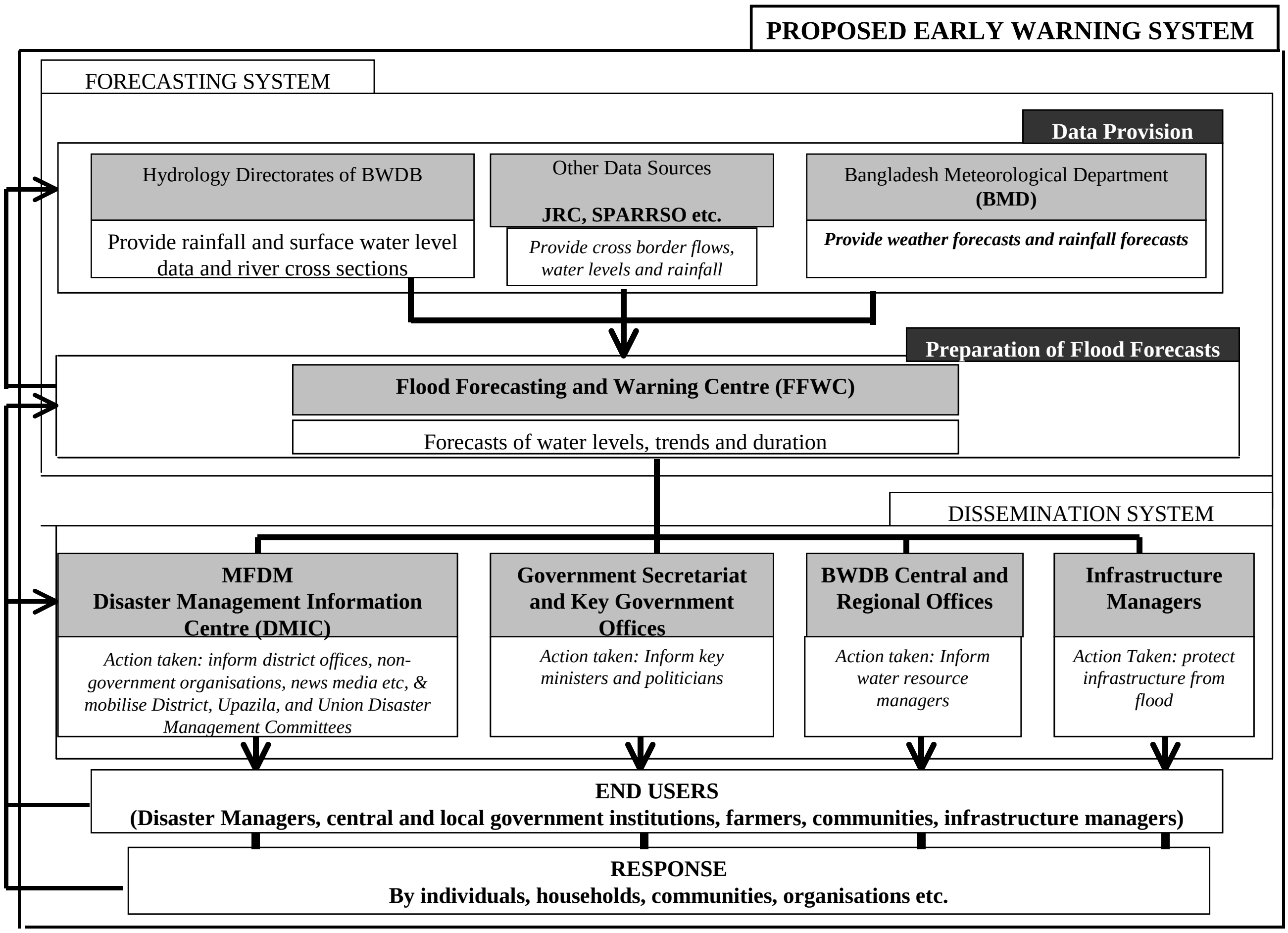


Figure 2.9: Proposed Early Warning System *(Early warning system study, ADB; 2006)*

2.7 Relevant Projects

2.7.1 Climate Forecast Application in Bangladesh (CFAB) Phase I and II

The Program on Atmospheric and Oceanic Sciences at the University of Colorado/Georgia Institute of Technology conducted a research project, “Climate Forecast Application in Bangladesh (CFAB),” to provide climate forecasts in seasonal and medium to short-term periods. The objective of CFAB, which began in November 2000, was to reduce societal vulnerability to climate hazards, such as floods or droughts, in Bangladesh through the generation and application of climate and flood forecast information.

After three years, CFAB developed a three-tier system to improve the lead-time of the forecast prepared by FFWC and BMD (ADB, 2006):

- Short-range forecast of rainfall and river discharge in a probabilistic form provided each day with six to10 days lead time;
- Medium range forecast of average five-day rainfall and river discharges, updated every five days, with 20-30 days lead time; and
- Seasonal outlook starting at the beginning of the monsoon season and updated each month, providing one to six months lead-time.

The short-term forecast schemes use rainfall over the Ganges and Brahmaputra catchments provided by the European Center for Medium Range Weather Forecasting (ECMWF) to perform statistical analysis. This forecast data (boundary data for the FFWC model) could increase the capabilities of FFWC to make flood forecasts for Bangladesh for six to 10 days. ***Figure 2.10*** shows discharge forecasts at the entry of rivers into Bangladesh for a five-day forecast.

Currently the CFAB model is able to correctly predict only the flood phases (peaks and valleys), but it consistently underestimates the peaks. While the short- and medium-run forecasts are of reasonable reliability in terms of accuracy of prediction, the long-run forecasts, still at a rather rudimentary stage, need improvement. This is especially due to the complexities in identifying the uncertainties and non-linearity associated with various atmospheric relationships on a long-term basis.

Based on some positive results, the CFAB project was extended for a second phase for the period 2006-09. The Asian Disaster Preparedness Center (ADPC) is implementing the project with support from the Climate Forecast Applications Network (CFAN), Institute of Water Modeling (IWM), and CEGIS (ADB, 2006).

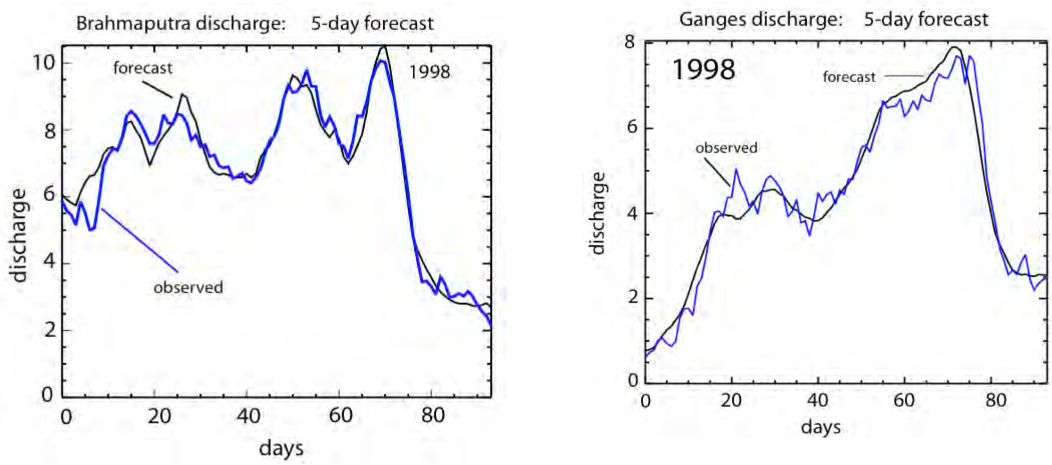


Figure 2.10: Five-day forecast by CFAB on discharge at Bahadurabad and the Ganges

2.7.2 GeoSFM Forecasting Model for the Ganges-Brahmaputra River Basins

Ninety percent of river discharge in Bangladesh originates upstream of its borders; extension of the present model beyond two days lead-time will require incorporation of forecasts of the cross-boundary flows from India. Despite years of effort to obtain hydro-meteorological data from India for flood forecasting applications, Bangladesh has yet to acquire the information needed for an accurate and reliable operational system.

This pilot project in 2007-08 developed an initial Geospatial Stream Flow Model (GeoSFM) model for the Ganges-Brahmaputra river basins to enable Bangladesh to extend the flood forecast in major rivers from two days to seven days. The main sources for data and model technology are from the Bangladesh and the U.S. Geological Survey.

The main deliverable for this GeoSFM project will be an initial, pilot-forecasting system, to be developed jointly by RTi, USGS, and CEGIS. This system will enable the FFWC to evaluate and define its long-term, in-house, operational forecasting needs by considering its current forecasting system, the statistical approach of the CFAN project as well as a range of data, and both deterministic and statistical modeling approaches.

This basin model will be developed using data available via CEGIS from the BWDB, rainfall estimates from NOAA and the U.S. Air Force, ground data from the World Meteorological Organization (WMO), and the GeoSFM model developed by the USGS for forecasting river flows in large basins with scarcely available ground data.

2.7.3 Consolidation and Strengthening of Flood Forecasting and Warning Services (CSFFWS)

For disaster management, priority should be given to appropriate dissemination of warnings to communities at local level. However, even though FFWC is equipped with the latest technology it is ineffective in the dissemination of flood forecasts and warning to communities.

In late 1999, FFWC initiated a project on the Consolidation and Strengthening of Flood Forecast and Warning Services (CSFFWS) funded by DANIDA, with its focus on a people-oriented flood warning dissemination system utilizing short-term forecasts. As described in the project report, three pilot areas (Lohajan, Chouhali, and Sundarganj *upazilas*) were selected and an extensive investigation was carried out by local NGOs to establish a baseline on people's perception about flooding and their knowledge on flood warning. The project also sought to understand the existing dissemination practice at the grassroots level, as well as to identify: a) people's needs with regard to flood warning,

b) local organizations involved in disaster related work, c) target groups for warning messages, d) effective communication media at the grassroots, and e) change agents for flood warning dissemination.

In this project, surveys were conducted using the participatory rural appraisal method, particularly with people with long-term experiences of floods and with landless people. Through these surveys, information was collected on what people thought about flood warning and what they needed. The most important finding was that 100 percent of the people said that they could not relate the information provided through forecasting to their local situations – that the language and the metric system of forecasting were alien to their culture and system. The participants also identified the agents through whom they would like to receive forecasting information (e.g., imams, teachers, etc.) and the ways they thought dissemination could be done effectively (e.g., microphones in mosques, beating of drums, etc.).

In an effort to improve the situation, change agents were identified, selected, and trained; the danger level of river flow for every village was identified; and flood warnings in local language were formulated including posters, photos and audio tapes for illiterate people with additional information on crops, boats, cattle, women, children, and emergency food. During a mock demonstration of dissemination, it took only three hours to disseminate information from the FFWC to the people in the villages. During the flood year of 2002, *upazila* disaster management committees were warned through the change agents, who also prepared damage and priority lists and participated in the distribution of relief materials. BDPC concluded in the CFAB workshop that focus should be given more on the dissemination of flood warning without underestimating the importance of an accurate flood forecasting mechanism (source: BDPC presentation at CFAB workshop, 2003).

Figure 2.11 shows the proposed system used to disseminate flood forecast warning information from FFWC to the village level, derived from surveys and reviews of the existing warning system. In the existing system, FFWC disseminate the forecast up to the district level.

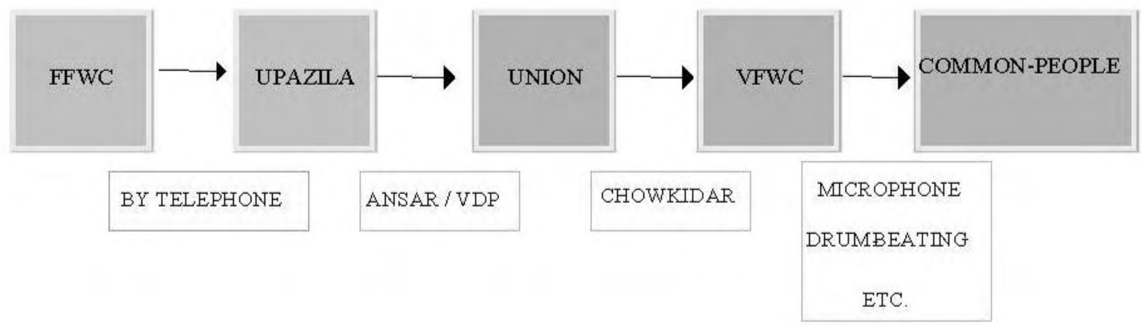


Figure 2.11: Flood information flow from FFWC to the community in pilot study

2.7.4 Environmental Monitoring Information Network (EMIN)

The Environmental Monitoring Information Network (EMIN) project facilitated planning and management of water and land resources including forecasting of flood and erosion monitoring. This initiative embodied a participatory and needs based process to improve coordination between key players in floodplain management, such as BWDB, FFWC, WARPO, and CEGIS. EMIN provided both a forum and a medium to facilitate co-management of water resources by improving approaches and tools for water management. EMIN started in 2000 and finished in March 2007. EMIN was implemented by ICT Development Group and RADARSAT International in association with CEGIS and RTi, with support from WARPO and FFWC.

EMIN functioned at the national level and at the local level. Under national level flood monitoring, EMIN established a national level network connecting key stakeholders such as WARPO, BWDB, and DMB. Different types of information, including river flood situation maps and national inundation extent maps, were generated and disseminated to meet the needs of different stakeholders.

At the local level, EMIN initially carried out an extensive information needs assessment (ICTDG and CEGIS 2004) and then, working closely with CFIS in their selected study area, developed methods to disseminate flood information to communities in the floodplain. Community-level flood information was calculated using the WATSURF program developed under the CFIS project. The flood information was communicated using different media such as SMS on mobile phones, a system of different flags displayed at prominent places, loudspeakers, and messengers. The EMIN system worked in 13 pilot locations and the communities responded to the flood information provided (ICTDG 2004). EMIN project's key recommendations on floods include the need for updated digital elevation models (DEM), development of flash flood forecasts and warnings, improvement in flood prediction lead time, further development of institutional linkages and information sharing between organizations involved in floods and flood preparedness, development of modes of dissemination to reach women, and raising awareness of local-level institutions on how to use flood forecasts and how to effectively prepare for floods.

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Chapter 3
Study Area Selection and Needs Assessment

3.1 Study Area

The study area is situated in a flood prone zone on the left bank of the Jamuna River and includes parts of Daulatpur *Upazila* of Manikganj District and Nagarpur *Upazila* of Tangail District. The area is designated by CARE Bangladesh as "medium vulnerable to flood" (CARE, 1999).

3.1.1 Selection Method

The selection of a flood prone study area followed a systematic approach after identifying a set of criteria (***Table 3.1***). Information against the criteria was checked in the field with local stakeholders and interested projects to ensure collaboration.

Table 3.1: Selection criteria for study area

Criteria	Status of study area
Hazard	
Medium-high flood risk.	Based on the vulnerability map produced by CARE, Daulatpur *Upazila* is “medium vulnerable to flood,” while Nagarpur is “highly vulnerable to flood.”
The area partly goes under water during normal flood years.	About 60 percent of the area is inundated during normal flood condition based on CEGIS’ flood monitoring study report.
The agricultural practices of the area are influenced by the uncertainties of flooding.	Though the major crop of the area is dry season rice, the farmers also practice wet season rice including *T.Aman* and *B.Aman.*
Protection	
The area is not protected with flood control structures.	No flood control infrastructure exists along the Jamuna River in Daulatpur or Nagarpur *upazilas.*
Interest of Other Agencies	
Government and NGOs have particular interest in the area.	Flood Forecasting and Warning Centre has interest in the area. Daulatpur *Thana* is included in the CARE disaster management program.
Other relevant projects have interest in the area.	Environmental Monitoring Information Network (EMIN) project, under planning at the time of study area selection, expressed interest in working there; meetings with cellular telephone company (Grameen Phone) indicated that the area was targeted for full cellular coverage within a year.
Availability of Information	
Flood related information on the area is available to develop the methodology.	Yes.
Access for researchers to conduct study.	Limited access as roads and bridges damaged in 1998 flood; access by boat in flood season is adequate.

Moreover, both Daulatpur and Nagarpur *upazilas* are seriously affected by flood and erosion. In Daulatpur, the five major bridges damaged during the 1998 flood had not been repaired or reconstructed by 2003. An additional problem affecting the flood hazard is siltation of riverbeds in the area.

After the preliminary selection of the study area, discussions with relevant stakeholders were conducted to ensure their collaboration. A field visit to the site was conducted to collect information on the study area. During the visit, a meeting with the *upazila nirbahi* officer (administrative head) of Daulatpur Upazila was arranged to exchange views on flood hazard in the area.

3.1.2 Location

The total study area of the CFIS project covered part of Daulatpur *Upazila* under Manikganj District and part of Nagarpur *Upazila* under Tangail District, an area of about 400 km^2 (***Figure. 3.1***). Four unions of Daulatpur *Upazila* and 10 unions of Nagarpur *Upazila* fall within the study area (***Table 3.2***). The west side of the area is the left bank of the Jamuna River, and the east side is the Dhaleswari River. The northern boundary is the road going from Mokhna Union to Salimabad Union, while the southern boundary follows the Ghior *Khal* in the east and the Daulatpur *Upazila* boundary in the west. This floodplain was selected based on the following criteria:

1. Floodplain without major flood protection.
2. A range of land uses that are vulnerable to flood.
3. People expressed interest in receiving flood information (based on reconnaissance).

It was decided to work at two levels. Hydrological analysis, and flood forecasting and information would cover the entire area, but community-based flood information and warnings provided through CFIS would cover two unions and, as will be seen in Chapter 5, focused more intensively on two *mauzas*: Boro Bonna *Mauza* of Jiyonpur Union under Daulatpur *Upazila* and Dhunail *Mauza* of Duptiair Union under Nagarpur *Upazila*.

Table 3.2: Mauzas covered by more intensive flood warnings in the study area

District	Upazila	Union Name	Mouza Name	Dissemination / Flag Sites
Manikganj	Daulatpur	Dhamshar	Nirali	1
			Kakna	1
		Kalia	Baora	1
		Chak Mirpur	Char Mastul	1
		Jiyanpur	Bara Bania *	2
Tangail	Nagarpur	Nagarpur Sadar	Nagarpur Sadar	1
		Mokna	Mokna	1
		Mamudnagar	Mamudnagar	1
		Gayhata	Goihata	1
		Salimabad	Salimabad	1
		Bekra Atgram	Bekra Atgram	1
		Bhadra	Bhadra	1
		Duptiair	Duptiair	1
			Dhunail *	2
		Bhara	Chaubaria	1
		Dhubaria		Only SMS to union parishad

** INTENSIVE WARNINGS THROUGH BDPC SUPPORT*

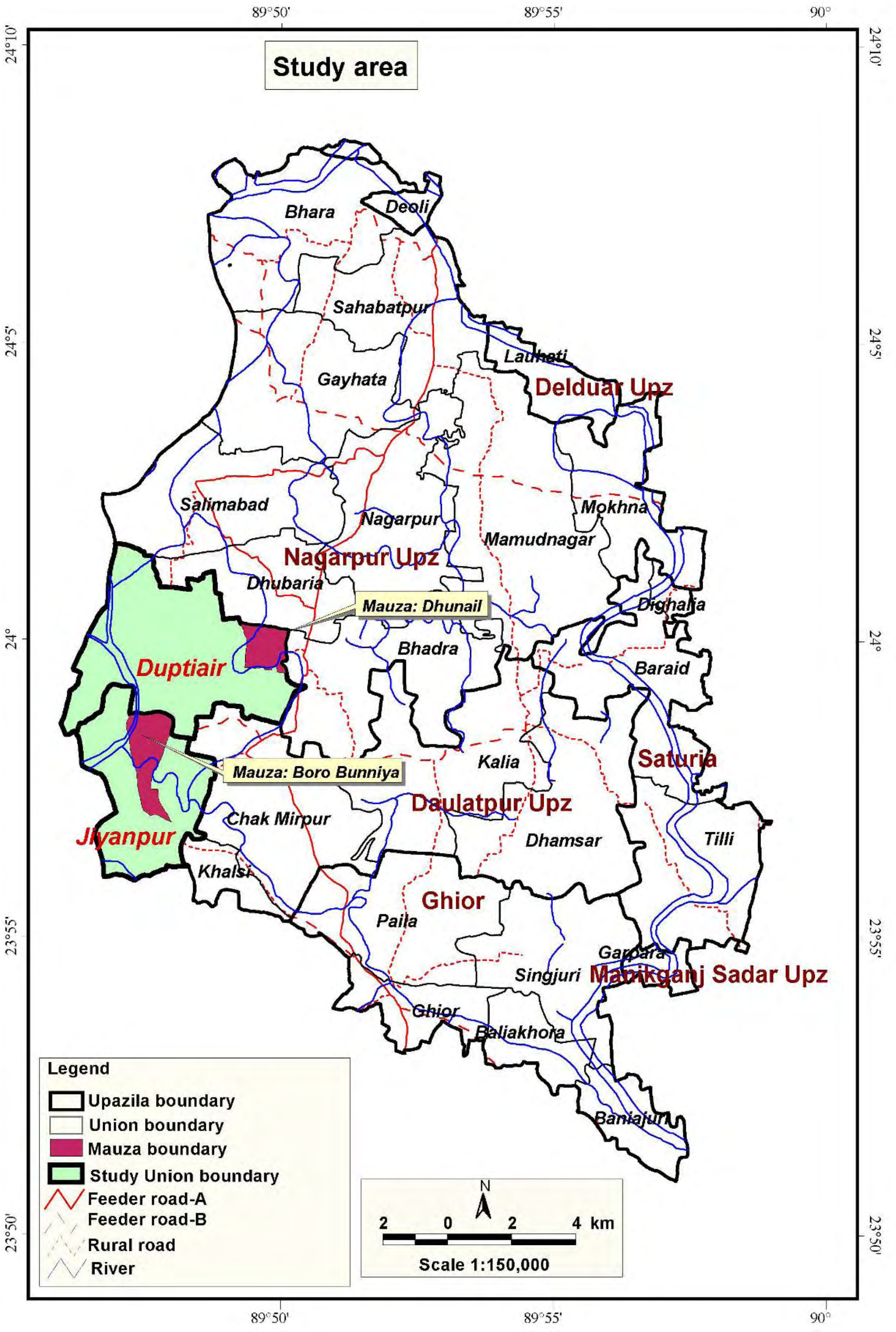

Figure 3.1: Study Area

3.1.3 Hydrology

The hydrological setting was identified through a reconnaissance field survey. The following criteria and materials were considered for monitoring the hydrological setting:

- Topographic map
- Satellite images
- DGPS/GPS reading
- Community concerns
- Physical visit to observe water resources system

Figure 3.2 shows the main sources of flooding and the network of gauges. Gauge locations were identified in the field in relation to different flood cells of the study area to understand and analyze the hydrological influences that contribute to floods.

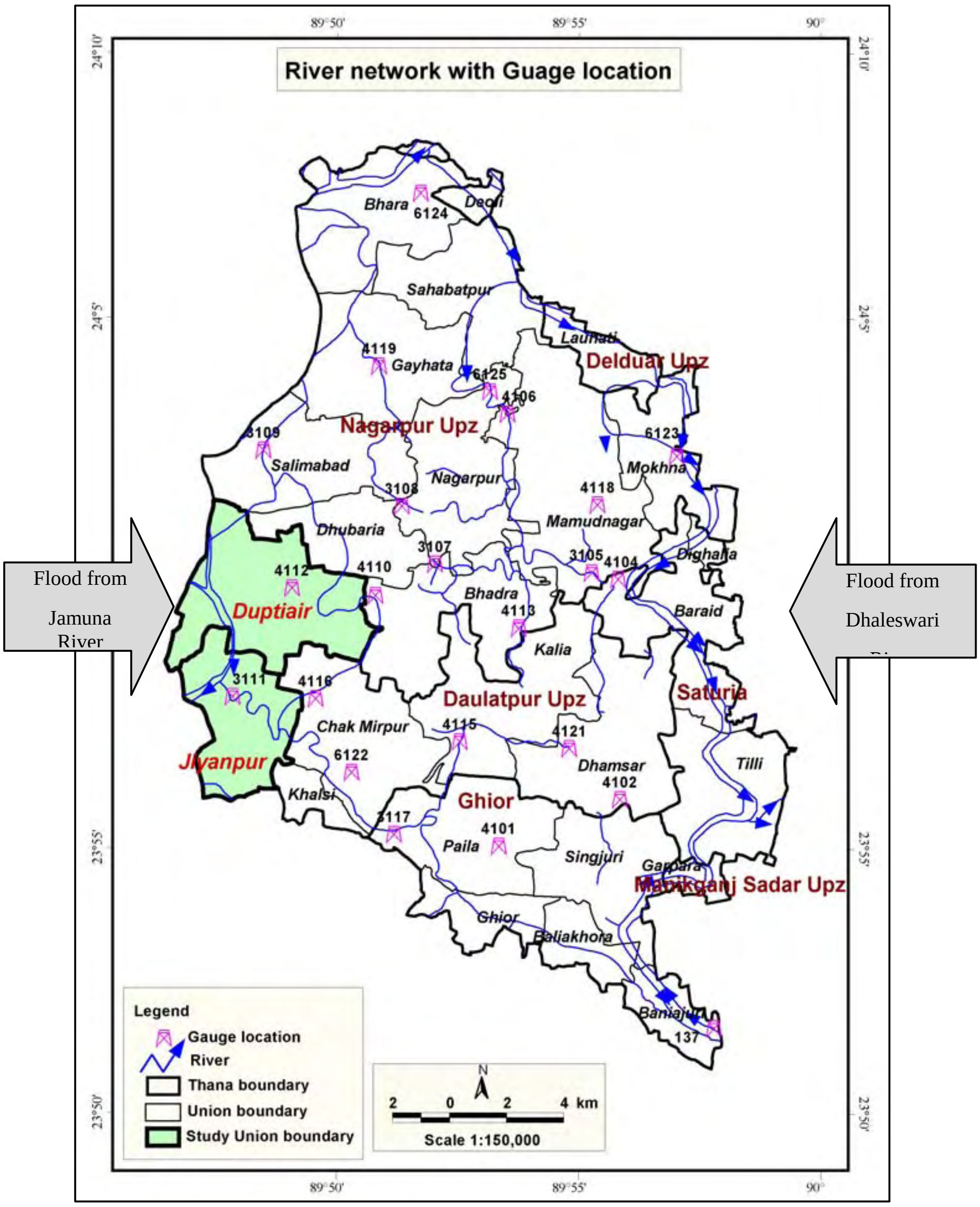

Figure 3.2: Sources of flooding in study area

3.1.4 Agriculture Land Use

The agriculture land use map prepared by the Soil Research and Development Institute (SRDI) and shown in ***Figure 3.2,*** gives an overall picture of the area. Based on field information, union-wise land use practices are described below.

In *char* Kataria, Bachamara, and Baghutia Unions, approximately 90 percent of the area consists of river channels and sand bars or sand deposits. *Boro* paddy is grown in the cultivable areas during the *rabi* season (between January/February and May/June). In February/March, groundnuts are sown along with B. *Aman* paddy. In July, groundnuts are harvested and the B. *Aman* remains until it is ready for harvesting in October/November. Some sugarcane is also grown.

In Jiyanpur and Chak Mirpur unions, the major area falls within the active off-take of the Dhaleswari River, and hence, sand deposits cover large areas in Jiyanpur and western Chak Mirpur. *Boro* paddy is grown in areas where there has not been any continuous sediment deposit for two or three years.

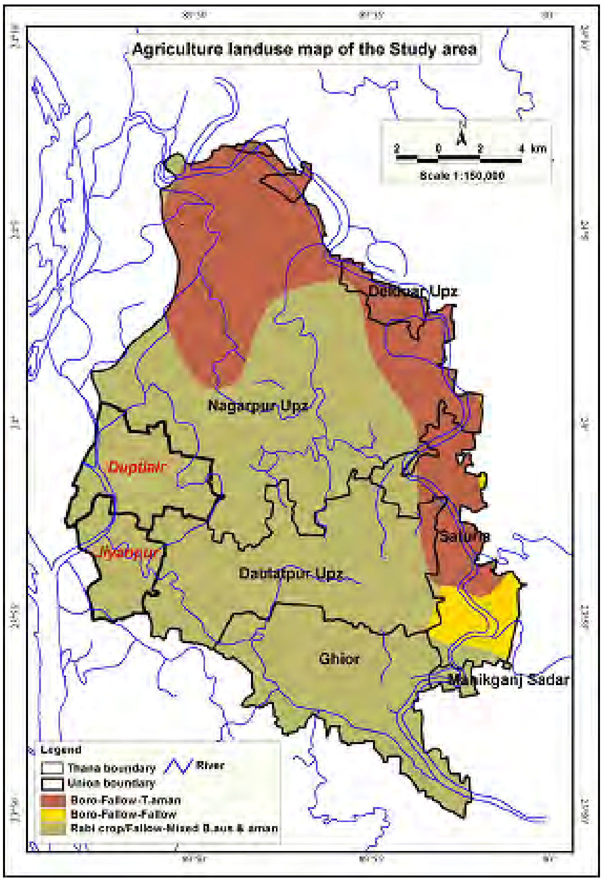

Figure 3.3: Land use based on SRDI

In Dhamsar Union, the general cropping pattern is mustard in November to mid-January, followed by *Boro* paddy in the remainder of the winter (rabi) season. Very little *Aman* paddy is grown here because of deep flooding. The depressed areas are used for fisheries.

In Kalia Union, the situation is similar to that of Dhamsar Union where no crops are grown in the depressed areas, but these form fishing grounds. In higher lands, the cropping pattern is generally mustard followed by a late *Boro* paddy crop in March to June. Relatively more land is cultivated with *Aman* paddy in Kalia Union than in Dhamsar Union.

3.1.5 Cropping Pattern

Boro paddy is the major crop grown in the winter *(rabi*) season from January to May. In some areas, during November to mid-January, mustard is also grown. In the monsoon, most of the areas are left fallow with B.*Aman* and T.*Aman* cultivated in some places.

Cropping intensity in the area overall is 158 percent, but is considerably higher in Nagarpur (173 percent) than Daulatpur (136 percent); this is a result of more double cropping in Nagarpur in the *rabi* season (oilseeds followed by *Boro* paddy), and higher cultivation of *Boro* paddy and jute (***Table 3.3***). Of the other *rabi* crops, pulses include lentil, *mugbeen*, *khesari*, and *maskali*. Oil seeds include *til*, *tesee*, mustard, and sunflower. Almost all the cultivable land is utilized during the *rabi* season, but due to flooding, especially in Daulatpur, the area cultivated in the monsoon is limited.

Table 3.3: Cropping pattern (percentage of cultivable land) by season

Upazila	Kharif-1			Kharif-2	Rabi				
	Aus	Jute	Summer vegetables*	B Aman & T Aman	Pulses	Sugar-cane	Oil seeds	Boro	Wheat
Daulatpur	9.6	3.9	2.4	30.1	34.3	1.1	21.8	30.0	3.4
Nagarpur	9.0	22.1	7.9	28.2	18.2	3.1	14.3	51.3	19.3
Total	9.2	14.5	5.6	29.0	24.9	2.3	17.4	42.5	12.7

** red spinach, green spinach, snake gourd, sweet potato, bitter gourd, okra, watermelon.*

Kharif-1 = early monsoon season; *Kharif*-2 = late monsoon season; *Rabi* = dry season

Aus = early monsoon rice*; B Aman* = broadcast local varieties of monsoon rice, often varieties that elongate with flooding; *T Aman* = late monsoon transplanted rice varieties (local and high yielding) that do not elongate; *Boro* = dry season irrigated rice mostly comprising of high yielding varieties.

Source: *Upazila* agriculture offices, March 2003

The production of *Boro* paddy in the study area in 2002 was reported to be 63,920 metric tons, followed by *Aman* paddy (19,450 metric tons), wheat (18,882 metric tons) and *Aus* paddy (3,229 metric tons), according to the *upazila* agriculture offices in March 2003.

3.1.6 Population and Poverty

The population density is high in the study area, especially in Nagarpur. According to national census data, the population density of Nagarpur Upazila (263 km^2) was 754 per km^2 in 1981, 905 per km^2 in 1991, and 970 per km^2 in 2001 (BBS 2004). The population density of Daulatpur Upazila was about 641 per km^2 in the 1991 census, rising to 727 per km^2 in 2001 (BBS 2004). The average household size in the study area was approximately 5.2 persons. In 1996 in Manikganj District, 41 percent of rural households had no land to cultivate, and in Tangail District 30 percent of rural households had no land to cultivate (BBS 1999). Overall, more than 70 percent of people in the Daulatpur and Nagarpur study area depend on agriculture, with the main source of household income coming from cultivation, including sharecropping.

The reconnaissance team collected primary information on the pattern of food intake from both Daulatpur and Nagarpur. Ten people (four men and six women) between 40 and 60 years of age (average 52) were interviewed. Of the respondents, two were from rich families and four each from poor and middle class families. This indicated that the poor in the project area hardly eat two meals a day, while the rich and the middle class people eat three meals a day. The poor eat adequate quantities of rice, vegetables, and pulses at dinner, their main meal, while they eat rice (sometimes stale), mashed potato, and green chili in the morning. Most of the time, the poor cannot afford a full meal. The rich and the middle class families eat rice, vegetable, pulses, and fish/meat almost every day at both lunch and dinner. Normally, they eat chapati (hand-made bread), vegetables, and sometimes eggs at breakfast. They drink milk at least once or twice a week.

3.1.7 Communications

Nagarpur *Upazila* is connected with the district headquarters by road and waterways. The basic means of transport available are bus, boat, and rickshaw. The *Upazila* headquarters is connected with most of the union *parishads* by *kutcha* roads. Country boats play a vital role in the rainy season. There are 10 post offices and one telegraph office in Nagarpur *Upazila*. Surface and mobile phone communication exists in Nagarpur *Upazila* as well as eight post offices and one telegraph office. There was no mobile phone network in Daulatpur *Upazila* in 2003, but by late 2007, both *upazilas* had network coverage.

3.1.8 Baseline Condition of Flood Information

The baseline condition of the project areas was investigated for different stakeholders revealing the following:

- Pre flood condition:
  - ◊ No flood warnings were issued or received at community level.
  - ◊ Local people used their indigenous knowledge for their flood preparation.
- During flood condition:
  - ◊ Limited national flood information/warnings were received through radio, television, and newspapers, but no area specific forecasts were available.
  - ◊ Adjustments and coping initiatives were taken based on indigenous knowledge.
- Post flood condition:

◊ No post flood information was collected or made available to the communities (e.g., assessments of loss or information on where to get disaster assistance), nor did the communities expect such information.

The views of the main stakeholders on their baseline flood information are summarized in ***Table 3.4***.

Table 3.4: Baseline level of flood information and warning

Stakeholders	Responses
Farmers Own land cultivator Sharecropper	Poor and marginal farmers had limited or almost no access to formal flood information. Farmers did not get any type of flood information from the *upazila* or union *parishad*. Farmers did not understand the existing formal warnings and they could not relate the information within their local context; i.e., how and when the flood might affect their crops.
Laborers Agricultural Laborer Non-Agricultural Laborer	Laborers had very poor access to existing information and were not reached by warnings. They did not understand the language and meaning of national media on flood-related issues. They could not relate the national warnings within their local context.
Fishery Fishers Fish farmers	They did not get any flood information from the existing government system in time. Radio and television information were not useful for them as the media did not say anything relevant about the local flood situation; i.e., how the information would affect their fishing activity. Additionally, the information was hardly understood by the fishers or fish farmers.
Other professions Weavers and potters	Did not receive any information from the local government or NGOs. Sometimes they got flood information from radio and television during or after a flood. If they could receive early flood information and warning, they could better preserve their goods and properties and find alternative marketing options for their products.
Women	Women did not know about government's information dissemination and warnings. They received little flood information from any local government agencies. They got some information from elderly people and the male members of their families. Poor women did not have access to radio and television. Sometimes the women of rich families had access to radio and television, but they barely understood the meaning of flood warnings in their local context as it might relate to their household management.
Local Administration/ Government	They did not receive any official early warning of floods. They only received warnings from national media; they also could not relate these warnings within their local context. They did not design any response or relief operation based on any flood warnings.

3.2 Need Assessment of Community

At the outset of the project a community needs assessment was conducted by BDPC. The main focus of the assessment process was to identify the needs and priorities for flood information and appropriate flood warnings of the key stakeholders, including marginal and poor farmers, wage laborers, fishers, small traders, rural industries, women, social leaders, and local youths. This was expected to be typical and representative of those who were the most vulnerable to early, normal, and late monsoon floods (induced by heavy rainfall or flow of water from up-stream) in the north central region of Bangladesh. The study used key informant interviews and focus group discussions to obtain people's stated needs for flood information before, during, and after floods. The stakeholders from different villages of the project area (covering deep, medium, and shallow flooded areas) said that they require flood information prior, during, and after floods to better prepare and cope with floods, and to help them reduce their vulnerability, both to devastating floods and to the moderate floods that they face almost every year.

Flooding is a common phenomenon in the project villages. Almost every year floods occur in the area, causing severe damage to the lives and properties of the local people. During a normal monsoon season, the water depth ranges between 1.5 m to 2.4 m in the croplands. The people experienced the full onslaught of the devastating floods of 1988 and 1998. The water level in these severe floods was reported to have been 3.6 m to 4 m on cropland. Most every monsoon, normal floods damage the foundations and plinths of houses, and affects livestock, standing crops, fisheries, and rural communication networks. The local people of Kustia village said they were seriously affected by the devastating floods of 1988 and 1998. Their standing crops were totally damaged, goats were lost, vegetable fields went under water, and the sanitation system was disrupted. Most of the villagers used floodwater for drinking and domestic uses, and different types of water-borne diseases affected them. Although they had access to medical treatment, they had to travel long distances by raft or boat to reach the facilities. The poor went without food for days at a time.

The stakeholders emphasized that they need better information and warning regarding early and late monsoon floods because these types of floods damage their crops, household properties, and raw materials and products of their businesses. These floods also cause the escape of pond fish, although fishers were often interested in the information to help them compete to catch wild fish when water levels fall. The particular types of information they need included knowing when the onset of floods would occur, and the depth and duration of the flood at specific locations. Such information, they reported, would enable them to better prepare to minimize losses to agriculture, fish culture, fishing, and trading and marketing of products. Also, it would enable them to explore alternative livelihood activities to compensate for flooding. ***Tables 3.5*** to ***3.7*** summarize the information needs of the key local stakeholders at the three stages in the flood process.

Table 3.5: Flood Information Needs of the Local Community before Floods

Stakeholders	Responses
Farmers Own land cultivator, Sharecropper	At least one week's warning of early monsoon and late monsoon floods, vulnerable areas, and possibility of damages to crops on different types of land. Marketing opportunities of crops and goods, and storing of crops. Prediction about recession of floodwater. Information on preparedness measures to reduce flood impacts on their lives and livelihoods.
Laborers Agricultural laborer Non-agricultural Laborer	Nature and extent of floods. Affect on their agriculture or non-agriculture related employment and wage earning. Possible alternative employment and sources of money for credit if needed. Information on protecting houses, poultry, cattle, trees, plants, and other assets, and where to take shelter during severe floods.
Fishery related Open water fishers Fish farmers	Information on start, duration, and intensity of floods. Possible impacts on pond fisheries and capture fishers, income loss, and alternative employment and income generation. How to protect houses, homestead, trees, and plants. Information on access to market during flood, new fishing ground and strategies, fishing instruments, and flood preparedness.
Business Large traders Rural industries Retail/small traders Weaver and potters	Prediction of nature and intensity of floods. How floods might affect their business and trade, production process, and products. Information on marketing problems and opportunities (for the weavers and potters). Information on flood preparedness measures.
Women	Intensity and duration of floods, and level of water. Possible damages to their home, household belongings, vegetable gardening, poultry rearing, fuel and food preservation, drinking water sources, and sanitation. Suggestions for flood preparedness. Particular information on care for pregnant women, lactating mothers, and children.

Source: KII and FGDs

Table 3.6: Flood Information and Warning Needs for the Local Community during Floods

Stakeholders	Responses
Farmers Own land cultivator Sharecropper	Warning of level, intensity, and duration of floods, and conveying the risk of damage to standing crops in different types of lands. Information on price of necessities in the market, rural communication, flood risk to household assets and belongings, and employment opportunities.
Laborers Agricultural laborer Non-agricultural laborer	Warning about potential damages to houses, livestock, poultry, and other belongings. Information about loss of incomes and employment during flood. Assistance for health, relief, and flood shelters.
Fishery related Open water fishers Fish farmers	Information about trends and intensity of flood. Suggestions on proper management and preservation of nets, boats, and pond fisheries. Information on markets and price of fish, foods, and essential goods.
Business Large traders Rural industry Retail/Small traders Weaver and potters	Information on communications (road transport, etc), and price of the commodities in markets. Suggestions on preservation of goods and commodities, and how to get to shelter during severe floods.
Women	Information about extent and duration of floods. Prefer warnings conveying the likely damages to their plinth and foundation of houses and belongings, including food, fuel, and fodder for cattle. Need information as well as assistance to access safe drinking water, better sanitation, childcare, and caring of elderly people and pregnant women.

Source: KII and FGDs

Table 3.7: Information Needs of the Local Community after Flood

Stakeholders	Responses
Farmers Own land cultivator Sharecropper	Information and suggestions for post flood cultivation, sources of good quality seeds, fertilizer, credit, and regeneration of agricultural activities. Guidance and assistance for income=generating activities, reconstruction of rural infrastructure, relief and rehabilitation programs, and medical facilities.
Laborers Agricultural laborer Non-agricultural laborer	Information about sources of employment, assistance for income generating activities and alternative livelihoods, and relief and rehabilitation supports.
Fishery related Open water fishers Fish farmers	Information on support for fishing gear (net, boat, baskets) and fish culture for regeneration of their livelihood activities, and on relief and rehabilitation support for reconstruction of houses and other income options.
Business Large traders Rural industry Retail/Small traders Weaver and potters	Information on reconstruction of rural communication networks, financial support for regenerating and rehabilitation of their businesses, and on commodity price in different markets.
Women	Information on sources of financial support for poor women, seeds and fertilizers for home gardening, income generating activities, relief and rehabilitation resources, and on the location of *upazila*- and union-level health services.

Source: KII and FGDs

The consultations indicated that the existing flood warning dissemination procedure is not appropriate in the local context. The people did not understand the official language of weather forecasts on the radio and television. They felt that the flood warnings should be location specific and dissemination should be in colloquial dialects. Local people expressed their preference that flood-warning messages be disseminated by the representatives of local government institutions, using microphones in the mosques, and through drum beating in local markets and community centers. If a warning is given one week prior to the impending flood, people could not only save their belongings, but also take the crops ready for harvesting to a safe place. Some local people also said that it requires three or four days for netting (surrounding pond banks with nets so that during flood-cultured fish cannot escape) and other preparations, and that it would be helpful to get messages with at least four days lead-time.

People in this area, as throughout Bangladesh, have their own coping mechanisms and survival techniques developed through tradition, long experience, and family wisdom. Every year before the monsoon, most of these resourceful people raise the earth plinth of their houses. A small number of people plant trees to protect their houses from wave erosion. It is a very common practice for village women to make movable earthen cooking stoves and preserve fuel materials for cooking during the floods. However, at the community level, preparedness measures are not organized and most of the people are not aware of what actions should be taken to prepare for excessive floods.

Chapter 4
CFIS Flood Forecasting System

4.1 Overview of CFIS Flood Forecasting System

The CFIS project developed an operational system for the study area that produces accurate, local daily flood forecasts for the target communities. Along with frequency analyses using historic data, these forecasts also were used for determining the risk to communities from flooding.

The relational model WATSURF, described in detail below, was developed to forecast water levels in the floodplain based on regression relations between 17 floodplain gauges and 3 river system gauges. The floodplain gauges were setup and maintained by the CFIS project, and used to determine their relation with the established river gauges that are observed and maintained by the Bangladesh government, and for which the government's flood warning system is operated. As a GIS-based model, WATSURF extends the point forecasts for the 17 floodplain gauges to a continuous flood forecast map for the entire project area, as shown in ***Figure 4.1***. From the forecast map, WATSURF extracts a specific forecast for any point within the study area and creates a SMS text message that is transmitted to mobile phones at selected sites in the field.

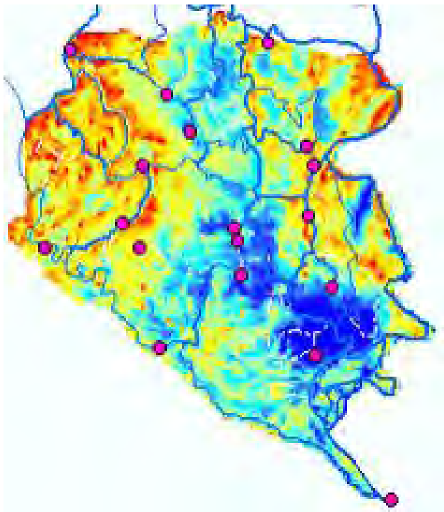

Figure 4.1: Example of Forecasted Flood Map for the CFIS Project Area Produced by WATSURF

Individuals were selected by the local community to serve as operators, to receive the SMS message, and to operate a flag system and bulletin boards for informing the community of the local flood forecast. The message and symbols were designed with active participation of the local people. The flood warning messages, expressed in the local measuring unit "*bighat*" (one *bighat* = 22 cm), were generated by WATSURF and sent via SMS to mobile phones of the flag operators, who in turn hoisted the colored flags to symbolize the flood forecast.

This chapter describes the CFIS flood forecasting system including data inputs, the study area, WATSURF, and the automated SMS dissemination. The evolution of the local warning system is described in ***Chapter 5***.

4.2 Data and Information Availability

4.2.1 Digital Elevation Model (DEM)

The digital elevation model (DEM) served as key information in initializing a comprehensive floodplain flood forecasting mechanism. The DEM was the key input for local-level flood prediction, but the accuracy of such prediction depended on the accuracy of the DEM itself. In Bangladesh, the present DEM developed by CEGIS has coarse resolution (500m x 500m) based on the BWDB maps of the 1960s. It is therefore not appropriate for many applications and needs to be updated and improved for use in flood management.

- <u>BWDB's Topographic Map.</u> BWDB has a series of topographic maps compiled between 1952 and 1964 under the authority of the surveyor general of East Pakistan. These topographic maps comprise two scales: four inch to a mile and eight inch to a mile. The maps are in two different sets of datum: the Public Works Department datum (PWD) and the Survey of Pakistan datum (presently known as the Survey of Bangladesh or SOB datum). Between these two sets of datum, there is a difference of 1.51 feet where the PWD datum is higher than that of SOB. These maps are one of the main sources for the DEM used in Bangladesh, covering approximately 60 percent of the total land area. BWDB maps contain topographic data including elevation points, contour lines, rivers, *beels*, roads, forests, vegetation, homesteads, and political boundaries. The land elevation points were recorded primarily on agricultural land. Areas that were inaccessible due to the presence of river, *beels,* and dense forests were excluded from the survey.

- FINNMAP. In 1991 FINNMAP, a Finnish mapping and surveying organization, under the supervision of SOB, surveyed the coastal areas of Bangladesh for the Bangladesh Inland Water Transport Authority (BIWTA) and printed the outputs as hard copy maps in the 1:10,000 scale. The area surveyed by FINNMAP covers about 20 percent of the total land (in 1100 sheets) located in the coastal regions. The data was derived from aerial photographs of the coastal zone taken during the 1991 dry season. Both spot heights and contour lines with an interval of 25 cm are depicted on the maps. Besides these, many other features -- administrative boundaries, infrastructure, water features, relief, and others – also are shown on these maps.
- Comparison of BWDB and FINNMAP. Regional and national level DEMs of Bangladesh have been prepared by CEGIS during the past decade. A study conducted by EGIS based on some selected locations showed a distinct difference, as shown in ***Figure 4.2***, between the DEM prepared by using the old BWDB topographic maps and the new FINNMAP surveyed topographic maps. ***Figure 4.2*** shows not only the difference in elevation over the 30-year period, but also reflects the changes in the hydrological systems in the local areas.

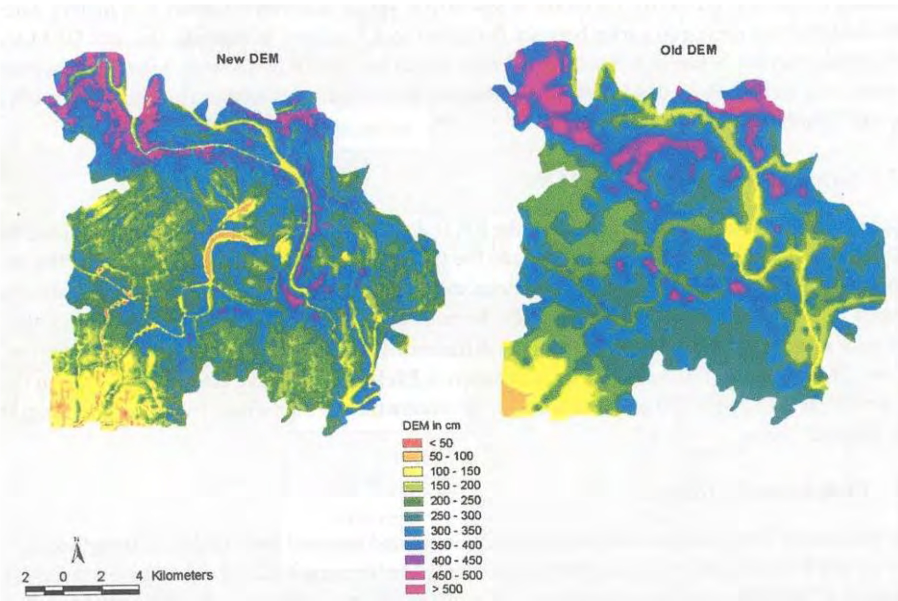

Figure 4.2: Comparison between the DEM from BWDB and FINNMAP, Rampal Upazila

4.2.2 Stream Gauge Data

- Water Level. Water level data are collected by BWDB and BIWTA. The latter mainly collects tidal water level data, while the former collects and stores daily water-level data from different water-level stations throughout the country. BWDB collects data from two types of water-level stations: non-tidal and tidal. It has a total of 259 non-tidal water-level stations and at all these stations, the water levels are measured with wooden staff-gauges, five times a day at 6:00, 9:00, 12:00, 15:00 and 18:00 hours. BWDB also has some mechanical gauges that are called auto record water level gauges. The water levels received from the field are adjusted for vertical shifts according to check leveling. The daily mean data are generated from the average of two times value per day taken at 6:00 a.m. and 6:00 p.m. National Water Resources Database (NWRD) has checked for obvious errors in this data layer from BWDB and stored them in an orderly format. Data from BWDB for all non-tidal water-level stations is available from 1910 to 1997, but the extent of data availability is different for different stations with some data missing at some stations. There are 176 tidal water-level stations from where BWDB collects data on daily maximum and minimum water levels. Daily tidal water-level data are available from 1909 to 1996 for some stations, but most of it is available from 1965 to 1995, although here too there are some missing data. The quality of this data set depends, in part, on the quality of the collection, storing, and processing of data by the collecting agency.

- Discharge. BWDB collects tidal and non-tidal discharge data from different stations throughout the country. Daily discharge data is an essential parameter in hydrological analysis and modeling and is important in environment-related studies. The discharge is measured at five locations in the main rivers, generally at intervals of one week during the monsoon season (May-November) and fortnightly during the rest of the year. At the Hardinge Bridge and, since October 1992, at Bahadurabad, daily flow measurements are made during the lean season. There are 134 non-tidal discharge stations in regional and minor rivers, but data is available for only 125. Of the 16 tidal discharge stations throughout the country, data is available for only 12 stations.
- Rainfall. In Bangladesh, rainfall data are collected by two government organizations: BMD and BWDB. BMD has collected and stored data from 31 rainfall stations throughout the country over a long period. NWRD collated data between 1960 and 1999; however, these data are not available for all stations.

  BWDB also collects and stores data from different rainfall stations throughout the country. Of the 304 rainfall stations under BWDB, data are available only for 295 stations. NWRD contains rainfall data from BWDB stations for the period April 1957 to March 1997.

4.2.3 Other Data

- Agriculture Land Use. Agriculture land use maps were derived from the satellite images of the study area. The T. *Aman* area statistics were derived from multi-temporal RADARSAT fine beam images of 2004 and compared with the T.*Aman* area estimated by the *upazila* agriculture office (***Figure. 4.2***).

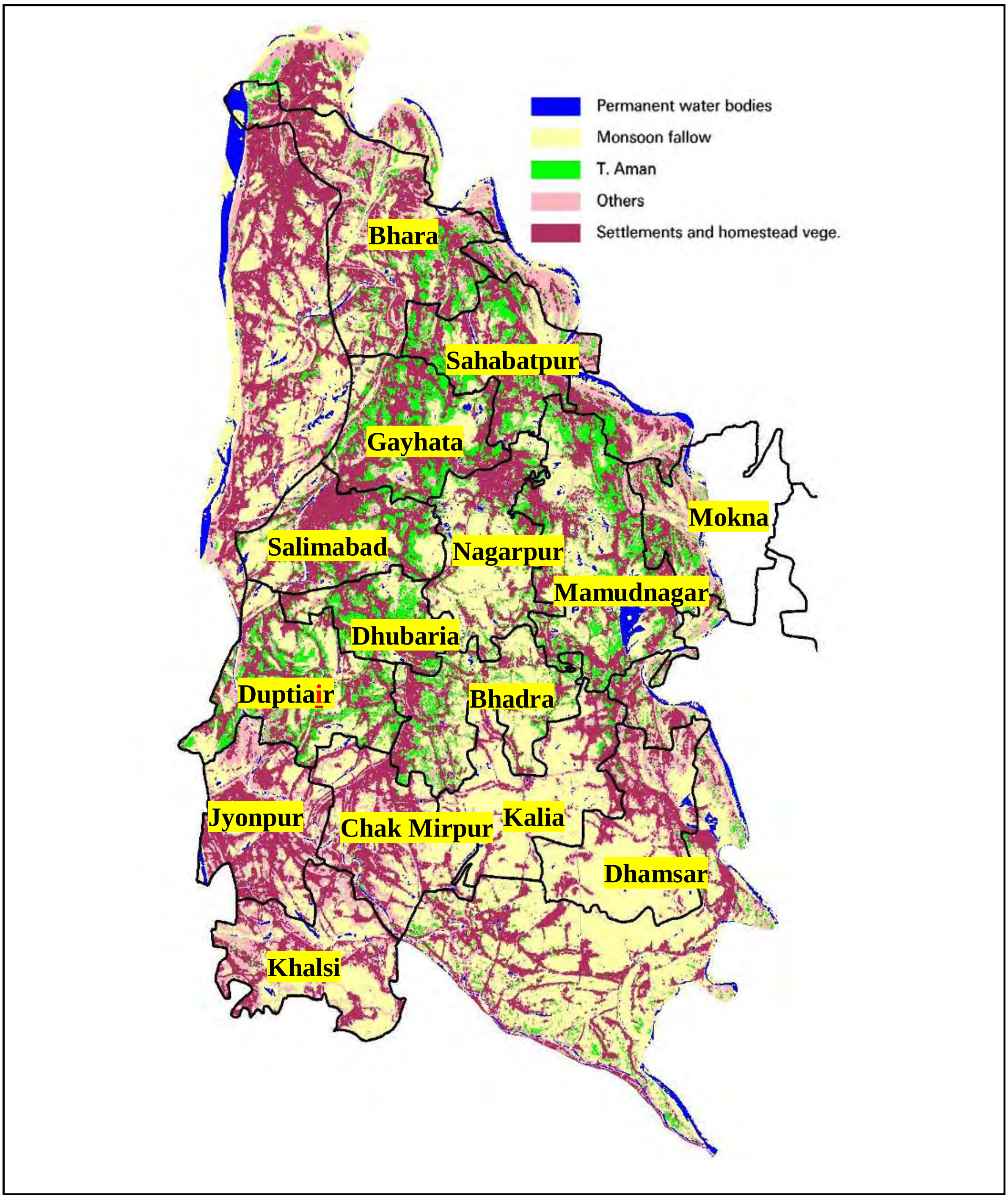

Figure 4.3: Monsoon Agriculture landuse map of the study area (derived from analysis of multitemporal RADARSAT images, 2004)

Water bodies were extracted for the western half of the study area from satellite imagery from the high-resolution Quick Bird satellite (shown in ***Figure 4.3***), while water bodies on the eastern part of the study area were extracted from IRS PAN images. Using both the images as backdrops on a screen, digitizing was done to capture the water bodies. Water bodies for the eastern half of the project area were further updated using the latest Quick Bird image.

Figure 4.4: Example showing water bodies, rivers, and road network extracted from Quick Bird satellite image

- Road Network. Major roads were digitized from survey of Bangladesh topographic maps. Detailed roads were on-screen digitized from Quick Bird images and India Remote Sensing. PAN images as shown in ***Figure 4.4.*** Immediately after the Quick Bird images became available, the road coverage was updated using screen digitizing.
- Settlements. Settlement boundaries were very easily extracted as Quick Bird images and are of a very high resolution (0.55 m pixel). In the areas where Quick Bird images were not available, IRS PAN images were used. ***Figure 4.5*** shows the settlement boundaries extracted from Quick Bird images.

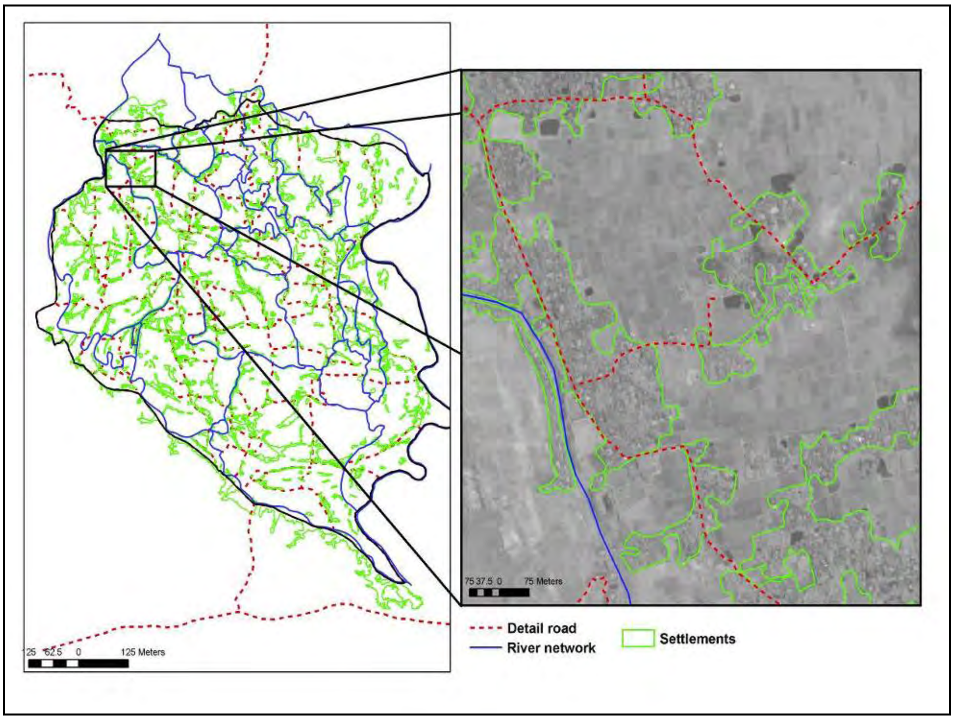

Figure 4.5: Settlement boundaries extracted from Quick Bird satellite image

4.3 Hydrological Monitoring

4.3.1 Monitoring

The flood depth mapping methodology under the CFIS project required information on flood dynamics between the rivers and floodplain, including the delineation of land and water interface. To understand the process of flood dynamics and interaction with the floodplain, it was necessary to establish a hydrological monitoring information network in the floodplains. BWDB has no floodplain monitoring stations. Hydrological water-level monitoring sites were selected in the floodplain areas to monitor the water levels, and the temporal and spatial variability of the flood dynamics and its responses.

Two main rivers control the major flooding and drainage of the study area. Water enters the floodplain through different channels and creeks originating from the Jamuna River and the Dhaleswari River. High water levels and potential flooding begin around the first week of June and finish during November. Water enters the study area from the northwest through the Jamuna River, and from the north and south through the Dhaleswari River. When the water levels in the Jamuna rise above danger level, many parts of the study area are at high risk. Additionally, when the water levels in the Jamuna surpass the bank-full discharge, most of the study area inundates and many standing crops are destroyed, including T. *Aman* and B. *Aman* rice crops. Approximately 60 percent of the study area is inundated under normal flood conditions.

4.3.2 Drainage Network

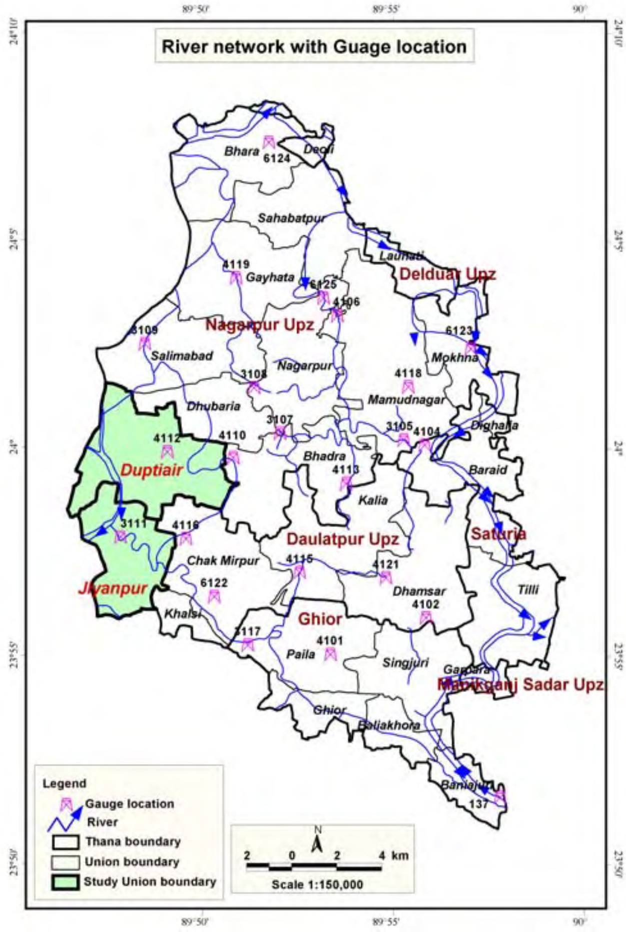

Figure 4.6: Drainage Network of the Study Area

A preliminary assessment of the drainage network during the monsoon season was made through consultation with local inhabitants and field observation. From this assessment, it was clear that most of the floodwater drains through the Dhaleswari. The floodwater remaining on the western side of the Nagarpur-Daulatpur road drains into the Jamuna River. The drainage flow network is shown in ***Figure 4.6***.

4.4 Field Data

4.4.1 Leveling Survey

During the initial phase of the project, a team of CEGIS professionals performed a reconnaissance survey in the study area. The team visited villages, channels, river systems, and land of different topography to assess the hydrology and flood information needs of people vulnerable to severe flooding. Based on the river network flow patterns, hydrological monitoring sites were identified in the floodplains. These hydrological monitoring sites or gauge locations were determined to allow for easy interpolation of the water levels in the floodplain.

After determining the gauge locations, a field-leveling survey was carried out by IPM Technocrats under the supervision of CEGIS engineers to establish benchmarks for the hydrological monitoring network. The hydrological-leveling survey was conducted with the following objectives: to establish temporary bench marks at close proximity to the gauge points, to install water level gauges and connect them with the existing datum, and to assess the drainage and flow patterns during the monsoon.

4.4.2 *Gauge Installation*

After completion of the leveling survey, floodplain gauge installation was initiated. Six gauges were installed in 2003, thirteen in 2004, and four in 2006, totaling twenty-two gauges by 2007. Seventeen of these gauges were used in the initial model development. Eleven gauges were installed in Nagarpur Upazila and another eleven gauges were installed in Daulatpur Upazila. ***Figure 4.7*** shows the location of gauges in CFIS area. When determining the locations of the floodplain gauges, several factors were considered, including: the water level should be easily read from the gauge; the gauge is located in a level area that requires minimal shifting and is not likely to be disturbed by boats or other human contact; and, the gauge is installed with proper support and straight enough to reduce the error in gauge reading.

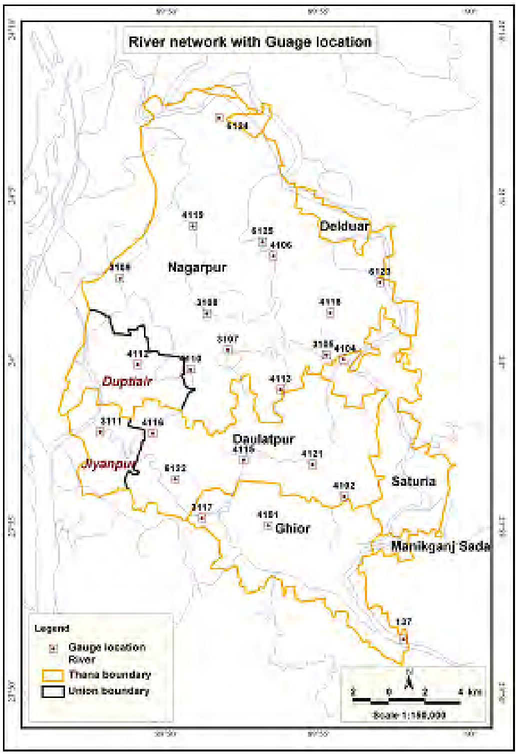

Figure 4.7: Gauge Locations in the Study Area for 2007

Selected community members were trained to properly read and maintain the gauges. During the flood season, gauge readers collected data twice daily at 6:00 am and 6:00 pm for each of the 22 gauges. They recorded the data in a logbook, which was collected every 15 days by a field supervisor working for CEGIS. The gauge readers also reported the data daily via SMS back to CEGIS. CEGIS field supervisors checked the logbooks regularly. Once every month, CEGIS field engineers checked the leveling of all the gauges, assuring accurate and consistent data. Data collection of water level began in July of 2003, after the first six gauges had been installed.

During the flood season, field data was entered into a spreadsheet and monitored to ensure that the flood forecasts were reasonable. If there were any significant inaccuracies with the forecast, as compared with the monitoring station data, then the forecast would be corrected or suspended until the error was identified.

4.5 Study Area Analysis

Several analyses were conducted in the study area in hydrological, technological, and social context; the details of these analyses are presented in prior sections of this chapter, and in the appendices. For the study area in Nagarpur and Daulatpur upazila, the following conditions were assessed: hydrological characteristics of the rivers and channels; flooding relationship with the FFWC forecasting; connectivity and network of channels; entry and exit point of floodwater; and, duration and extent of flooding.

The state of knowledge about flood early warning, including the needs of the community, was investigated via field study of the area, analysis of literature and secondary data, and consultation with local community members. In addition, the possible flood forecast dissemination network, efficient route, media, mode, and monitoring and dissemination sites were evaluated. In addition, the means for building community ownership, acceptability, and sustainability of the CFIS system was evaluated.

4.6 WATSURF

At the heart of the CFIS Flood Forecasting System is WATSURF, a relational model, developed to forecast and disseminate water levels in the floodplain. WATSURF is an ArcGIS tool written in Visual Basic (VB) to run in ArcMap GIS environment. WATSURF uses regression relations between 17 of the CFIS floodplain gauges and 3 FFWC/BWDB gauges on the main rivers. As a GIS-based model, WATSURF extends the point forecasts for the 17 floodplain gauges to a continuous flood forecast map for the entire project area.

From the forecast water level map, WATSURF extracts a specific forecast for any point within the study area and creates a SMS text message that is transmitted to mobile phones at selected sites in the field. At each field location, a volunteer was contracted to help disseminate the flood warning information. Each day during the flood season, the volunteer received an SMS message describing the category of the water level change in the next 48 hours and raised color-coded flags to match this change. During the 2007 flood season, in addition to the flag operators, SMS text messages were sent out in bulk to registered members of the community directly to their cell phones.

There are a number of steps between data processing and dissemination of the flood information. The overall process of the CFIS Flood Forecast System/WATSURF is shown in ***Figure 4.8***. The major components in this figure are described in the following sections of this chapter.

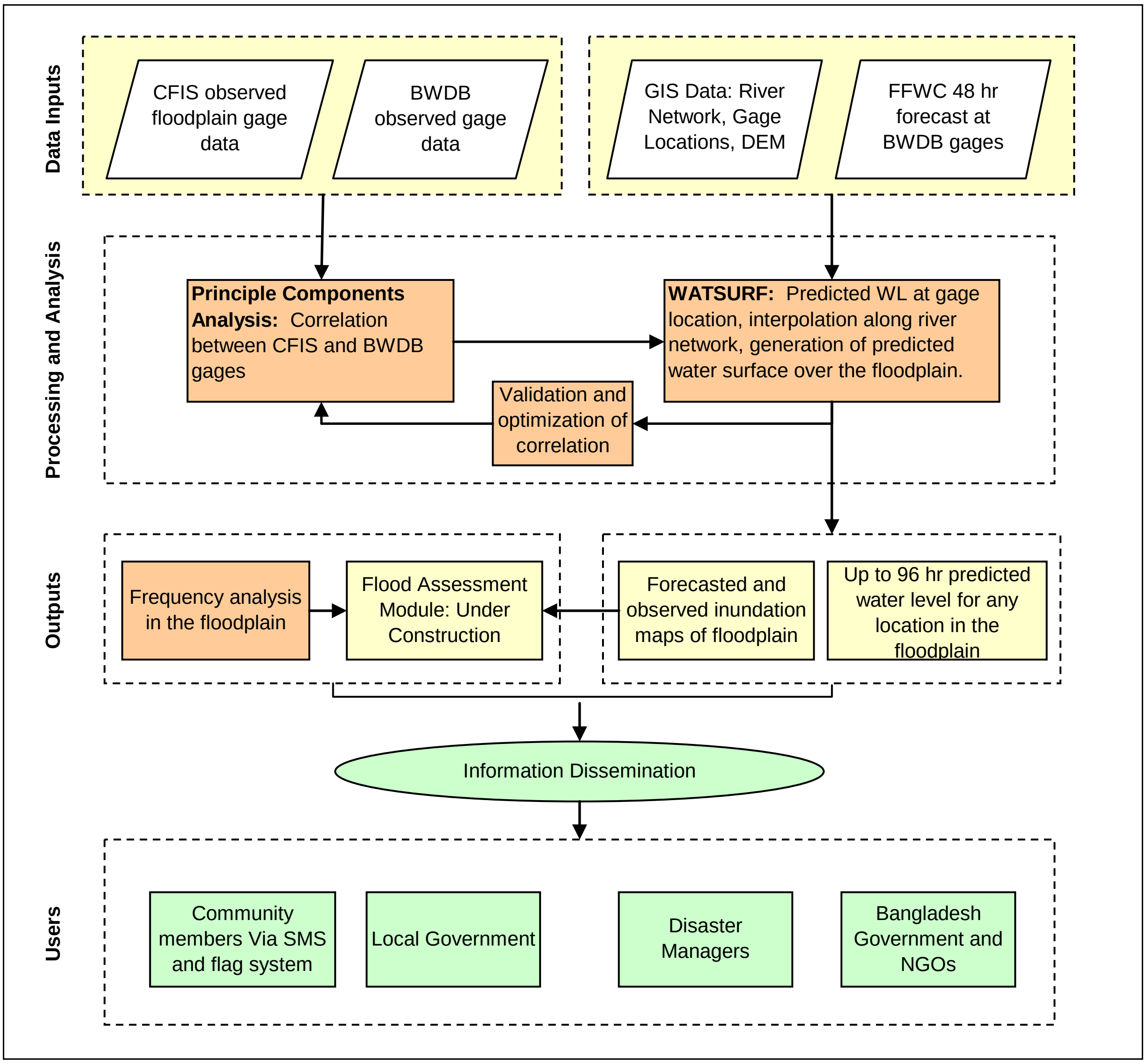

Figure 4.8: CFIS/WATSURF Operational Flow Chart

4.6.1 Data Inputs

The GIS inputs to WATSURF consist of three datasets: DEM, river network, and gauge location. ***Figure 4.6*** shows a map of the river network and gauge location for the CFIS study area.

The rivers within the study area were ranked in orders (one to eight) according to the flow capacities and connectivity. River of order one is larger than two, and so on. River lines were split at gauge locations to create nodes (gauges). This data structure was necessary for the program to interpolate water levels between nodes.

WATSURF's forecast required observed and predicted water levels at the reference gauges (Sirajganj and Aricha) and relational equations between the reference gauges and each field gauge. These inputs were used to estimate water levels at the gauge stations, which in turn were used to generate forecasted water levels through the entire study area.

Because of analysis of the water levels of contributing rivers, FFWC gauge 49 (Sirajganj) and 50.6 (Aricha) on the Jamuna river, located upstream (about 55 km) and downstream of the study area, respectively, were selected to be used as the reference stations. Measured and forecasted water levels at the reference gauges are posted on the Web by FFWC (www.ffwc.net) and are read directly by the WATSURF program.

The equations relating reference water levels to predicted gauge water levels were derived by regression analysis of the data collected during the 2003 season, as described in the following section.

4.6.2 Relational Equation Development

The principle components analysis was performed in 2003 to create a relationship between the water levels of the FFWC forecast points, or reference gauges, and the water levels at the individual field gauges within the study area.

- Time Series Data Used. Data were used for two FFWC forecast points—gauge 49 at Sirajganj and gauge 50.6 at Aricha (Figure. 4.9). Data were also provided for one regular, non-forecast point 137A at Tora. Field data for the flood season of 2003 were provided at 12-hour intervals for 17 gauges labeled G01, G02, . . . G16, G17 by CEGIS.

  For analysis, additional time series were created by lagging Aricha and Sirajganj data at intervals up to 120 hours. Similarly, additional time series were created for Tora, but by lagging it negatively, or shifting values backward.

- Correlation Investigation and Lag-time Consideration. Correlations were calculated for each gauge against all other gauge time series. For the CFIS purpose of developing predictions, only the correlations between the field gauges and the various Aricha, Sirajganj, and Tora time series were considered. Limitations were imposed on the period of analysis and minimum values at Sirajganj and Aricha. The correlations were recalculated. This process was repeated in an attempt to determine the best correlation through iteration.

  Results of the correlations showed incremental improvements with Sirajganj, the further the Sirajganj time series was lagged. Gauge G01 correlated worst (of those investigated) with the non-lagged Sirajganj. Review of the actual time series suggested a physical lag time of approximately 12 to 72 hours. Although the statistics improved beyond this time, they were judged meaningless for predictive purposes. Perhaps they have some meaning in suggesting significant system memory, but the limited data (from one season only) did not provide means to make rational, useful conclusions.

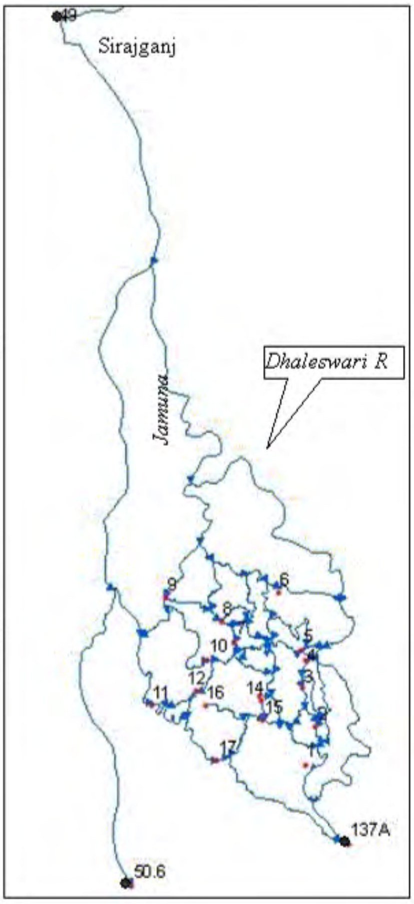

Figure 4.9: Location of FFWC Forecast Points

- Tora as Predictor. While many of the field gauges closer to the outlet of the basin correlated well with the Tora gauge, it was not used as a predictor for the field gauges mainly because FFWC does not forecast for the Tora gauge station. It would be useful if FFWC forecasted at Tora gauge station.

- Principal Components Analysis and Equation Development. With the understanding gained in the initial gauge analysis, and by enforcing lag time constraints, a principal components analysis was conducted for each gauge against Aricha and appropriate Sirajganj time series. Only increments of 24 hours were allowed, considering that only 24-hour values were available at Sirajganj. It was found that the exclusive use of the 72-hour lag of Sirajganj best described six of the gauges, and a 48-hour lag of Sirajganj best described six other gauges. The remaining four gauges, which corresponded best with Sirajganj, were predicted by a combination of Sirajganj and Aricha lag time series. An example regression for one of the floodplain gauges is shown in Figure 4.10.

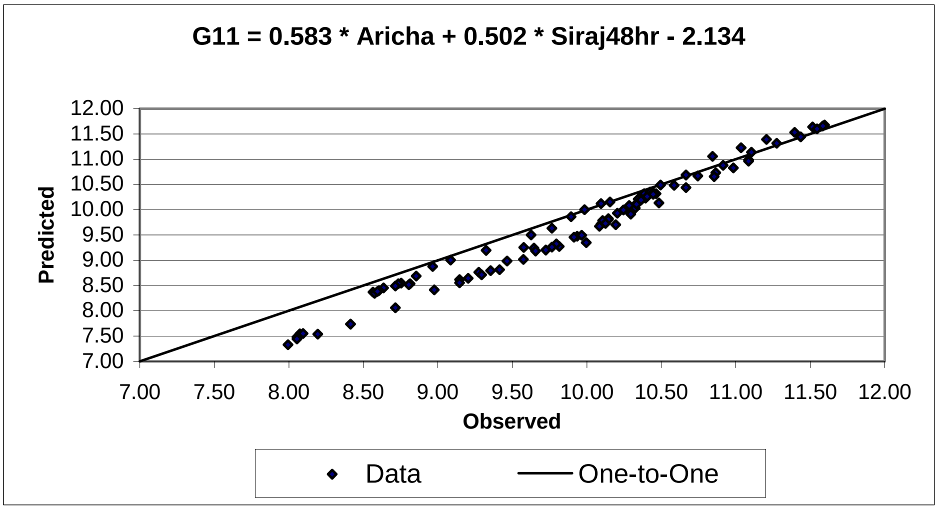

Figure 4.10: Example Regression Equation for One of the Floodplain Gages (G11)

4.6.3 Community Flood Information Dissemination

One of the main activities of the CFIS project was to develop and operate a system that disseminated flood forecasts to the floodplain inhabitants. The primary system designed in the beginning of the project used a system of volunteers receiving SMS messages about the flood and then operating a series of flags to inform the surrounding communities about the flood forecast. During the last year of the study, 2007, this flag network was complimented with a more direct communication to the local communities during which SMS messages were sent directly to registered cell phone users in the study area. This more direct communication was possible during the last year of the study because of the rapid growth of cell phone coverage, and their use, in the area. In addition, the CFIS project secured an operating agreement with one of the major cell phone operators in the country that provided the SMS message dissemination at no cost as a social service to the community.

In the initial stages of the CFIS project, prior to the flood season 2004, at selected locations throughout the study area, volunteers were solicited to help disseminate flood information. Each day during the flood season, the volunteer received an SMS message to his or her cell phone (initially provided by CFIS) describing the magnitude of the forecast water level change in the next 48 hours. This SMS message was generated and sent automatically to the volunteer in the study area. For simplicity and local effectiveness, the value was sent in the local measurement unit, a *bighat* (approximately 22 cm). Each volunteer also was equipped with a flagpole, where he or she could raise blue or white flags. If the water was predicted to rise in the next 48 hours, the operator would raise the number of blue flags corresponding to how many *bighats* the water level would rise. White flags were raised to signify a decrease in the water level.

For clarity, it was also necessary to define a bound around zero for which no change in water level was sent. This bound was one-half *bighat*. One flag represented a change of between 11 cm and 33 cm, and two flags represented a change of 33 cm to 55 cm and so on. A schematic of this is shown in ***Figure 4.6***.

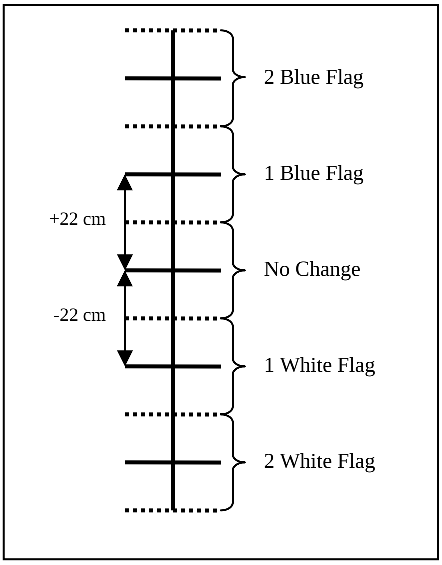

Figure 4.11: Schematic of Flag System, and a flag system in operation in the floodplain

In addition to the blue and white flags, communities also identified flood danger level in the field. Three different levels where defined by the colors green, yellow, and red, which represented a normal, moderate, and high flood level, respectively. These levels were surveyed in the field and input into WATSURF. Therefore, WATSURF also output the current danger level at each field location. For the first two years of operation, each flag operator also was given a separate pole in which he or she raised a green, yellow, or red flag when an SMS informing of the danger level was issued. This system of communicating the present danger level was confusing to the local residents and did not offer much useful information for them. It was discarded after the second flood season of operation (see Chapter 5).

4.6.4 WATSURF Modules and Information Products

- <u>WATSURF Modules.</u> WATSURF was developed in a modular format. As more functionality is needed, it easily can be built into the program. The following describes the modules that were incorporated into the current version of WATSURF.

  1) Adding Module: The adding module was developed to easily add dissemination points for water level messages. The user can easily expand the dissemination coverage by updating the database and spatial files.

  2) SMS Module: The SMS module was developed to automatically disseminate community flood messages over the commercial cellular network. The module sends SMS messages from the WATSURF software to the following levels:

  - Union bulletin board
  - Field volunteers (flag operators)
  - Registered users

  3) Database Module: The database module was used to archive incoming SMS messages from the gauge operator in the WATSURF database.

  4) Monitoring and Assessment Module: The monitoring and assessment module generated tables and graphics based on the predicted and observed water levels. The system analyzed the observed water level received through SMS, against the predicted water level, and then generated a report that was sent to the quality control managers. The module also is able to produce evaluation reports on the flood prediction utilizing all the floodplain gauges.

- <u>Information Products.</u> WATSURF produced four types of products for the government administration, community, and households. These products were generated in the form of table, map, and text message, and disseminated to the target groups through fax and mobile SMS service. A list of the products is shown in ***Table 4.1***. A sample of some of the products and description is provided in the following sections.

Table 4.1: List of WATSURF Products Table

Name of product	Format	Time of product preparation	Extent of the product	Time to produce product	Target Group	Dissemination Medium
District level flood situation	Printed table	Any date	*Upazila*-wise flood warning (Nagarpur and Daulatpur *upazilas*)	1 hour	District and *upazila* administration	Fax
Upazila 48-hour flood warning	Printed map and table	Any date	*Upazila*-wise flood warning (showing all water level gauge station)	1 hour	*Upazila* administration	Fax
Union 48-hours flood warning	Printed text message	Any date	*Mauza*-wise flood warning	1 hour	Union administration	Mobile SMS
Community and household level 48-hours flood warning	Printed text message	Any date	*Mauza*-wise flood warning	1 hour	Community and household level	Mobile SMS

a. District level flood situation

Water level situation and forecast for 24 and 48 hours at gauge stations in the main rivers near Tangail and Manikganj districts were presented in tabular form and sent to the district and *upazila* administrations via Fax. An example of these district level products is shown in ***Figure 4.12 and 4.13***. ***Figure 4.12*** shows danger levels, water level on the previous and current day, and expected levels in 24 hours and 48 hours time at the FFWC gauging stations in the main rivers. From this message, the government officers could understand the present and future flood situation around their districts.

নদী বাহিত বন্যা পরিস্থিতি ও পূর্বাভাষ তথ্য
জেলা ঃ মানিকগঞ্জ
তারিখ ঃ ২৯-সেপ্টেম্বর-২০০৭

নদীর নাম	স্থানের নাম	বিপদসীমা (*meter PWD*)	পানির অবস্থান (*meter PWD*)			
			গতকালের অবস্থা	আজকের অবস্থা	২৪ ঘন্টা পরের অবস্থা	৪৮ ঘন্টা পরের অবস্থা
যমুনা	সিরাজগঞ্জ	১৩.৭৫	১২.৪২	১২.২৮	১২.১৫	১২.০১
যমুনা	আরিচা	৯.৪০	৮.৩০	৮.২৫	৮.১৭	৮.০৮
তরাঘাট	তরাঘাট	৮.৩৮	৭.৮৬	৭.৭৪	৭.৪৮	৭.২৩
ধলেশ্বরী	জাগীর	৮.২৩	৭.৫৯	৭.৪২	৭.২১	৭.০০
পদ্মা	গোয়ালন্দ	৮.৫০	৭.৮৩	৭.৭৭	৭.৬৯	৭.৬১
পদ্মা	ভাগ্যকুল	৬.০০	৫.৫৫	৫.৪৭	৫.৪০	৫.৩৩

উৎস ঃ এফ এফ ডব্লিউ সি, ওয়েবসাইট

Figure 4.12: Flood situation information for Manikganj District

নদী বাহিত বন্যা পরিস্থিতি ও পূর্বাভাষ তথ্য

জেলা ঃ টাঙ্গাইল

তারিখ ঃ ২৯-সেপ্টেম্বর-২০০৭

নদীর নাম	স্থানের নাম	বিপদসীমা (*meter PWD*)	পানির অবস্থান (***meter PWD***)			
			গতকালের অবস্থা	***আজকের অবস্থা***	২৪ ঘন্টা পরের অবস্থা	৪৮ ঘন্টা পরের অবস্থা
ব্রহ্মপুত্র	নুন খাওয়া	২৭.২৫	২৪.১৪	২৪.০০	০.০০	০.০০
ব্রহ্মপুত্র	চীলমারী	২৪.০০	২১.৫৮	২১.৪১	২১.২৭	২১.১৫
যমুনা	বাহাদুরাবাদ	১৯.৫০	১৭.৬০	১৭.৪৩	১৭.৩০	১৭.১৭
যমুনা	সিরাজগঞ্জ	১৩.৭৫	১২.৪২	১২.২৮	১২.১৫	১২.০১

উৎস ঃ এফ এফ ডব্লিউ সি, ওয়েবসাইট

Figure 4.13: Flood situation information for Tangail District

b. Upazila 48 Hour Flood Warning

Two types of products are produced for *upazila*-level flood warning: one is a 48-hours *upazila* flood forecast map (***Figure. 4.14***) showing forecasted water level change by symbol at each gauge station in the *upazila,* and the other is a 48-hours *upazila* flood forecast table (***Figure. 4.15***) showing magnitude of forecasted water level change at the same gauges. In the 48-hours upazila flood forecast map, up arrows or down arrows mean rising or falling of water level where each arrow represents a magnitude of one *bighat*. The map and table are produced daily with Bangla notations and exported to MS-WORD for dissemination to the respective *upazila* office through Fax. From this information, the *upazila* officers can understand the future flood situation at each gauge station located in selected unions in the *upazila.* The information dissemination was continued up to 2007 in two *upazilas.*

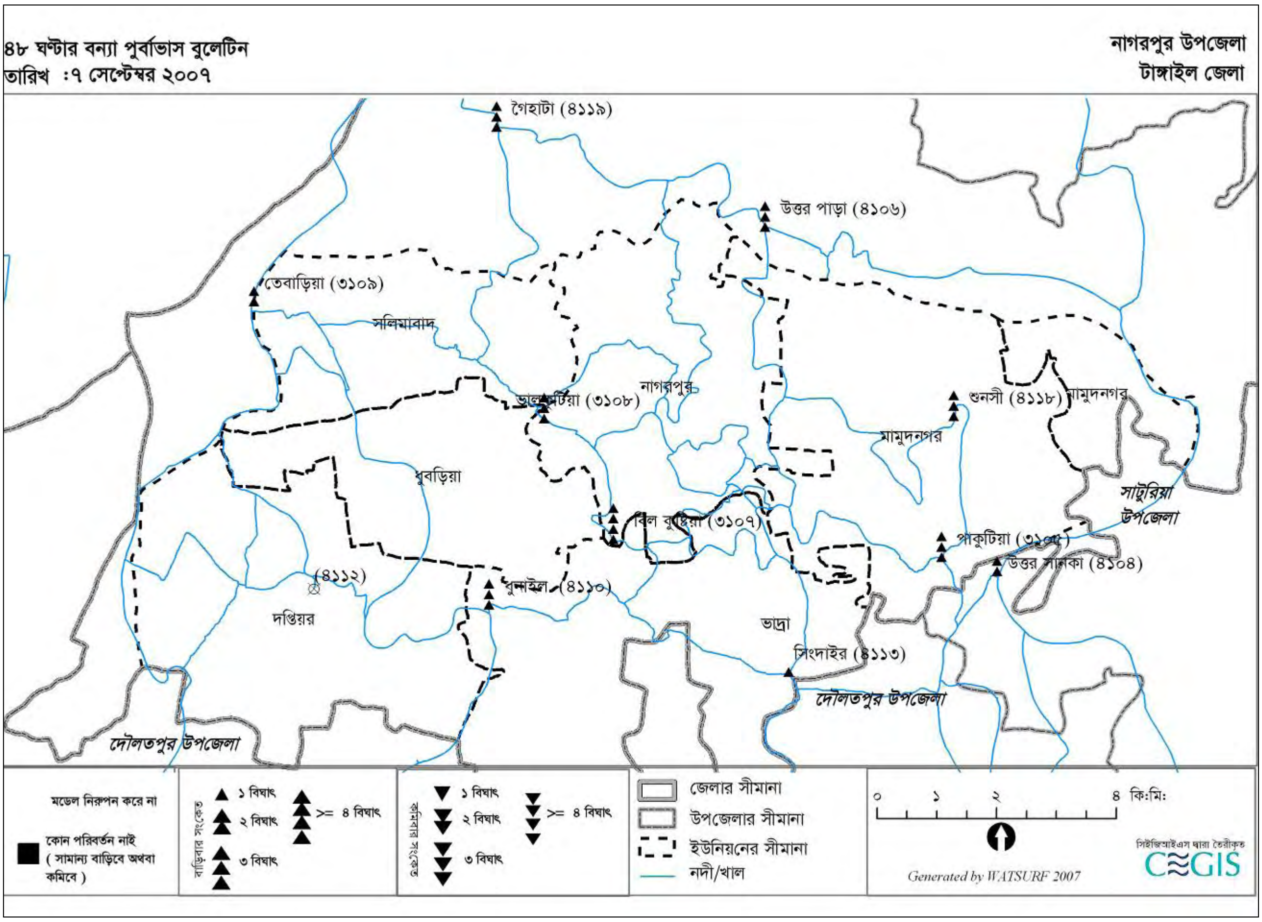

Figure 4.14: 48-hour *Upazila* Flood Warning Map showing rise/fall of water level in gauges

গেজ স্টেশন ভিত্তিক বর্তমান ও আগামী ৪৮ ঘন্টার বন্যা পূর্বাভাষ

উপজেলা : *নাগরপুর*

তারিখ : *৭ সেপ্টেম্বর ২০০৭*

গেজ নং	গেজের অবস্থান	বর্তমান পানির লেভেল (m+PWD)	৪৮ ঘন্টা পর পানির লেভেল (m+PWD)	পরিবর্তন	
				পরিমান (meter)	পরিবর্তন
৩১০৫	পাকুটিয়া, মামুদনগর ইউনিয়ন	৮.৯৪	৯.৫৫	০.৬১	বাড়িবে
৪১০৬	উত্তর পাড়া, মামুদনগর ইউনিয়ন	৮.৮৪	৯.৫৫	০.৭০	বাড়িবে
৩১০৭	বিল কুষ্টিয়া, ধুবড়িয়া ইউনিয়ন	৮.৩৭	৯.১৮	০.৮১	বাড়িবে
৩১০৮	তালকুটিয়া, বেকড়া আটগ্রাম ইউনিয়ন	৮.৩৮	৯.১৭	০.৭৯	বাড়িবে
৩১০৯	তেবাড়িয়া, সলিমাবাদ ইউনিয়ন	৯.৯৩	১০.৪৭	০.৫৩	বাড়িবে
৪১১০	ধুনাইল , ধুনাইল ইউনিয়ন	৯.১০	৯.৭৪	০.৬৫	বাড়িবে
৪১১৮	গুনসী, মামুদনগর ইউনিয়ন	৮.৮৪	৯.৪৭	০.৬৩	বাড়িবে
৪১১৯	গৈহাটী, গৈহাটী ইউনিয়ন	৯.৭৯	১০.৪২	০.৬৩	বাড়িবে

Figure 4.15: 48-hour *Upazila* Flood Forecast Table

c. Union Level 48-Hours Flood Forecast

At the union level, bulletin boards in 13 union *parishads* of Daulatpur and Nagarpur *upazilas* were set up to display *mauza*- and union-level flood warnings. Forty-eight-hours flood forecast messages were sent to the selected bulletin board operators in the respective unions through mobile SMSs. The mobile SMSs contained the name of the *upazila*, acronyms of the *mauza*, and the symbol for water level rise (+) or fall (-). The format of the mobile SMS is shown in ***Figure 4.16***. The bulletin boards were used by union parishad chairmen, members, and DMC members. ***Figure 4.17*** shows one of the bulletin boards set up at Mokhna Union *Parishad* of Nagarpur *Upazila*.

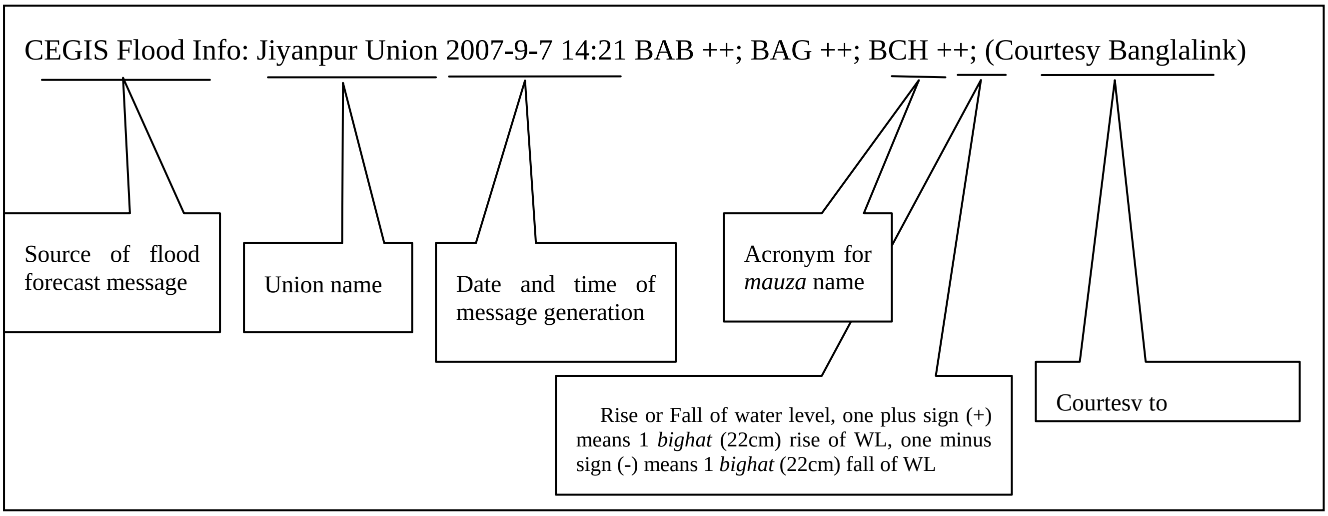

Figure 4.16: Format of union level, 48-hour flood warning via mobile SMS

Figure 4.17: Bulletin Board at Mokhna Union *Parishad* of Nagarpur *Upazila*

d. Community and Household Level 48-Hours Flood Warning

At the community and household level, *mauza*-specific, 48-hours flood warning messages were sent to the flag operators and households through mobile SMSs. The format of mobile SMS is shown in ***Figure 4.18***.

Flags were hoisted at selected places, such as rural markets, schools, or offices, in each *mauza* by the flag operators to show the expected change of water level in that specific *mauza* (***Figure. 4.19***). The operator hoisted the number of flags according to the magnitude of the rise or fall, and the direction of change was indicated by the color of the flags. For example, if the flag operator received one plus sign (+) via SMS message for the location, the operator would hoist one blue flag; if the SMS was two minus signs (--), the operator would hoist two white flags.

The evolution of these local warning systems is discussed in ***Chapter 5***. During the 2007 season, a campaign was undertaken to register individual mobile phone owners to receive the SMS message for their specific location. At the household level, registered mobile phone users received the same mobile SMS as the flag operators (Figure. 4.20). The registered users were trained to understand the flood forecast by converting the plus or minus sign into forecasted change in water level.

CEGIS Flood Info: Lautara 7-Sep-2007 14:21 ++ (Courtesy Banglalink)

Here,

A = Source of flood forecast message
B = *Mauza* name
C = Date
D = Time of sending message
E = Rise or fall of water level: One plus sign (+) means one *bighat* (22cm) rise of water level, one minus sign (-) means 1 *bighat* (22cm) fall of water level.
F = Courtesy to Banglalink

Figure 4.18: Format of Mobile SMS for Flag Operators and Households

Figure 4.19: Flag hoisted at the community at Bhalkutia *Mauza*, Nagarpur *Upazila* showing rise in water level (blue flag) by 3 *bighat*

Figure 4.20: Household receiving a SMS, Nagarpur *Upazila*

4.6.5 Partnership with Banglalink and Direct SMS Use

CEGIS and RTi presented the concept of the CFIS project, and identified the needs and benefits of a flood forecasting system in flood vulnerable communities, to Banglalink (a private mobile operator in Bangladesh). It was recommended that the CFIS concept be replicated throughout Bangladesh. Understanding the importance and benefits of community-based flood forecasting, Banglalink expressed their interest to participate in disaster management activities in the disaster prone areas of Bangladesh through providing support to the flood-forecast SMS service under the Corporate Social Responsibility (CSR) program of Banglalink.

Following the discussion with Banglalink, a technical team was formed to develop the format of communication protocol between CEGIS and Banglalink. CEGIS prepared flood-forecast SMSs for bulletin board writers, flag operators, and households using WATSURF (Figure.4.21) in text file format, then uploaded the text files of SMS to Banglalink's website, http://202.22.194.79/smscorp0 (***Figure. 4.22***). A pre-set database in the Banglalink server determined which SMS would go to which mobile number. The SMSs were forwarded to the mobile numbers through two or three routings within 30 minutes.

Figure 4.21: WATSURF tool where a text format of the messages is generated by clicking at the "Text Message" button

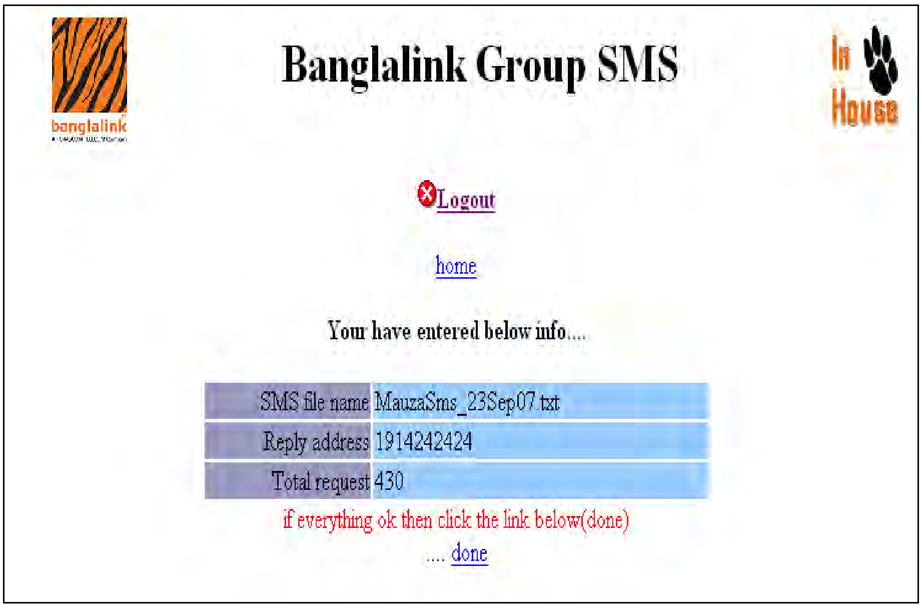

Figure 4.22: Uploading text files of flood-forecast SMS to the Banglalink website

A memorandum of understanding was signed between Banglalink and CEGIS on 8 August 2007, regarding flood-forecast dissemination using Banglalink SMS service (***Figure. 4.23***). Under the agreement, the following services were performed:

- Relayed flood information via SMS from August to November in 2007, and from June to November in 2008 to a maximum of 500 mobile numbers each day.
- Provided recipients' mobile phone numbers for Banglalink reference. The recipients' list may be changed, but information will be provided to Banglalink for reference.
- The SMS message contained CEGIS flood information.
- If the recipient of the flood information was a subscriber of an operator other than Banglalink, CEGIS had to have prior consent before sending any message.

Figure 4.23: Director of CEGIS and Banglalink along with others in signing ceremony between CEGIS and Banglalink

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Chapter 5
Dissemination of Flood Information and Warning

5.1 Introduction and Overview

Following the baseline study and needs assessment conducted during 2003, Baraboinna and Dhunail villages - located in Daulatpur and Nagarpur *upazilas*, respectively - were identified for intensive intervention and piloting. In this chapter, the findings from the intensive exercises in these two *mauzas* are explained and presented; dissemination and results for the remainder of the study area are described in less detail, and presented in ***Chapter 6***.

With technical support from CEGIS, BDPC began disseminating early flood warnings at Baraboinna in 2004 and at Dhunail in 2005. The system for community-based flood information was developed using participatory methods with full involvement of the communities.

The primary CFIS objective was to develop and demonstrate a system for disseminating timely and useful flood forecasts, area-specific, to local people in a typical rural area. In the first year of operation, some technical problems were experienced that compromised the project's credibility in these intensive intervention (also referred as "pilot") locations. The WATSURF model was not completed until a few days after the initial floodwaters entered the study area, and the flag system operators were not fully trained and confused some of the forecast messages later in the season. These issues were identified and corrected for the 2005 season; however, the monsoons of 2005 and 2006 were unusually dry and the stakeholders were less interested in the CFIS system's flood information. During the exceptional 2007 flood, local people regarded the CFIS as providing accurate and useful information that local people used to substantially reduce their losses and damages.

5.2 Pilot *Mauzas*

Based on the needs assessment and local information on differences in the incidence of flood risk between villages, two *mauzas* were selected for intensive intervention. Baraboinna *Mauza* is adjacent to the Amtoli River (one of the main branches of the Jamuna); while Dhunail *Mauza* is more distant from the river, but is also flood prone. The idea was to work in an area often flooded (Baraboinna) and another slightly higher, but flood-prone area (Dhunail). ***Table 5.1*** summarizes demographic information for the two *mauzas*.

Table 5.1: Basic characteristics of the two pilot *mauzas*

Indicator		Baraboinna	Dhunail
Area	Acre	532	426
Households	Number	548	195
Population	Male	1286	463
	Female	1229	477
	Total	2515	940
Literacy rate	% of population 7 years or older	23.34	33.68
Main source of drinking water (tube-well)	% of households	79	98
Own agriculture land	% of households	86	57
Main source of income (% of households)	Farming	57	33
	Farm laborer	14	23
	Other laborer	2	0
	Fishing	12	0
	Business	7	11
	Job/Service holder	4	14
	Others	5	18

Source: Community Series of Population Census 2001, BBS, 2006, and 2007.

5.3 Training and Orientation

For a flood warning dissemination system to be effective, the community should be prepared. They should understand the meaning and relevance of warnings, how they relate to their lives, and what responses are appropriate according to the magnitude and characteristics of the flood that has been predicted. At the outset of the project, BDPC identified local change agents who were non-paid community trusted people, and volunteers that were found to be enthusiastic young men and women who could play an important role in disseminating warnings to households. To guide the local warning system, Village Flood Management Committees (VFMC) were formed for which the change agents were the office bearers (president and secretary) and other interested local people were general members; the volunteers implemented warnings on behalf of the VFMCs. Change agents and volunteers were trained to be a link between households and the information dissemination system, and to build their capacity to interpret the flood information and relate to their risk environment. For this purpose, and to develop capacity of households to undertake preparedness measures in response to the imminent threat perceived when a flood warning is issued, the change agents and volunteers organized household level discussions. After discussion with the community people, BDPC organized mock demonstrations and cultural shows to enhance public awareness. BDPC had regular meetings with the committees to facilitate community level discussion and decision making (***Figure 5.1***). Flood information materials are shown in ***Figure 5.2.***

Figure 5.1: Discussions with community members about flood early warning messages

In the last two years of the project, local administration and government institutions were involved in the warning and dissemination system to ensure that it would continue after the project. For that reason, roles and responsibilities orientation courses for *Upazila* and Union Disaster Management Committees were organized.

In the last flood season of the project (2007), flood information was sent via SMS directly to those mobile phone users of these communities who wanted to receive the warning by SMS, and who were ready to disseminate the warning to their neighbors. The mobile phone users were registered and trained to open SMS text boxes, to understand the warning messages and symbols (shown in Section 4.7), and to disseminate flood prediction information to local flag operators. 25 mobile phones in the study area were provided with flood warning. Within the two pilot intensive intervention areas, 133 mobile phones were registered of which 72 (54 percent) were to households trained on opening the SMS and on understanding the warning symbols (***Table 5.2***).

Table 5.2: SMS mobile phone warning participants in the two intensive pilot areas in 2007

Level	Number of mobile phones
Household (at Boinna and Dhunail)	72
Community (related with flag operators at Bara Bania and Dhunail)	15
Upazila and Union Disaster Management Committees (Nagarpur and Daulatpur Upazila)	32
Personnel of NGOs (Nagarpur and Daulatpur Upazila)	10
BDPC personnel (at Boinna and Dhunail)	4
Total	133

5.4 Participation in the Warning and Information System

Each component of the CFIS system evolved based on participatory decision-making. Village Flood Management Committees were formed, and change agents and volunteers were identified who acted as community spokespersons throughout the project duration. Preferences for information dissemination identified in the discussions included the use of teachers at schools, through imams (Muslim religious leaders), through flags, at *hats* and bazaars (local markets), and in other public gathering places. The change agents and volunteers developed their risk and resource maps, identified local danger levels, marked out the most logical points for installing flood makers and flag hoisting sites, and chose the colors of flags to indicate increase and decrease of floodwater. After every monsoon, the impact of the system and its deficits and gaps were discussed in coordination meetings with the Village Flood Management Committees. The VFMCs came up with plans to revise the system to improve its functionality and usefulness. In this way, an effective community-based, area-specific flood information system evolved and successfully disseminated flood forecasts up to the household level during the 2007 flood.

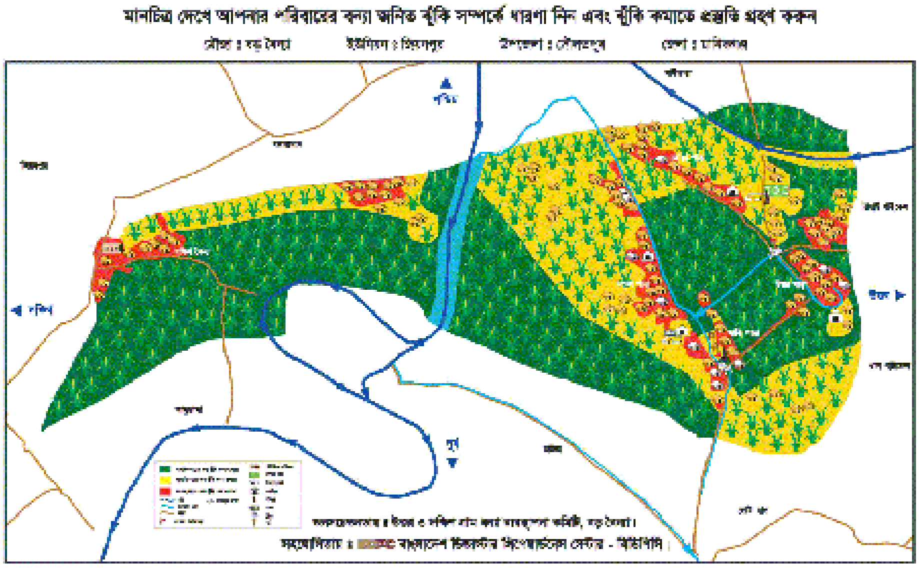
5.5 Warning System Evolution

5.5.1 Year 2003

The first year of the CFIS project was spent selecting study areas and for assessing baseline conditions, assessing the need for early warnings and coping means of the community members, identifying change agents and volunteers, and identifying media for flood information dissemination. Through a participatory process, BDPC identified three different colored flags to indicate the flood situation. A green flag indicated a normal flood situation, a yellow flag indicated a moderate flood situation, and a red flag was hoisted to indicate a severe flood situation. Flood markers were installed at well-known, visible locations that were relevant to the majority of the community, and established risk-map billboards in visible places so that people could identify the risk to their houses (***Figure 5.2***).

(a) Flag for understanding flood situation

(b) Flood Marker showing flood level



(c) Flood prone area vulnerability map prepared by the community

Figure 5.2: Examples of materials used for raising awareness about flood risk in the community

5.5.2 Year 2004

In 2004, Bangladesh faced a moderately severe flood and the CFIS intervention areas were inundated. Unfortunately, CFIS became operational before the flood peak, but after the initial on-rush of floodwaters into the study area. Moreover, the system of two types of flags and lack of experience in the system caused confusion in the dissemination and interpretation of information and warnings.

The flow of warning information dissemination for 2004 is shown in ***Figure 5.3***. BDPC received flood warning through SMS and informed the flag operator of the flood warning who hoisted flags accordingly. Although a simple linear flow of information was involved, it was not effective because of the confusion described above.

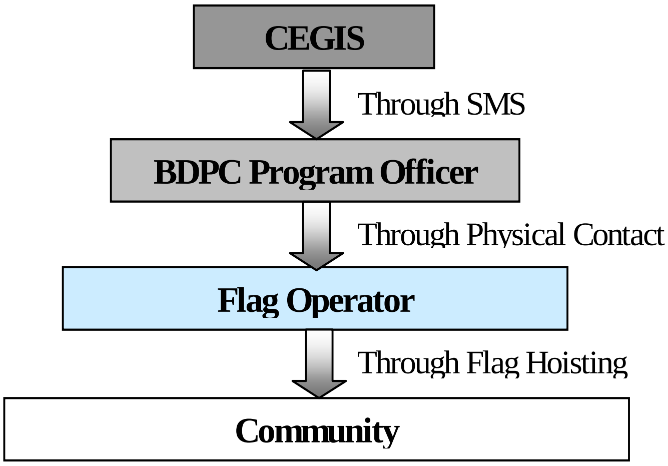


Figure 5.3: CFIS flood warning dissemination pathway in 2004

5.5.3 Year 2005

Based on the lesson learnt in 2004, particularly the lack of understanding by local staff and volunteers, the dissemination method was revised for the 2005 monsoon. Early warning dissemination started in the field on 13 July and continued until 17 September 2005, with 51 flood information messages received, out of which 49 messages were received through SMS, and two messages came through mobile phone on two days that the mobile phone operator's text message servers were not functioning. Due to the server failure of Grameen Phone (the leading mobile phone operating company in Bangladesh), messages from CEGIS on 22 July and 30 August were not received by the field organizations and individuals.

It was reported that water levels did rise in most areas where flood warnings were disseminated, although in Baraboinna Village, the water level actually fell in the following 48 hours in 19 percent of the areas that received warnings. The magnitude of predicted and actual floodwater level changes differed considerably, as described for the overall study in Chapter 6. Another problem was that the flag operators hoisted two types of message-indicating flags: one for the existing flood situation and another for the predicted change. Consequently, a possible five colors of flags were used. Although the flag operators understood, the villagers were still confused about the meaning of so many colors.

5.5.4 Year 2006

The main lesson learned from these two pilot areas in 2006 was that messages were more easily understood when the flood situation flags (green-yellow-red) were removed from the system. It was decided that only flags for indicating water increase and decrease would be used in the communities. In addition, after the second year of operation, the concern shifted to sustaining the system, the warning dissemination pathways were revised, and the UzDMC and UDMCs were included. Mobile phone use in the flood warning system was expanded by providing two mobile sets to UzDMCs and UDMCs to inspire and involve those bodies. The warning flow for 2006 evolved to that shown in ***Figure 5.4***.

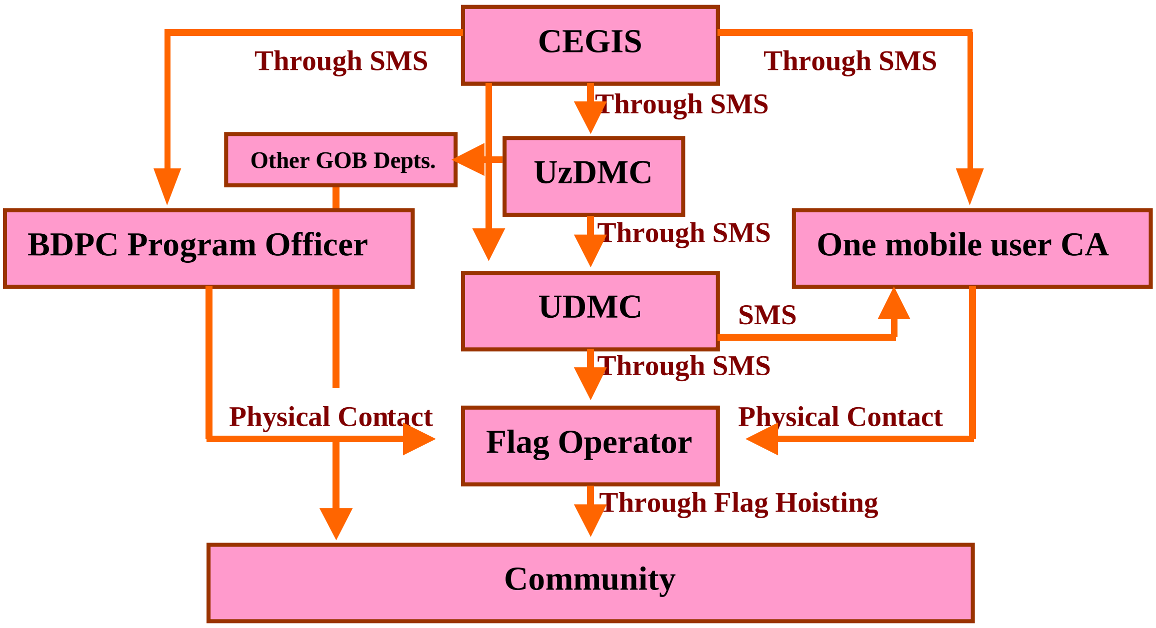


Figure 5.4: Flood warning dissemination pathway in the two pilot areas in 2006

The *Upazila* Disaster Management Committees (UzDMC) assigned as CFIS project implementation officers were the member secretaries of the UzDMCs. Their responsibility was to receive flood warning from CEGIS through mobile SMS and transmit the message to the other *upazila*-level government officers from different departments and to all the Union Disaster Management Committees (UDMC) in their *upazila*. The responsibility of officers from different government departments was to inform communities of flood warnings through their field level staff, if they considered that the predicted flood would threaten the sector and field activities of their department. The UDMCs selected the union *parishad* secretaries, who were also the member secretaries of the respective UDMCs, to receive the flood warning messages sent from the UzDMC. The selected village mobile users, who were the change agents (active over the past three years in CFIS), passed on the warning message to the flag operators. Flag operators were the final disseminators of the warning messages. To ensure flag hoisting in the villages, CEGIS also sent the same warning SMS not only to the UzDMCs, but directly to the UDMCs and one pre-selected change agent with a mobile phone. Under CFIS, there were two flag sites in each *mauza*. In addition, for effective warning dissemination and to enhance discussions regarding CFIS, the Village Flood Management Committees were expanded to include 20 change agents and 22 volunteers in Dhunail, and 2 separate committees for 2 wards within Baraboinna, comprising a total of 55 change agents and 59 volunteers.

In 2006, the early warning dissemination began operations on 13 July and continued for 90 days throughout the monsoon season. However, the field staff intervened because 2006 was one of the driest monsoons on record and, although people reported that the predictions were generally accurate, they had little interest in the forecasts.

5.5.5 Year 2007

Since the 2006 monsoon was dry, it was not possible to test the functionality of the CFIS modifications introduced that year. However, in discussion with different government and village level key actors, and through discussion among RTi, BDPC, and CEGIS, it was decided in 2007 to send SMS messages for flood information to more government officers and directly to village level people who could play an important role in warning dissemination. To follow this saturation approach, BDPC registered as many as 99 mobile numbers for automatic SMS receipt at household, community, and institutional (government and NGO) levels.

Cell phone communication through SMS was the key media for the flow of warning message in 2007, complemented by flags. When the CFIS project began in 2003, mobile phone ownership and network coverage in rural areas was low, and it was hardly imaginable that mobile technology would expand as rapidly as is underway. However, by the end of 2006, most of the CFIS area villages had mobile network coverage and many of the villagers in the intensives intervention sites at Baraboinna and Dhunail began to use mobile phone. The early warning dissemination of 2007 had three levels for these two villages:

I. **Household Level -** Mobile phone users of Baraboinna and Dhunail who were interested in receiving SMS early warnings from CEGIS directly were enlisted and received automated SMS. They used the messages for their own preparedness activities as well as disseminating the message to their neighbors.

II. **Community Level -** CEGIS sent SMS directly to the flag operators, who were oriented and who passed on the message. For each flag site, three mobile users agreed to pass on the message, increasing the probability through crosschecking and peer pressure that the flag would be duly hoisted. Again, each group of mobile users linked with a flag operator was to receive SMS from the UDMC. However, the UDMCs were found to be indifferent to transmitting the messages, and the only messages the users received were the automated ones sent directly by CEGIS.

III. **Institutional Level**

***Upazila* –** The UzDMC received messages from CEGIS through SMS. The UzDMC's responsibilities were to transmit the messages to the UDMCs and all the *upazila*-level government officers by SMS, and to monitor whether the UDMC transmitted these messages to the mobile users properly. The UzDMCs used the warnings for their own planning during the 2007 flood, and transmitted the messages when the warnings were considered to be threatening. The responsibility for message transmitting was completely focused on Baraboinna and Dhunail; when the UzDMC felt the situation was sufficiently bad, it decided to warn others. However, despite CFIS work to define the relevance of local flood levels to the communities, the UzDMC was not given specific guidelines on when it should pass on warnings; instead, it depended completely upon its general understanding of the situation. In addition, the UzDMC did not monitor whether the UDMCs and other government departments acted accordingly. The other *upazila*-level government officers were not very serious in warning local people about floods through their field staff.

***Union Parishad* -** UDMCs received messages through SMS from the UzDMC and CEGIS at the same time. The responsibility of UDMCs was to transmit the message to the flag site mobile users and monitor flag hoisting accordingly. However, the union *parishad* chairmen, despite being the chairpersons of UDMCs, did not show much interest in the system. The UP secretaries, also the secretaries of the UDMC working under the direct orders of the UP chairmen, were expected to implement the warning system, but were inactive presumably because of a lack of direction and priority set by their chairmen.

***NGOs* –** CEGIS also sent SMS warnings to NGOs active in the two *mauzas*. These included BRAC, STEP, Grameen Bank, PROSHIKA, ASA, and Alor Prottasha. They used the information for their own project activities and warned their project staff and participants.

***Hat-Bazar-Mosque committees* –** CEGIS also sent warning SMSs to*hat*, bazaar, and mosque committees in 2007. These committees used the flood warning for their own preparedness and disseminated the message to people involved in their activities.

***School/Madrasa* –** Local village school and madrasas played a vital role in disseminating the flood forecasts received from CEGIS through SMS. The school and madrasas could effectively reach local households by sending warning messages through their students.

The overall system for flood warning messages in 2007 is shown in ***Figure 5.5***.

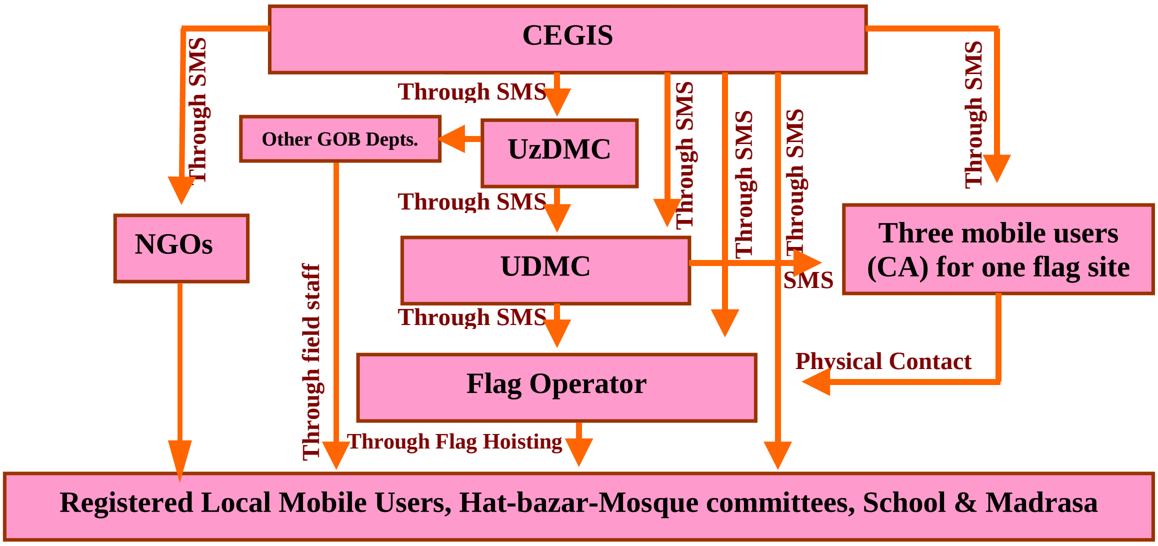


Figure 5.5: Flood warning dissemination pathway in the two pilot areas in 2007

Although the stakeholders of all levels received SMS warning messages from CEGIS, the emphasis was on involving the UzDMC and UDMC through the warning flow system as they were the established government institutions at the local level. Unfortunately, their performance and interest was less than ideal, even though a serious flood affected the communities that they served.

In 2007, CEGIS began sending warning messages to most stakeholders on 8 July, but delayed sending the messages to the *upazila* and union levels until the flood levels began to rise on 31 July. In these two pilot areas, the UzDMC and UDMC in the flood warning system were involved for a shorter period in the hope of keeping their interest alive. Messages continued to be disseminated up to 11 October. The flag hoisting activities of the flag operators was monitored, and it was reported that the flag raising was fully consistent with the SMS messages. However, the main problem in the 2007 flood in Bara Boinna was that the overall slow-onset flood was transformed into what was, in effect, a flash flood. The flash flood occurred because the bank of the river was high and the land area was low, while the mouth of the canal that flowed through the village and connected with the river was closed due to siltation in the 2004 flood (there was no flood in 2005 and 2006). The canal did not connect with the river, therefore water levels inside the village did not respond to river levels. The local people could not see the changed water level in their village until the water overflowed the river bank within a night, flooding their fields under two to three feet of water. At that time, people saw that the flood predictions matched their observations. From that time onward, the people in Bara Boinna used the disseminated flood predictions for the higher lands that were yet to be inundated.

5.5.6 Comparison of Years

Based on the annual community reviews of the CFIS, it was concluded that effectiveness of the system in the intensive intervention areas in 2004 was compromised due to a misunderstanding of one of the flag operators, whereas in 2005, operation and understanding of the warning disseminators improved, but the multi-colored flag system covering two types of message were confusing for local people. The system was simplified and multiple dissemination pathways were added in 2006, but due to the lack of flooding, the local disseminators were not very interested. During the excessive floods of 2007, the system worked well and, by adding more pathways including direct community SMS warnings to the target villages, penetrated successfully to the communities.

5.6 Links with Existing Institutions

CFIS has gradually been integrated with local institutions including *upazila* and union *parishads*, schools and madrasas, mosques and temples, *hat* and bazaar committees. These institutions are essential components of the system. The *upazila*-level government departments and NGOs were in the system and played a considerable role in disseminating messages. The responsibility of *upazila* and union *parishads* were not only to receive warning messages, but also to disseminate the warnings and to monitor dissemination activities. It was important from the context of sustainability as these are the formal local government bodies that will continue indefinitely. In the two pilot areas, the *upazila parishad* used the information for their own planning, but they were not very useful for disseminating information or for monitoring dissemination activities. The union *parishads* did not play a significant role in these activities either. While this might be because they had no direct instruction from above (such as the district level), it also reveals a lack of initiative and interest in flood warnings on their parts. Schools and madrasas played an effective role by sending flood information to the families through students. NGOs, religious institutes, and *hat*-bazar committees also contributed much in effective message dissemination in the communities. Table 5.3 shows the extent that local institutions were involved in disseminating warnings in 2007 in the pilot area. The flag system provides a base level for passing on all information/messages, while most SMS receivers reported passing on most messages, but, in the two pilot areas, all other agencies decided to pass on about half of the messages received, or, in the case of union *parishads*, none of the messages.

Table 5.3: Institutional involvement in disseminating flood warnings in the two pilot areas in 2007

Institution	Daulatpur		Nagarpur		How disseminated	Why not disseminated
	% warnings received	% disseminated	% warnings received	% disseminated		
Upazila	90	61	92	63	Through cell phone, Notice board	Messages were not threatening at the time
Union	96	0	96	0	Not done	Busy with relief, believed direct SMS was enough
School	93	51			Through students	Not threatening at the time
NGOs	93	67	94	61	Through field staff	Not threatening at the time
Mosque	93	49	NA		In mosque after prayer	Not threatening at the time
Hat/ Bazaar Committee	93	47	NA		Face to face	Not threatening at the time
Flag Operator	93	100	94	100	Flag hoisting	None
Mobile user (community)	93	73	94	67	Face to face	Not threatening at the time

5.7 Assessment of Project Experience

CFIS could be termed as an action research and development project. Over the course of the project, much was learned about warning system performance and applied in consecutive years to develop a better framework, strategy, and plan of warning dissemination. Destructive floods are not desirable, yet for testing the system, a serious flood was essential. During the last year of the project, the area experienced two serious flood peaks, providing an opportunity to assess the system performance and its effectiveness for the people at risk. The community- and household-level warning dissemination system was developed through a participatory process. The volunteers and change agents contributed to planning the system and to modifications during the project on behalf of the communities. After training by BDPC, the change agents and volunteers also had the opportunity to more effectively enhance community response to the flood forecasts. Every year, just before the monsoon, the trained change agents and volunteers organized household-level discussions about how to interpret the flags, understand the risk in connection with the hoisted flags, and how to prepare. Thus, the communities were better prepared to make use of any flood warning information received.

> Md. Aslam Sheikh, a farmer of Dhunail Village, received a warning SMS on his mobile on 27 July 2007. He decided to harvest his gourd field although the gourds were not mature. During normal conditions, he would have harvested later to earn about Tk 12,000. By harvesting early he earned only Tk 8,000, but within 48 hours he realized that he did the right thing. The flood that came would have destroyed the entire crop and he would have had no income whatsoever.

The basic challenge faced in the CFIS project was to disseminate useful and timely flood warnings, and related information to the communities. In these two pilot areas, the dissemination was overall successful, especially in 2007. To ensure location specific early warnings to communities, two routes of dissemination were adopted: one through government channels (UzDMCs and UDMCs) and the other from the forecast agency (CEGIS) direct to the community through mobile SMS, with each having a route into a third visible warning (flags). The second warning dissemination pathway using SMS worked effectively. The flags showing the flood forecasts were regularly hoisted and were found to be consistent with the provided information. The communities were interested in receiving early flood warning during the 2007 monsoon. People of different professions made use of the flood information and reported that they reduced their losses and damages from what they might have been otherwise (see ***Section 6.3.3***). Conversely, there were some people who did not take interest in or respond to the flood warnings, and some regretted this consequently.

> In Bara Bania, Mr. Manik Mondol did not heed flood warnings received on 27 July 2007. His jute field was flooded within 48 hours and, as a result, he had to sell the damaged jute at a low price, losing Tk 8,000. After that, he realized he should have responded to the warning.

Dissemination of early warning messages was not an assigned responsibility for the local *upazila* administration or local union *parishad* government, and there was no accountability for failing to perform responsibilities under the standing order on disaster; we believe these are the reasons that the government bodies only used the information for their own purposes such as planning relief distribution and response activities. They did not take an active role in disseminating warnings to the public or for monitoring CFIS dissemination activities in the two study areas.

Chapter 6
Assessment of Pilot CFIS

6.1 Flood Forecasts: WATSURF Accuracy

6.1.1 Introduction

The WATSURF tool was used to predict and disseminate flood levels for the CFIS study area during the flood seasons from 2004 to 2007. This section assesses the overall performance of WATSURF during this four-year period. To assess the performance of WATSURF, data were used from seven representative gauges out of the total 17 floodplain gauges set up throughout the study area during the first year of the CFIS project. These 17 floodplain gauges were correlated to three of the gauges on the main rivers, operated by the Bangladesh Water Development Board (BWDB) and Flood Forecasting and Warning Center (FFWC). FFWC uses a hydrodynamic-hydraulic model to predict the river stage up to two days in advance at the BWDB/FFWC gauges.

Four separate methods were used to assess WATSURF and the findings are reported in the sections below:

- Assessment of error between forecasted and observed 48-hr change in water level.
- Assessment of error between forecasted and observed water levels.
- Assessment of WATSURF flag dissemination system.
- Assessment of WATSURF accuracy through regression analyzes.

To better understand the performance of WATSURF, it is helpful to observe variation in flood levels from year to year. ***Table 6.1*** presents the peak water level and return period for the four study years at the Sirajganj gauge site, which is one of the BWDB/FFWC gauges used in model correlation, located just outside the study area on the Brahmaputra/Jamuna River. The frequency analysis was performed using data provided by FFWC from 1945 to 2007. A “normal” flood year, defined as a flood year with a 2.33-year return period, has also been included in the table for comparison.

Finally, ***Figure 6.2*** presents an example hydrograph for one of the gauges in 2007. The “high” danger level shown in ***Figure 6.2*** is the gauge water level that corresponds to the river danger level as determined by FFWC. This and the other danger levels were established in the field with input from the local communities and observations. As shown in ***Figure 6.2***, the flood peak in 2007 was a full meter above danger level, during a flood event with only an 8.6-year return period. This illustrates the frequency and severity of flooding to which these floodplain residents were subjected.

Table 6.1: Peak Water Level and Return Period for Study Years at Sirajganj

Value	Normal	2004	2005	2006	2007
Return Period (yrs)	2.33	6.8	1.4	1.2	8.6
Peak Water Level (m)	13.8	14.81	13.31	12.94	14.95

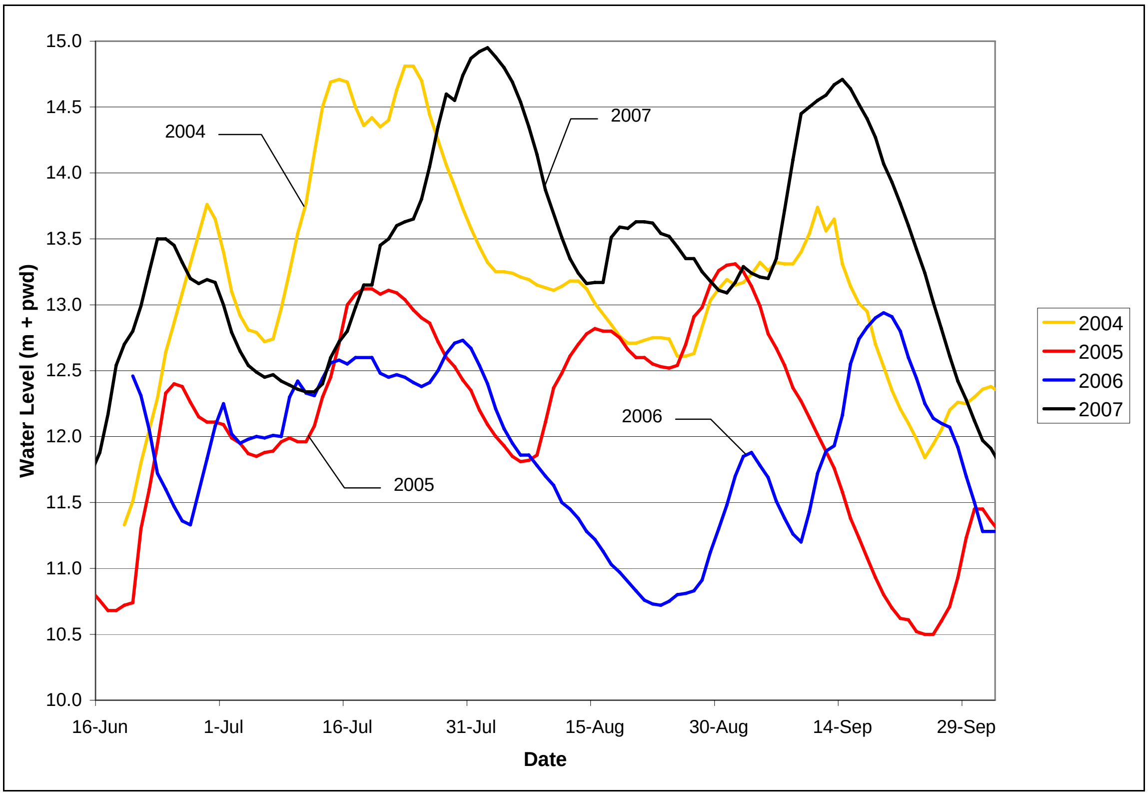


Figure 6.1: Hydrographs at Sirajganj for 2004-2007

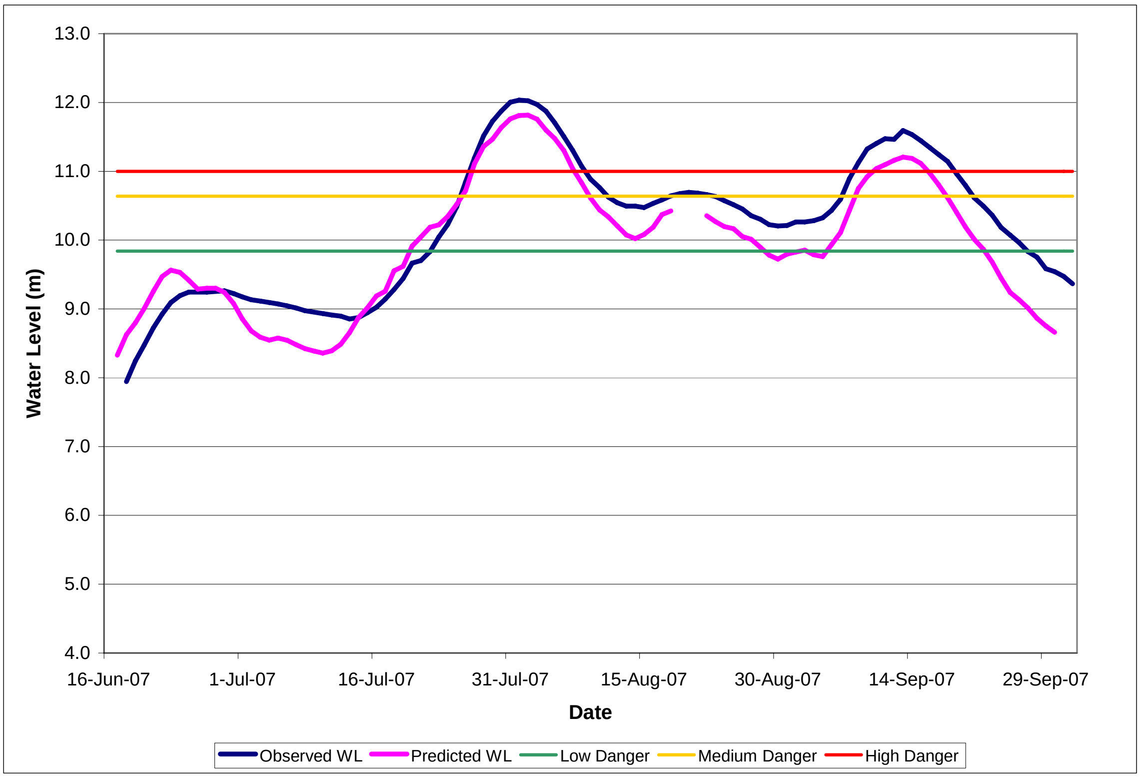


Figure 6.2: Example Hydrograph for Floodplain Gauge 3109 in 2007

6.1.2 Results

- Average Error in Forecasted Change in Water Level. The first method used for assessing WATSURF was to compute the error between the 48-hour predicted and observed change in water level. The most important role of flood warning to the end user (community member) in Bangladesh is how much the water will rise or fall in the future. The forecasted change in water level was distinguished from the forecasted actual water level (in height above datum) that was used in CFIS for generating inundation maps and for damage assessments. The CFIS system did not disseminate the water levels to the communities; instead, it disseminated only the predicted change in water level.

Although WATSURF could predict up to 72 and 96 hours, these predictions were less reliable than the 48-hour forecast. The 48-hour prediction was disseminated to the communities in the study area and was used in this accuracy assessment. The results for the average and standard deviation of the error in the 48-hour forecasted change in water levels are shown in ***Tables 6.2*** and ***6.3***, and ***Figure 6.3***. Also, ***Table 6.2*** shows that the average error in 48-hour change in water level were virtually the same for each year (about 15 cm); only the standard deviation (***Table 6.3***) was slightly higher in 2004 and 2005, which reflects a slightly more variability in the error for those years.

Table 6.2: Average Absolute Error of 48-hr Forecasted Change in Water Level

Stn. Id	Stn. Name	Error in WL Change (m)			
		2004	2005	2006	2007
3108	Bhalkutia	0.22	0.19	0.17	0.23
3109	Tebaria	0.07	0.07	0.11	0.09
4110	Dhunail	0.10	0.10	0.13	0.12
3111	Boro Baynna	0.07	0.08	0.12	0.07
4115	Bohera	0.22	0.23	0.15	0.15
4118	Sunsi	0.17	0.17	0.14	0.19
4121	Kakna	0.24	0.22	0.24	0.22
Average		0.16	0.15	0.15	0.15

Table 6.3: Standard Deviation of 48-hr Forecasted Change in Water Level

Stn. Id	Stn. Name	St. Dev. of Error in WL Change (m)			
		2004	2005	2006	2007
3108	Bhalkutia	0.18	0.13	0.13	0.22
3109	Tebaria	0.06	0.06	0.09	0.08
4110	Dhunail	0.09	0.11	0.13	0.10
3111	Boro Baynna	0.09	0.08	0.15	0.06
4115	Bohera	0.18	0.28	0.12	0.12
4118	Sunsi	0.15	0.13	0.09	0.16
4121	Kakna	0.20	0.28	0.28	0.19
Average		0.13	0.15	0.14	0.13

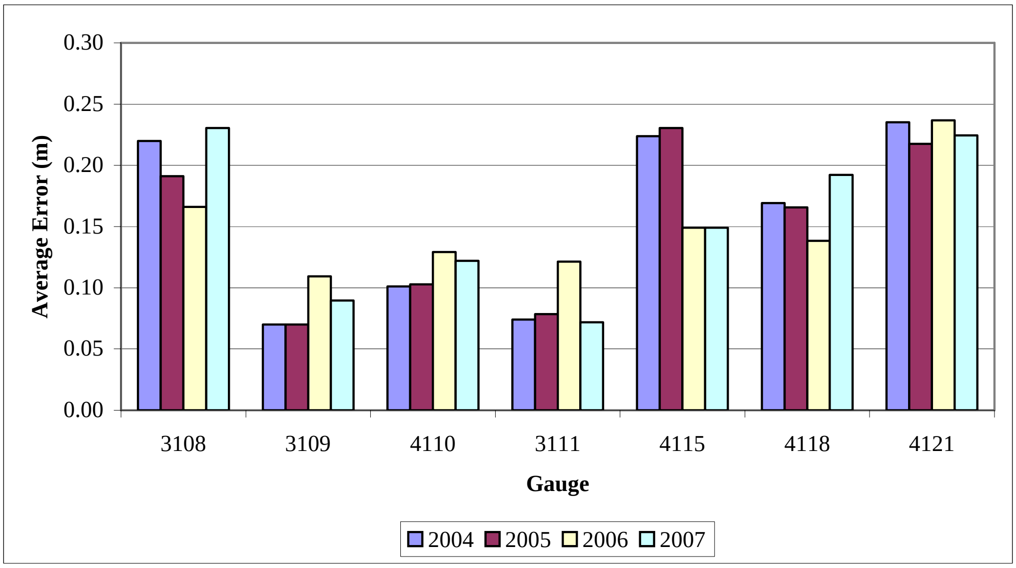


Figure 6.3: Average Absolute Error of 48-hr Forecasted Change in Water Level (Showing Data Presented in Table 6.2)

- Average Error in Water Level. The error in predicted water levels was estimated by computing the average and standard deviation of the absolute difference between the 48-hour predicted and observed water levels, as shown in ***Table 6.4*** and ***Figure 6.4***. The standard deviation of the error in the predicted water level is presented in ***Table 6.5***. In assessing the results, it was important to consider that the flood levels were considerably higher in 2004 and 2007 than in 2004 and 2005. WATSURF performed better in the higher flood years of 2004 and 2007, with an average water level error of 0.28 and 0.47 meters, respectively. In 2005 and 2006, average error was 0.61 and 0.65. The better performance of WATSURF for 2004 and 2007 was likely the result of the increased connectivity of the river network with the floodplain after reaching a higher flood level. As the floodplain progressively inundated, the connectivity of the river networks increased and the floodplain hydrology was more predictable and consistent. To view this difference in the water levels for each year, an example hydrograph for all four years is shown above in ***Figure 6.1***.

  Another consideration was the number of days in each flood season that the accuracy assessment was performed (shown in ***Table 6.6***). The period of the analysis was confined by when both observed and predicted data were available. During the 2005 and 2006 flood seasons, much less data were available because the floodwater did not reach the floodplain gauges for a substantial part of the normal flood season.

Table 6.4: Average Absolute Error in Forecasted Water Levels

Stn. Id	Stn. Name	Error in WL Prediction (m)			
		2004	2005	2006	2007
3108	Bhalkutia	0.35	0.97	0.87	0.56
3109	Tebaria	0.14	0.86	0.57	0.38
4110	Dhunail	0.16	0.59	0.40	0.25
3111	Boro Baynna	0.33	0.19	0.54	0.29
4115	Bohera	0.33	0.58	0.77	0.77
4118	Sunsi	0.30	0.69	0.68	0.59
4121	Kakna	0.35	0.36	0.70	0.42
Average		0.28	0.61	0.65	0.47

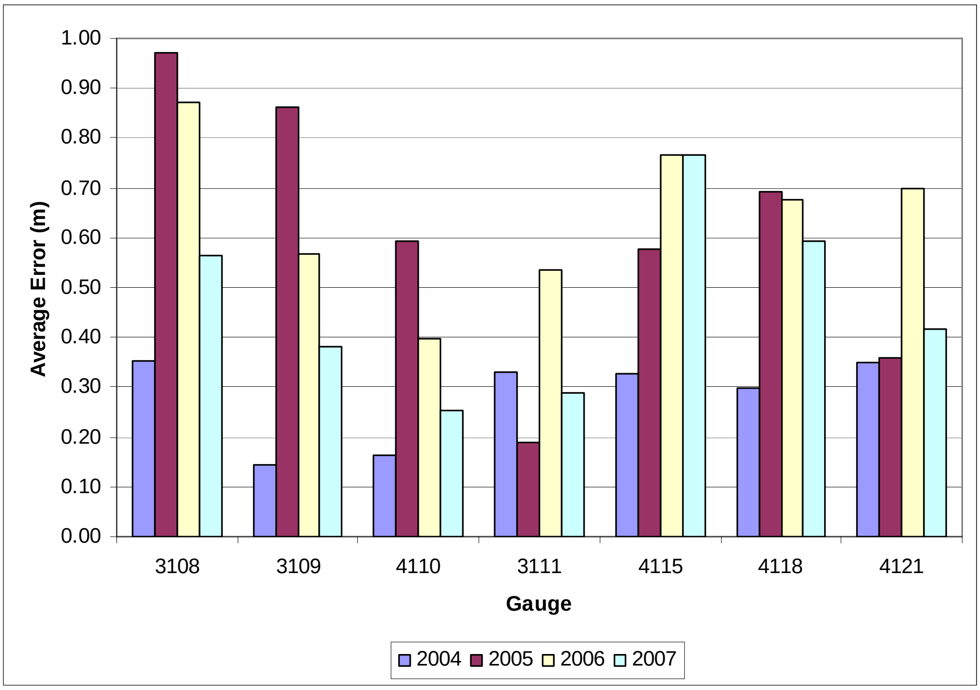


Figure 6.4: Average Error of Forecasted Water Levels

Table 6.5: Standard Deviation of Error in Forecasted Water Levels

Stn. Id	Stn. Name	St. Dev. of Error in WL Prediction (m)			
		2004	2005	2006	2007
3108	Bhalkutia	0.26	0.49	0.76	0.40
3109	Tebaria	0.15	0.17	0.37	0.20
4110	Dhunail	0.13	0.23	0.25	0.18
3111	Boro Baynna	0.14	0.15	0.16	0.19
4115	Bohera	0.25	0.34	0.72	0.72
4118	Sunsi	0.23	0.37	0.48	0.38
4121	Kakna	0.27	0.26	0.45	0.32
Average		0.20	0.29	0.45	0.34

Table 6.6: Period of Analysis for Each Flood Year

Stn. Id	Stn. Name	Number of Assessment Days			
		2004	2005	2006	2007
3108	Bhalkutia	111	65	48	105
3109	Tebaria	111	65	69	103
4110	Dhunail	111	66	79	110
3111	Boro Baynna	111	58	69	112
4115	Bohera	111	65	51	60
4118	Sunsi	111	67	51	93
4121	Kakna	111	67	61	108
Average		111	65	61	99

- Assessment of Flag Dissemination System. The flood warning information was disseminated to the floodplain inhabitants using a flag system, which is fully described in Chapter 4. In brief, at specific locations throughout the study area, volunteers equipped with flag poles and instructed to raise one or two blue flags (for rising water) or one or two white flags (for falling water). Each flag represented a magnitude of floodwater rise/fall during the following 48 hours of one "*bighat*," a local unit of measurement that corresponds to a span of the hand or approximately 22 cm. As described in Chapter 4, the flag operators received the flood warning messages via SMS messages on cell phones.

The assessment of the WATSURF flag dissemination system is shown in ***Table 6.7***. In determining whether the number of flags raised was correct, a bound was defined as halfway between each change in flag. For example, one blue flag was determined as an increase in water level between 11 and 33 centimeters, two flags from 33 to 55 cm, and so on. For more clarification on how the number of flags was determined, reference ***Figure 4.11***.

In addition to the assessment of the flag system, the results were analyzed with regard to the forecasted direction of the floodwater – whether the flood was predicted to rise or fall within the next 48 hours. A bound of one-half *bighat*, or 11 cm, was defined around zero for no change in water level. The results for the direction of the forecast are shown in ***Table 6.8***.

The results in ***Tables 6.7*** and ***6.8*** show similar results in the accuracy of the flag warning system in the four years of the CFIS operation. The WATSURF prediction, converted into the categories of warnings used in the flags, was correct in terms of the magnitude of water level change (number of flags) 45 to 50 percent of the time, and was correct in terms of the direction of flood rise/fall (correct flag color) approximately 90 percent of the time. To be considered "correct", the number of flags raised versus the equivalent observed had to be equal and this may under represent utility of the information for the local stakeholders. For example, if the flood level was predicted to rise by five *bighat* and a rise of four *bighat* was observed, then the result would be counted as "incorrect" even though the interpretation and action taken by the stakeholder would be nearly the same whether four or five *bighat* increase was observed.

Table 6.7: Assessment of WATSURF Flag Dissemination System

Stn. Id	Stn. Name	Correct Number of Flags (%)			
		2004	2005	2006	2007
3108	Bhalkutia	41%	37%	44%	32%
3109	Tebaria	69%	66%	45%	58%
4110	Dhunail	61%	61%	51%	45%
3111	Boro Baynna	69%	66%	55%	62%
4115	Bohera	40%	34%	49%	49%
4118	Sunsi	48%	42%	31%	40%
4121	Kakna	38%	39%	44%	30%
Average		52%	49%	46%	45%

Table 6.8: Assessment of Forecast Direction (Rise or Fall)

Stn. Id	Stn. Name	Correct Rise or Fall (%)			
		2004	2005	2006	2007
3108	Bhalkutia	82%	89%	88%	90%
3109	Tebaria	98%	100%	88%	94%
4110	Dhunail	96%	92%	94%	97%
3111	Boro Baynna	97%	95%	90%	100%
4115	Bohera	83%	91%	84%	84%
4118	Sunsi	86%	88%	84%	86%
4121	Kakna	84%	93%	89%	89%
Average		89%	93%	88%	91%

- Coefficient of Determination (R-Squared). The coefficient of determination, R-squared, ranges between 0 and 1 and can be interpreted as the variation in a set of data, such as actual water level change, that is explained by another factor or data set, such as predicted water level change. The coefficient of determination was computed between the forecasted and predicted water levels for each of the six representative floodplain gauges during the study period as presented in ***Table 6.9***. The average coefficients of determination are substantially higher for 2004 and 2007, with values of 0.90 and 0.81, respectively; this confirms the higher accuracy of the model for the higher flood years of 2004 and 2007.

Predictions at some gauges had low R-square values (e.g., Gauge 4118), particularly for the low flood years of 2005 and 2006. This indicates that the regression equations used in developing the flood model were not as good a predictor for some sites in the floodplain study area as in other sites. In addition, these results indicate that the regression equations were a better predictor in higher flood years than in lower flood years.

Additionally, several example regressions are included below. First, a regression was completed for all the gauges in 2007 (***Figure 6.5***) with an R-squared of 0.87. Next, an example regression with good results is shown for Gauge 3111 in ***Figure 6.6***. Finally, an example regression for Gauge 4121 in 2007 with mediocre results is shown in ***Figure 6.7***. From examining the data used to construct these regression curves, the predicted values for the regression diverted from the line on both the rising and falling limb. The falling limb trails off beneath the regression line and the rising limb above it.

Table 6.9: Coefficients of Determination (R-Squared) between Predicted and Observed Water Levels

Stn. Id	Stn. Name	2004	2005	2006	2007	Average
3108	Bhalkutia	0.86	0.49	0.39	0.73	0.62
3109	Tebaria	0.96	0.92	0.51	0.87	0.82
4110	Dhunail	0.96	0.93	0.83	0.93	0.91
3111	Boro Baynna	0.97	0.83	0.91	0.95	0.92
4115	Bohera	0.87	0.71	0.49	0.81	0.72
4118	Sunsi	0.83	0.19	0.20	0.52	0.44
4121	Kakna	0.86	0.66	0.53	0.84	0.72
Average		0.90	0.68	0.55	0.81	0.73

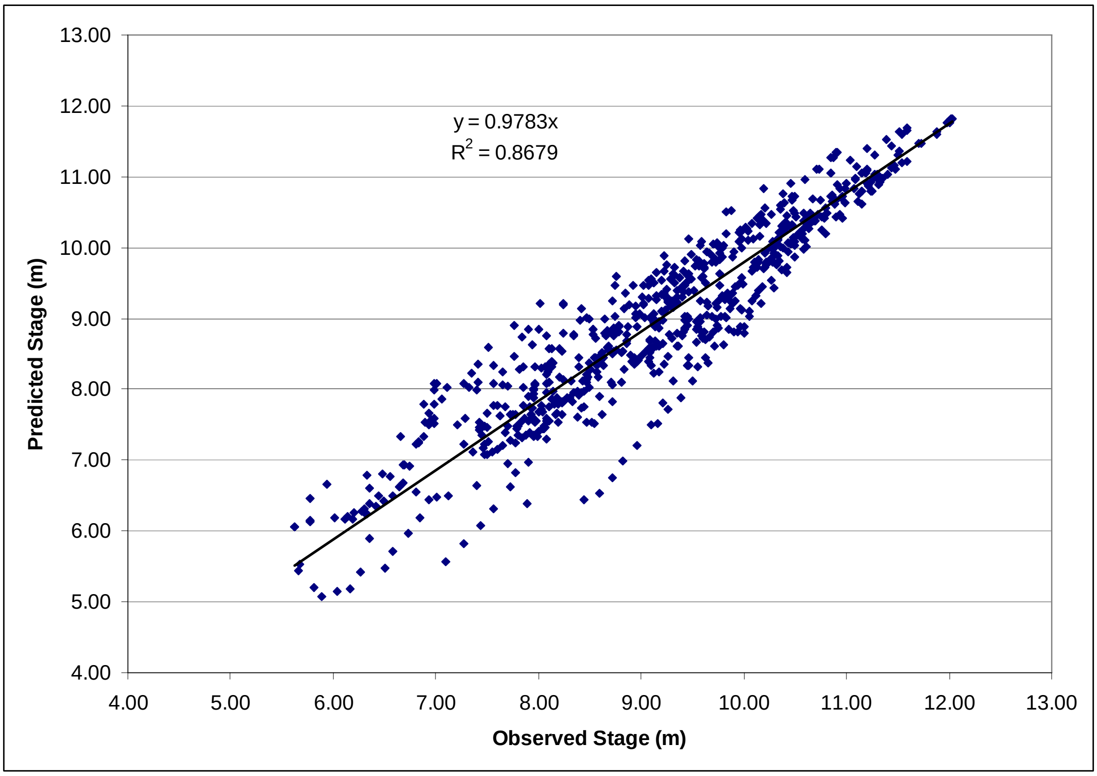


Figure 6.5: Regression for All Gauges in 2007

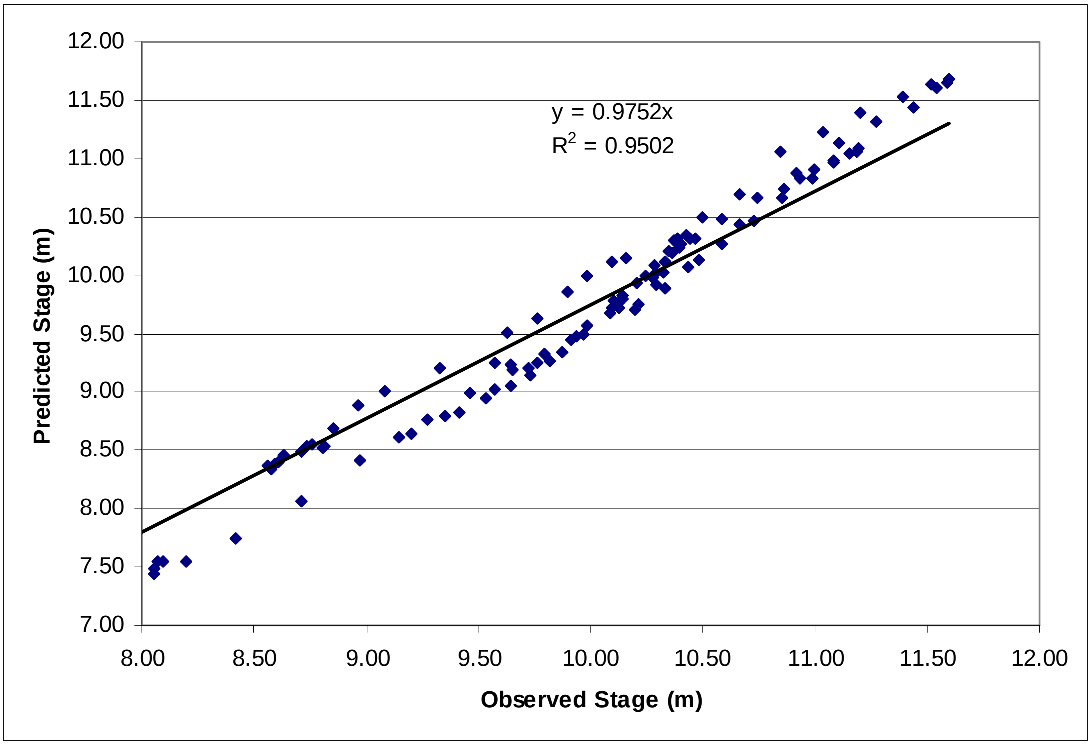


Figure 6.6: Example Regression of Good Results for Gauge 3111 in 2007

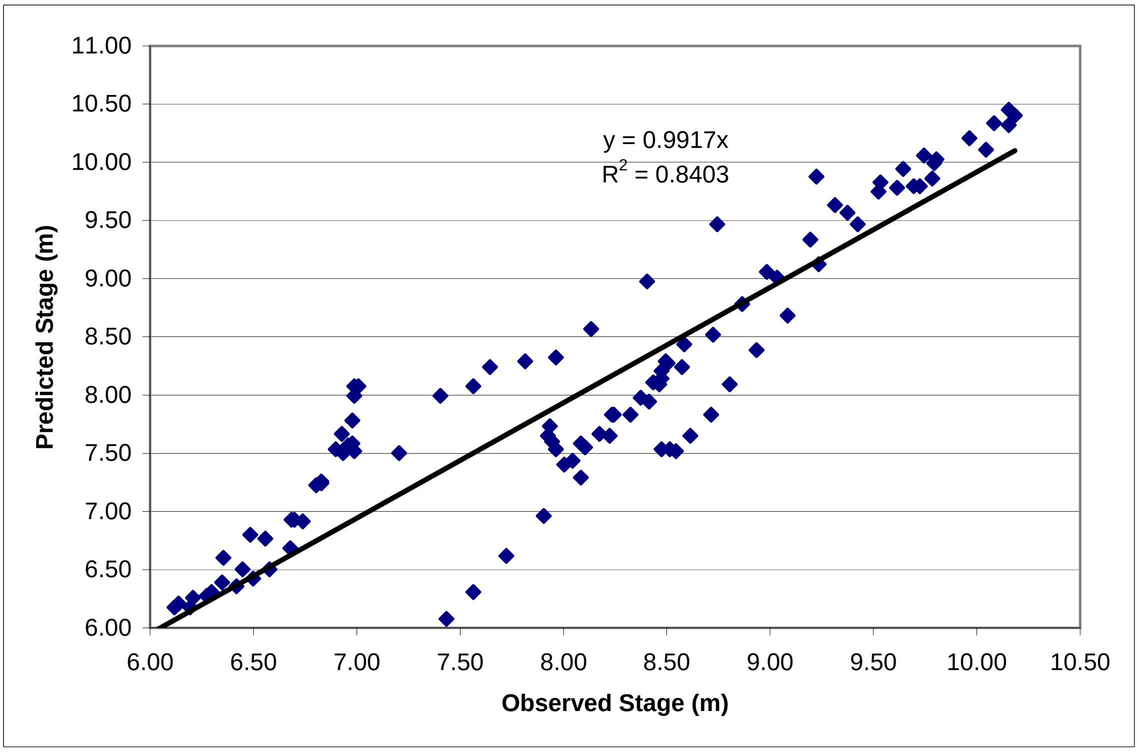


Figure 6.7: Example Regression of Mediocre Results for Gauge 4121 in 2007

6.1.3 Summary and Conclusion

Four different measures were used to represent the accuracy of WATSURF: (1) average error in 48-hour predicted water-level change, (2) average error in 48-hour predicted water level, (3) average error in the forecasted number of flags, (4) and the coefficient of determination (R-squared) for linear regression of predicted and actual water levels.

In general, WATSURF performed well. The error in the forecasted water level change was approximately 0.15 meters for each of the four years. For the normal to high flood years, including 2004 and 2007, the average error of predicted water levels was 0.28 and 0.47 meters, respectively. Additionally, the coefficients of determination (R2) for 2004 and 2007 were 0.90 and 0.81. For the low flood years, 2005 and 2006, the average water level errors were 0.61 and 0.65 meters, and the coefficients of determination were 0.68 and 0.55, respectively. The results for the correct number of forecasted flags varied from 45-50 percent over the study years. The model correctly predicted the direction or rise/fall in the water level approximately 90 percent of the time.

Initially it was suspected that WATSURF would perform better at higher flood levels, which was confirmed by the results for the predicted water level and the coefficient of determination. The improved performance of WATSURF at higher water levels was likely due to the increased river network connectivity. As the floodplain became progressively more inundated, more of the river networks were hydraulically connected with the floodplain.

Another interesting point is that both 2004 and 2007 had similar magnitudes for peak flows, yet the system was less accurate in 2007 for the predicted water level. The less accurate result for 2007 was likely due to the complexity of the flood in 2007, which had two peaks, as opposed to only one peak in 2004. The larger flood volumes and complex changes in water levels may be more challenging to model correctly. The river systems in Bangladesh are dynamic and complex and change over time due to erosion and sedimentation. The stream networks shift and change patterns, which in turn may alter the WATSURF model regression equations that represent the correlation between the river gauges and the floodplain gauges. Finally, the field gauge observers could have introduced error into the model in shifting the gauges to accommodate excessively high flood levels in both 2007 and in 2004.

A useful addition to WATSURF would be a module for updating the regression equations as more data are obtained. This module would obtain data from field gauges located throughout the study area and redevelop the equation at each of the gauge locations. The regression equations were originally developed under the principle component analysis (described in ***Chapter 4***) and are used to predict the water levels at the gauge locations based on the forecasted water level from the FFWC/BWDB gauges.

Throughout all the flood years, the results for the error in predicted change in water level average about 0.15m. This result was important because the user or community member were most concerned about rise versus fall of floodwater and the magnitude of change. The actual water level was used for creating inundation maps and for assessing flood damage, and was designed for use by managers and relief agencies.

It should be noted that the actual water level predictions at some gauges were not as good as at others, particularly for the low flood years of 2004 and 2005 flood season. As stated above, this supports the concept that the floodplain model was most appropriate for moderate to high flood conditions, which were of most concern to the local stakeholders. In addition, because of the dynamic nature of the stream network in the floodplain, the regression equations at gauges may have a limited life.

6.2 Examples of Flood Forecast Use and Responses

The following cases illustrate some of the more notable examples of uses made of early warnings in 2007.

- <u>Early warning saved my nursery.</u> My name is Rowshan Ali Shaikh and I live in Baraboinna Village. I have a little tree nursery that is the only means of my livelihood. I, like all other inhabitants of Baraboinna, have to come to Boinna *Hat* (village market) regularly for different purposes. During monsoon, I saw the early warning flag every day to find out how water levels would increase or decrease. One day I came to the *Hat* on some urgent activities. I forgot to look at the flag and after three hours, I saw two blue flags had been hoisted. Within a moment I realized that the floodwater might increase one hand (i.e., about 50 cm) in the next two days.

I promptly considered my risk and immediately returned home to my nursery. On the way, I met some villagers and shared the warning. After half an hour, I reached my home and with the help of my family, I removed 1,500 saplings to a raised and safe place. The value of the saplings was approximately 20,000 Taka. Next day my nursery was inundated as I had anticipated. If there had been no early warning in my village, I would have lost the saplings and, subsequently, my only source of income, the nursery, would be destroyed.

- Flood early warning benefits a fisher. I am Gobinda. Fishing is my only profession. I live with my children in great hardship. Now a days we cannot catch as many fish by casting nets in the river as we did before. Earnings from fishing decreases day-by-day; therefore, I must have other means of earning, like day laborer. While my ancestral profession is endangered today, monsoon is a blessing for us. During the flood, we can catch more fish, so, for three months of the monsoon we are busy fishing. Mr. Mintu, the flag operator is one of my closest neighbors. This year I regularly asked him about the prediction of floodwater for which we, the fishers, await eagerly. From the regular information of Mr. Mintu, I got the idea that water was rising every day and I prepared for fishing. One day I got the information from him that within two days, the water level might rise one hand and I realized that if it were so, it would be the right time to start fishing. Since I started my preparation earlier according to the prediction of water level, I was ready to start fishing just on time. I started fishing two to three days before all other fishers and earned 2,000 Taka more.

- Early warning saved a small trader. Mintu Sheikh is my name. I live in Baraboinna. Since the very beginning of CFIS project, I have been performing the role of a change agent-cum-flag operator. I took the responsibility on my own for the welfare of the villagers. I feel proud for performing this duty. My religion encourages such activities for humanity. This year I observed the gradual increase of water level along with my flag hoisting. Living in a flood prone area, I anticipated a flood was likely based on the early warning. The increase of water level continued and gradually water came close to the plinth of my house where I have a small shop, my only source of income. One day I received "+ +" message from Mr. Mukter (who is one of three mobile phone owners who agreed to give me messages for flag raising) and I hoisted two blue flags accordingly. According to the prediction, if water rose up to one hand (i.e., approximately 50 cm) in the next two days, the lower part of my shop would be submerged and materials valued at approximately s 5,000 Taka, would be destroyed. With the help of my family, I shifted the materials to a safe place. After two days, I saw the lower part of my shop was under floodwater. Thanks to Allah, thanks to BDPC and CEGIS, my shop is saved.

- Flood did not harm the family of Tara Rani Rajbangshi. My name is Tara Rani Rajbangshi. My UzDusband is Khogen Rajbangshi. My family of five and I have a hard life living on the small income of my husband. I have one cow and ten hens to contribute to our family income. During this year's flood, I saw two blue flags flying one day that indicated floodwater would increase by one hand (about 50 cm) within the next two days. Seeing that, I discussed the risk with Mr. Mintu, the flag operator, and he informed me that floodwater might enter into the houses like mine that were adjacent to the market during the next two days. At once, I shifted our household materials -- dried ghuta (cow dung fuel), cattle-food, and my livestock -- to one of my neighbors' house that was safe from flooding. I prepared a portable oven for cooking during the flood.

The water rose according to the prediction and inundated the houses adjacent to the market, including mine. Our house remained inundated for seven days. My family suffered a lot during that time. Still, due to my preparedness, the flood did not damage our household properties. I could cook food with my portable oven and I saved my livestock. The early warning saved my family at least Taka 3,000 in damages, reducing our sufferings.

- <u>SMS warning via mobile phone saved a villager's home.</u> I am Anser Ali Molla, one of the registered mobile users under the CFIS project who received early flood warning through SMS directly and shared the information. I feel proud to perform such a duty. One day, during the recent flood, I saw my neighbor, Niranjan Rajbangshi, preparing to build a new room on low land next to a channel adjacent to his house. That day I received a flood warning of "+ +". That meant water might increase one hand (approximately 50 cm) in the next two days. I anticipated that the bank of the channel might be breeched if the level of water increased by one hand. If the canal bank breeched, Niranjan's room would be destroyed, so, I convinced him not build the room during monsoon, and he agreed.

  After two days, the warning came true; the canal bank was breeched. Niranjan Rajbangshi expressed his heartfelt gratitude to me as the warning saved him about Taka 30,000.

- <u>A teacher prepared her students' families and prevented her own loss.</u> I am Jharna Rani Sutradhar. I have been a teacher in BRAC primary school in Baraboinna for 13 years and presently I have 33 students. I received training under CFIS project on early warning interpretation and dissemination. On my way to school, I receive early warning regularly from the hoisted flags. My students also can see the flags from the window of the school. All of my students can interpret the early warning flags. From the very beginning of the monsoon in 2007, I spent five minutes each day discussing the early warning of the day. I taught them various flood preparedness measures. The children discussed the warnings and flood preparedness measures with their parents during the monsoon. That is one of the major reasons why their families kept their losses at minimum during the 2007 flood.

  Since my home is on the riverbank, it was threatened by erosion. When I saw continuous hoisting of the blue flag, I decided to cut and sell one rain tree. I sold it for Taka 3,000. Within a few days, the part of my homestead where the tree had stood was eroded. Thus, I prevented the loss of the value of the tree.

- <u>A student prepared her family after seeing early warning flags</u>. My name is Momotaj Akhter. My father's name is Mofij Goni. I read in the BRAC School. I come to my school every day with my classmates. Every year flood occurs in our village. Our teacher has taught us the meaning of flags and the colors of flood markers. During monsoon, she discusses the status of floodwater with us and suggests we inform our parents so that they can prepare accordingly. In this monsoon, for some days, I had seen the blue flag flying. One day I saw two blue flags flying and I informed my parents. They promptly started shifting straw, cattle, and fuel wood to a high and safe place. My mother made a portable oven. Together we made a raised platform in our room. Within two days, our house plinth was inundated and we were flooded. After some days, the floodwater went down again and everything was okay. The flood passed without our suffering much because of early flood warning in our village.

- Farmer saves crops because of early flood warning. I am Md. Aslam Sheikh. I live in Dhunail Village and perform the role of a registered mobile operator and member of VFMC. On 27 July 2007, I got the SMS that floodwater might rise one hand (i.e. 50 cm) in the next 48 hours. The message made me wonder what I should do with my gourd field where about 400 gourds were growing. If water rose one hand, I would lose all of them. If I could wait a few days, I could sell them for Taka 30 per gourd and earn about Taka 12,000. If I followed the prediction, I would have to harvest all the gourds early, but once in 2006 such a prediction proved wrong. I was in a dilemma: "should I ignore the prediction or should I harvest all at once?" In such a puzzling condition, I discussed the situation with the president of Village Flood Management Committee and decided to harvest. At once, I met with a wholesale vegetable buyer and sold all the gourds for Taka 8,000, Taka 20 per gourd. In the next two days, my entire land was inundated. The early warning saved me from a losing Taka 8,000.

- Jute saved by early flood warning. I am Imarat Hossain. I live in Dhunail Village. There are five in our family. Hardship has been with us like the shadow of a body. Often I am affected by various hazards, especially during flood, and I have to borrow money from the local moneylenders at a high interest rate. I am always in debt. Under CFIS project, the Headmaster of Dhunail Primary School hoists flags of flood warning. On 27 July, during flood season, I saw one blue flag and realized that within two days water might increase by half a hand (about 25 cm). If the prediction were correct, it would adversely affect my jute field. I made a prompt decision, gathered some laborers, and cut the jute immediately. Finally, I saw I made the right decision, otherwise my jute would have lost its quality in the floodwater, and the market price of my jute would have been much less. By reacting to the early warning, I sold my jute for Taka 30,000, when the damaged crop might have sold for only Taka 15,000. This year I will not have to borrow money at high interest.

6.3 Warning Use and Impacts

6.3.1 Overview of Warning Dissemination and Use in 2007

As explained in Chapter 5, the system for community-based flood information and warning dissemination evolved through participatory processes throughout the five-year project period, and the excessive flood of 2007 presented an opportunity to test and validate the system. The system was capable of disseminating early flood warnings down to the household level. The reliable lead- time was 48 hours, although local communities, especially farmers, would have preferred a longer lead-time.

A total of 443 mobile phones were registered to receive SMS flood information in the two *upazilas,* of which 415 were individual households, 15 were flag operators, and 13 were union *parishad* bulletin board writers. Among the 415 households, 72 households lived in the two intensively supported *mauzas* (Dhunail and Baraboinna). This arrangement in 2007 reflected the project plan to saturate the communities with flood information. There were two flag sites in Baraboinna and two in Dhunail, with three change agents/volunteers with mobile phones for each of the flag sites who were responsible for disseminating SMS warnings and ensuring flag hoisting through the flag operators. However, in 2007, community level message dissemination was developed that not only was dependent on the change agents and volunteers, but on community mobile users and other local institutions. Boys and girls in the community, those attending school as well as those who did not, could interpret the color and number of flags. Almost all households reported that they had access to flood warnings (see below) and the dissemination of warning messages was as expected. In 2007, two flood peaks occurred. Both times, CFIS worked well at community and household levels, and was helpful in reducing people's losses and damages. Evidence of the use of the warnings is given in ***Tables 6.10*** to ***6.13***.

Just over two-thirds of households in the two *mauzas* were interviewed after the first flood peak, and about 40 percent after the second flood peak in 2007 (***Table 6.10***). Approximately two thirds of respondents were housewives since men were often away working when interviews took place, and over 80 percent were over 30 years of age.

Table 6.10: Respondent characteristics for flood information use survey 2007

Indicator	Baraboinna				Dhunail			
	1st flood		2nd flood		1st flood		2nd flood	
	Number	%	Number	%	Number	%	Number	%
Gender								
Male	115	35	64	32	30	37	41	37
Female	217	65	136	68	103	63	69	63
Total	332	100	200	100	163	100	110	100
Age Group								
16-20	13	4	4	2	6	4		
21-30	46	14	24	12	26	16	13	12
30+	273	82	172	86	131	80	97	88
Total	332	100	200	100	163	100	110	100

Almost all respondents in 2007 reported receiving some form of flood warning (***Table 6.11***). Over half reported receiving warnings from CFIS sources directly – mostly by observing the flags or receiving a warning verbally from the change agents and volunteers (***Table 6.11***). Multiple sources tended to be reinforcing, improving the credibility and response to warnings. On average, each respondent received warnings from almost two sources.

Table 6.11: Incidence and source of flood warning in 2007

Indicator	Baraboinna				Dhunail			
	1st flood		2nd flood		1st flood		2nd flood	
	Number	%	Number	%	Number	%	Number	%
Reported receiving a warning	326	98	200	100	162	99	110	100
Warning source								
Observed flags	176	54	107	54	95	58	59	54
Other family members	181	56	118	59	72	44	65	59
Change agents	124	38	56	28	56	34	44	40
Volunteers	66	20	13	7	34	21	36	33
Neighbors	57	17	34	17	24	15	43	39
Observed flood marker	5	2	12	6	16	10	19	17
Others	3	1			2	1		

Note: multiple responses possible, percentage are out of all those receiving any form of warning. Each person could be warned by more than one means

The respondents in both *mauzas* reported that, in general, the flood warnings had been correct (in terms of direction of change in water level), and the vast majority of respondents reported that warnings for the first flood peak had been partially useful (***Table 6.12***), indicating some unfulfilled expectations. However, the warnings of the second flood peak were regarded as not useful; the reason being that in both *mauzas,* little land was cultivated with T. *Aman,* therefore, there was little to do to save crops. The first flood peak, however, occurred when it was possible, with warning, to harvest early and avoid a total crop loss. Moreover, before the first flood peak, some people used the flood information to save their household assets, shifting them to a safe place. They did not use flood information for saving households assets during the second peak as they had already shifted those items and assets.

Table 6.12: Extent that respondents reported flood warnings were useful in 2007

Response	Baraboinna				Dhunail			
	1st flood		2nd flood		1st flood		2nd flood	
	Number	%	Number	%	Number	%	Number	%
Highly useful	20	6			16	10		
Partially useful	285	88	9	4	142	87	15	14
Not useful	21	6	191	96	5	3	95	86
Total	326	100	200	100	163	100	110	100

The most common uses reported for warnings were for activities that households might undertake as typical flood and monsoon preparedness in Bangladesh, namely storing fuel, and tending livestock (***Table 6.13***). Between one-half and one-third of households made rafts as a means of escape and temporary movement during floods, although few prepared for flooding inside their houses.

Table 6.13: Type of use made of early flood warning in 2007

Response	Baraboinna				Dhunail			
	1st flood		2nd flood		1st flood		2nd flood	
	Number	%	Number	%	Number	%	Number	%
Fuel storage	267	88			142	90	10	67
Livestock management	205	67	2	22	121	77	6	40
Farming	103	34			88	56		
Making raft	162	53	7	78	60	38	13	87
Food storage	59	19			43	27	1	7
Taking shelter in safe place	10	3			4	3		
Children/women/elderly care	5	2			6	4		
Ensuring safe water	8	3			8	5		
Making *macha* (raised platform)	6	2			8	5		
Health care					1	1		
Others	9	3			2	1		

Note: percentages are out of those reporting that the warning was useful to them

6.3.2 Results of Survey of Warning Impacts in 2007

A survey was conducted to assess the impact of the CFIS system of local flood warnings following the 2007 flood. The survey was planned to cover random samples of 12 households in each of six villages within and adjacent to the study area, including: the two intensive pilot or "direct contact" project villages of Baraboinna and Dhunail, two other project villages Chak Haricharan and Kachpai that received warnings through less intensive systems in the study area through EMIN/CEGIS support using forecasts issued through CFIS, and two "control" villages of Bachamara and Jayatkashi that did not receive any project-based warnings or information. The objective was to make a comparative assessment of the use and impacts of flood warnings compared with responses of households that did not receive warnings through CFIS.

Average household sizes were similar at just over six persons, with an average of 1.5 school age children and 99 percent school enrollment of children aged five to14 years. The heads of household in the direct contact villages averaged seven years of education compared with four years in the other villages. The direct contact villages interviewed consisted of more people who had registered for SMS and thus were better off economically than average. The three samples differed in occupations: 53 percent in the direct contact villages named farming as their main occupation compared with 37 percent in the other project villages and 20 percent in the control villages (most of whom were sharecroppers). The direct contact villagers were relatively well off with fewer being laborers and fishers than in the other villages. This was borne out by reported landholdings, although some respondents refused to give their landholding area that for the direct contact village sample were three times larger than in other project villages and four times larger than in the control villages. Consequently, only 19 percent of sample households in the direct contact villages owned under 50 decimals (0.2 ha) of land compared with 76 percent in the non-project village sample (***Table 6.14***). This is consistent with the reported food security of the households – only a quarter in the direct contact villages reported that they were in deficit compared with almost half in the other project villages and almost three-quarters in the non-project villages (***Table 6.15***). In all cases, most reported an occasional food deficit and all averaged about one month a year when they could not eat three meals a day.

Table 6.14: Landholding characteristics of sample households

Land category	Project direct contact	Project other	Not project	Total
Sample number	N=16	N=21	N=17	N=54
Total area owned (decimals)	334	116	77	168
Owner cultivated land (decimals)	298	78	45	133
Land owned but cultivated last year by others (decimals)	173	33	18	70
% Households with no own cultivable land	6%	43%	82%	44%
Landholding category (% households)				
Total own land <=0.5 acres	19%	57%	76%	52%
Total own land >0.5 acres and <= 2.5 acres	43%	29%	12%	28%
Total own land > 2.5 acres	38%	14%	12%	20%

Table 6.15: Food security status of households

Status	Project direct contact	Project other	Not project	Total
Sample	N=24	N=24	N=24	N=72
% Occasional or usual deficit	25	46	71	47
% Break even	54	50	25	43
% Surplus	21	4	4	10

Despite these differences in poverty between the samples, and obvious differences in the potential household crop losses from flooding, the houses of the sample households have very similar structures and hence potential for structural damage in floods. Most have tin walls and roofs, although half of those in the other project villages have “thatch” walls, and thinner tin was more commonly used for their roofs (***Table 6.16***).

Table 6.16: Structure of sample houses

Type of material		Project direct contact	Project other	Not project	Total
Sample		N=24	N=24	N=24	N=72
Wall (%)	Straw/leaves/jutesticks/bamboo	20.9	50.0	20.8	30.6
	Tin (poor quality)	58.3	20.8	75.0	51.4
	Tin (good quality)	12.5	20.8	4.2	12.5
	Brick/concrete	8.3	8.3	0.0	5.6
	Total	100.0	100.0	100.0	100.0
Roof (%)	Straw/leaves	0.0	4.2	0.0	1.4
	Tin (poor quality)	20.8	41.7	20.8	27.8
	Tin (good quality)	79.2	54.2	79.2	70.8
	Total	100.0	100.0	100.0	100.0

Section 6.2 showed that most households in the direct contact (pilot) villages received flood warnings in 2007, and most of the direct contact sample received information from multiple sources (flag, mobile/SMS, school children, and community members) (***Table 6.17***). Given that only a modest percentage of households in these pilot villages were registered for SMS warnings, this means that the sample was biased in favor of mobile phone owners. Few households in the other project villages received any warning, and none from project related sources, even though there is a low density of warning coverage (SMS and flags) in the wider project area. Incidental information indicates that the range of flag-based warnings covered only a modest radius around the flag sites, and it would appear that the sample households in these two villages did not receive information from flags or SMS recipients (it should be remembered that most of the approximately 65,200 households in the 13 unions in the study area were not registered for SMS in 2007). Warning coverage was slightly better in the non-project area suggesting that a few households there had contact with warning sources from CFIS. Warning lead-time was two days for almost all sources, although it was slightly longer for radio. However, radio and television warnings were considered of limited or little use in the other project and non-project villages. Almost three-quarters of respondents found the CFIS-related warning sources to be very useful in the direct contact villages. Accuracy apparently did not vary between warning sources – almost all respondents considered all warnings to have good accuracy, the exception being the accuracy of radio warnings that was rated lower by the non-project sample.

Table 6.17: Source of flood information in 2007

Source of information		**% Got warning**	**Lead (days)**	**Assessment of use (%)**				**% Reported good accuracy**
				Very	Some	Little	Not reported	
Project direct contact	Community	58	2	69	31	0	0	93
	Flag	92	2	76	14	0	10	100
	Mobile/SMS	75	1.9	71	18	0	12	94
	Neighbor	33	1.8	100	0	0	0	100
	NGO	4	2	100	0	0	0	100
	Radio	4	2	100	0	0	0	100
	School going children	63	2	71	29	0	0	100
Project other	Neighbor	4	3	0	100	0	0	100
	Radio	13	2.7	0	67	33	0	100
	TV	4	2	0	100	0	0	100
Not project	Community	4	2	100	0	0	0	100
	Flag	4	2	100	0	0	0	100
	Mobile/SMS	4	2	100	0	0	0	100
	Radio	17	2.5	0	50	50	0	75
	School going children	4	2	100	0	0	0	100

Flood warnings were expected to help households reduce their flood losses. Evidence of this depends on the extent that sample households were affected by flooding. In the direct contact and other project samples, few households had flooding above floor level in their home, although over a third experienced flooding in their homestead courtyard (surrounding their home), whereas in the control villages, homestead flooding was more severe since more houses flooded to greater depth (***Table 6.18***). Although there is limited scope for flood warning to reduce structural damages, there is some indication that households in the direct contact villages had less damage when their courtyard was flooded than in the other villages where they received no warning (***Table 6.19***). The higher "damages" for the non-flooded direct contact households were the costs one household reported that it incurred to prevent flooding in its home, presumably averting even higher damages.

Table 6.18: Homestead flooding incidence in 2007

Indicator	Project direct contact	Project other	Not project
Sample number	N=24	N=24	N=24
House flooded in Jul-Aug (%)	16.7%	4.2%	41.7%
Depth (inch, cm)	6 (15)	12 (30)	14 (35)
Duration (days)	6	8	8
House flooded in Sep (%)	.0%	.0%	16.7%
Depth (inch)	.	.	7 (17)
Duration (days)	.	.	5
Courtyard flooded (%)	37.5%	50.0%	83.3%
Depth (inch)	11.0 (27)	16.0 (40)	19.6 (49)
Duration days	9.3	11.2	13.0

Depths were recorded in locally understood units (inches)

Table 6.19: Reported house damage (Tk) in 2007 floods according to flood condition and flood warning receipt

		Project direct contact				Project other				Not project			
		No. of HHs	No. of HHs with damage	% with damages	Av damage (Tk) for all HH	No of HHs	No. of HHs with damage	% with damages	Av damage (Tk) for all HH	No. of HHs	No. of HHs with damage	% with damages	Av damage (Tk) for all HH
Not flooded	CFIS warning	15	2	13.3	1467	0	0		.	0	0		.
	Other warning	0	0		.	3	0	0.0	0	1	0	0.0	0
	No warning	0	0		.	9	2	22.2	444	3	1	33.3	667
Only courtyard flooded	CFIS warning	4	2	50.0	1625	0	0		.	0	0		.
	Other warning	2	0	0.0	0	1	1	100.0	4000	3	1	33.3	5667
	No warning	0	0		.	10	8	80.0	3600	7	5	71.4	2429
House flooded up to 12 inches	CFIS warning	3	3	100.0	1667	0	0		.	1	1	100.0	1500
	Other warning	0	0		.	0	0		.	0	0		.
	No warning	0	0		.	1	1	100.0	2000	5	4	80.0	2500
House flooded more than 12 inches	CFIS warning	0	0		.	0	0		.	0	0		.
	Other warning	0	0		.	0	0		.	0	0		.
	No warning	0	0		.	0	0		.	4	4	100.0	6750

Table 6.20: Reported damages to household assets including loss of livestock (Tk) in 2007 floods according to flood condition and warning receipt

		Project direct contact				Project other				Not project			
		No. of HHs	No. of HHs with damage	% with damages	Av damage (Tk) for all HH	No of HHs	No. of HHs with damage	% with damages	Av damage (Tk) for all HH	No. of HHs	No. of HHs with damage	% with damages	Av damage (Tk) for all HH
Not flooded	CFIS warning	15	3	20.0	1200	0	0		.	0	0		.
	Other warning	0	0		.	3	0	0.0	0	1	1	100.0	500
	No warning	0	0		.	9	1	11.1	4444	3	0	0.0	0
Only courtyard flooded	CFIS warning	4	0	0.0	0	0	0		.	0	0		.
	Other warning	2	0	0.0	0	1	0	0.0	0	3	1	33.3	1667
	No warning	0	0		.	10	3	30.0	330	7	2	28.6	143
House flooded up to 12 inches	CFIS warning	3	0	0.0	0	0	0		.	1	0	0.0	0
	Other warning	0	0		.	0	0		.	0	0		.
	No warning	0	0		.	1	1	100.0	200	5	1	20.0	1200
House flooded more than 12 inches	CFIS warning	0	0		.	0	0		.	0	0		.
	Other warning	0	0		.	0	0		.	0	0		.
	No warning	0	0		.	0	0		.	4	2	50.0	1575

Although the samples of households with homestead flooding were small (***Table 6.20***), it is notable that direct project households with only courtyard flooding reported no damages to assets and contents (not house structure) compared with about a third of households in the other two areas in the same flood depth category (average damages of Taka 1,550 per household suffering damages or Taka 440 per household with courtyard flooding). Similarly, for households with up to 12 inches of water inside their house, all three in the direct contact villages got CFIS warnings and suffered no content or other asset damages, as did one household in the control area. In the control area, of six households with no warning, two suffered damages of an average of Taka 3,100 per household, or Taka 1,030 per household with one to 12 inches of above floor flooding. The samples were small, but they suggest that two-thirds of households suffering moderate homestead flooding would minimize their damages without a CFIS warning, but that one-third would suffer losses that they could have fully prevented with a CFIS warning system in place.

Flood warnings also were expected to reduce flood losses to agriculture and other economic activities. However, none of the other project and control households reported crops in the monsoon and so it was not possible to attribute any change in net returns to agriculture to flood warnings, although some of the projects direct contact households reported saving their crops. For other economic activities, both project and control households took damage saving actions with broadly similar benefits (***Table 6.21***). The direct contact households tended to spend more on damage saving actions, possibly having greater confidence due to the warning system, although the few fish farmers who tried to protect fish spent more than was financially worthwhile for them.

Table 6.21: Households that took loss-reducing actions for non-crop economic activities

Location	Activity	No. of loss saving action taken	No. of households			% by reason		Cost of action (Tk/hh)	Damage saved (Tk/hh)	Benefit (Tk/hh)
			Moved	Protected	Sold	Saw flood water	Warning from flag			
Project direct contact	Fish culture	3	2	1	0	33	67	8667	3333	-5334
	Livestock	6	6	0	0	0	33	733	9333	8600
	Nursery	3	0	0	3	0	67	500	3500	3000
	Small trading	1	1	0	0	0	0	2000	20000	18000
Not project	Livestock	4	0	4	0	0	0	308	14250	13942
	Nursery	2	1	1	0	100	0	0	0	0
	Small trading	4	3	1	0	100	0	100	2250	2150

Notes: The incidence of sample household's involvement in these activities is not known; only households taking loss-reducing actions are shown. None did this in the "other project" villages; several households did not say why they took actions, but some noted that they had to move house. hh = household

Overall, the limitations of the sample reduced the utility of the assessment of flood warning responses and impacts, but it did indicate that household actions to protect assets such as livestock, house contents, and homestead assets in response to warnings were economically beneficial.

Chapter 7
Sustaining and Scaling Up CFIS

7.1 Arrangements to Continue CFIS in Pilot Areas

Flood forecasting through CFIS was piloted in an area of about 400 km^2 with additional support from EMIN. The WATSURF model showed an acceptable and useful level of accuracy in forecasts that can be disseminated 48 hours ahead of the predicted change in flood levels and were useful for local communities in reducing the damages and disruption caused by flooding.

The CFIS system for local community-based flood information provision and dissemination was intensely field tested in two *mauzas* (Bara Bania and Dhunail) that have a total population of 3,455 in about 743 households. These two *mauzas*, like many in Bangladesh, need area specific early flood warning because they are far from a main river and do not receive useful or relevant flood forecasts from FFWC. During the project period, the evolved project dissemination system consisted of two channels: one through the local government and the other directly to the communities. The government channel never performed as effectively as was desired due to the lack of initiative and support from the local government. The direct community dissemination techniques tested under CFIS proved to be effective and worthwhile.

In 2007, the CFIS warning dissemination system was widely understood in the local communities. Even 10-year-old boys and girls in the local school could correctly interpret the meaning of the flags. Members of the community could easily relate to the predictions and their individual risk factors. If people felt there was a threat to their property and livelihoods from a predicted change in water level, they knew what to do to reduce their losses and damages. People believed they needed to continue receiving flood information to reduce their losses and damages. In 2007, it was reported that warning flags were always hoisted in response to warning messages received through the system. The community SMS receivers proved effective in monitoring flag hoisting. It was reported that if the change of flag was delayed after a warning was issued from Dhaka; the community SMS receivers pushed the flag operators to change the flags. Regular receipt of reliable flood information during an above average flood allowed the communities to make greater use of the system.

The CFIS generates forecast and automated warning generation for a 400 km^2 area and local warning dissemination across representative parts of this area. For continuity of the automated warning sent via SMS to cell phones, maintenance of computer software and hardware, and about one and a half hours per day of a trained operator in Dhaka during the monsoon (about 100 days) is required. CEGIS has committed to provide this during the 2008 flood season.

Continuity of warning dissemination to local institutions and community members requires a continued arrangement to send SMS warning messages. Banglalink has committed to provide free SMS to existing recipients in 2008, but this only covers part of the cell phone connected population of the area. The commitment of union *parishads* and other local institutions to disseminate warnings and flood information in 2008 and beyond is also required.

For continuity of CFIS in the two pilot *mauzas*, the following arrangements are needed:

- Community members must understand the disseminated message – this was achieved under the CFIS project. Hopefully, the existing institutions and volunteers will continue to remind and explain the meaning of the dissemination messages to the community so no additional support is needed.
- People need to relate the warnings within their professional and household context – achieved and expected to continue since few people migrate into rural areas.
- People need to know what to do in the perceived threatening situations for risk reduction. This was demonstrated to a considerable extent in 2007, but if there were several years without any floods, or if there are years with “false warnings,” then their response might diminish. There should remain a process for review of the flood warnings each year with feedback to the service

providing the information. Feedback could come from the UzDMC or via SMS from the change agents or flag operators.

- Communities must receive flood information through flags and other mechanisms in a timely, regular, and consistent manner. BDPC oriented and prepared communities to operate and use this system, but does not have any funds to provide any additional support after project completion.

7.2 Future Needs for Community-based Flood Warnings

Based on four years of flood forecasting and warning dissemination, it is understood that local people have well defined needs and expectations for flood warnings, some of which were met by the CFIS project and some of which could be met more effectively if improvements were made.

7.2.1 Dissemination Method

Local people have concluded that they are satisfied with the current dissemination methods developed under the project (i.e., by flags in public places and by individual SMSs).

7.2.2 Warning Message Detail

Categorizing changes in water level, for example, a one *bighat* (half hand) increase or decrease can be confusing for people. Under the CFIS system, one flag means a change in water level of one inch to nine inches. According to the local people, this is a big difference or range in water level change, which can amplify the difficulty of making some decisions. The difference between a five- and nine-inch increase in water level can considerably change the risk to specific property. The local communities would like information that is more specific.

7.2.3 Timing of Warnings and Use of Thresholds before Warnings are Issued

Local people are in favor of receiving flood information throughout the monsoon season. However, the change agents and volunteers thought that providing information only when a flood could be threatening or damaging would be more effective in drawing attention to the warnings. Limiting the period when warnings are issued might also focus the attention of warning system stakeholders and help ensure that the messages are as accurate as possible. Additionally, limiting the period would be more cost effective and therefore help the long-term sustainability. However, limiting the time period might prevent the system from operating when a threatening flood occurs. Instead, a threshold water level could be used to initiate the flood forecast dissemination. Three issues would need to be considered when setting a threshold, including: (a) hydrological system and connectivity of channels, (b) social needs (the events for which people want to get information), and (c) when flood levels become threatening to agriculture and property. Threshold levels could be obtained through hydrological modeling and consultation with the community. Usually, during the CFIS project, flood forecast dissemination started when the flood water level reached one meter below the yellow line of the flood pillar, which was defined as the starting point of moderate flooding in the area.

7.2.4 Role of Local Government

The involvement of local administration and government needs be more effective. This could be ensured if an official order is in place requiring the local government to play an active and well-defined role in disseminating warning messages. They should receive flood status information only when a flood is threatening, otherwise they do not need to play an active role in the system and warnings. If the local government plays an official role in the process by issuing flood predictions only when they cross some threshold, the use of warnings, their onward transmission/dissemination, and monitoring by the local disaster management committees (DMCs) is more likely to be ensured. Both the union and *upazila* DMCs have the scope to spend money for these purposes.

7.2.5 Role of Private Sector

Automated warnings via SMSs appear to work well once mobile phone owners have been oriented. Ideally, there should be a feedback mechanism to obtain the views and experiences of registered SMS recipients. The extent that mobile phone owners pass on warnings to poor neighbors and the resulting proportion of at-risk households warned needs to be investigated. The private sector has shown it is willing to provide a free flood warning service to its subscribers, but it is uncertain to how many people they will extend this service. The service also could be limited to the most threatening messages for all subscribers, with a full information service available for payment. Currently, the service is restricted to one mobile company; the possibility of expanding the service to multiple companies would also need to be investigated.

7.2.6 Warning Lead Time

The communities are interested in having longer lead times. Warning with 48 hours lead-time were found to help reduce losses and damages in the 2007 flood. ***Chapter 6*** and the case studies give testimony to these benefits. Early warnings disseminated through CFIS created opportunities for local people to prepare just before flooding affected them, but the farmers wanted longer lead times. Flood predictions 48 hours ahead often could not be used to save many crops. This is especially important, considering that the main source of livelihood in many rural areas of Bangladesh, such as the pilot area, is agriculture. Nonetheless, according to qualitative observations, farmers were the most benefited group within the communities.

7.2.7 Facilitation

Developing a system for effective community-based early flood warnings that reach at-risk communities is not the sole achievement. To link community people with the system so that they can relate the warnings with their individual risk factors, and can identify and adopt appropriate actions for loss and damage reduction, is essential. To establish this link, social mobilization is necessary, which can be most easily achieved through NGOs because communities are too numerous and dispersed for capacity building by a central agency, and because local government has limited staff and experience in this area. The key issue is what level of input to community organization will be needed, and how far existing or new local institutions can be involved. The UDMCs might be able to serve this role if they are trained and they could develop action plans for linking communities with the warning system. However, this would require a major effort, not only to formally assign them with this responsibility, but also to closely monitor them through either the *upazila* administration or an external agency. In a union *parishad*-based system, NGOs would train the UDMCs so that they could undertake the responsibility to prepare the communities.

7.2.8 Accountability

The CFIS experience shows that communities can take responsibility to disseminate flood information. Orienting and delivering warnings to a wide range of mobile phone owners provided a level of direct local accountability for flag operators to their community, complemented by local committees. For example, three volunteer flag operators were terminated due to poor performance, which was only possible after the community had been mobilized and oriented.

To replicate CFIS throughout the country, each stakeholder in the forecast-warning system needs to be accountable to their clients. Weak governance has been a persistent problem in Bangladesh, which makes a multi-path warning system with multiple stakeholders including government, NGOs, and community-based organizations necessary to provide checks, balances, and encouragement.

After the 2007 flood and super-cyclone Sidr, there is a window of opportunity for improving warning systems. Community-based early warning is a topic of interest and the CFIS project has shown how this can be implemented and developed through a combination of forecasting tools, dissemination methods, and practical experience.

7.3 CFIS Initiatives to Replicate and Mainstream CFIS Concept

Since the initiation of the CFIS project, there has been a substantial increase in awareness and interest among government agencies, donors, and projects in community disaster preparedness. It is already proven that the concept of CFIS is well accepted and received by the local community, local institutions, and national government. The motivated and active participation of the local communities in the development and implementation of CFIS made the system highly beneficial and improved its sustainability considerably.

In order to mainstream the CFIS concept three types of initiative have been taken:

- Government mainstreaming
- NGO mainstreaming
- Public private partnership

7.3.2 Government Mainstreaming

To involve government of Bangladesh as a follow up and facilitate the replication of CFIS, a memorandum of understanding between the Bangladesh Water Development Board (Flood Forecasting and Warning Centre), the Water Resources Planning Organization, and the Center for Environmental and Geographic Information Services (CEGIS) (referred collectively as the Parties) was signed. The purpose of this memorandum is to establish and define a collaborative relationship among the Parties to share the broad goals of pursuing project opportunities and developing the technology and applications for disseminating early flood warning information in Bangladesh.

Another memorandum of understanding between the Bangladesh Water Development Board (Flood Forecasting and Warning Center), the Center for Environmental and Geographic Information Services (CEGIS), the World Food Programme (WFP), and Riverside Technology, inc. (RTi) was initiated, but has not yet been applied.

7.3.3 Non-Government Organization (NGO) Mainstreaming

To popularize the concept of CFIS, RTi, CEGIS, and BDPC incorporated the concepts in different project proposals made to the Comprehensive Disaster Management Programme (CDMP), CARE, USAID, and World Vision. Two or three projects have already started and have adopted the CFIS methodology.

"Community-Based all Hazards Early Warning Dissemination System Development," a project under the framework of the Local Disaster Risk Reduction Fund (LDRRF), has been undertaken in pilot areas of Lalmonirhat District in a joint venture between CEGIS and BDPC with financial assistance from CDMP. Under the project, the CFIS concepts are used for a different purpose. For the pilot sites, suitable and acceptable early warning information packages for each hazard will be developed and disseminated to the local community through SMSs, flags, and bulletin boards.

"Climate Forecast Application Network (CFAN)" financed by USAID and CARE was implemented by Asian Disaster Preparedness Centre, Institute of Water Modeling (IWM), and CEGIS in 2006. Five flood prone unions (Kaijuri Union in Shahjadpur *Upazila* under Sirajganj District, Uria Union in Fulchhari *Upazila* under Gaibandha District, Rajpur Union in Lalmonirhat Sadar *Upazila* under Lalmonirhat District, Gazirtek Union in Char Bhadrasan *Upazila* under Faridpur District, and Bekra Union in Nagarpur *Upazila* under Tangail District) were selected as pilot areas under this project. The project uses the technical concept behind WATSURF, meaning that the river water level forecasts by FFWC are transformed into local water level forecasts. The CFIS dissemination approach is also used to disseminate flood warnings to the community in the form of SMSs to targeted union managers (members of UDMC), communities, and households. Committees are responsible for flag operation and for disseminating the messages to community voluntarily. In the pilot sites, flags and bulletin boards are also used for flood warning message dissemination. In 2007, the accuracy of four-day flood forecasts was found to be approximately 50 to 70 percent in the pilot areas.

In addition, to disseminate the concepts of CFIS, CEGIS made contacts with CARE- Bangladesh, World Vision, and Save the Children. A series of meetings were held to focus on the usefulness of the CFIS concepts and to partner for further implementation in other areas.

7.3.4 Public Private Partnership

As mentioned in ***Chapter 4***, partnership with Banglalink brought the CFIS project into focus among information dissemination networks. Banglalink agreed to continue to support the CFIS approach in disseminating flood forecasts and will provide the free SMS service to registered users in 2008. Beyond 2008, the arrangement has not yet been defined. Banglalink has shown interest in replicating the CFIS project throughout Bangladesh, but the feasibility and possible arrangements of this have not yet been determined. Banglalink could develop a "push-pull" system for flood forecast information, pushing SMS as part of its corporate social responsibility to selected local warning agents and offering information to other mobile subscribers who pull by requesting the service and then pay normal costs of a subscriber to SMS service. Nonetheless, this is not the only mobile phone service in Bangladesh, and the issue of exclusivity regarding warning services for information that is a public good being disseminated through a private service will need to be resolved.

7.4 National Replication

7.4.1 Potential Replication Locations

Bangladesh has 64 districts, of which more than half are vulnerable to flooding. ***Table 7.1*** shows the areas vulnerable to riverine floods that can be forecasted locally using WATSURF in Bangladesh. This section summarizes how the area of potential replication was derived.

Table 7.1: Riverine flood vulnerable areas

Vulnerable	No. of Districts	No. of *Upazilas*	No. of Unions	No. of Wards	No. of *Mauzas*	Area (Sq. Km.)
High	19	56	656	43	7,601	15,540
Medium	29	79	842	93	14,625	21,910
Low	6	10	99	18	1,957	2,150
Total			1,597	154	24,183	39,600

The suitable replication area was selected based on the following three criteria:

- Whether the area is flooded by river or rainfall only (i.e., no flash flooding or tidal effects), moreover the WATSURF modeling system would not be effective for areas protected by embankments. However, FFWC has the potential to address the important issue of embankment overtopping/breaching in flood forecasting. If FFWC can provide flood forecasts with scenarios of the probability of embankment overtopping/breaching, then WATSURF can generate the flood forecast for areas protected by embankments that could be used to issue warnings of sudden flooding due to overtopping/breaching.
- Water level data of existing FFWC flood monitoring stations will be applicable for the potential area – FFWC flood predictions do not cover all of Bangladesh with sufficient detail.
- Whether the area has mobile telephone coverage to support information dissemination everywhere. Areas without mobile telephone coverage would not easily be covered by the system, but by now, coverage is almost nationwide.

Considering the three criteria, the replicable area was determined to be 39,600 sq. km, with a population of 39.6 million.

Based on the above criteria, potential areas for WATSURF tool replication were identified using GIS data and overlay techniques, according to the process described in the flow diagram in ***Figure 7.1***.

The spatial distribution of the floodplain, where land goes under water in normal flooding, has been captured from physiographic maps. The area of Bangladesh vulnerable to riverine flooding hazards was delineated by the intersection of relevant areas of a floodplain map and flood-type map. The resulting flood-type map reflects types of flood sources including rainfall, upstream flow, tidal inundation, and flash flood.

The Flood Forecasting and Warning Center (FFWC) maintain 85 flood-monitoring stations in the country, categorized in three groups:

- Real-time flood forecasting stations
- Flash flood monitoring stations
- Rain-flood monitoring stations.

Only the 46real-time flood-forecasting stations on the main and regional rivers can be used with WATSURF.

Figure 7.2 shows the feasible area. The *haor* areas of northeast Bangladesh are not considered feasible as water levels there are mostly influenced by rain. CARE Bangladesh's vulnerability map was used to prioritize the replication of WATSURF within the potential replication area using three categories of vulnerability: high, medium, and low (these are shown in ***Table 7.1***).

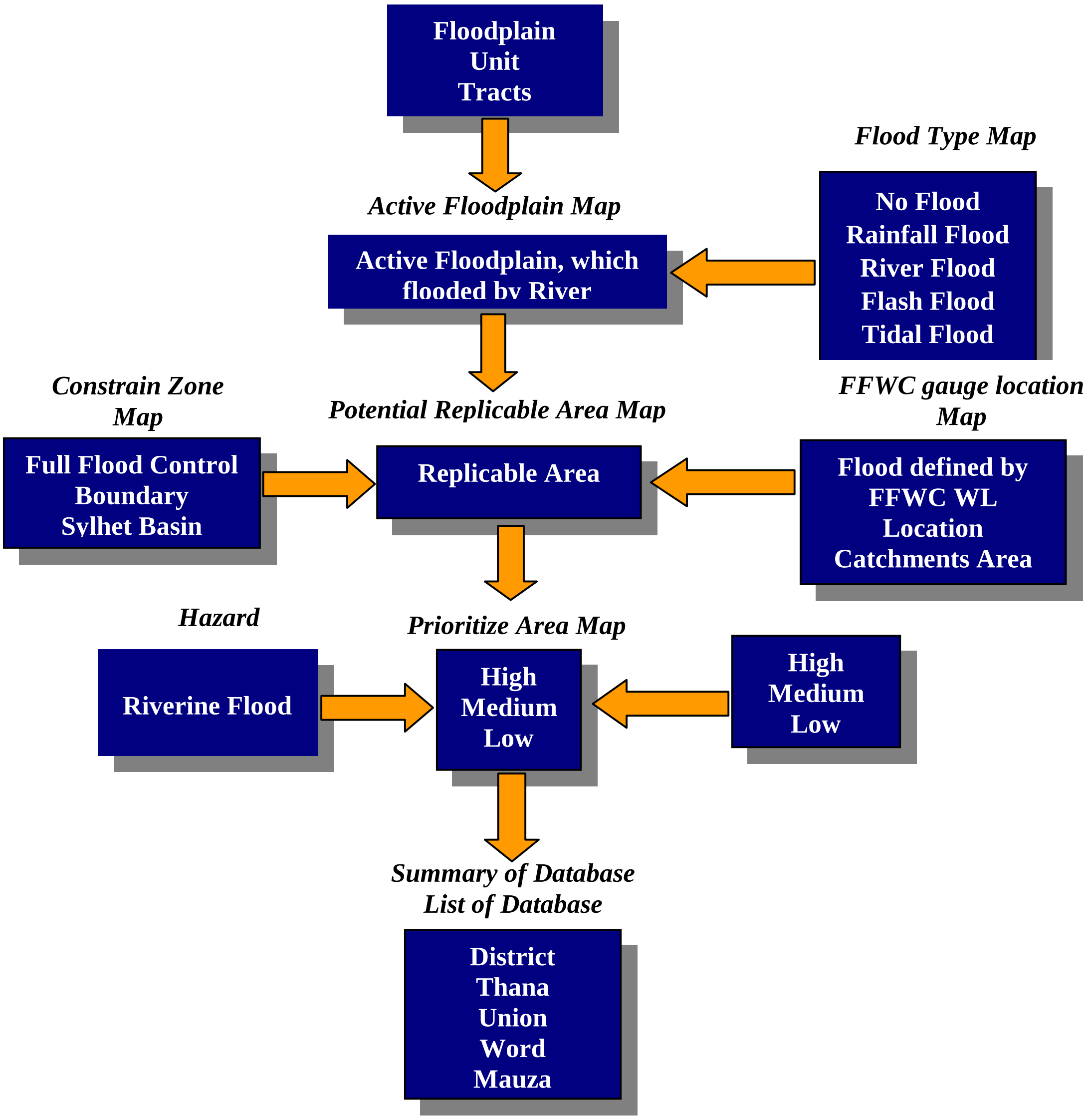


Figure 7.1: Flow diagram for CFIS replication

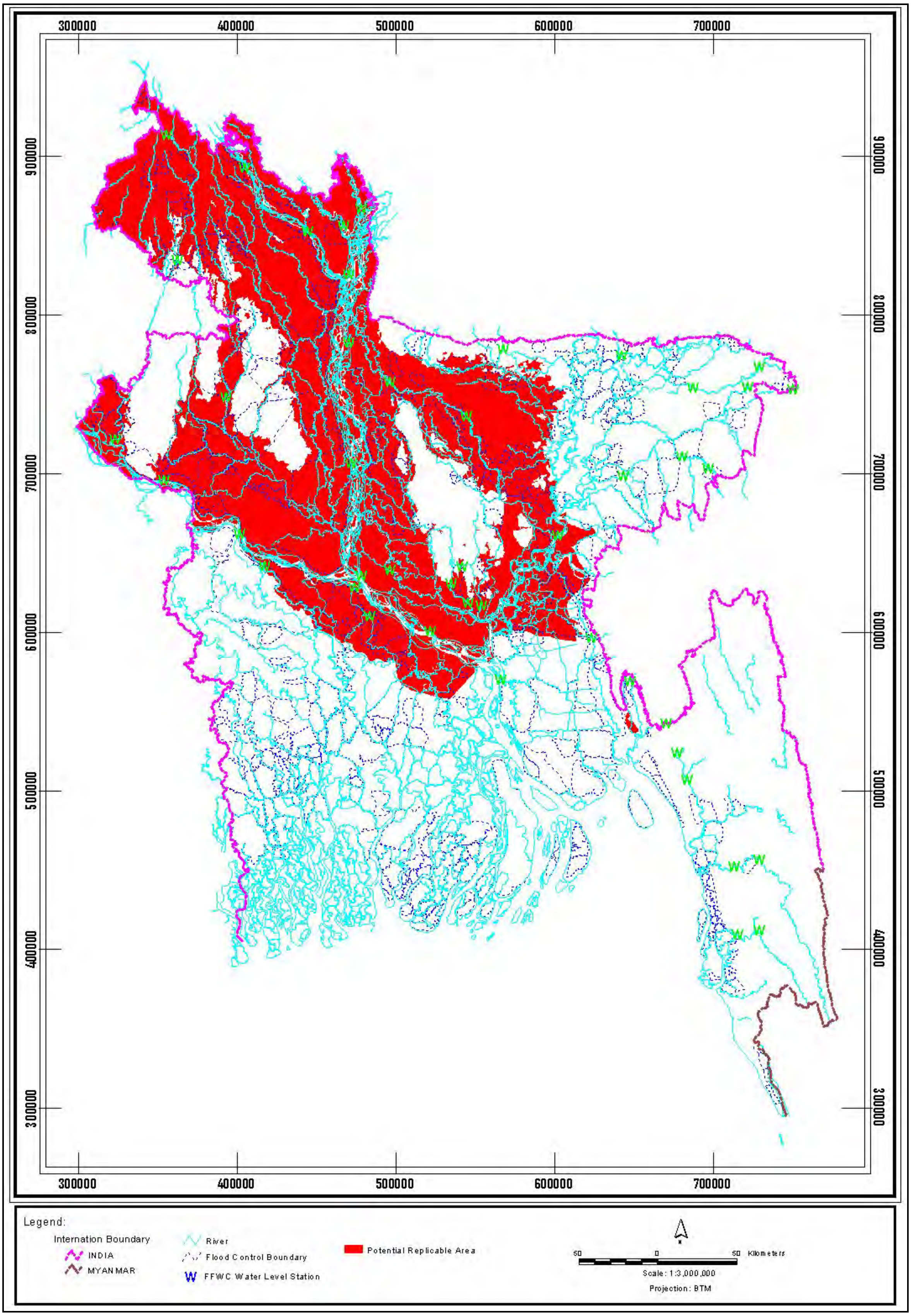


Figure 7.2: Potential Replication Area Map of Bangladesh

7.4.2 Replication Steps and Issues

WATSURF needs to be configured according to hydrology, topography and several other factors.

Hydrological setting: Hydrological and level surveys, and hydrological data analysis from secondary sources are needed.

Identifying hydrological monitoring sites: Establish and verify the model links between BWDB main river gauges and local warning dissemination reference points. Local water level monitoring stations have to be established; the station density is primary in designing the application/replication of CFIS. A higher station density will result in greater accuracy of locally relevant information, but is more expensive to set up. The density of sites also depends on hydrological conditions and flow connectivity. ***Appendix 3*** provides an analysis of optimizing the number of monitoring sites. The most likely compromise for this is to have one monitoring site per union or one per 40 to 60 sq. km. area depending on the area and topographic condition of the union.

Water level monitoring: Staff gauges are used at the monitoring sites and should be sufficient to collect data for two monsoon seasons (four to five months in a year).

Social and hydrological survey: Community-defined red (severe flood), yellow (moderate flood), and green (normal flood) elevations, tied to Survey of Bangladesh benchmarks, should be recorded.

Water level correlation: Based on one-year hydrological data, establish relationships among water levels at the FFWC gauge stations and the WATSURF floodplain gauges in the replication area.

WATSURF configuration: Set up WATSURF based on the relationship between and the thresholds of elevation values of green, yellow, red, and minimum moderate flood connectivity levels of each gauge. Other parameters, including historic hydrological data, river network topology, flow directions, local topography, and village and infrastructure locations, also are required.

Model validation: Second year hydrological data will be used to validate the WATSURF outputs of the first year.

Operator training: Train the flood forecasting service provider to operate and produce the WATSURF outputs.

Dissemination pathways: Identify suitable pathways, make agreements, and train those responsible for warning dissemination. This is expected to include agreements with voluntary SMS subscribers, agreements with local institutions such as bazaar and school committees on flag raising points, and recruiting and orienting local volunteers. Similarly, agreements with and orientation of local government are needed.

Dissemination assessment and review: In years one and two, establish and operate a review process for accountability of local dissemination agents, and to give feedback to the forecasting service provider and other intermediaries from the local communities.

Community orientation: Sessions are needed to explain the meaning of warning messages to local people, what they can do, and how they can inform others. Should be particularly focused on those who have their own networks of local contacts and who are respected as local leaders.

The density/numbers of monitoring stations required to model an area depends on the expected/ acceptable level of accuracy of the flood prediction information. ***Table 7.2*** shows the required density of monitoring sites for arbitrary levels of accuracy, based on floodwater surface slope and country terrain. For example, accuracy useful at the union level requires replication with a grid size of 25 km^2, corresponding to about 1,600 monitoring stations in the entire replication area.

Table 7.2: Monitoring station density

Accuracy Level	Proposed grid size (km)	Accuracy (cm, flood depth)	Administrative Level	Number of monitoring stations
I	20	100	District	99
II	10	50	*Upazila*	396

Accuracy Level	Proposed grid size (km)	Accuracy (cm, flood depth)	Administrative Level	Number of monitoring stations
III	5	25	Union	1,584
IV	2.5	11.5	*Mauza*	6,337

Table 7.3 shows four types of prediction information that the WATSURF tool can produce, and the required input data.

Table 7.3: WATSURF input and output data

Product Type	**Information Depth**	**Monitoring Station Density km/unit**				**Pillar**	**Datum Survey**	**Connectivity**	**Old DEM**	**DEM/Topography corrected using RS data**	**New DEM (ALS survey)**
	Administrative level →	Dist	*Upazila*	Union	*Mauza*						
	Flood depth accuracy level →	100	50	25	12.5						
1	Flag message: rise and fall only	20	10								
2	Flag message: rise and fall with magnitude		10	5	2.5						
3	Flood extent and flag message (type 2)	10	5	2.5							
4	Flood depth and extent:		5	2.5							
5	Flood damage map		5	2.5							

The EMIN project has tested product types one and two in the pilot area. The CFIS project has tested product types three and four, and has the potential to be part of a flood damage assessment tool.

7.4.3 Options and Simplifications

Replication methods depend on the type and depth of information dissemination to stakeholders, from *upazila* to village level, which is desired. The forecasting system can be replicated with or without detailed local warning dissemination; however, the benefits achieved in the CFIS pilot areas cannot be expected if there is no community-based warning dissemination system. Three different replication methods are considered here.

Table 7.4: Type of information dissemination

	Rise/Fall (Qualitative)	Rise/Fall (Quantitative)
Upazilla	**I**	
Union		**II**
Mouza		**III**

Method I

This method would disseminate *upazila*-wise flood prediction information to the district center. Flood information will be generated for each *upazila* in the district, which gives an indication of change in water levels with reference to a local vulnerable level in each *upazila*. The district administration and resource managers could use this information for short-term preparedness management planning.

Method II

This method would disseminate union-wise flood prediction information to the *upazila* center. Information on water level rise and fall will be predicted and transformed in local units (*bighat)* for each union in the *upazila* with reference to a local vulnerable level. *Upazila* disaster management organizations and local government institutions can use this information for short-term preparedness management planning. Such information could be disseminated by SMS to the public, but there would be some risk that the union-level water level changes predicted would not be locally relevant to users.

Method III

This would generate quantitative *mauza*-wise water level predictions at hydrological and socially representative locations with reference to a local vulnerable level. The water level information is transformed into local units. In addition to the Union Disaster Management Committee members and other community organizations, people at the household level would get access to this flood information.

Chapter 8
Conclusions

8.1 Main Findings and Lessons Learned

The CFIS project has demonstrated that it is possible to generate reasonably accurate flood forecasts, particularly of forecasted water level change, for specific local areas of floodplain, and to disseminate the appropriate local warning messages through an automated system to the many people living within the floodplain through a mixture of direct SMS, flags, and word of mouth.

8.1.1 Achievements

Specific major accomplishments and findings include:

- Developing and demonstrating a hydrological modeling system that works well and incorporates an unprecedented methodology for creating local flood forecasts required the development of an efficient and automated system, WATSURF. WATSURF automatically generates and sends reliable flood forecasts, along with many other useful products such as inundation and flood-depth maps.
- Developing innovative dissemination methods that are semi-automated, where one operator can reach thousands of people through the rapidly expanding coverage and ownership of cell phones – SMS messaging directly to the community (developed in 2007) is the future. SMS text messaging allows for forecast information to be fed through multiple pathways to local governments, to key opinion leaders—such as school teachers, imams, and shopkeepers—and directly to vulnerable households. Recipients had previously agreed to, and succeeded in, passing on warnings to their neighbors and wider community, and this was reinforced by a network of flag sites, bulletin boards, and awareness raising exercises.
- Using public-private partnership and cell phone technology to disseminate flood warning information is also an important trend. The opportunity for partnerships is growing rapidly, particularly for using technology for development. All of the three cellular telephone companies approached by CFIS were interested in supporting the project with low- or no-cost dissemination of flood forecasts via SMS as an area of corporate social responsibility. CFIS secured an agreement with Banglalink, the second largest mobile company, for transmitting flood forecasts via SMS for both the 2007 and 2008 flood seasons at no cost. This pilot arrangement is the first known in Bangladesh for using mobile phone technology to disseminate early warning messages; such arrangements will be critically important as effective, low-cost methods for operational early warning for floods and other hazards.
- CFIS works! Communities developed their own preparedness plans and people use and appreciate the flood warnings and information that reach them, and have shown that local community organizations and institutions, when guided by NGOs, are effective warning agents.
- CFIS built national level awareness and recognition of the need for community-based warnings and the potential to deliver the warnings. The CFIS project raised the awareness of all relevant government agencies, at levels from national to local, about the need for accurate local flood information and for communicating in understandable formats to the affected stakeholders.
- CFIS revealed the limitations of the current flood warning system. Over a two-year period, CFIS conducted detailed assessments to understand the complex needs of communities and local government for flood information, and the limitations of the current system.
- Local government has a greater understanding of the importance of early flood warning, although it showed limited interest in taking an initiative in warning dissemination.
- Centrally, the Flood Forecasting and Warning Center is enthusiastic about the approach and reaching communities with warnings.

The CFIS approach was also publicized and extended in collaboration with the EMIN project, particularly in 2007 when there was unusual flooding, and the approach proved effective in the pilot area. This resulted in interest in the project among development partners and in the media (newspaper articles and press releases); although at the end of the project, there was limited time to leverage funding for an expansion on the pilot project. Nevertheless, the positive results in 2007 raise the scope for replicating the CFIS concept through projects and organizations such as the Comprehensive Disaster Management Project, WFP, and other government projects.

A more intensive community-based warning dissemination mechanism was developed and demonstrated to work in two pilot villages. This success depended on:

1. Relevant and timely flood forecasts reaching local warning dissemination agents.
2. These agents implemented multiple effective warning dissemination mechanisms that were self-reinforcing.
3. The communities were consulted about, and took ownership of the system.
4. Local people developed their response capacity to the specific flood warnings they could expect, and could interpret their own livelihood implications and make appropriate responses.

8.1.2 Qualifications and Issues

Local ownership and effectiveness were achieved because the dissemination mechanism was developed in a participatory way through an evolutionary process. The long duration of the project created an opportunity to enhance the capacity of the communities to interpret the warnings, understand their personal risks in relation to warnings, and understand what actions could work to reduce their losses. This evolution improved the CFIS approach, but cannot be repeated on a large scale. The lessons for scaling up must come from this pilot since a successful national system would only be feasible with a relatively low cost per household that could be covered through taxation and sponsorship. Most members of rural communities have little ability to pay for flood information.

In each year of CFIS, there were local exceptions that limited the utility and benefits from the warning system, and in two out of four years there was no significant flooding to test the system. In 2004, warnings only started to be issued when flooding had started and there were gaps in timely dissemination of warnings and interpretation of the information. In 2005, normal inundation occurred, the warning system was improved, and community trust was developed. In 2006, warnings were of little relevance as water levels were low. In 2007, siltation of channels into the pilot villages meant that flood warnings only translated into reality after local riverbank thresholds were passed. This highlights the issue that floodplain physical characteristics change and that the relation between main river floods and local flood levels needs to be reviewed and updated quite frequently.

However, to date there has been limited commitment from government, particularly at local levels, and this is unlikely to change without external pressure. The local government and administration played less of a role in the warning system than was expected because of their lack of commitment, and because they did not perceive warning dissemination to be their assigned responsibility. Sometimes they used the warnings for planning their own activities, but their performance in warning dissemination and monitoring community-based warnings was not very significant. It was observed that there was no accountability of the UDMCs to different levels of stakeholders or expectation that they would provide this service. Therefore, if they did not disseminate warnings, the local community did not consider this a failing.

The use of SMSs for warning dissemination to the public was very effective in directly reaching households, and it reinforced messages for flag hoisting for community level dissemination, which was also highly appreciated by local people. However, in the future, the flag operators expect to receive some payment for the service they provide. The schools played a significant role for warning dissemination and awareness building. It was reported that even young schoolchildren were well aware of flag meanings and they updated their families on water level information every day during the monsoon. The *hat* and bazaar committees shared the information among local people for their safety. Hence, the set of local stakeholders and mutually reinforcing messages from several sources helped to ensure that warnings reached those people living close to the flag posts. However, this appeared to result in a division of local communities - those who got warnings from multiple sources and those who were left out.

Lastly, establishing formal and effective flood warning dissemination systems that meet community needs will require long-term attention. Unfortunately, the government and donors tend to react to events – a series of dry monsoons will lessen interest. At present there is greater attention focused on cyclones after the disastrous cyclone Sidr.

8.1.3 Opportunities

Based on this pilot project and the lessons learned, there are now major opportunities to improve the lives of floodplain people through expansion of the CFIS approach:

- People use and want flood information.
- Private sector development in cellular phone/SMS technology is tremendous.
- Cell phone companies are interested in offering warning services as corporate social responsibility.
- Public-private partnerships could include free flood warning services, more detailed flood information where customers pay for SMS, and joint sponsorship of expanded CFIS.
- There is substantial scope to leverage support through other existing projects and the current interest of development partners.
- CFIS can easily be expanded, and use of a river basin model could extend forecasting lead-time.
- The approach and warning dissemination methods can be adapted for use in all types of flood hazards in Bangladesh, including flash floods and cyclone storm surges.
- WATSURF outputs of flood-risk maps and future application for assessment of potential flood losses could be used for wider planning purposes including climate change adaptation.

8.2 Recommendations

8.2.1 Expansion and Replication

The assessment of optimizing gauges when implementing WATSURF indicates that savings can be made when the system is scaled up to a larger area compared with the CFIS pilot area. Moreover, much of the operating costs are largely fixed irrespective of an area covered once a system is established. However, the effectiveness of SMS information dissemination raises the issue of message costs – each SMS, even in bulk, would cost about 1 Taka, and if 90 messages were issued in a flood season for each of the millions of floodplain inhabitants who by now have mobile phones, the commercial cost would be quite large. Contrasting this is the opportunity for mobile phone companies to make an innovative public-private partnership and provide such a service free or highly subsidized, as part of the corporate social responsibility of a rapidly growing and very profitable business. The most feasible approach, therefore, is to expand in the main river floodplains and active channels of the main rivers, where many of the most flood-vulnerable people live. This can be done as a sequential replication, moving the set-up for WATSURF and for orienting local warning agents from district/*upazila* to the next and allowing two years for establishing the system in each area. As already mentioned, a number of programs already have an interest in such a service, which could help leverage funding.

8.2.2 Local Relevance

The objective of early warning is to create methods for emergency response and to prepare for flooding. During the 2007 flood, the crops of Bara Boinna Village were inundated overnight by the overflow of water from Amtoli River. People reported that households living near the Amtoli River could relate to the warnings as they could see the changes of water level according to the predictions. However, the people living further inside the village could not, as the mouth of the canal was silted up after the 2004 flood. Instead, they were affected by sudden flooding when the canal bed was overtopped. This type of local change is a challenge for the production and dissemination of accurate area-based flood warnings. Therefore, the system needs to be open to regular review and revision, both in the technical and social dimensions.

8.2.3 Accountability

Establishing accountability in the flood forecasting and warning system is one of the most important factors for ensuring effective warning dissemination. Top-down accountability will only be ensured if the standing order on disaster is enforced by the higher authorities on the UzDMC and UDMC, requiring the *upazila* and union *parishad* to take responsibility for flood warnings. For example, the deputy commissioner could issue an official order for local government and administration to receive, transmit, disseminate, and monitor the flood warning at local and community levels. Bottom-up accountability will require that forecast and warning service providers such as CEGIS and Banglalink are responsive to feedback from the local communities and their organizations.

8.2.4 Role of Union Parishad

Intensive involvement of UDMC is important for sustainability. Being a long established and sustainable institution of the local government, the union parishad can ensure the sustainability and functionality of the flood information and warning system. Though the UDMC has no budget for warning dissemination, the union *parishad* has the capacity to generate local funds for keeping the system functional. This is feasible since the cost per year of keeping the system functional is no more than Taka 5,000.

8.2.5 Sustainable Funding

If poor/destitute people are chosen as flag operators, they could be brought under the government's Food for Work or Cash for Work programs as an incentive for providing the service. It would also make the flag operators more accountable to the community. Overall, and in the long term, some government budget allocation would be needed for a large-scale system and could be placed through the UzDMC and UDMC system. This could cover maintenance of local information markers, flags, etc., but the aim should be on a cost-sharing basis with local communities through existing or new institutions (whether VFMC, other community-based organizations, or local bodies such as mosque committees) taking on a voluntary but formally recognized role. This would minimize the need for local funding.

8.2.6 Local Institutional Arrangements

The Village Flood Management Committees (VFMC) were ad hoc bodies for the purpose of this project. For a large-scale sustainable system, one option is to replicate many VFMCs, however, this requires attendant effort and costs to form them and the issue of their sustainability, or to incorporate flood warning dissemination and feedback into the roles of existing institutions (where these exist) and limit the creation of new committees. This latter course seems more appropriate and cost effective since much of the demonstrated community-based warning dissemination was done by existing institutions (schools, mosques, markets), each of which has its own local committee and could form a flood warning sub-committee. Moreover, there are various community organizations for local resource management in the floodplains that could take a similar role. However, it must be recognized that the coverage of existing institutions may be patchy, so at the lowest level below the union *parishad* there may be some areas where new committees would be formed, and that participatory planning sessions with a focus on flood warning and management would need to be conducted with these local institutions.

8.2.7 National Institutional Arrangements

Currently in Bangladesh, there is a wealth of government agencies involved in flood management and response, but a lack of clear legal responsibilities for providing flood warnings (something that internationally is an important aspect of effective systems). Moreover, there is a lack of organizations that have a large workforce on the ground that could disseminate warnings. CFIS addressed this through a mix of voluntary visual and individual warning disseminators linked with the ad hoc VFMCs. Any links with national institutions came through CEGIS. For the long-term mainstreaming of CFIS, it should be formally linked to FFWC under a long-term agreement with CEGIS. As a government supervised organization, CEGIS has a mandate to support bodies such as FFWC under the Ministry of Water Resources. This would take care of forecasting and warning message generation. The combination of public-private partnerships for SMS and local government and local informal institution/CBO partnerships for flags and local warning networks, would maintain the warning dissemination system. To oversee this, one unit would need to be established to review operations and advise the stakeholders in the system, as well as to be a channel for feedback to the technical flood forecasters for identifying any need to update or adjust the system.

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Appendix – 1
List of CFIS Deliverables

The following table shows a list of the CFIS project deliverables and reports.

Deliverables	Date	Principle Author
Power Point presentation, RTi to USAID/OFDA Washington	December-2002	RTi
EMIN Needs Assessment Report (conducted jointly with CFIS)	March-2003	EMIN
CFIS Community Flood Information Needs Assessment	March-2003	BDPC
Power Point presentation, RTi to FFWC/Dhaka	May-2003	RTi
Inception Report	July-2003	RTi
Beel Topography Report	August-2003	CEGIS
Establishing a Hydrological Monitoring Network for the CFIS Study Area	September-2003	CEGIS
Database Preparation Report	January-2004	CEGIS
SAR Flood Tool User Manual, Version 1	February-2004	RTi
Baseline Survey Report	March-2004	BDPC
CFIS Flood Tool, Version 1	March-2004	CEGIS
Technical Report Principle Components Analysis	May-2004	RTi
Disaster Management Training Report	July-2004	BDPC
Community Mitigation and Monitoring Activities	July-2004	BDPC
How the People are Coping with Floods	August-2004	BDPC
Review of WATSURF Results for 2004 Flood	September-2004	RTi
Community Mitigation Report 2004	April-2005	BDPC
WATSURF User Manual, Version 2.2	May-2005	CEGIS
WATSURF, Implementation and Experiences in Flood 2004	May-2005	CEGIS
Replication Strategy of CFIS/EMIN Local Level Flood DST	November-2005	CEGIS
Vulnerability and Risk Reduction through CFIS, Paper and Presentation, Presented at Mekong River Commission Flood FOrum	May-2006	RTi
Floodplain Gage Optimization Assessment	August-2006	RTi
Performance of WATSURF - 2004 and 2005 Flood Season	August-2006	RTi
Community Dissemination of Flood Warning in Bangladesh	August-2006	RTi
WATSURF 2007 User Manual	October-2007	CEGIS
Field Report on Gages, Flood Pillars, and Benchmarks	November-2007	CEGIS
Performance of WATSURF - 2007 Flood Season	November-2007	CEGIS
Community Mitigation Report 2007	November-2007	BDPC
Report on CFIS Awareness Raising	November-2007	BDPC
Report on Mock Demonstration on Dissemination	November-2007	BDPC
Summary of 1st and 2nd Survey	November-2007	BDPC
Final Report	March-2008	RTi, CEGIS, BDPC

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Appendix – 2
Roles and Responsibilities of Key Agencies Involved in Flood Management in Bangladesh

Based on the Standing Orders on Disaster, the responsibilities of the key agencies in a flood or disaster are as follows. Key responsibilities related to riverine flood forecasts and warning dissemination relevant to the CFIS project have been highlighted in bold.

Disaster Management Bureau

- Work as advisor of the government on all matters relating to disaster management and maintain liaison with all related organizations.
- Undertake various activities for creating awareness and reducing risks during disaster.
- Assist in the preparation and implementation of a framework for an Action Plan on disaster management at District, Upazila, and Union levels.
- Impart training to all related government and non-government employees and disaster management committee members.
- Establish an Emergency Operations Centre (EOC) with improved communication facilities and operate it 24 hours.
- Establish and coordinate all activities related to flood forecasting and warning dissemination.
- Monitor progress of rescue, relief and rehabilitation operations, identify the problems and needs and to draw the attention of the proper authority.

Directorate of Relief and Rehabilitation

- Ensure stock, security, and maintenance of adequate materials in disaster-prone areas.
- Open a Control Room in the Department and maintain link with the EOC of the Ministry.
- Inform the Ministry about relief preparedness in affected areas
- Ensure quick dispatch of relief materials and grants to affected areas.

Bangladesh Water Development Board

- Ensure an efficient Flood Forecasting and Warning system.
- Operate a “Flood Information Centre” from April to November every year.
- Collect, during the monsoon period, weather forecasts and water level of all principal rivers originating from different places in Bangladesh and India.
- Quickly assess the loss and damage and prepare required plans for repair and reconstruction work on priority basis.
- Ensure the restoration of infrastructure, logistics, and installations in shortest possible time for domestic, industrial and export use. Projects connected with agriculture, fisheries and industrial rehabilitation will be given top priority.
- Render assistance and cooperation in the rehabilitation programs of the civil administration and other agencies.

Bangladesh Betar

- On government orders, Bangladesh Betar would, especially at the stage of pre-disaster period, alert the people, and motivate and inform them about the disaster position and their duties in this respect.

Bangladesh Television

- Establish contact with Meteorological Department and ensure proper functioning of telephone and teleprinter.
- Telecast special programs as authorized by the Meteorological Department and the Ministry of Disaster Management and Relief for information and action of the public.
- Telecast special precautionary signals of the Meteorological Department along with their meanings.
- Bangladesh Television must telecast on receipt of warning signal No. 4 along with explanation given by Meteorological Department every one hour and continue such telecast if advised by the Ministry of Disaster Management and Relief without any interval even after normal broadcasting hours. As soon as signal No. 3 is hoisted, Bangladesh Television will establish contact with the Ministry on a full-time basis for non-stop broadcast beyond normal broadcasting time.
- Dhaka Television shall telecast all announcements issued by the Ministry of Disaster Management and Relief and the Meteorological Department
- Announce instruction relating to precautionary measures issued by the Ministry of Disaster Management and Relief and the Meteorological Department.
- Telecast programs to keep the morale of the affected people high and short and long term programs regarding rehabilitation

Mass Communication Department

- To increase public awareness about disaster preparedness and response activities through video, cinema, films, slides, booklets etc.
- Take technical advice on the above subjects from the Disaster Management Bureau.
- Keep the people of the disaster prone areas informed through different publicity media about their duties at these stages.
- After the disaster, conduct publicity work in affected area with a view to keeping mental spirit of the people high and advise people of epidemic, self reliance in reconstruction work, general security, agricultural rehabilitation, etc.

Directorate of Health

- Prepare medical team; arrange supply of medicine and other emergency goods.
- Operate the Control Room round the clock (24 hrs).
- Supply water purification tablet, bleaching powder etc and ensure supply of pure drinking water.
- Remain always alert in respect of outbreaks of occurrence of epidemic and take effective measures against the spread of diseases.

Armed Forces Division

- Maintain a full-time liaison with the EOC of the Ministry of Disaster Management and Relief.
- Ensure appropriate preparedness planning of the three services in respect of the security of the people, establishment, equipment, installation materials, and transport in the cyclone/flood prone areas before the cyclone/flood season starts.
- Keep the appropriate units of Army, Navy and Air force in readiness for conducting rescue, evacuation, and relief operations as per requisition.

Meteorological Department

- Keep ever-careful watch over weather conditions, and ensure improvement of cyclone forecast procedures and supply of information on regular basis.
- Ensure full time effectiveness of the quickest channel of communication for disseminating weather warnings to all concerned.
- Issue as soon as possible the alert warning signals of cyclone, at least 36 hours ahead of formation of depression in the Bay of Bengal.
- Publicize warning signals for Cyclone at each of the following specified stages:

(a)	Warning	24 hours before
(b)	Danger	At least 18 hours before
(c)	Great Danger	At least 10 hours before

- The same warning signals are to be repeated to the EOC at the Ministry of Disaster Management and Relief, Control Room of the Disaster Management Bureau, the Directorate of Relief and Rehabilitation, the Cyclone Preparedness Programme and the Bangladesh Red Crescent Society.

Union Disaster Management Committees

Normal Times:

i. Arrange training and workshops on regular basis on disaster issues and keep the Disaster Management Bureau informed.

ii. Prepare a Disaster Action Plan with a view to enabling local people, Union authority and local organization to take up security arrangement in the perspective of imminent danger related warnings or occurrence of disaster.

iii. Take steps for quickest and effective publicity of forecasts/warnings relating to cyclone and floods, and informs people about their responsibilities of saving their lives and properties from disaster.

iv. Determine specific safe centre/shelter where the population of certain areas will go at the time of need and assign responsibilities to different persons for various services at the shelter/centre.

v. Arrangement for rehearsals or drills on the dissemination of warning signals/forecasts, evacuation, rescue and primary relief operations.

During Disaster

i. Organize emergency rescue work by using locally available facilities in times of need and if directed assist others in rescue work.

ii. Collect statistics of loss incurred in disaster in the light of guidelines of Disaster Management Bureau and Upazila Authority and send the same to UzDMC/Upazila authority.

iii. Take steps for distribution of articles for rehabilitation received locally or from the Relief and Rehabilitation Directorate and any other source following guidelines from the Disaster Management Bureau and UzDMC/Upazila authority.

Upazila Disaster Management Committee

Normal Times

i. To ensure increased alertness, disaster risk reduction and informing about ways of sure and effective survival.

ii. To arrange training and workshop on disaster related issues regularly by keeping the Disaster Management Bureau informed.

iii. To prepare a Disaster Action Plan in the light of warning signals for impending disaster, keeping in view whether Upazila authority and local organizations are prepared to meet the disaster effectively and efficiently

iv. To hold mobilization drills in cooperation with District and Union authority for intermittent publicity of information and warning signal/forecasts and of matters related to evacuation, rescue and primary relief operations in the interior of the Upazila.

v. To raise public awareness at the village level by wide publicity of disaster forecasts.

During Disaster

i. To operate an emergency operation centre (Information Centre and Control Room) for coordination of activities related to evacuation, rescue, and relief at Upazila level.

ii. To prepare plans carefully for rehabilitation work at local level including possible arrangements for risk minimization.

iii. To allocate and distribute relief based on actual needs.

iv. To supervise the distribution work of relief and rehabilitation and to maintain its accounts and send the same to district authority and other relief donors.

v. To be responsible for coordination among different offices at Upazila level.

District Disaster Management Committee

Normal Times

i. To ensure that the risk factor of disaster and the possibilities of reduction of risks have been fully considered while preparing and implementing development programs at District level.

ii. To disseminate forecasts and warnings of disaster, and to make the people conscious about them.

iii. To prepare a District Disaster Action Plan with a view to keep the District authority and local organizations well prepared to meet disaster effectively and efficiently in the light of warning signals about imminent disaster and the occurrence of disaster

During Disaster

i. To operate an Emergency Operations Centre (Information Centre and Control Room) for maintaining coordination of activities at all places in the interior of the district in respect of evacuation, rescue, relief, and primary rehabilitation work.

ii. If necessary, to operate rescue work with the facilities locally available and to coordinate mobilization of rescue teams for rescue operations in severely affected Upazilas.

iii. To collect, verify and supply statistics relating to loss according to instructions issued by the Disaster Management Bureau and other national authorities.

iv. To prepare plans for rehabilitation work carefully based on priority measures for risk reduction at District level.

v. To allocate and distribute relief to Upazilas on a realistic basis according to necessity.

vi. To supervise distribution of relief and rehabilitation activities and maintain their account and send the same to national authority and other relief donor organizations.

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Appendix – 3
Gauge Optimization Summary

Introduction

The CFIS team investigated the feasibility of replicating the project on a large scale, where cost considerations are important. One of the more costly components of CFIS was in setting up and maintaining the floodplain gauges, used to correlate the water levels in the study area to the water levels on the main river. These floodplain gauges are used for initial model set-up and development of the regression equations used by WATSURF.

The objective of this exercise was to determine the most effective location and number of gauges in the study area. This study was used to indicate the number of gauges necessary for other replicable areas and future cost savings from a reduced number of gauges. Once the relationship between the main rivers and the gauges in the floodplains are established, then the number of gauges could also be reduced. This is dependent on how long the regression equations will remain valid, considering the dynamic nature of the floodplains in Bangladesh. This analysis focused only on reduction of number of gauges used for set-up, and not what is required for monitoring and long-term maintenance of the model.

To determine the optimum number of gauges in the study area, a feature in WATSURF was used that allows the user to choose which gauges to include in a selected model run. When gauges are no longer included in the model run, then the regression equation for those points were not used. The water surface elevation is determined by interpolation along the river network between other gauges that are included in the model run, ignoring the removed gauges. An Excel spreadsheet containing all the water surface elevations for each gauge, with and without selected gauges, was created for this analysis using WATSURF.

Results

Following is a brief summary of the results found from the gauge optimization exercise, the full report of the gauge optimization exercise is presented in the CFIS technical report titled "Floodplain Gauge Optimization Assessment". Some of the key results are presented in ***Figure A3.1***. This figure shows the resulting error in the 48-hour predicted water level and the 48-hour predicted *change* in water level with different sets of gauges included in WATSURF. There were four different sets of gauges examined, which include two gauges, five gauges, seven gauges, and all fifteen gauges. ***Figure A3.1*** shows the average errors over the period from July 1 to October 15, 2004. This period encompasses the entire 2004 flood season and was chosen because it contained a range of flood levels from low to above average.

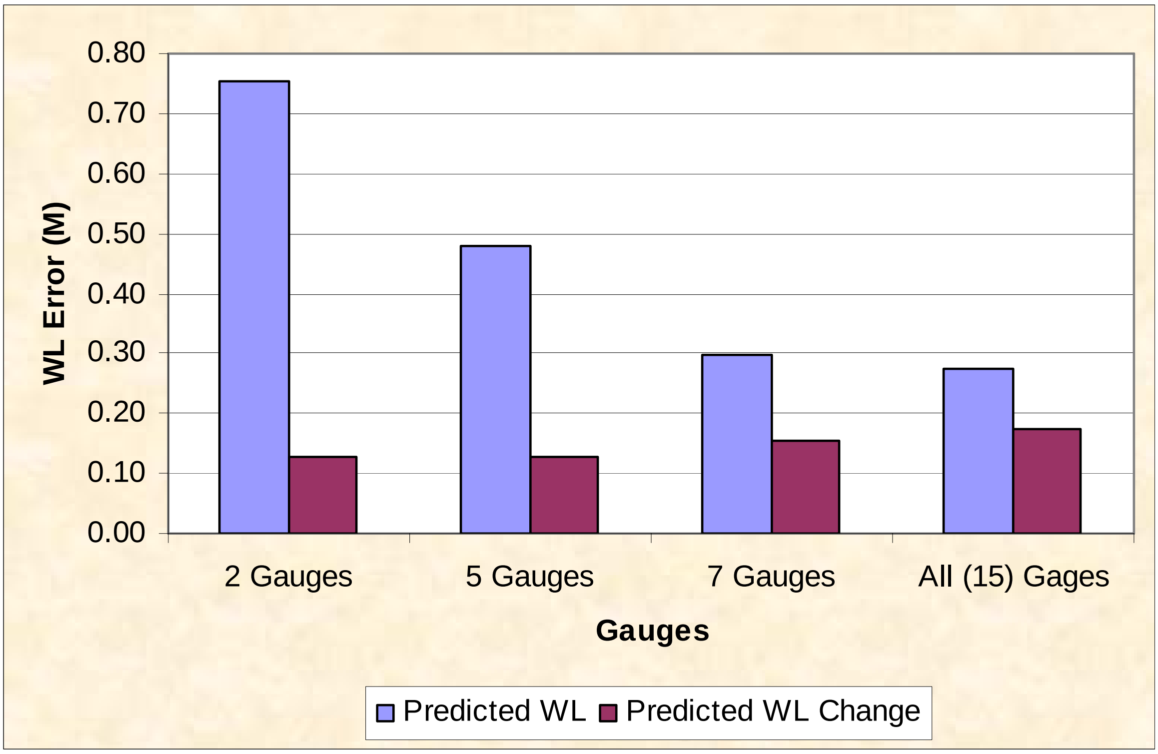

Figure A3.1: Error in Water Level and Change in Water Level with Different Sets of Gauges for the Period from 01 July to 15 October 2004

The results from this exercise illustrate that the number of gauges in the current study area can be significantly reduced while still providing an acceptable level of accuracy. Seven gauges provide a similar level of accuracy as compared to all fifteen gauges, with only a 3 cm decrease in accuracy. The set seven of gauges in the study area are shown in ***Figure A3.2***. The stars indicate the gauges that were used.

If only the predicted *change* in water level is needed, then two gauges provide a similar level of accuracy as all fifteen gauges. As can been seen from the above figure, the error in the forecasted water level for both two and fifteen gauges included are approximately 0.15 meters. With fewer gauges included, the lower water levels are particularly not estimated as well, creating a sizeable positive offset from the observed hydrograph. The resulting error or offset in the modeled water level is often over one meter in some periods. Nonetheless, the water level *change* still tracks fairly well with the observed water level *change*. An example hydrograph of this case for gauge 4121 is presented in ***Figure A3.3***. Note from this figure that the general shape of the hydrograph with two gauges included is very similar to the observed hydrograph, only a large offset is present for the majority of the period. This is the reason for the similar level of accuracy between two and fifteen gauges included in terms of the forecasted water level *change*, but the low accuracy with regard to the forecasted water level.

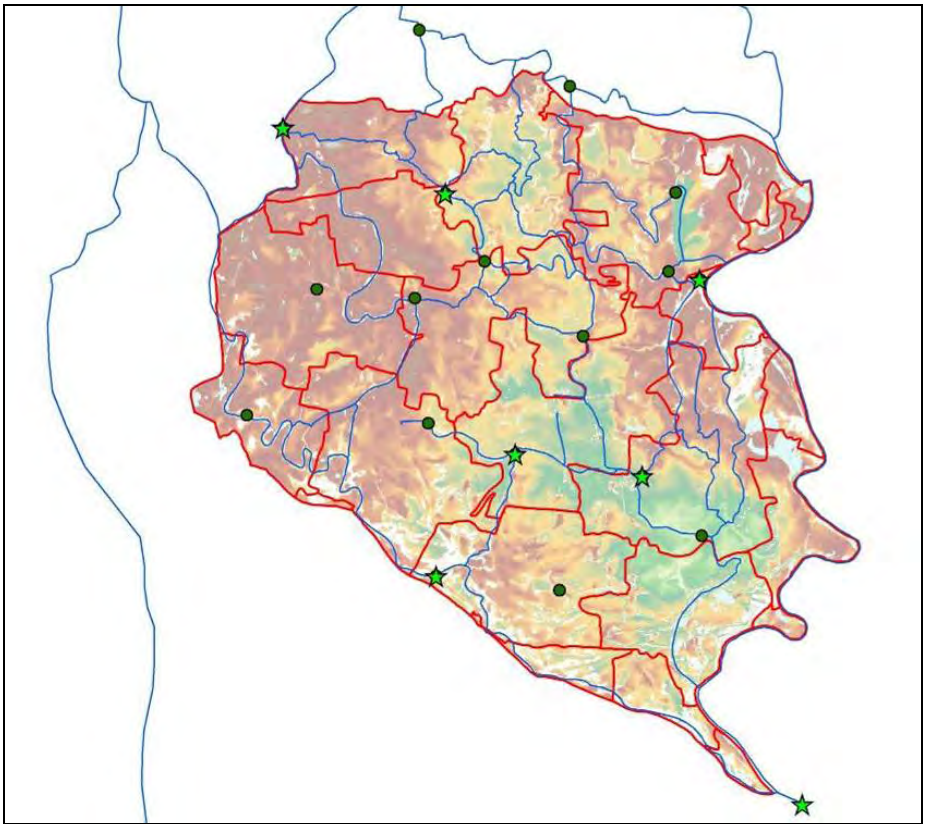

Figure A3.2: Location of Optimum Number of Gauges (Set 7) for Accurate Water Level (Gauges Used Shown as Stars)

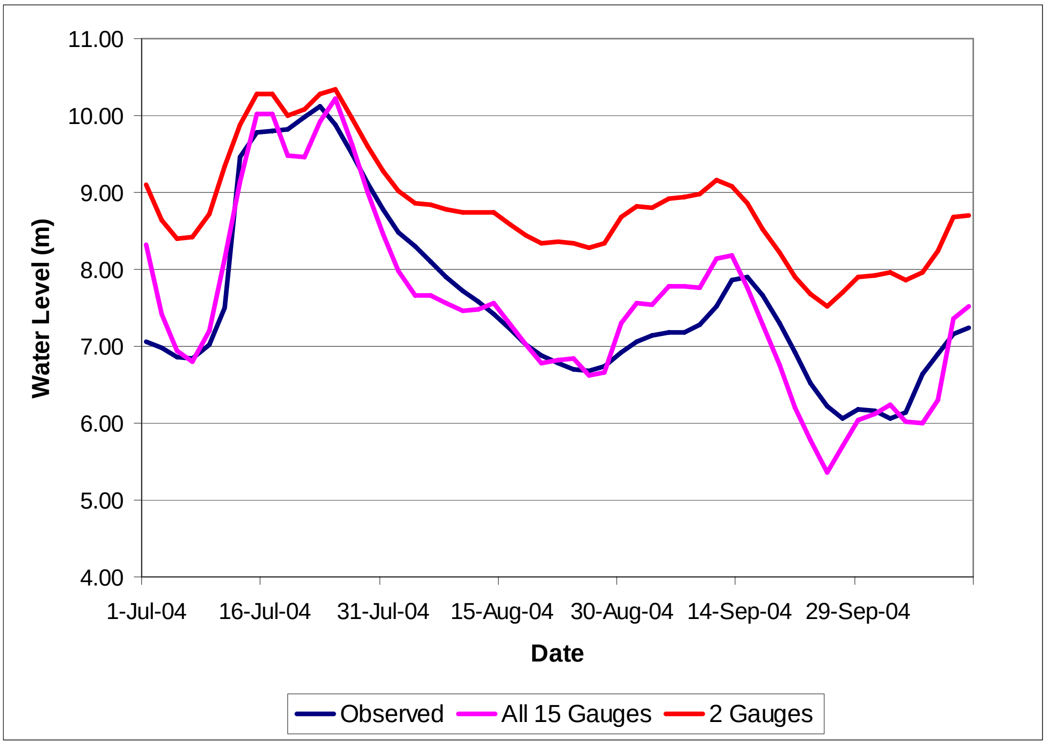

Figure A3.3: Example 48 Hr Forecasted Hydrograph for Gauge 4121 in 2004 with Two and Fifteen Gauges Included

In addition to the number of gauges, the location of the gauges is an important consideration. The two-gauge set includes one gauge at the downstream end and one in the center of the study area. These two gauges are required by WATSURF to run, and were considered the control gauges. The study area is contained on both sides by two larger rivers. Inside the study area is a complex network of smaller rivers and streams. For an accurate water surface, the results of this analysis show that the gauges are required on larger rivers flowing around the perimeter of the study area. For the five and seven gauge analysis, three gauges along the perimeter were included. The seven-gauge analysis also included two other gauges in the floodplain. The other gauges chosen for the seven-gauge analysis reflect changes in topography. They are located at low points in the study area and displayed the largest error when not included. This indicates that considering significant differences in topography is essential in determining the optimum gauge locations.

Conclusion

This analysis shows that in the CFIS study area the number of gauges can be significantly reduced to either seven or two gauges, depending on whether an accurate water surface or water surface *change* is desired. When determining the location of these gauges, important hydrological and topographical features must be considered.

Appendix – 4
Cost of Replication

Potential costs and cost-effectiveness of options

The cost of CFIS application in a new area will include major two items: (a) Cost of setting up the WATSURF model for new area and (b) Cost of operations and dissemination cost (***Figure A4.1***). The WATSURF model will be set up for new area through analyzing hydrological network, monitoring flood plain behavior, defining local vulnerability level, and calibration and validation of WATSURF. Operational cost includes the early warning SMS message generation, flag operation at community level, SMS message dissemination at community and household level, and monitoring and evaluation of the dissemination system.

The cost-effectiveness of replication depends on the scale of area to be applied, whether it is at the national, regional, or local level. Besides the scale of dissemination, the mode of dissemination will also play a role in determining the cost-effectiveness. The potential cost of CFIS replication is detailed in the following sections.

<u>The cost for setting up WATSURF model in a union:</u>

According to CFIS experience, one gauge station can represent the water level situation for two unions. Based on this, the cost of hydrological monitoring and analysis has been determined. Thus, the cost of setting up WATSURF model in a union is determined as follows:

Setting up hydrological network:	TK. 39,500
Monitoring floodplain behavior:	TK.110,000
Define local vulnerability:	TK. 52,500
Set up, calibrate, and validate WATSURF:	TK. 98,000
Total:	**TK. 300,000**

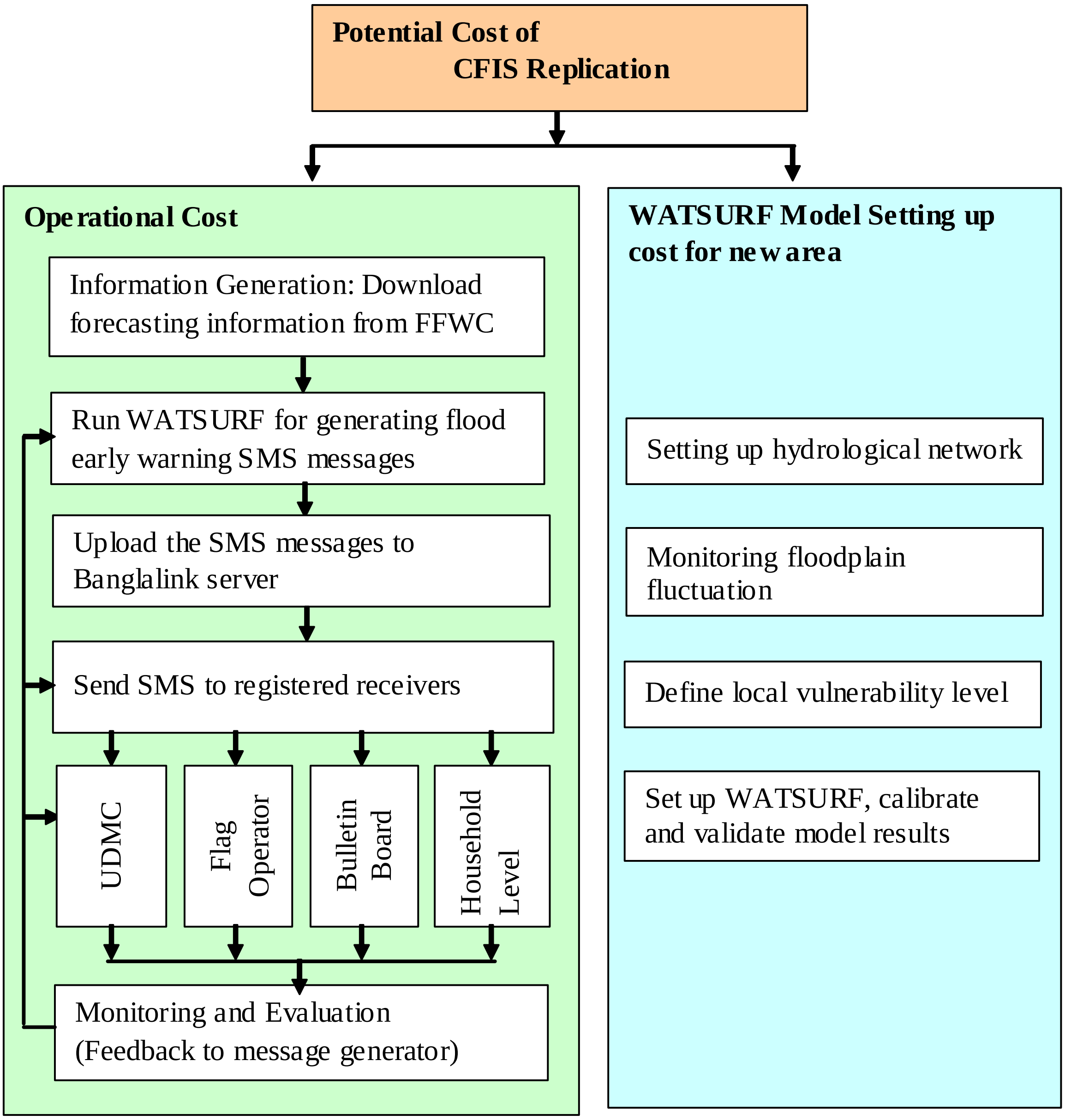

Figure A4.1: Issues/Factors in Potential Cost of CFIS Replication

The Operational Cost of early warning dissemination every year in a Union is given in the following table:

The operation of flood early warning dissemination will be about 4 months (June – September or July – October, depending on the location).

Sl. No.	Items	Cost (BDT)		
		Option 1	**Option 2**	**Option 3**
1	Setting up the awareness network (community training, bill board, leaflet, flag installation)	30,000	30,000	30,000
2	WATSURF operator: (Downloading information, run WATSURF software and send SMS)*	60,000	60,000	60,000
3	SMS Cost (depends on the dissemination level)	10,350	6,900	3,450
	Total =	**100,350**	**96,900**	**93,450**

** The WATSURF operator's cost will remain fix, i.e. cost will be same for one or more unions*

Option 1: Dissemination start when water rise at upper Green level, 30 days

Option 2: Dissemination start when water rise at Yellow level, 20 days

Option 3: Dissemination start when water rise at Red level, 10 days

Therefore, total cost of implementing CFIS in a union is as follows:

Sl. No.	Items	Cost (BDT)		
		Option 1	Option 2	Option 3
1	WATSURF model set up	300,000	300,000	300,000
2	Operation cost	100,350	96,900	93,450
	Total =	**400,350**	**396,900**	**393,450**

Considering the total number of households in a union is 1000 and total population is 5000:

Investment Cost (model setup cost) per household = 300,000/1,000 = TK. 300

Operation cost per household per year = 100,350 / 1000 = TK. 100.35 for Option 1
= 96,900 / 1000 = TK. 96.90 for Option 2
= 93,450 / 1000 = TK. 93.45 for Option 3

Investment Cost (model setup cost) per person = 300,000/5,000 = TK. 60

Operation cost per person per year = 100,350 / 5000 = TK. 20.07 for Option 1
= 96,900 / 5000 = TK. 19.38 for Option 2
= 93,450 / 5000 = TK. 18.69 for Option 3

Thus, the cost of replication in national level based on flood vulnerability could be as follows:

(a) For High flood vulnerable area (656 unions):

The cost for setting up WATSURF model in 656 unions: Tk. 300,000 x 656 = Tk. 196,800,000.00

Cost of Operation in 656 unions is given in the following table.

Sl. No.	Items	Cost (BDT)		
		Option 1	Option 2	Option 3
1	Setting up the awareness network (community training, bill board, leaflet, flag installation)	19,680,000	19,680,000	19,680,000
2	WATSURF operator: (Downloading information, run WATSURF software and send SMS)*	60,000	60,000	60,000
3	SMS Cost (depending on the option of dissemination level)	6,789,600	4,526,400	2,263,200
	Total =	**26,529,600**	**24,266,400**	**22,003,200**

Therefore, total cost of implementing CFIS in highly vulnerable unions is as follows:

Sl. No.	Items	Cost (BDT)		
		Option 1	Option 2	Option 3
1	WATSURF model set up	196,800,000	196,800,000	196,800,000
2	Operation cost	26,529,600	24,266,400	22,003,200
	Total =	**223,329,600**	**221,066,400**	**218,803,200**

(b) For medium flood vulnerable area (842 unions):

The cost for setting up WATSURF model in 842 unions: Tk. 300,000 x 842 = Tk. 252,600,000

Cost of Operation in 842 unions is given in the following table.

Sl. No.	Items	Cost (BDT)		
		Option 1	Option 2	Option 3
1	Setting up the awareness network (community training, bill board, leaflet, flag installation)	25,260,000	25,260,000	25,260,000
2	WATSURF operator: (Downloading information, run WATSURF software and send SMS)*	60,000	60,000	60,000
3	SMS Cost (depending on the option of dissemination level)	8,714,700	5,809,800	2,904,900
	Total =	**34,034,700**	**31,129,800**	**28,224,900**

Therefore, total cost of implementing CFIS in medium vulnerable unions is as follows:

Sl. No.	Items	Cost (BDT)		
		Option – 1	Option – 2	Option – 3
1	WATSURF model set up	252,600,000.	252,600,000	252,600,000
2	Operation cost	34,034,700	31,129,800	28,224,900
	Total =	**286,634,700**	**283,729,800**	**280,824,900**

(c) For low flood vulnerable area (99 unions):

The cost for setting up WATSURF model in 99 unions: Tk. 300000 x 99 = Tk. 29,700,000.00

Cost of Operation in 99 unions is given in the following table.

Sl. No.	Items	Cost (BDT)		
		Option 1	Option 2	Option 3
1	Setting up the awareness network (community training, bill board, leaflet, flag installation)	2970000	2970000	2970000
2	WATSURF operator: (Downloading information, run WATSURF software and send SMS)*	60000	60000	60000
3	SMS Cost (depending on the option of dissemination level)	1024650	683100	341550
	Total =	**4,054,650**	**3,713,100**	**3,371,550**

Therefore, total cost of implementing CFIS in low vulnerable unions is as follows:

Sl. No.	Items	Cost (BDT)		
		Option 1	Option 2	Option 3
1	WATSURF model set up	29,700,000	29,700,000	29,700,000
2	Operation cost	4,054,650	3,713,100	3,371,550
	Total =	**33,754,650**	**33,413,100**	**33,071,550**

Thus, the total cost of replication in all flood vulnerable area of Bangladesh would be maximum TK.543.60 million. The cost of different options does not vary in large amount (breakdown for different options is given in the following table).

Sl. No.	Items	Cost (BDT)		
		Option 1	Option 2	Option 3
1	WATSURF model set up	479,100,000	479,100,000	479,100,000
2	Operation cost	64,498,950	58,989,300	53,479,650
	Total =	**543,598,950**	**538,089,300**	**532,579,650**

The fund for replication can be allocated from different government and non-government organizations as planned below:

Items	Potential Investors
Technical assistance (training and improvement of model)	Government of Bangladesh Development Partners
Training of Community level operators and general people	National NGOs
SMS service for community level dissemination of flood early warnings	Mobile Operators