ADB

Technical Assistance Partner's Report

Project Number: 7276
June 2013

Japan: Supporting Investments in Water-Related Disaster Management

(Financed by the Japan Special Fund)

Prepared by

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under the auspices of UNESCO (ICHARM)
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For Regional and Sustainable Development Department, Asian Development Bank
International Centre for Water Hazard and Risk Management (ICHARM), Public Works Research Institute (PWRI)

CURRENCY EQUIVALENTS

(as of 10 June 2013)

Currency Unit	–	Yen (¥)
¥1.00	=	$0.010
$1.00	=	¥98.72

ABBREVIATIONS

ADB	–	Asian Development Bank
APWF	–	Asia-Pacific Water Forum
BWDB	–	Bangladesh Water Development Board
BBWS	–	BalaiBesarWilaya Sungai
BTOP	–	Block-wise Top Model
CBDRM	–	Community Based Disaster Risk Management
FEWS	–	Flood Early Warning System
FFWC	–	Flood Forecasting and Warning Centre
FID	–	Flood Inundation Depth model
FMMP	–	Flood Management Mitigation Programme
FVI	–	Flood Vulnerability Indices
FVI-AF	–	Flood Vulnerability Indices for Average Flood
FVI-EF	–	Flood Vulnerability Indices for Extreme Flood
GIS	–	Geographical Information Systems
HV	–	House Value
ICHARM	–	International Centre for Water Hazard and Risk Management
IFAS	–	Integrated Flood Analysis System
IHGM	–	ICHARM's Hydro-Geo Method
LMB	–	Lower Mekong Basin
MCA	–	Multi-Criteria Analysis
MRCS	–	Mekong River Commission Secretariat
NRM	–	National Road Map
PAGASA	–	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PAR Model	–	Pressure and Release Model
SRTM	–	Shuttle Radar Topography Mission
SWOT-AHP	–	Strength Weakness Opportunity Threat-Analytical Hierarchical Process
TA	–	Technical Assistance
WFP	–	Water Financing Program
WRDRI	–	Water-Related Disaster Risk Index

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1. Introduction

1. The regional capacity development technical assistance for Supporting Investments in Water-Related Disaster Management (TA7276) has been implemented since 13 November 2009 and until the end of March 2013. Asian Development Bank (ADB), through the Sustainable Infrastructure Division and the Public Management, Governance, and Participation Division of the Regional and Sustainable Development Department, is the executing agency of the TA. ICHARM, the regional water knowledge hub of Asia-Pacific Water Forum (APWF) for disaster risk reduction and flood management, is the implementing agency of the TA. The TA is financed by ADB from its Japan Special Fund for the preparation and implementation of flood management projects.

2. The TA has two components: (i) in-country project support, and (ii) program quality support through regional cooperation. The in-country support component provided support for country-specific projects located within Bangladesh, Indonesia, the Mekong River Commission Secretariat (Lower Mekong Basin) and the Philippines. More countries participated in the regional cooperation activities under the program quality support component. The program quality support component provided support to improve knowledge networking and regional cooperation among interested developing member countries of ADB and development partners in the Asia and Pacific region.

3. This report is a brief overview of the TA, describing the objectives, approaches and main outcomes of in-country project support components (within Bangladesh, Indonesia, Lower Mekong Basin and Philippines) and program quality support component.

2. Objectives of the TA

4. The main objective of the TA7276 is to support preparation and implementation of flood management investment projects through knowledge and capacity development services that will reduce vulnerability to water-related disasters with in-country and regional assistance. The TA contributes to the achievement of targeted outcomes of ADB's Water Financing Program (2006-2010) (WFP) for reducing vulnerability to floods for 100 million people in the Asia and Pacific region.

3. In-country Project Support

5. This in-country project component supported Bangladesh, Indonesia, the Mekong River Commission Secretariat and the Philippines, in cooperation with counterpart agencies recommended by ADB. Figure 1 shows the TA coverage areas and river basins for in-country project support. Table 1 outlines project support content in each country and lists the counterpart agency of each project components. Brief descriptions of objectives, approaches and outcomes of each in-country project support component are described in the following text.

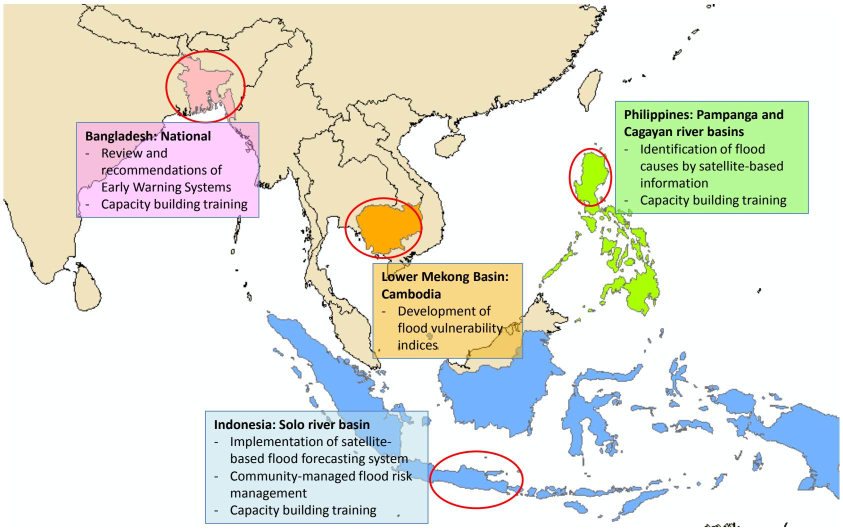

Figure 1 TA coverage areas for in-country project support

Table 1 Brief information of the in-country project supports

Country/Region	Area	Project support content
Bangladesh	Countrywide	**Counterpart:** Bangladesh Water Development Board (BWDB) ➢ Technical support for improvement of current Early Warning System (EWS) ➢ Capacity building of engineers and managers
Indonesia	Solo River Basin	**Counterpart:** BBWS Solo (BalaiBesarWilaya Sungai) ➢ Satellite-based flood alert system ➢ Capacity building on local disaster management ➢ Implementation of community based flood disaster risk management
Lower Mekong Basin (LMB) (Cambodia)	Cambodian Floodplain	**Counterpart:** Mekong River Commission Secretariat (MRCS) ➢ Supporting Mekong River Commission Secretariat in developing flood vulnerability indices
Philippines	Pampanga and Cagayan River basins	**Counterpart:** Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) ➢ Applying Integrated Flood Analysis System (IFAS) in the Pampanga and Cagayan river basins ➢ Identifying causes of historical floods by satellite-based information ➢ Training on utilization of IFAS in practical work as supplementary information for the existing flood monitoring systems

3.1 Lower Mekong Basin Component

3.1.1 Objectives of the Lower Mekong Basin Component

6. Lower Mekong Basin (LMB) is frequently affected by floods, particularly, within the low-lying floodplains of Cambodia. Populations living in the Mekong River floodplain of Cambodia

are vulnerable to flood disasters. It is thus necessary to identify flood vulnerability in flood-prone areas of the LMB to support decisions for flood management. Cambodia is the target country of this component in LMB area. The main objective of the TA in the Lower Mekong Basin Component is as follows.

(i) To support the Mekong River Commission Secretariat (MRCS) in developing flood vulnerability indices, which have been identified as a priority requirement for preparing further investment projects in the LMB region.

3.1.2 Methodology to achieve objective of this component

7. In this component, flood vulnerability is defined as the amount of potential damages, considering damage to agricultural production and houses. Agricultural damages here refer to damages to wet-season rice crops, which is a major source of rice production in Cambodia. House damages account for damages occurring to household residential assets. Through ICHARM's Hydro-Geo Method (IHGM), integrating hydro-meteorological analysis and digital elevation model obtained from the Shuttle Radar Topography Mission (SRTM) data, flood water depth is calculated as the difference between flood water level and elevation at each grid cell (3 seconds, approximately 91.8 m cell). Then, by integrating damage curves for both crops and houses, amounts of both agricultural and house damages are calculated at each grid cell and their additive combination is considered for vulnerability assessment. Figure 2 shows the flow chart of IHGM for vulnerability assessment.

3.1.2 (a) Water depth calculation

8. The floodplain inundation water level has approached river water level during past floods; indeed, when floods are large enough, flood level and river water level coincide. This characteristic was then extrapolated to the entire zone considered. For example, water stage data (hydrographs) at KampongCham and Phnom Penh were used to interpolate hydrographs in between the two stations.The floodplain between the two stations was divided into 31 bands and hydrographs were plotted for each band from the interpolated water levels for the same dates.

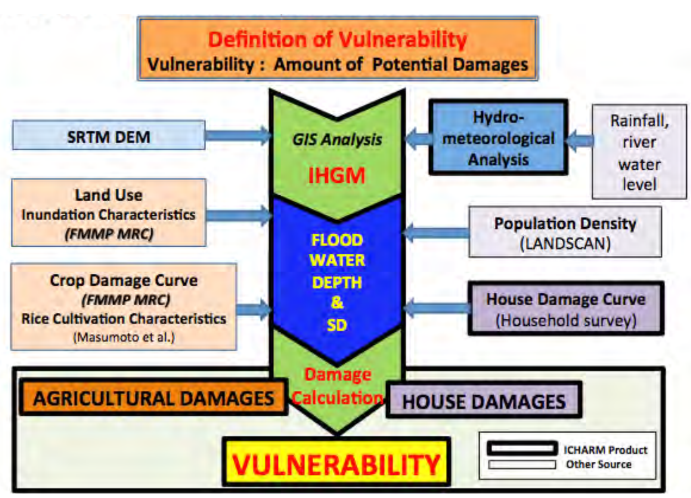

Figure 2 Flow chart of ICHARM methodology for vulnerability assessment

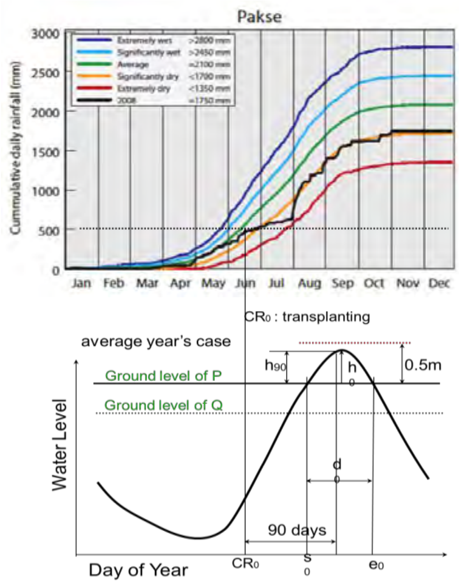

Figure 3 Schematic of rice cultivation and water level hydrograp

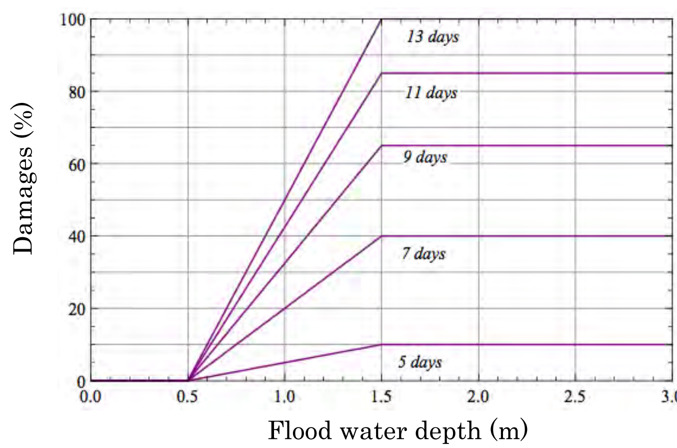

Figure 4 Agricultural damage curve (FMMP, 2010)

3.1.2（b）Agricultural damage calculation

9. Traditionally, farmers in Cambodia start cultivation of wet-season rice when land becomes soft enough to be cultivated which corresponds to the time that accumulated rainfall reaches approximately 500 mm, $\boldsymbol{t_{500mm}}$ (Figure 3).According to Flood Management and Mitigation Programme(FMMP) (2010)[1], crop damages due to flood were found to be a function of both duration of the flood event and its maximum water depth (Figure 4).Damages occur during the 90 days following the day $\boldsymbol{t_{500mm}}$, as this is the period during which rice plants are the most sensitive to prolonged submersion.

10. We used agricultural land use data observed in 2003 by Ministry of Public Works and Transportation, Cambodia and Japan International Cooperation Agency to estimate the area of

[1] FMMP (2010) Flood damages, benefits and flood risk in focal areas. The Flood Management and Mitigation Programme, C2, MRCS, **2C.**

cultivation land. Agricultural damages in each grid were calculated according to damages curves as shown in Figure 4 for wet-season rice developed by FMMP (2010). Then amount of agricultural damage for each grid was calculated by multiplying damage ratio with average yield (average yield 392 US$/ha, based on data of Ministry of Planning, Cambodia, 2009).

3.1.2（c）House damage calculation

11. House damages are the damages encountered at the household level and defined as a function of maximum flood water depth in relation to the flood level in an average year.Household survey data collected for the 2006 flood of FMMP project, MRCS, Cambodia was used to access the house value distribution in the area. The house value distribution function according to water depth in the yard is well fitted with the survey data (Figure 5 and Figure 6). Figure 7 shows the damage ratio curve calculated from actual damages after 2006 flood and potential damages that would have occurred if 2006 water depth had been 0.5m, 1.0m, 1.5m and 2.0m higher. By using the house value distribution function and damage ratio curve with population density in the area, we can calculate house damages at area of interest. The house value US$ 245 per person was used, which was determined based on household survey data for 2006 flood from FMMP project.

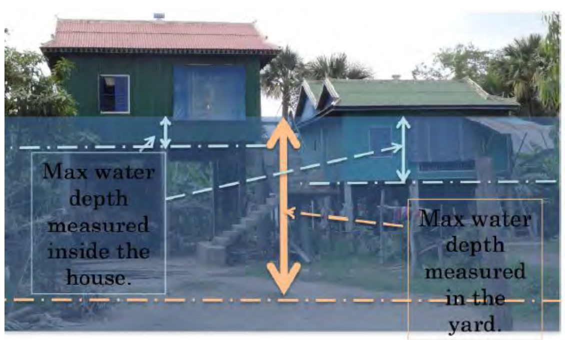

Figure 5Measurement of water depth in house

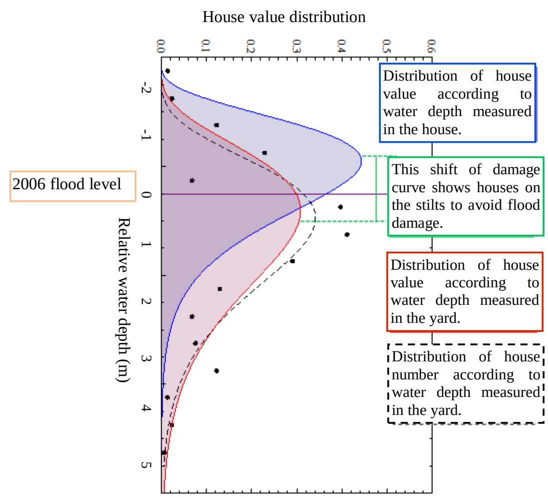

Figure 6 House value distribution curve

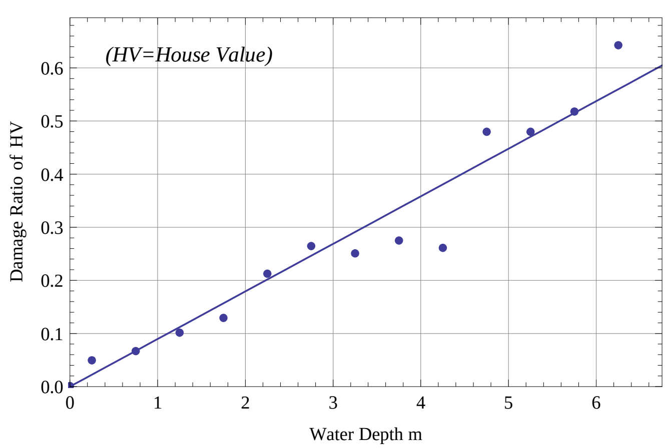

Figure 7 Damage ratio curve of house value

3.1.3 Definition of flood vulnerability indices

12. The agricultural and house damages were considered to identify Flood Vulnerability Indices (FVI). In this study, two kinds of FVI were developed: i) FVI for an average flood and ii) FVI for an extreme flood.

3.1.3（a）Flood vulnerability indices for average flood (FVI-AF)

13. The average flood water depth recorded during the 2006 flood is similar to the average flood water depth between 1991 and 2007. Thus, the 2006 flood is considered a close approximation of average flood. The Flood Vulnerability Indices for Average Flood (FVI-AF) for agricultural damages (AD) or house damages (HD) are defined as follows.

$$FVI\text{-}AF\ (AD\ or\ HD) = \frac{Value\ of\ AD\ or\ HD\ damage\ in\ \ a\ grid\ (2006)}{Maximum\ value\ of\ AD\ or\ HD\ damage\ (2006)} \qquad (1)$$

3.1.3（b）Flood vulnerability indices for extreme flood (FVI-EF)

14. Flood Vulnerability Indices for Extreme Flood (FVI-EF) are defined to identify the damage gap area between average floods and extreme floods. Based on flood observation data from 1991 to 2007, the average water depth of the 2000 flood is higher than any other flood recorded during this period. Thus, the 2000 flood is taken as an approximation of an extreme flood. The FVI-EF is identified by relating it with average flood as follows.

$$FVI\text{-}EF\ (AD\ or\ HD) = \frac{Value\ of\ AD\ or\ HD\ damage\ (2000) - Value\ of\ AD\ or\ HD\ damage\ (2006)}{Value\ of\ AD\ or\ HD\ damage\ (2006)} \qquad (2)$$

3.1.4 Results of flood vulnerabilityindices

15. Figure 8(a) shows FVI of potential agricultural damages for an average flood. The FVI-AF is defined from areas of low to very high vulnerability based on discretization of value ranges from 0 to 1. The discretized value ranges of 0 to 0.25, 0.25 to 0.5, 0.5 to 0.75 and 0.75 to 1 are respectively defined as low, medium, high and very high vulnerability. Figure 8(b) shows FVI of agricultural damages for extreme floods. This figure shows identification of gap areas in agricultural damages between an average flood (2006 Flood) and extreme flood (2000 Flood). In blue colored areas, agricultural damages are higher in an average year flood than extreme flood case. In an average year also agricultural damages can be higher than extreme flood case because the agricultural damage is caused by significant inundation during growing period which is determined with accumulated rainfall of that area.

16. Figure 9 shows FVI of house damage for average floods and extreme floods. By utilizing FVI-AF, we can easily identify vulnerable areas where preparedness is needed. In average floods the Cambodian floodplain experiences agricultural and house damages. But when extreme floods occur, extensive damage occurs in this area. This indicates that serious preparations for extreme flooding are necessary in this area. By utilizing FVI-EF to identify gap areas between average floods and extreme floods, we can identify areas where preparedness for extreme flooding is needed.

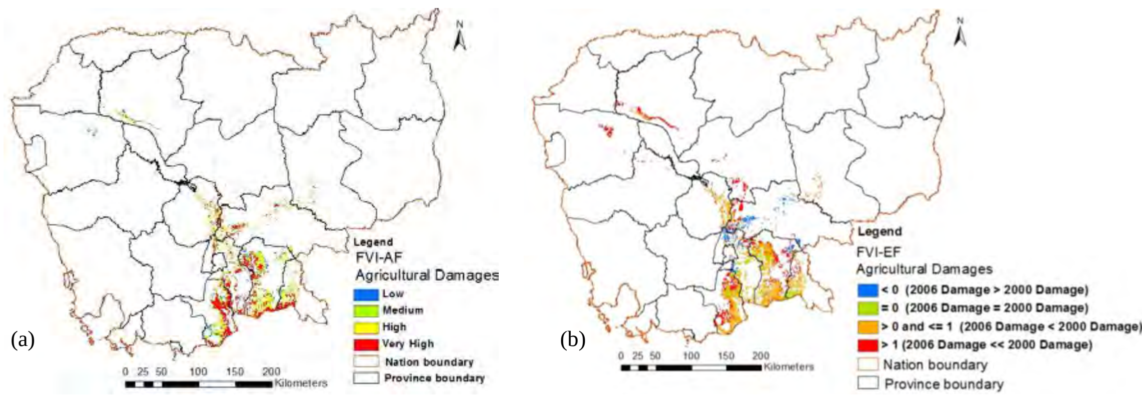

Figure 8 Flood vulnerability indices of agricultural damages (a) for average flood, FVI-AF, (b) for extreme flood, FVI-EF

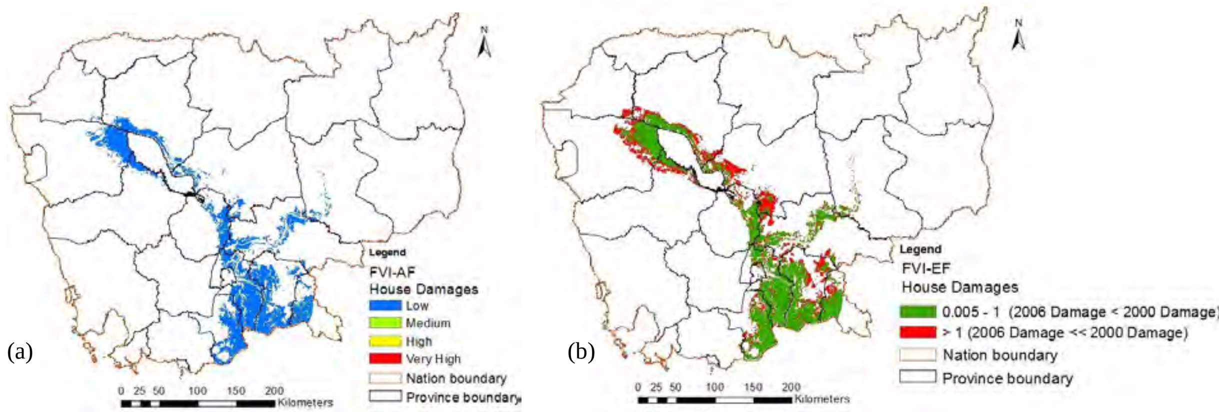

Figure 9 Flood vulnerability indices of house damages (a) for average flood, FVI-AF, (b) for extreme flood, FVI-EF

3.1.5 Conclusions and way forward

17. In this project component flood vulnerability has been approximated by potential for damage. Vulnerability was defined as the combination of damages occurring to income and damages occurring to assets. In the case of Cambodian floodplain, the major source of income affected by flood had been identified as wet-season rice and the major assets as residential assets. Therefore, flood vulnerability was calculated as the combination of wet-season rice damages and house damages. The FVIs were developed for agricultural, houses and total damages in LMB of Cambodian floodplain. The FVIs identify areas which are often affected by flood. The results of FVIs guide preparedness for flooding in agricultural practices as well as house and assets. The developed FVIs can be useful for local community, decision makers and developers.

3.2 Indonesia Component

3.2.1 Objectives of the Indonesia Component

18. The Bengawan Solo River Basin is the target river basin of the Indonesia Component of the TA (Figure 10). The Bengawan Solo River, the longest river on the island of Java, originates

from the Sewu Mountain range and flows into the Java Sea to the north of Surabaya. Its length is approximately 600 km and its catchment area is 16,100 km^2. The main objectives of the Indonesia Component in the TA are as follows.

(i) To improve flood forecasting in the Bengawan Solo river basin by using Integrated Flood Analysis System (IFAS).
(ii) To support capacity building on local disaster management.
(iii) To support community based flood risk management interventions for selected communities in the Solo river basin.

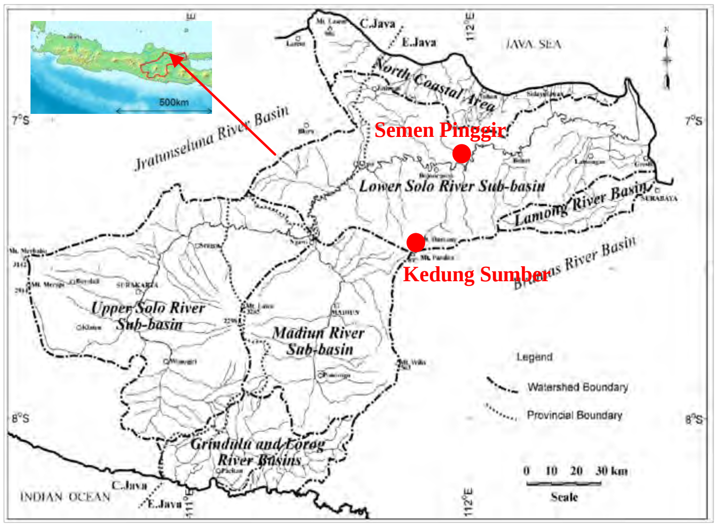

Figure 10 Study area and location of selected communities

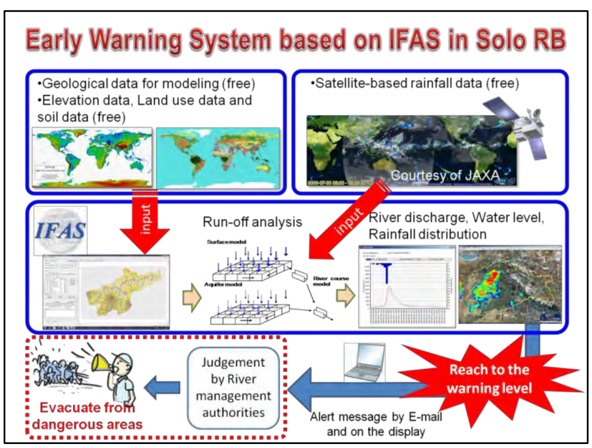

Figure 11 Flow of IFAS application and early warning system

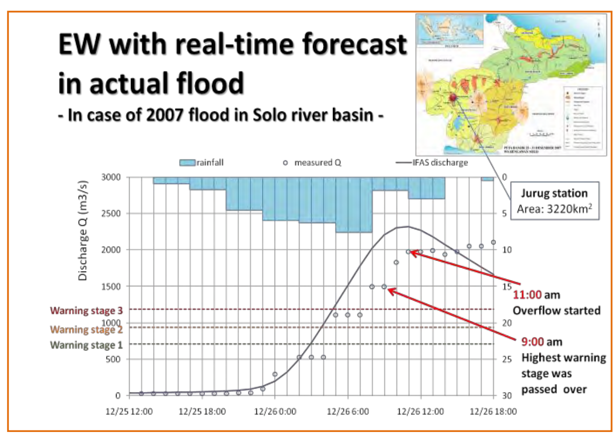

Figure 12 Application of IFAS for 2007 flood in Solo River

3.2.2 Improve flood forecasting in the Bengawan Solo river basin by using IFAS: Advanced Technology

19. IFAS consists of a comprehensive flood and runoff analysis package, which supports efficient and effective flood forecasting. IFAS is based on the integration of Geographical Information Systems (GIS) with ground-verified satellite-borne information. Incorporated

analysis software allows extraction of river networks and drainage areas from digital terrain elevation maps. IFAS has a rainfall-runoff module, which may be applied in data-poor regions, such as the Solo river basin. Figure 11 shows the IFAS application and early warning system and local ownership for reducing flood disaster.

20. An application of IFAS for the case of Solo River flood in 2007, which was verified by using river discharge data from the Jurug Station (catchment area 3,220 km^2), has provided an example on the possibility of using IFAS forecasting results as useful complementary information for the judgment of potential flood warnings (Figure 12). However, such an application requires cautious consideration according to case-by-case conditions.

3.2.3 Building capacity for local disaster management

21. To develop the sense of local ownership of IFAS technology that enables local engineers to master operation, data updating and further development of IFAS according to the local requirement, two main training workshops and three additional intensive trainings on IFAS were carried out for local engineers. The organized workshops helped local engineers in improving their capacity for flood forecasting by using satellite-based rainfall data and IFAS.

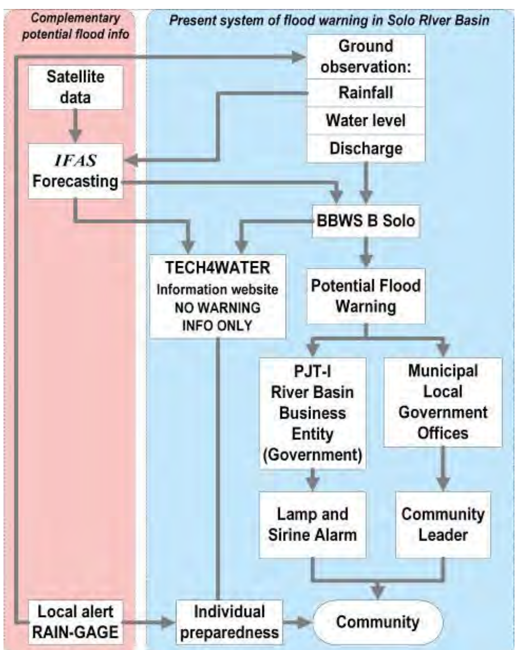

Figure13 Complementary potential flood information to support individual flood preparedness in Solo River basin

Figure 14 Automatic-alert rain gauge station installed at Pajeng village

3.2.4 Community-based flood risk management interventions for selected communities in the Solo river basin

22. We integrated the advanced technology and enhanced capacity of community and practitioners (institutions) (Figure 13). The advanced technology is introduced to the local community as complementary information to enhance the capacity of community-managed flood risk management.

23. Two villages (Semen Pinggir and KedungSumber villages) in the basin were selected as pilot areas for demonstration of an evacuation drill (Figure 10).

24. The demonstration activities were developed through intensive interaction and communication with local government officials as well as local community members, and were designed to facilitate self-evaluation of risk within target communities. The key activities included: (1) facilitate participatory hazard and risk assessment and mapping at the community scale, (2) facilitate preparing risk maps, flood risk management action plans and manuals for early warning system and evacuation plan, (3) support the community in technical aspects for carrying out emergency drills and exercises, and (4) conduct awareness-raising and skill-development workshops and training at the community level. The actual evacuation drills were performed with active collaboration of local people. Figure 14 shows the installed automatic-alert rain gauge station at Paieng village. Figure 15 shows a) the flood hazard and evacuation map prepared by the community, b) participation of Community Based Disaster Risk Management (CBDRM) in Semen Pinggir and c) the evacuation drill at KedungSumber.

Figure 15 (a) Flood hazard and evacuation map made by community (Semen Pinggir), (b) The residents actively participated in the CBDRM training (Semen Pinggir) and (c) An evacuation drill carried out at KedungSumber

3.2.5 Conclusions and way forward

25. The conclusions of this component are as follows:
   (i) Application of IFAS to the case of 2007 flood has shown its reliable performance to support the improvement towards effective and efficient flood warning in Solo river basin.
   (ii) Effective integration of advanced technology and enhanced capacity of the community and practitioners in flood disaster management were demonstrated in the two pilot cases of community-based evacuation drill.

26. The way forward can be described as follows:
   (i) To improve the accuracy of IFAS application in Solo river basin, parameter updating (land use, soil data, etc.) and increasing the number of ground based observation facilities are indispensable.
   (ii) It is expected that lessons and practical knowledge learned from this evacuation drill demonstration can be used by the government officer to implement similar activities in other relevant locations.
   (iii) In order to improve the quality of local CBDRM in the future, potential for utilization of automatic-alert rainfall system or IFAS simulation forecast as a supplementary source of warning alert should be seriously elaborated.

3.3 Philippines Component

3.3.1 Objectives of the Philippines Component

27. In the Philippines, at present the Pasig-Marikina River basin, the Pampanga River basin, the Agno River basin, the Bicol River basin and the Cagayan River basin are covered by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)'s hydrological monitoring system for flood forecasting and flood early warning. Each river basin has several ground rainfall and water level gauges. Hydrological data observed at each station is delivered through the system to sub-centers at near real-time. In addition to point data, such as ground-gauge stations, spatial information such as meteorological radar is also beginning to be introduced. PAGASA has been applying a "water level correlation method" as the existing flood forecasting method during flooding in the Pampanga and Cagayan River basins. The main objectives of the Philippines Component are as follows.

(i) To support the PAGASA in applying IFAS in the Pampanga and Cagayan River basins (Figure 16).

(ii) To apply IFAS in the Pampanga River basin to identify causes of historical floods in the basin by incorporating satellite-based and ground-observed data.

(iii) To apply IFAS in the Cagayan River basin, mainly to identify causes of historical floods in the middle reaches including Tuguegarao City by incorporating satellite-based rainfall data in the southeastern upstream and ground-observed hydrological data in the southwestern upstream.

(iv) To train PAGASA staff for applying IFAS to (a) identify causes of flood, (b) understand mechanism of floods, and (c) utilize IFAS on practical work as supplementary information to the existing flood forecasting system.

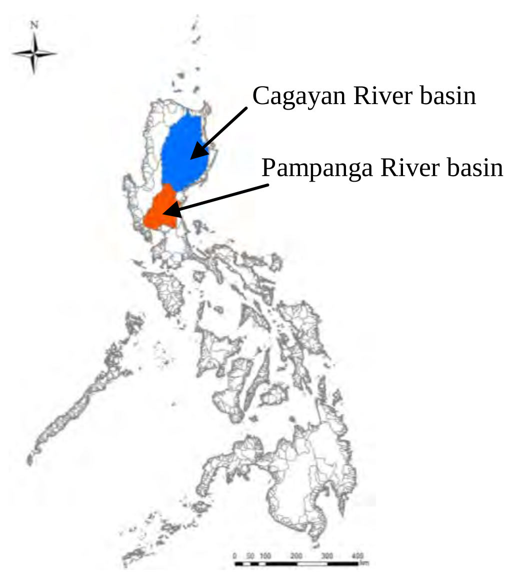

Figure 16 Location of Pampanga and Cagayan River basins

3.3.2 Fundamental analysis of flood characteristics in the Pampanga and Cagayan River basins

28. The following existing data were collected and analyzed in the Pampanga and Cagayan River basins; topographical, discharge and rating curves, flood traveling time, water level

correlation during flooding among stations, availability and spatial features of rainfall data. These collected data are used for hydrological modeling with IFAS. These river basins have unique hydrological characteristics. Most downstream area is relatively flat and discharge increases slowly during floods. Flood magnitude depends on distribution of rainfall in the catchment.

3.3.3 IFAS application in Pampanga and Cagayan River basins

29. Rainfall-runoff models are created by IFAS using digital elevation model, land cover data, basin boundary data and so on. To improve accuracy of model results, river courses created by IFAS must be modified by comparison with the actual river courses. By calculating and comparing model results using the actual rainfall data, past flood records, and satellite rainfall data set, the input parameters for IFAS were calibrated. Figure 17 shows the example of results.

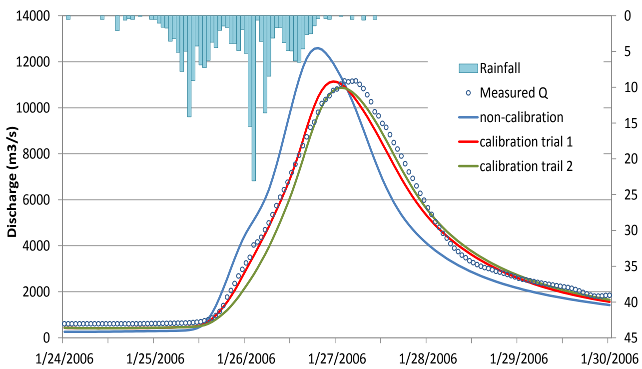

Figure 17 IFAS results at Gamu Station, Cagayan River basin

Figure 18 Training in Metro Manila

3.3.4 Trainings

30. Two training programs for flood risk management on 'Capacity Development for Effective Flood Management in River Basin of the Philippines' had been organized at Metro Manila in September 2012 (Figure 18) and at Tuguegarao City in October 2012. Advantages and limitations of IFAS and its effectiveness as supplementary information for the existing flood monitoring system were well recognized.

3.3.5 Conclusions and way forwards

31. The conclusions of this component are as follows:
   (i) IFAS was applied and calibrated in Pampanga and Cagayan River basins using satellite-based information and existing hydrological information.
   (ii) Trainings were conducted in Metro Manila and Tuguegarao City, and the participants understand well.
   (iii) Since the upstream catchment is wide, magnitudes of flooding depend on distribution of rainfall in the catchment. Satellite-based rainfall distribution information and IFAS calculation results are useful in practical work as supplementary information to judge flood forecasting in advance.

32. The way forwards can be described as follows:
   (i) Continuous support and collaboration is necessary between PAGASA and

ICHARM for more specific operation of IFAS.

(ii) Cooperation with other projects related to satellite-based rainfall is important to make the IFAS results more accurate and reliable.

3.4 Bangladesh Component

3.4.1 Objectives of the Bangladesh Component

33. Although the Bangladesh government recognized the need for a suitable national Flood Early Warning System (FEWS) and therefore established a Flood Forecasting and Warning Centre (FFWC) at Bangladesh Water Development Board (BWDB), the development of FEWS has not been progressed in a desired manner due to the lack of resources and mechanism. It was realized that a clear National Road Map (NRM) for FEWS development was missing, while the proper strategy and policy for effective implementation of NRM on FEWS is yet to be formulated. The main objectives of the TA in the Bangladesh Component are as follows.

(i) Technical review of early warning systems currently being practiced in Bangladesh and recommendation for improvement (i.e. development of NRM for FEWS development in Bangladesh), and

(ii) Capacity building of engineers and managers, who are responsible to look after disaster management projects and programs in Bangladesh.

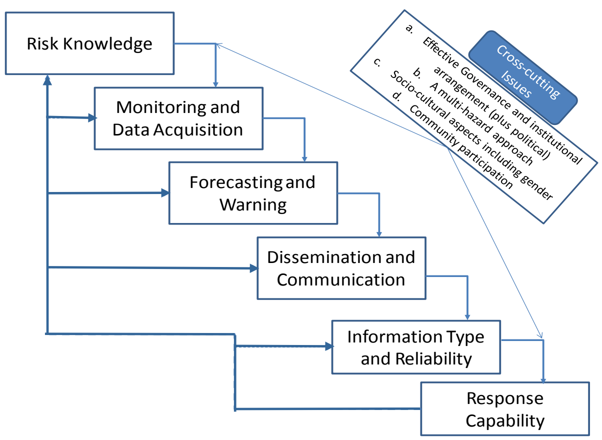

Figure 19 Cascades and cross cutting issues for FEWS(modified from UNISDR)

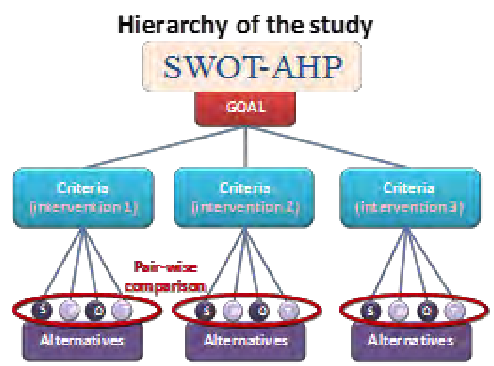

Figure 20 Schematic Hierarchy of SWOT-AHPstudy

3.4.2 Main steps taken to achieve objectives of this component

34. The main steps towards formulation of a NRM for FEWS development are as follows.

3.4.2 (a) ***Review:***The review process involves three independent parallel thematic activities a. technical assessment, b. institutional assessment and c. needs assessment at grass-root communities.

3.4.2 (b) ***Identification of key issues:*** The review summarizes the key findings that can be translated into key issues based on expert knowledge.

3.4.2 (c) ***Dependency test:*** All issues were classified within six steps of the FEWS development cascade cycle (Figure 19). All interventions address the most important issues as

identified by the first stakeholders consultation workshop in December 2010, while covering other less important issues at the same time. The conversion process also illuminated any duplication in the issues identified by the first stakeholders consultation workshop. Besides these six classes, there are also cross-cutting issues.

3.4.2 (d) *Priority ranking and selection of interventions:* In this phase, individual stakeholders were consulted and all proposed qualitative interventions were converted into quantitative form based on the current needs and requirements. A pair-wise comparison under *Multi-Criteria Analysis* (MCA) as well as *Strength Weakness Opportunity Threat-Analytical Hierarchical Process* (SWOT-AHP) analysis for all interventions within each cascade of FEWS was performed (Figure 20). Stakeholders contributed to decision-making processes (Figure 21). The output results from the SWOT-AHP are easily displayed in a quantitative way and are easily understood by various stakeholders. Therefore, these methods were applied in priority ranking of interventions.

3.4.2 (e) *Recommendations:* The pre-feasibility assessment of each intervention was done based on technical, socio-cultural, institutional and financial aspects for all top prioritized interventions in each cascade. This was the basis of conclusive recommendations to the Government of Bangladesh regarding investment in FEWS in Bangladesh.

Figure 21 Stakeholder consultation workshop with group discussion (16 March 2011)

Interventions	Time line/Sequence in 3 monthly (quarterly) sections: Year 2013 Q1 Q2 Q3 Q4	Year 2014 Q1 Q2 Q3 Q4	Year 2015 Q1 Q2 Q3 Q4	Year 2016 Q1 Q2 Q3 Q4	Year 2017 Q1 Q2 Q3 Q4	Year 2018 Q1 Q2 Q3 Q4	Year 2019 Q1 Q2 Q3 Q4	Duration in years	Approx. cost in Mil BDT	Implementing agency
FFWC capacity building				★				3	70	BWDB
National and local level risk assessment								1.5	60	WARPO
Expanding the range of data acquisition								3	90	BWDB-BMD
Model accuracy and upgrade software								1.5	90	BWDB
Flood forecast and model development								2.5	55	BWDB
More precise and location specific information								2	130	BWDB
Update warning information in timely manner								2	20	BWDB
More precise and user friendly warning								3	55	BWDB-DMB
Capacity building for dissemination								3	40	DMB
Formal and informal education								3	45	Department of education
Capacity development of community								3	35	DMB
Community preparedness								3	35	DMB
Operation & maintenance of the monitoring network								Yearly	20	BWDB
International cooperation			★					2	30	JRC

Time limited activity
Continuous activity
Sequence
★ To be repeated every 3 years
1 Min BDT = 1200 US$ (1 June 2012)
Total Cost excluding yearly O&M cost 755

Figure 22 Prioritized interventions after pre-feasibility study and timeline of interventions for FEWS development

3.4.3 Development of National Road Map for FEWS in Bangladesh

35. Finally the project approach and outcomes were drafted in the form of a NRM for FEWS in Bangladesh. In this NRM, projects are ranked in each stage of FEWS development and importantly, all the stakeholders agree that projects are free from individual interest but focused to national interest. The NRM was finalized by improving comments received at workshop on 23 January 2012. Figure 22 shows the prioritized interventions after pre-feasibility study and timeline of possible interventions for FEWS development.

3.4.4 Capacity building for flood disaster management

36. In Bangladesh three workshops were organized (in December 2010, March 2011 and January 2012), which helped to build capacity of engineers and managers of related organizations of Bangladesh in flood disaster management.

3.4.5 Conclusions and way forward

37. Based on the findings of this component, the following conclusions can be drawn as follows:

(i) The concept of a NRM for FEWS development in Bangladesh is broadly welcomed by all stakeholders throughout the sector of flood early warning,

(ii) Intensive contact with the main stakeholders and beneficiaries (BWDB – FFWC) is indispensable for ownership of the project and support for the outcome of the project,

(iii) This project was only possible due to the very well established network in the local flood early warning community of Bangladesh, and

(iv) The MCA and SWOT – AHP approach is very useful in complex ranking of interventions and investment decisions.

38. The way forward can be described as follows:

(i) Subsequent to better dissemination, it will be beneficial to create flood hazard maps and damage assessments. Based on such an assessment the dissemination of flood warnings could be more specific for a certain geographic region or end user group. More detailed flood hazard and damage maps per sector would need to be prepared,

(ii) New, more extensive pilots should be included with a combination of different techniques for communication and dissemination,

(iii) The model accuracy and subsequently forecast accuracy needs to be increased by improving the model validation procedure and to increase the range of data acquisition within the Ganges-Brahmaputra-Meghna basin.

4. Program Quality Support

39. The main objective of the program quality support component of the TA are to provide support for improving knowledge networking and regional cooperation among interested ADB's developing member countries and development partners in the Asia and Pacific region, as follows.

(i) Development of an index for water-related disaster risk management,

(ii) Organization of workshops and exchange visits among professionals to share experiences in flood management and early warning system,

(iii) Organization of training for river basin organizations in flood risk management.

4.1 Development of an Index for Water-Related Disaster Risk Management

4.1.1 Objectives

40. Water-related disasters are the most common and widely-distributed natural risks to life and property worldwide. There is a need to identify the risk of water-related disasters to support decisions for risk management. The development of a Water-Related Disaster Risk Index (WRDRI) is an important pre-requisite for effective water-related disaster risk reduction, which is a one of the key activities enabling decision makers to assess the possible impacts of disasters. The objectives of the development of WRDRI are as follows.

(i) Development of country-level WRDRI.

4.1.2 Strategies of WRDRI Development

41. The strategies of WRDRI development are as follows:

(i) WRDRI measures damage to assets and people separately.
(ii) Utilizes advanced technologies to overcome data unavailability.
(iii) WRDRI should be tangible indices.
- ➢ to be a good tool for monitoring risk.
- ➢ to be a good tool for measuring government effort to reduce disaster risk.

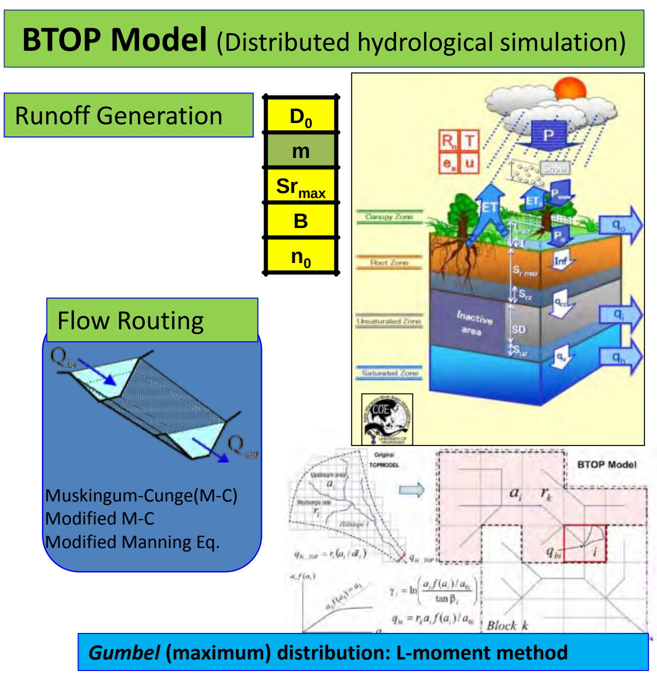

Figure 23 Description of BTOP Model

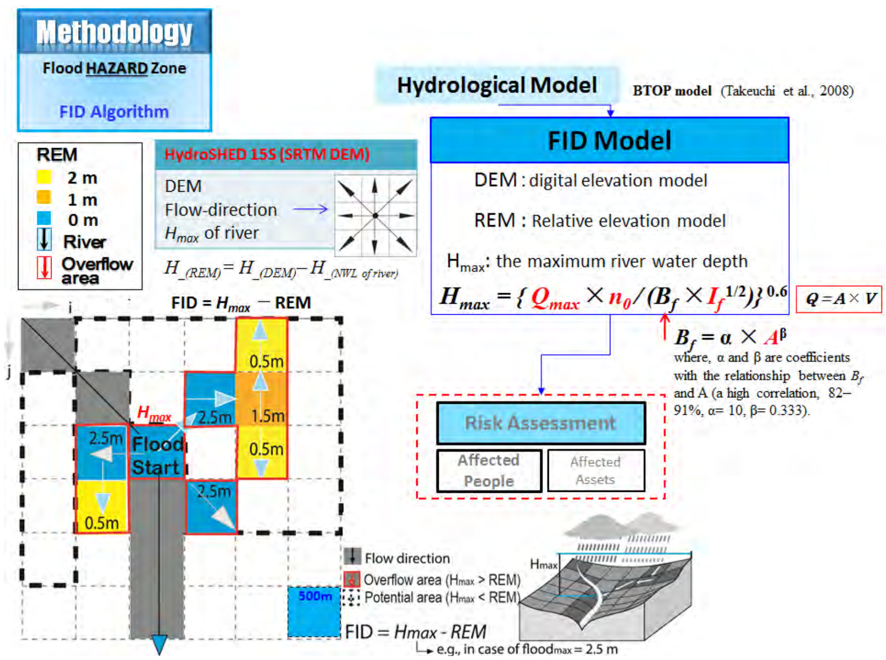

Figure 24 Methodology of flood inundation calculation (FID model)

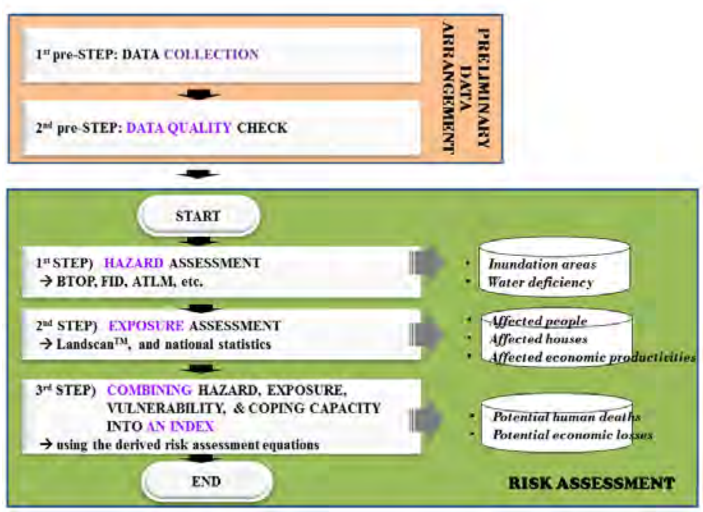

Figure 25 General procedures of WRDRI development

4.1.3 Development concepts of WRDRI

42. The WRDRI is developed by integrating ICHARM's GIS-based, satellite-based, and innovative technologies. The WRDRI is expressed as a function of hazards, exposure, vulnerability and capacity. Based on the concept of Pressure and Release Model (PAR model), the risk can be expressed as follows.

$$Risk = f\ (Hazard, Exposure, Baic\ Vulnerability, Coping\ Capacity) \qquad (3)$$

43. Three major types of water-related disasters such as floods, drought and storm surge are considered to develop WRDRI. The hydrological runoff model (BTOP Model, Figure 23) is employed to reproduce flood hazard areas and also to assess drought disaster. The flood inundation depth is calculated by using Flood Inundation Depth (FID) model at the river basin level (Figure 24). The exposure has been defined in two aspects, such as people and assets exposed to flood, drought and storm surge disasters. The vulnerability and capacity are also defined separately.

4.1.4 General procedures of WRDRI development

44. Figure 25 shows the general method of WRDRI development. The whole procedure can be divided into preliminary data arrangement and risk assessment. The main steps of WRDRI development are as follows:

(i) At the preliminary data arrangement procedure, data were collected from a variety of global data sources, and then carefully analyzed for availability and adequacy.

(ii) At the risk assessment procedure, this study started with hazard assessment.The three types of hazards, i.e. inundation locations and areas for flood and storm surges, and water deficiency for drought, were identified by concerting various technologies and data including APHRODITE data, the BTOP model and the FID model. A new methodology was also developed to identify drought hazard by determining threshold for drought based on past drought events. The flood and drought hazards were analyzed for 50 years return period. The storm surge hazard is analyzed based on low elevation coastal zone.

(iii) Then, exposure assessments were conducted, which aimed to identify affected people, affected houses, and affected productivities. The global LANDSCAN population distribution data of 2009 was used to estimate affected people.

(iv) After hazard and exposure assessments, various proxies for basic vulnerability and coping capacity were calculated from available global data sources. To combine all proxies into risk indices, such as human deaths and economic losses, risk calculation equations were used, which were previously formulated by multiple regress methods using data from 15 Asian countries. Therefore, the WRDRI method was found to largely identify risk-prone countries in a quantitative way, overcoming data unavailability problems. At the same time, the challenges related to this method were identified in detail, especially revealing that the statistical methods used to derive risk calculation equations were too strict to successfully incorporate many proxies, and proxies for vulnerability and coping capacity should be downscaled to capture local attributes. Example of risk index calculation equations in case of flood are described in Equation (4) and Equation (5) respectively for people and assets.

- ***Flood risk index for people:***

$$log R_p = -5.19+0.53\times log E_p +0.64\times FS \qquad [r^2 = 82.7\%] (4)$$
$$FS = 0.12\times CP+0.37\times DE-0.35\times EWS-0.37\times GG$$

whereR_p = flood risk index for people (persons/1,000 km^2); E_p = people exposure (persons/1,000 km^2); FS = a factor score (no.); CP = standardized value of critical people (%); DE = standardized value of deforestation (%); EWS

= standardized value of early warning systems (Hyogo Framework for Actions(HFA) score 2, 1-5 scale); *GG* = standardized value of good governance (WGI2, 0-100 scale).

- ***Flood risk index for assets:***

$$logR_a = 4.50+0.33\times logE_1+0.33\times logE_2+0.27\times GG \quad [r^2 = 68.0\%] \quad (5)$$

where R_a = flood risk index for assets (US$ /1,000 km^2); E_1 = house exposure (no./1,000 km^2); E_2 = productivity exposure (US$/1,000 km^2); *GG* = good governance (WGI1, 0-100 scale).

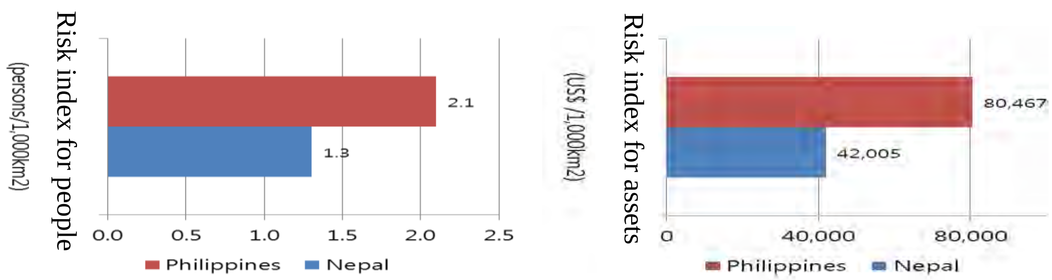

Figure 26 Comparison results of flood risk index between Philippines and Nepal

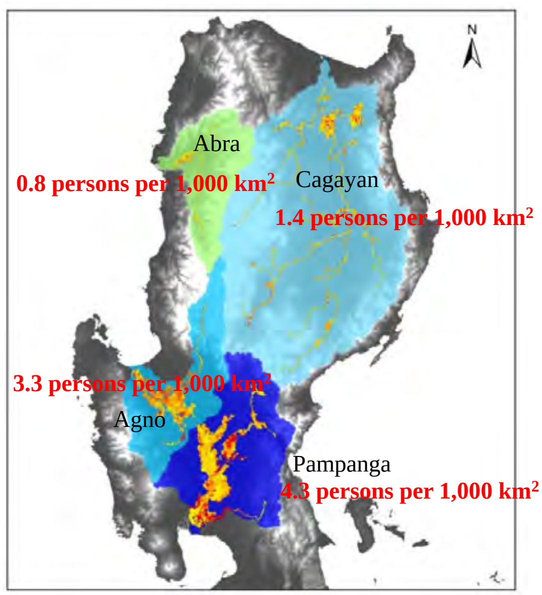

Figure 27 Result of flood risk index for people in main river basins of the Philippines

4.1.5 Outcomes of WRDRI development

45. As risk indices vary among people and assets, the risk index has been defined in two aspects i.e. one is risk index for people and other is risk index for assets. WRDRI is developed at the national level for the targeted countries Nepal and the Philippines. However, the hazards and exposures are analyzed at basin level in each targeted countries. Figure 26 shows the comparison results of flood risk indices between the Philippines and Nepal. Figure 27 shows the flood risk index for people in main river basins of the Philippines.

4.1.6 Conclusions and way forward

46. The following conclusions and way forward are described from this component:

- (i) An important framework was established as a prototype of the global risk assessment.
- (ii) This WRDRI can be used as a tool to estimate national-level risks of water-related disaster.
- (iii) The proposed methodology of WRDRI can be expanded to other countries.

4.2 Organization of Workshops and Trainings

47. ICHARM aims to contribute to reducing impacts of water-related disasters in the world and provides partners with support to improve knowledge networking and regional cooperation through regional workshops and trainings. Table 2 shows the list of workshops and trainings organized under program quality support component of the TA. Figure 28 shows the some photographs of the trainings.

Table 2 List of organized workshops and trainings

Organized Workshops and Training Courses	Organizers
Local Emergency Operation Plan with Flood Hazard Map (November, 2009 in Japan)	ICHARM/ADB/JICA
Local Emergency Operation Plan with Flood Hazard Map (January-February, 2010 in Japan)	ICHARM/ADB/JICA
Local Emergency Operation Plan with Flood Hazard Map (July-August, 2011 in Japan)	ICHARM/ADB/JICA
Space Application to Reduce Water-related Disaster Risk in Asia (December, 2010 in Bangkok)	ICHARM/ADB/UNESCAP/JAXA
Integrated Flood Analysis System (IFAS) regional workshop (November, 2011 in Indonesia)	ICHARM/ADB
A Knowledge Sharing Workshop on Water Related Disaster Risk Management (January, 2012 in Nepal)	ICHARM/ADB/WECS/DWIDP
Knowledge Sharing Workshop on Flood Vulnerability Assessment in Cambodian Flood Plains (February, 2012 in Cambodia)	ICHARM/ADB/MRCS
Capacity Development for Effective Flood Management in River Basin of the Philippines (September, 2012 for Pampanga river basin, Philippines) (October, 2012 for Cagayan river basin, Philippines)	ICHARM/ADB/PAGASA
Follow-up Consultation Workshop on the National Road Map for Floods Early Warning System Development in Bangladesh (November, 2012 in Bangladesh)	ICHARM/ADB/BWDB
Training on Development and Utilization of Flood Vulnerability Indices in Cambodian Floodplain (December, 2012 in Cambodia)	ICHARM/ADB/MRCS/CNMC
TA7276-REG Final Workshop on Supporting Investments in Water-Related Disaster Management (February, 2013 in Philippines)	ICHARM/ADB

Group discussion, 2010

Field survey, 2011

Practice on project management cycle, 2010

Figure 28 Photographs of training and exchange visit programs

5. Overall Conclusions of the TA

48. The overall conclusions of the TA are described as follows.

5.1 In-country Project Support

(i) In Bangladesh, the TA helped the Bangladesh Water Development Board (BWDB) prepare a National Road Map for Flood Early Warning System by developing a method which can indicates priority of actions proposed by wide range of stakeholders.

(ii) In Indonesia, the TA helped the BalaiBesarWilaya Sungai (BBWS) Solo improve their capacity on flood forecast in the Solo River basin by applying ICHARM's GIS-based integrated flood analysis system (IFAS) which can forecast floods by combining precipitation data obtained by satellites with topographic data. Training programs for the river basin organization in the Solo River basin were also conducted.

(iii) In the Lower Mekong basin, the TA helped the Mekong River Commission Secretariat (MRCS) develop a methodology to assess flood vulnerability in Cambodian floodplains, especially for houses and agriculture.

(iv) In Philippines, the TA helped the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) develop their capacity through training programs to identify flood causes in the Pampanga and the Cagayan River basins by applying IFAS to historical floods.

5.2 Program Quality Support

(i) A methodology to estimate indices for water-related disaster risk was proposed based on socio-economical and hydrological data in several Asian countries.

(ii) Workshops and training programs were conducted to improve knowledge networking and regional cooperation of ADB's developing member countries.

49. ICHARM’s innovative technologies could overcome difficulty of reducing risk in developing countries effectively. It is necessary to keep capacity sustainably.

Appendix 1

Design and Monitoring Framework

Summary	Performance Indicators/Targets	Data Sources and/or Reporting Mechanisms
Impact Reduced vulnerability and increased resilience in the face of water-related disasters in the Asia and Pacific region	Significantly decreased economic and human losses from water-related disasters People with reduced flood risk in selected countries	National statistics; water publications; reports of APWF, ICHARM, and knowledge partners ADB progress report on WFP; countries' sector reports on ADB water website; reports of APWF, ICHARM, and knowledge partners
Outcome Better-designed investment projects in flood management	Number of flood management projects identified and formulated	TA progress reports etc.;
Enhanced capacity in target countries for (i) flooding and flood-related disaster risk management and response services, and (ii) climate change adaptation	Number of successful workshops, training programs, exchange visits, demonstration projects, action research projects, and diagnostic assessments	TA progress reports; websites of APWF, ICHARM, and ADB etc.
Strengthened knowledge networking among countries in the region	Number of organizations collaborating effectively for knowledge management	TA progress report; websites of ICHARM, ADB, and APWF *KnowledgeHubs,* etc.
Output 1 A. Project Support Flood management investment projects, strategies, and programs	Design inputs for 2 investment projects, and recommendations for improved strategies in 3 countries and 1 region	TA progress reports etc;
Demonstration projects to improve flood forecasting and warning	1 local demonstration projects developed and implemented successfully	TA progress reports etc
Action research on community-managed flood preparedness and disaster risk management practices	1 local action research projects completed successfully	TA progress reports etc;
Identification of "no regret" investments in flood management to accommodate climate change impact	recommendations for improved strategies in 3 countries and one region	TA progress reports etc
Capacity development activities in water-related disaster management and climate change adaptation	3 countries will be benefited through ICHARM Local Disaster Management Training Course	Training reports

B. Program Quality Support Workshops, training, and exchange visits Mapping and stocktaking of initiatives in climate change adaptation Strengthened master's degree program in disaster management at ICHARM Pool of regional experts Regional index for water-related hazard vulnerability	1 regional workshop on flood alert system 1 regional workshop on flood and drought indices for the lower Mekong basin countries At least 1 exchange visits related to flood management List of initiatives in climate change adaptation effects in flood risk management Modules for policy and institutional aspects added Experts identified and their expertise mobilized Regional index developed and pilot-tested	Workshop report Workshop report Exchange visit, report TA progress reports TA progress reports TA progress reports TA progress reports

Activities with Milestones

A. Project Support
1. Flood management strategies and programs, and investment projects (first quarter, 2011)
2. Demonstration project to improve flood forecasting and warning (fourth quarter, 2010)
3. Action research on community-managed flood preparedness and disaster risk management practices (first quarter, 2011)
4. Identification of "no regret" investments to accommodate extreme climate change variation (fourth quarter, 2010)
5. Capacity development activities (fourth quarter, 2010)
6. Diagnostic assessments (fourth quarter, 2010)

B. Program Quality Support
1. Exchange visits related to flood management (first quarter, 2010)
2. Mapping of initiatives in climate change adaptation effects in flood risk management (first quarter, 2011)
3. Training workshops in flood risk management for Network of Asian River Basin Organizations (NARBO) (first quarter, 2010)
4. Review of ICHARM's master's degree program in disaster management (third quarter, 2010)
5. Establishment of pool of regional experts to enhance flood management and emergency response services (fourth quarter, 2010)
6. Regional index for water-related disaster preparedness (first quarter, 2011)
7. Collaboration with regional water knowledge hubs for climate change adaptation (first quarter, 2011)

Appendix 2 Reports

Volume 1 : Main Volume
Volume 2 : Bangladesh Component
Volume 3 : Indonesia Component
Volume 4 : Lower Mekong Basin Component
Volume 5 : Philippines Component

Asian Development Bank

Technical Assistance
for
Supporting Investments in Water-Related Disaster Management
(TA7276)

Final Report
(Volume 1)
Main Volume

March 2013

International Centre for Water Hazard and Risk Management
under the auspices of UNESCO (ICHARM)

Public Works Research Institute (PWRI)

Structure of Reports

(TA 7276 for Supporting Investments in Water-Related Disaster Management)

The reports of TA 7276 for Supporting Investments in Water-Related Disaster Management are divided into following volumes:

Volume 1: Main Volume

(i) Development of Index for Water-Related Disaster Risk Management
(ii) Organization of regional knowledge sharing workshops, exchange visit program and capacity development trainings, etc.

Volume 2: Bangladesh Component

(i) Technical support for improvement of current early warning system
(ii) Capacity building of engineers and managers

Volume 3: Indonesia Component

(i) Satellite-based flood alert system
(ii) Capacity building on local disaster management
(iii) Implementation of community based flood disaster risk management

Volume 4: Lower Mekong Basin Component

(i) Supporting Mekong River Commission Secretariat in developing flood vulnerability indices

Volume 5: Philippines Component

(i) Applying Integrated Flood Analysis System (IFAS) to the river basins
(ii) Identifying causes of historical floods
(iii) Training on utilization of IFAS as supplementary information of the existing flood monitoring systems

List of Authors of TA 7276 Final Reports

Overall	Toshio Okazumi, Shigenobu Hibino
Volume 1: Main Volume	Badri Shrestha, Lee Sangeun, Youngjoo Kwak
Volume 2: Bangladesh Component	Badri Shrestha, Mamoru Miyamoto
Volume 3: Indonesia Component	Seishi Nabesaka, Dinar Istiyanto
Volume 4: Lower Mekong Basin Component	Badri Shrestha, Ai Sugiura, Shigenobu Tanaka, Youngjoo Kwak
Volume 5: Philippines Component	Mamoru Miyamoto, Seishi Nabesaka

Asian Development Bank

Technical Assistance
for
Supporting Investments in Water-Related Disaster Management
(TA7276)

Final Report
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International Centre for Water Hazard and Risk Management
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Public Works Research Institute (PWRI)

List of Abbreviations

ADB	Asian Development Bank
ADB-DMCs	Asian Development Bank-Developing Member Countries
APHRODITE	Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation
AQUASTAT	FAO's Global Information System on Water and Agriculture, Developed by the Land and Water Division
ATLM	Applied Threshold Level Method
BBWS	Balai Besar Wilayah Sungai Bengawan Solo
BEH	Bündnis Entwicklung Hilft
BTOP	Block-wise TOP model
BWDB	Bangladesh Water Development Board
CBDRM	Community Based Flood Risk Management
CFIS	Community Flood Information System
CHRR	Center for Hazards and Risk Research
CIESIN	Center for International Earth Science Information Network
CNMC	Cambodia National Mekong Committee
CRBOM	Center for River Basin Organizations and Management
CRED	Centre for Research on the Epidemiology of Disasters
CRR	Cambodian Red Cross
DEM	Digital Elevation Mode
DRI	Disaster Risk Index
DRR	Disaster Risk Reduction
DWIDP	Department of Water Induced Disaster Prevention
EM-DAT	Emergency Events Database
FAO	United Nations Food and Agriculture Organization
FEWS	Flood Early Warning System
FFWC	Flood Forecasting Warning Center
FID	Flood Inundation Depth
FMMP	Flood Management and Mitigation Program
FVIs	Flood Vulnerability Indices
GIS	Geographical Information System
GPW	Gridded Population of the World
GWSP	Global Water System Project
HFA	Hyogo Framework for Actions
HydroSHEDS	Hydrological Data and Maps based on Shuttle Elevation Derivatives at Multiple Scales
IBNET	International Benchmarking Network for Water and Sanitation Utilities
ICHARM	International Centre for Water Hazard and Risk Management
ICIMOD	International Centre for Integrated Mountain Development
IDNDR	International Decade for Natural Disaster Reduction
IFAS	Integrated Flood Analysis System
IRI	International Research Institute for Climate Prediction
ISDR	International Strategy for Disaster Reduction
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency
JMA	Japan Meteorological Agency
Lao PDR	Lao People’s Democratic Republic
LDEO	Lamont-Doherty Earth Observatory

LECZ	Low Elevation Coastal Zone
LMB	Lower Mekong Basin
MAFF	Ministry of Agriculture, Forestry and Fisheries, Cambodia
MLMUPC	Ministry of Land Management Urban Planning and Construction, Cambodia
MDGs	Millennium Development Goals
MOE	Ministry of Environment, Cambodia
MPWT	Ministry of Public Works and Transport, Cambodia
MOWRM	Ministry of Water Resources and Meteorology, Cambodia
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
NCDM	National Committee for Disaster Management, Cambodia
NDRH	Natural Disaster Risk Hotspots
NGI	Norwegian Geotechnical Institute
NGOs	Non-Governmental Organizations
NRM	National Road Map
OCHA	Office for the Coordination of Humanitarian Affairs
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PAR	Pressure and Release
PWRI	Public Work Research Institute
REM	Relative Digital Elevation Model
RRI	Rainfall Runoff Inundation
SPI	Standardized Precipitation Index
SWOT-AHP	Strength Weakness Opportunity Threats- Analytic hierarchy process
SRTM	Shuttle Radar Topography Mission
TA	Technical Assistance
TSA	Tonle Sap Authority, Cambodia
UN	United Nations
UNDP	United Nations Development Programme
UNEP-GRID	United Nations Environment Programme-GRID
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNU-EHS	United Nations University-Institute for Environment and Human Security
USGS	U. S. Geological Survey
WASP	Weighted Anomaly Standardized Precipitation
WDI	World Development Indicator
WECS	Water and Energy Commission Secretariat
WFP	World Food Programme
WGI	Worldwide Governance Indicator
WMO	World Meteorological Organization
WRDRI	Water-Related Disaster Risk Index

Summary

The Technical Assistance for Supporting Investments in Water-Related Disaster Management (TA7276), there are two kinds of supports, i.e. in-country project supports and program quality support.

In this Main Volume, the activities of program quality support are reported. The objectives of this program quality supports are to provide supports to improve knowledge networking and regional cooperation among interested DMCs and development partners and pacific region. Workshops, trainings and exchange visit etc. were conducted.

A prototype water related disaster risk index (WRDRI) for the purpose of risk assessment at the national level was also developed under program quality support of the TA and applied to Nepal and the Philippines.

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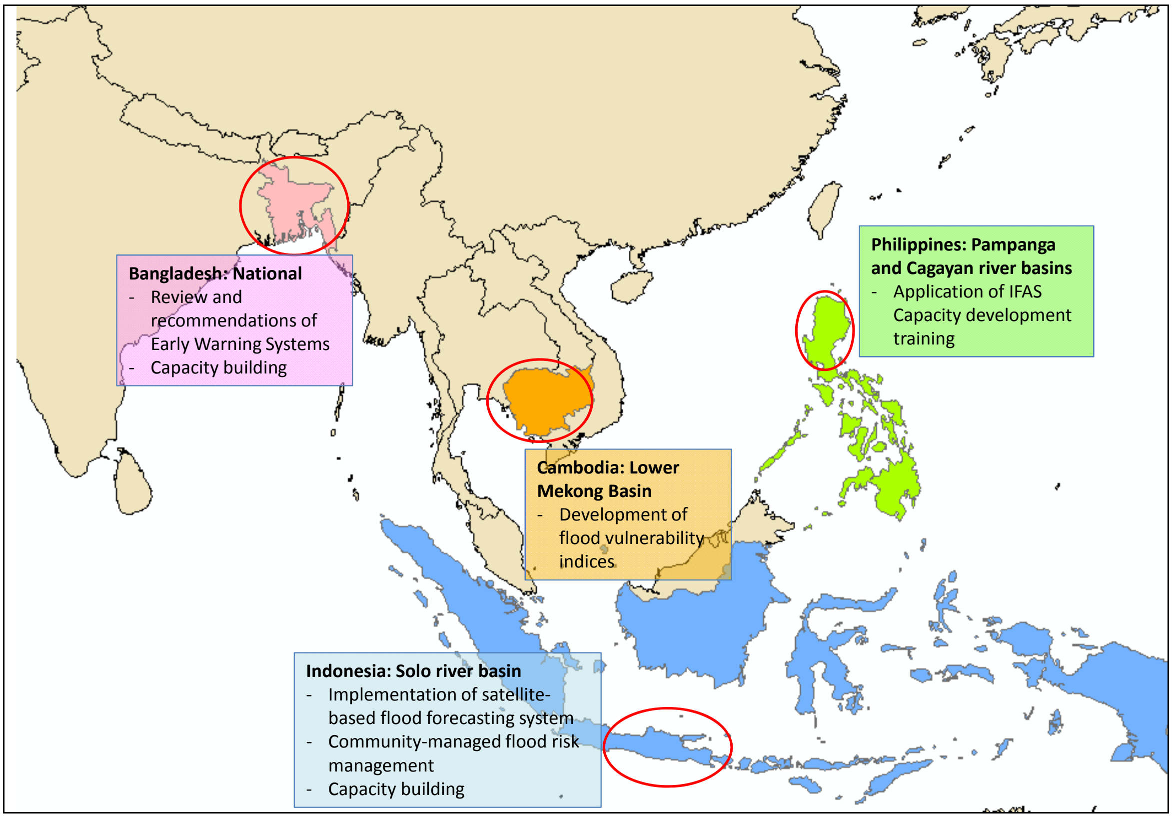
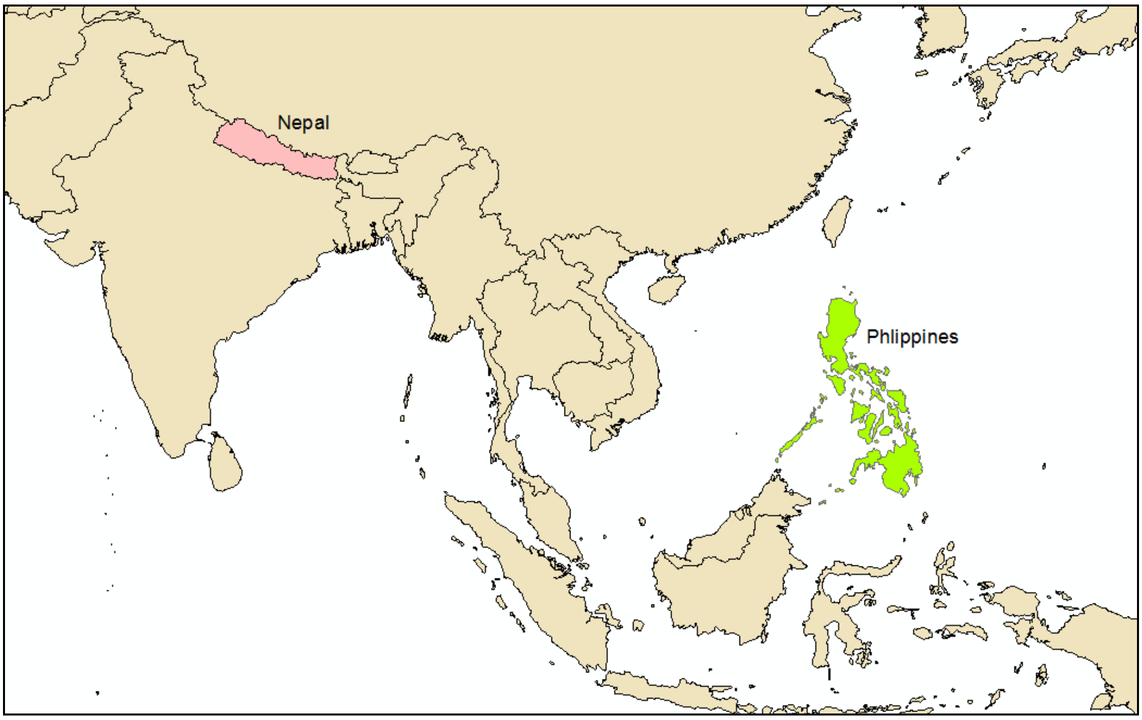


Location Map of the Target Countries for In-Country Support Projects of the TA



Location Map of the Target Countries for the Development of Water Related Disaster Risk Index

1. Introduction

1.1. Background

The past 50 years have seen a sharp rise in large-scale disasters. In the Asia and Pacific region, water-related disasters, more than other types, have been increased. It is a matter of serious concern that many countries face catastrophic water-related disasters, while having few resources to cope with them. The risk of these disasters has been increasing tremendously by climate change, and urbanization, constituting an increasing threat to economies, population and sustainable development. According to the global disaster data base (CRED, EM-DAT) water-related disasters in Asia killed around 21,576 people each year on average in 2000-2010, 86% of the world's total. Economic damage resulting from water-related disasters has soared for the same period. Economic damage, estimated to be 22.0 billion US$ on average in 1990s, amounted to 66.9 billion US$ in 2000s. Worldwide, flood disasters were responsible for 84% of disaster-related deaths (2000-2005) and 65% of disaster-related economic losses (1992-2001). More people than ever before live and work in vulnerable floodplains. By 2050, more than 2 billion people are expected to be at risk from flood damage. Therefore, water-related disaster management becomes a priority area in the supporting investments.

In this context, Asian Development Bank (ADB) and International Centre for Water Hazard and Risk Management (ICHARM), Public Works Research Institute (PWRI) started collaborating on implementation of Technical Assistance (TA) for Water-Related Disaster Management. The Technical Assistance for Supporting Investments in Water-Related Disaster Management (TA7276 for short) has implemented from 13 November 2009 and until end of March 2013 to help prepare and implement flood management investment projects through knowledge and capacity development services that helped to reduce vulnerability to water-related disasters with in-country and regional assistance. The TA7276 has two components: i) In-Country Project Support and ii) Program Quality Support. The project support provided to Bangladesh, Indonesia, the Mekong River Commission Secretariat and the Philippines. More countries participated in the regional cooperation activities under the program quality support component through knowledge sharing workshops and capacity building trainings. A prototype of water related disaster risk index (WRDRI) for the purpose of risk assessment at the national level was also developed under program quality support program and applied to the Philippines and Nepal. Detailed approach and methodology is given under the consecutive sections below for each of the project components.

This report describes the activities related to the Program Quality Support and also briefly describes In-Country Project Support. Details of the technical report of in-country supports are described in-country reports of each component.

1.2. Program quality support

The Project Quality Support involved improve knowledge networking and regional cooperation among interested ADB's developing member countries and development partners in the Asia and Pacific region. Besides supervising the development and implementation of the project components in the targeted countries and region, Project Quality Support also aimed at disseminating the key knowledge developed at ICHARM on flood forecasting, risk mapping and indexing and community based flood risk management.

ICHARM provided support to improve knowledge networking and regional cooperation among interested Asian Development Bank-Developing Member Countries (ADB-DMCs) in the Asia and Pacific region, as follows:

- Organization of workshops and exchange visits among professionals to share experiences in flood management and EWS,
- Training for river basin organizations in flood risk management,
- Mapping and stocktaking of initiatives in climate change adaptation,
- Strengthened master's degree program in disaster management at ICHARM,
- Pool of regional experts, and
- Development of water-related disaster risk index

1.3 In-country support

In-country support was provided to Bangladesh, Indonesia, the Mekong River Commission Secretariat and the Philippines. National executing and implementing agencies were assisted with a package of advisory services in formulating and implementing the following:

- flood management investment projects, strategies, and programs, including flood hazard mapping applications;
- demonstration projects to improve flood forecasting and warning through a regional, satellite-supported flood alert system with advanced geophysical data integrating satellite, radar, and ground observations;
- action research on innovative practices in community-managed flood preparedness and disaster risk management; and
- capacity development activities.

2. Integrated Approach

2.1 Introduction

A common methodology was used by taking account of physical and socio-cultural diversity among regions and countries. This common approach is very important because it enables synergy, easy communication and cooperation between the many actors involved. It supports a facilitating and guiding role in flood risk management in the region and it provides a basis for training and capacity building activities.

2.2 Terminology

In Figure 2.2.1 the concept of and the various terms used in Flood Risk Management for rivers are presented, as introduced by the Consulting Consortium for the Mekong Flood Risk Management and Mitigation Project component 2: Structural Measures and Flood Proofing (FMMP, 2010). This figure distinguishes between hazards, risks and vulnerability in a way which is generally accepted in international disaster management.

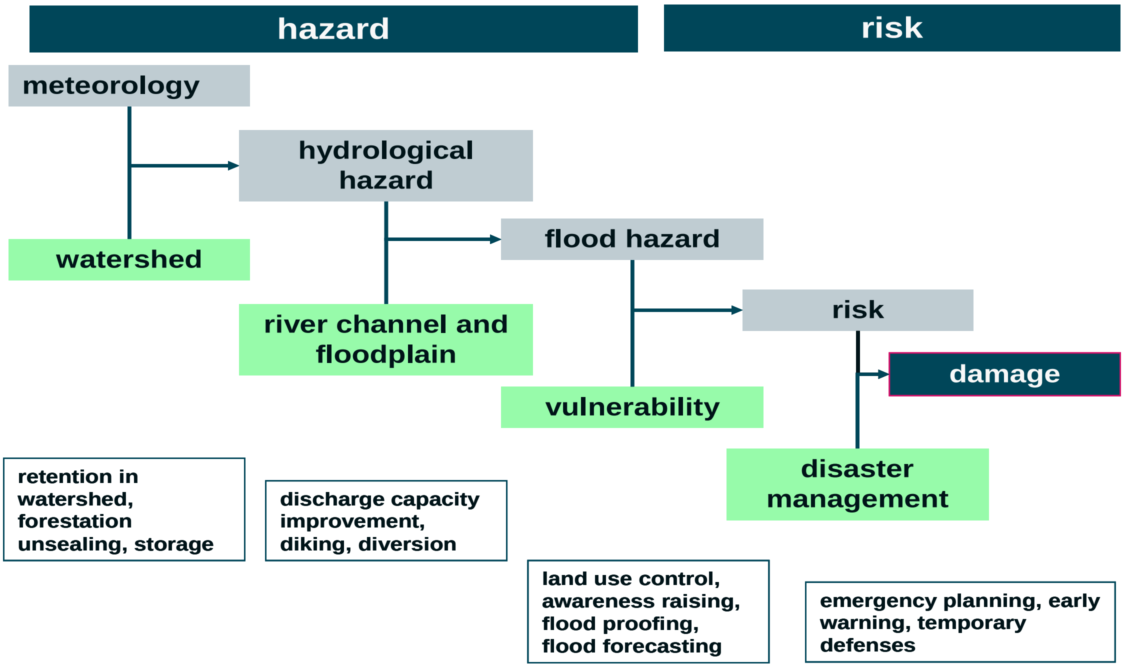


Figure 2.2.1 The concept of and definitions in Flood Risk Management

Risk is a very broad term and for scientific/practical purpose it has been interpreted in dozens of different manners by researchers/practitioners (e.g. Thywissen (2006) of UNU-EHS collected 22 different Risk definitions). Based on the concept of Pressure and Release Model (PAR model), the risk can be expressed as follows.

Risk= f (Hazard, Exposure, Basic Vulnerability, Coping Capacity)

The ‘Hazard’ part, being a natural phenomenon such as intensity of rainfall, temperature and wind-speed, is normally unchangeable by human actions, with the exception of the arguments that today’s human actions would increase/decrease future effects by future climate change.

2.3 Disaster management cycle

The methodologies for the project components are linked to the common method of disaster management so that the outcomes can be shared in an efficient manner by the disaster management agencies of the countries. Disaster management is considered a cyclic process. It is often described as consisting of four steps (see Figure 2.3.1):

1. Prevention/Mitigation
2. Preparedness
3. Emergency response
4. Recovery

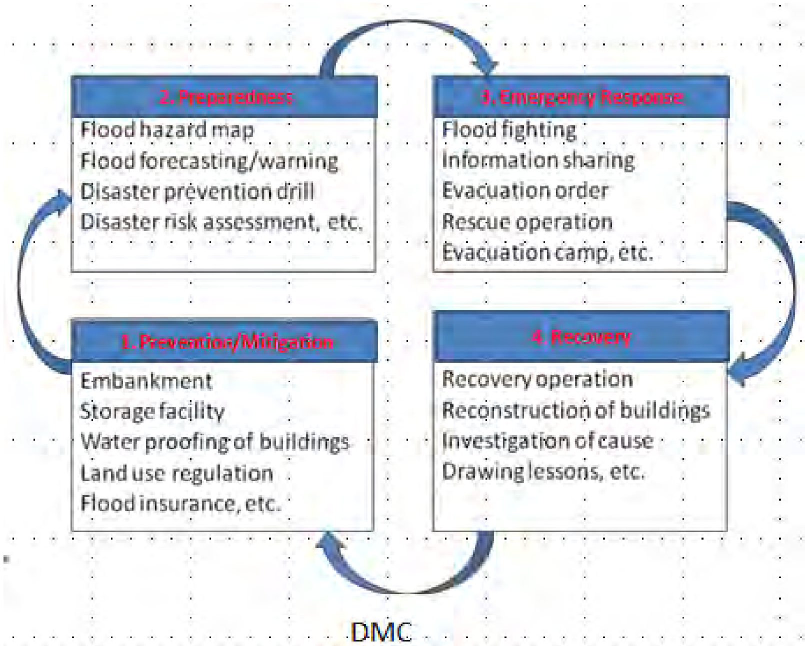


Figure 2.3.1 Disaster Management Cycle

Note that disaster management can include measures that reduces the exposure to a hazard (such as embankments and land use regulations), but also can involve reduction of the vulnerability of the society, such as water proofing of buildings or flood insurance.

In this diagram the Integrated Flood Analysis System (IFAS), being considered a measure for flood forecasting and warning, can be located in the 'Preparedness' category. However, as IFAS outcomes are strongly connected to flood fighting and information sharing, it also contributes to the 'Emergency Response' stage. Likewise, Flood Early Warning System (FEWS) development falls mainly in the 'Preparedness' category, but as it also contributes to the information sharing or evacuation actions, it also has a strong relation to the 'Emergency Response' stage.

Finally, the Flood vulnerability Indices development and WRDRI development, being one of the risk assessment measures, contributes mainly to the 'Preparedness' stage. However as its outcomes will be used for the formulation of a long term disaster risk management policy and therefore assist in land use regulation and future investment for hardware facilities, it contributes to the 'Prevention/Mitigation'" stage as well. The Community Based Disaster Risk Management (CBDRM) naturally involves various actions to be taken in local community level - such as disaster prevention drills, rescue operations, information sharing, and recovery operation; it contributes to 'Preparedness', 'Emergency Response' ánd

'Recovery' stages. This way, though the target locations are different for action by action, the Project includes actions that more or less contribute to all ADB-DMCs stages in overall terms.

2.4 Linkages between project components

In the Figure 2.4.1, the four in-country project support components are summarized. The Lower Mekong Basin component targeted at the identification of vulnerability indices at basin scale. In Bangladesh component the focus was on the development of national road map for flood early warning system at country scale. The Indonesia component focused on integration of advanced technology such as application of IFAS and community based flood risk management in Solo river basin at basin scale with local cases. In the Philippines component, the focus was on the identification of causes in Pampanga and Cagayan river basins by using ground-observed and satellite based information at basin scale and it also focused on capacity building trainings.

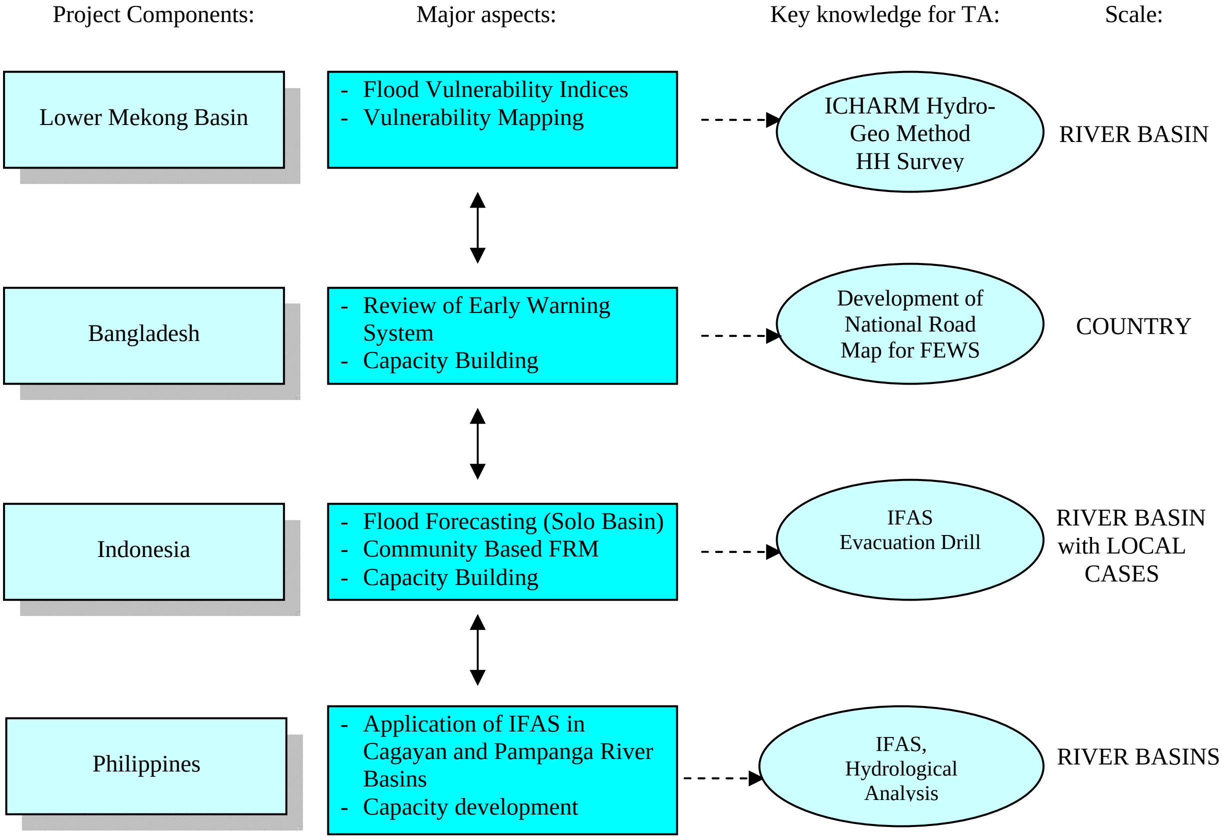


Figure 2.4.1 Overview of project components

Each of the components addressed different aspects of the Disaster Management Cycle, as described in section 2.3. They form building blocks for an integrated risk management policy and the results of each component can be useful for the other countries.

The importance of the different components is their interdependence: it makes no sense to develop a flood forecasting and warning system if there is no clear decision making protocol and response strategy, such as an evacuation. Also the other way around it is useless to define safety levels and vulnerability indices if these cannot be quantified and defined due to a lack of data for an appropriate flood forecasting and modeling instrument.

The project also shows the use of a more science and technology driven approach for flood analysis, forecasting and flood modeling and the (community based) disaster management that requires an insight in the perception of risk, the costs and benefits of mitigating measures etc. Although these two words are often wide apart and sometimes develop independent from each other, the approach shows that they should be brought together. One of the major challenges of this project therefore was to connect the hydrologists with the political, socio-economic as well as local communities. Therefore many workshops and meetings were organized to expose these different stakeholder groups and exchange ideas, knowledge and information on flood risk management.

2.5 Institutional analysis and stakeholder identification

The key national counterpart agencies for each project components were identified and they worked closely with ICHARM. The stakeholders related to each component were therefore those who were the stakeholders of the counterpart agencies. Though there was no direct requirement for institutional analysis and stakeholder identification and consultation for the implementation of project, it is an important aspect to understand the context as in many cases it was an important issue in all donor related projects in the region in the last 10 to 15 years. TA7276 interventions through each project component were primarily focused at the beneficiaries, which in most cases are the grass root communities.

Communities affected by floods are generally poor and vulnerable and the impact of floods limits their possibilities to escape poverty and to increase resilience for floods. Improved flood risk management increases the standard of living in these communities and their ability to cope with floods. In this way, the interventions should break the negative feedback loop of poverty and vulnerability and change it into a positive loop of increased standard of living and resilience. It is here that the local community focus approach including Community Based Flood Risk Management (CBFRM) comes into view.

The each and every project component and related interventions look very technical and focus at specific governmental departments in the TA reports; it is understandable that each component requires direct involvement of the local community. In Bangladesh, the technical review of early warning systems comprises the review of the impact of the existing FEWS at the grass root level. This requires detailed investigations at the community level. While recommending interventions to improve the quality of service at the community, the community's issues and needs should be carefully considered. In Indonesia, the IFAS application and community based disaster risk management activities are closely tied up, as community based emergency response activities are dependent of early warning information that depends further on the result produced by the IFAS based flood forecasting system. In the Lower Mekong Basin the project component is more related to flood vulnerability and consequently for this component social aspects play a strong role. In Philippines, the project supported for IFAS application in Cagayan and Pampanga River basins and the community's needs such as flood forecasting system should be carefully considered. The WRDRI in the targeted countries such as Nepal and Philippines was developed by analyzing the key indictors in basin level and social information also plays a strong role in developing indices.

3. Activities of the TA

3.1 Program Quality Support

3.1.1 Workshops and training

Regional workshop on IFAS

(1) 1st IFAS Workshop

Although IFAS system is easy to use, BBWS requires basic capacity to run the system and to analyze the IFAS-based results. As a part of IFAS establishment in Solo river basin, ICHARM planned to carry out two workshops on IFAS especially for BBWS engineers.

The first workshop centered on the training of IFAS application conducted during 2-4 March, 2010 in Solo city, by strong support by BBWS Solo. This was intended to help Indonesian engineers learn satellite-based flood forecast, which is a new technology contrary to conventional flood forecasting system. The key features and outcomes of the first workshop are listed as below.

- The workshop was attended by about 30 responsible local engineers (affiliated with BBWS, PJT, Municipalities, and CRBOM) from different parts of Solo basin including sub-basins.
- Participants made presentations on current challenges of flood forecasting as well as current situation of hydrological observation and flood hazard situation in Solo river basin.
- Aiming at addressing the questions and concerns rose by participants, ICHARM researchers lectured on importance of rainfall observation for flood forecasting, the main features of satellite-based rainfall, its accuracy and a correction method, etc.
- Participants carried out several related exercises/assignments in which they compared observed ground-based rainfall and satellite-based one, and checked the relevancy of satellite-based and ground-based data for flood forecasting and methods to correct and improve the accuracy of the data.
- The workshop helped participants understand on what Integrated Flood Analysis System (IFAS) mean in this context, and how can it be applied for actual/real- time flood forecasting in Solo river basin.
- The next workshop/training is conducted to strengthen the capacity of engineers on the installation and operation of IFAS so that local engineers can independently conduct flood forecasting by using IFAS.

(2) 2nd IFAS Workshop

ICHARM organized an IFAS training workshop as a part of the ADB TA7276-REG project from 23 to 25 November 2011 in Solo, Indonesia. In this workshop, ICHARM also transferred three sets computers with the IFAS-based flood early warning systems to the Solo river basin agency of Indonesia's Ministry of Public Works. Participants learned that it is important to make frequent observations and repeat analysis in order to get more accurate results for better evacuation. Some participants quickly learned how to tune parameters of IFAS and became able to get highly accurate results. IFAS is expected to help mitigate flood damage in the Solo basin.

This workshop was held as a regional workshop. Not only the participants from Indonesia, but also participants from Bangladesh, and Cambodia (MRC) were joined in this 2nd IFAS

workshop. Below is a list of the main organizations of the workshop participants:

- Ministry of Public Works, Indonesia
- Solo river basin agency, Ministry of Public Works, Indonesia
- Climatological Meteorological and Geophysical Agency, Indonesia
- Bangladesh Water Development Board
- Disaster Management Bureau, Bangladesh
- Mekong River Commission
- PERUM JASA TIRTA1

Regional workshop on flood indices

Knowledge Sharing Workshop on Flood Vulnerability Assessment in Cambodian Flood plains was held on 9 – 10 February 2012, at Hotel Cambodiana, Cambodia.

Objectives of this workshop are 1) Learning the Mekong River Flood 2011 and present status of Mekong River basin, 2) Clear definition of hazard, vulnerability, etc. in general as well as in ICHARM methodology, 3) Understanding of hydro-meteorological, topographical, social and economic characteristics in each river basin, 4) leaning basic functionality and efficiency of satellite information, GIS and hydro-meteorological analysis, 5) Leaning mechanism of house and crops damage through household survey, and 6) Attempting to apply ICHARM methodology to each river basin through learning, exchange experience and discussion, and find out necessary further steps.

Participants of the workshop

About 24 participants including ICHARM (6), ADB (1) and Deltares (2) members actively joined the workshop. The participants were invited from Cambodia (6), Vietnam (2), Lao PDR (2), Indonesia (2) and Bangladesh (3).

Content

The contents of the workshop are presentations by resource persons, presentations by ICHARM, presentation by MRC, group discussions, plenary discussions and wrap up. For the group discussions, participants were divided into 3 groups, as group A (Cambodia 6 + the Netherlands 1), group B (Indonesia 2 + Bangladesh 3 + the Netherlands 1) and group C (Vietnam 2 + Lao PDR 2 + Japan 1).

Outcome of the Workshop

Definition of "vulnerability" was clearly shown and the ICHARM method to assess the agricultural vulnerability and household vulnerability in the Cambodia flood plains were described. Both agricultural and household vulnerabilities were expressed by monitory values (Annex 2).

The pilot area was the Cambodian flood plains. As next steps, the possibilities to apply this ICHARM Hydro-Geo Method in different countries were discussed and presented by each groups.

Workshop on water-related disaster risk management

A Knowledge Sharing Workshop on Water –related Disaster Risk Management was held on 15 – 18 January 2012, at Hotel Himalaya. Kathmandu, Nepal

Background

The main aim of implementing knowledge sharing activities among member countries under the program quality support component of TA 7276 is to share knowledge and lessons

learned in the field of water-related disaster risk management. In line with this objective, a knowledge sharing workshop on Water-related Disaster Risk Management was planned on 15-18 January, 2012 in Nepal. Two days field trip on January 16-17, 2012 at Koshi River Barrage site was also organized during the workshop. The workshop mainly focused on sharing international experiences and best practices on flood forecasting and early warning system inviting participation from regional member countries such as India, Bangladesh, Bhutan and Nepal as well as experts from other Asian countries from Indonesia, the Philippines and Cambodia. The countries in the basins of Ganges and Brahmaputra rivers, which have been playing a significant role in socio-economic development but also often put a major set-back in the development due to massive annual floods, can be benefited from this knowledge sharing workshop. The knowledge sharing on best practices of disaster risk management is one of the key activities prioritized in the framework. In the workshop, the outcomes of TA 7276 related to flood forecasting and early warning such as implementation of IFAS based flood forecasting and early warning and community based flood risk management in Indonesia, national road mapping on flood forecasting and early warning system in Bangladesh together with experiences from Lower Mekong Basin floods of 2011 as well as floods in South Asian region were shared.

Participants of the workshop

About 44 participants including ICHARM, ADB and Deltares members actively joined the workshop. The participants were invited from India, Bangladesh, Bhutan and Nepal as well as experts from other Asian countries such as from Indonesia, Cambodia and the Philippines.

Content

The contents of the workshop were presentation by resource persons, presentation by ICHARM, presentation by participants, review, panel discussion, field site survey at Koshi River, flood simulation game by Deltares, the Netherland.

Outcomes of the workshop

The knowledge sharing workshop was very much fruitful to share international experiences and best practices on flood forecasting and early warning at policy and operational levels. Also, it was helpful for way forward for our River Basins’ management by innovative flood disaster methodologies. Further main outcomes of the workshop are as follows (Annex 1):

- learning of lessons from the implementation of water related disasters, flood forecasting and early warning practices from around Asia.
- sharing of innovative methodology and results from ADB TA 7276-REG mainly IFAS application in Indonesia, national road mapping of flood early warning in Bangladesh, risk mapping in LMB and bring discussions to promote know-how and application in the region,
- sharing and discussion of the experiences on flood forecasting and early warning among countries,
- learning of best practices and quick responses of Koshi Flood 2008.

Consultative meeting on Vulnerability Indices and Mapping

On January 14, 2011 a consultative meeting was organized at the Hotel Cambodiana, Phnom Penh on vulnerability indices and mapping. The objectives of the meeting were defined as follows:

- To discuss the needs and user requirements of vulnerability maps;
- To discuss and assess the key vulnerability factors and indices for mapping.

The outcome of the meeting is a shared view on the desired development of vulnerability maps in the TA project.

The workshop consisted of a mixture of presentations and break-out sessions. In total 34 people actively participated in the workshop. The workshop was chaired by His Excellency Mr. Watt Botkosal, chairman of CNMC. Opening speeches were given by H.E. Mr. Watt Botkosal and Dr. Son, FMMP coordinator of MRC. Besides staff members from MRC, CNMC and the consultants a large number of representatives from national line agencies and NGOs were present.

The workshop resulted in a clear picture of the high, medium and low priority maps for three different groups of users: crisis managers, water managers and development planners. Also valuable information was collected with regard to the three hypotheses on flood vulnerability which was discussed during the break-out sessions. A questionnaire on data for vulnerability mapping was handed out at the end of the meeting in order to achieve an overview of flood damage data.

Table 3.1.1 List of trainings

Organizer	Activities
ICHARM / JICA	Local Emergency Operation Plan with Hazard Map (Nov, 2009)
ICHARM / JICA	Local Emergency Operation Plan with Hazard Map (Jan-Feb 2010)
ICHARM / JICA	Local Emergency Operation Plan with Hazard Map (Jul-Aug 2011)
ICHARM / UNESCAP / JAXA	Space Application to Reduce Water-related Disaster Risk in Asia (Dec, 2011 in Bangkok)

Training activities

In order to improve the capacity development for the staff of water-related risk management, ICHARM invited them to the JICA training courses, etc. The list of training course is shown in the Table 3.1.1.

(1) JICA Training of Local Emergency Operation Plan with Hazard Map

ICHARM conducted JICA training courses "Local Emergency Operation Plan with Hazard Map in 3 times in 3 years, namely, November 2009, January-February 2010 and July – August 2011. These training courses were originally scheduled to be offered for 3 consecutive years. The trainees funded by ADB are listed in Table 3.1.2.

The ultimate goal of these courses were to increase local flood resilience through the development of local emergency operation plans combined with Flood hazard Map and flood forecasting and warning system and thereby reduce flood damages in the project-target countries. The conceptual image of the training courses is shown as Figure 3.1.1.

In the first year (2009), senior personnel were strategically recruited from the target organizations. Their assignment was to make a training plan and select appropriate training candidates from their organizations for the following 2 years.

In the second year (2010), according to the plans prepared by the senior personnel of each organization, the selected trainees learned knowledge and skills needed for flood hazard mapping, such as flood analysis.

The third year (2011) was the final year of this course. Another set of selected trainees worked on the development of action plans that include the direction and schedule of local emergency operation planning for the target area of their countries.

Table 3.1.2 List of trainees funded by ADB

FY	Country	Name	Position
2009 (First year)	Bangladesh	Mr. Md. Abdul Wadud Bhuiyan	Chief of Monitoring Department, Bangladesh Water Development Board
	Indonesia	Ms. Gemala Suzanti	Data and Information Manager, Bengawan Solo River Basin Development Agency
2010 (Second year)	Bangladesh	Mr. Md. Saiful Hossain	Executive Engineer, Directorate of Planning-3, Bangladesh Water Development Board
	Indonesia	Ms. Ika Yulianti	Engineer of data and Information section, Bengawan Solo River Basin Development Agency
2011 (Third year)	Bangladesh	Mr. Robin Kumar Biswas	Sub-Divisional Engineer, Office of the Chief Planning, Bangladesh Water Development Board (BWDB)
	Indonesia	Mr. Muhammad Arwan Fatchul Aziz	Staff of Water Resources Operation and Maintenance Planning Division, Bengawan Solo River Basin Agency

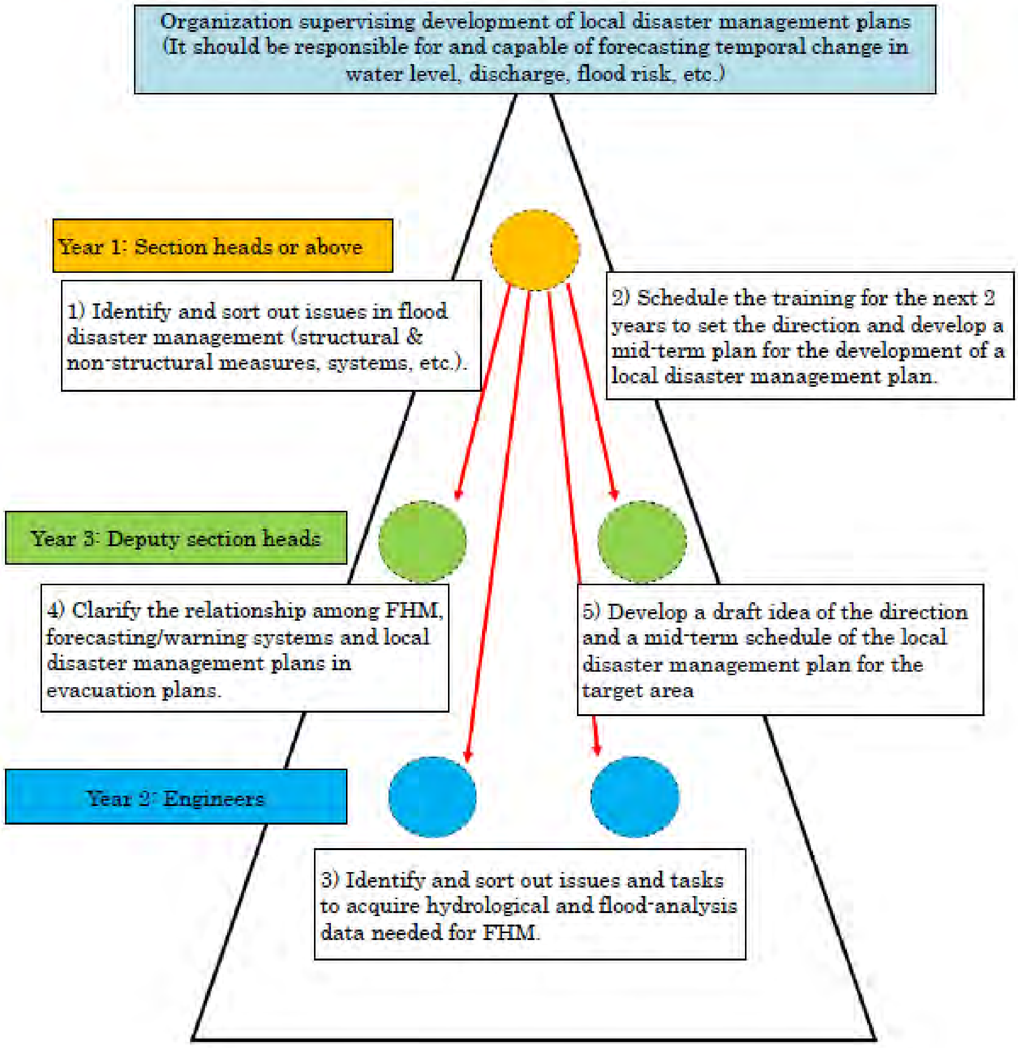


Figure 3.1.1 Conceptual image of the training courses

(2) Workshop on Space Application to Reduce Water-related Disaster Risk in Asia. (Bangkok, Thailand, 7-9 February 2010)

ICHARM and UN/ESCAP (United Nations Economic and Social Commission for Asia and the Pacific) co-organized a workshop on satellite application to reduce water-related disaster risk in Asia at the United Nations Conference Centre in Bangkok, Thailand, on 7-9 December 2011.

Over 60 people participated from 12 countries such as Bangladesh, Cambodia, China, Indonesia, Laos, Malaysia, Pakistan, the Philippines, Republic of Korea, Vietnam, Thailand, and Japan. Some international organizations also joined the workshop, including ADRC (Asian Disaster Reduction Center), MRC (Mekong River Commission), and our partners for this workshop such as WMO (World Meteorological Organization) and ESCAP/WMO Typhoon Committee.

The workshop was organized as an addition to a satellite application workshop originally planned by ESCAP with the cooperation of JAXA (Japan Aerospace Exploration Agency). ICHARM was given opportunity to provide a related workshop to promote the Integrated

Flood Analysis System (IFAS) to Asian countries as a part of an ongoing project which ICHARM has been jointly implementing with ADB.

The objectives of the workshop were to exchange information on space application to water-related disaster risk reduction measures such as flood risk assessment, flood forecast and early warning and evacuation, and also to conduct training on how to use IFAS.

From Day 1 to the first half of Day 2, space application to reduce water-related disaster risk in Asia was outlined by JMA (Japan Meteorological Agency), JAXA, and ESCAP. Each participating country also reported actual disaster response cases utilizing space technology, followed by general discussion on the issue.

From the second half of Day2 to Day3, the participants had a hands-on training on how to use the IFAS software and perform run-off analysis using data of their own country. Some of them quickly learned even how to calibrate parameters and obtained highly accurate simulation results. The training was very successful in helping many participants understand satellite technology and IFAS as a practical satellite application.

After the joint workshop, the participants were asked to fill in a feedback sheet, and their comments were almost all about IFAS. This confirmed the usefulness of IFAS in flood management and revealed a strong demand for IFAS training. The workshop was a great opportunity for the ICHARM staff, too, to realize a high level of interest in IFAS in Asian countries and the need for providing more training such as this.

For the report and presentation materials of "the Workshop on Space Application to Reduce Water-Related Disaster Risk in Asia", held on 7-9 December 2010 in Bangkok, visit the following UN-ESCAP website;
http://www.unescap.org/idd/events/2010-JAXAicharm7-9DEC/

Annual flood workshop MRC (August 2011)
MRC had the annual flood workshop on 10 August 2011. MRC member countries (Cambodia, Vietnam, Lao PDR and Thailand) made presentations about the flood situations and current problems. ICHARM was invited to this workshop and as an innovative study case, the method developed by ICHARM was described in the workshop.

ADB Water Week (November 2011)
ADB organized the ADB Water Learnig Week from 7 to 11 November 2011 at the ADB head quarters in Manila, the Philippines. Researchers and other experts who study water-related issues in Asian countries attended the conference and shared knowledge and information with other participants (20 Countries, 110 Perticipants).

In this week-long event, ICHARM organized a one-day session “Managing Disaster Risks and Building Resilience” on 9 November and mainly discussed the results of ADB TA 7276-REG, a Regional Capacity Development Technical Assistance project, conducted under the ADB-ICHARM partnership agreement.
There were 3 sub-sessions and the titles and objectives of the sub-sessions are listed as below;
Session 1: What have we committed to do?

- Share the status of water-related disasters in the Asia and Pacific

- Review our overall commitments, goals and policies by the international community and ADB, including Hyogo Framework of Actions and ADB's Disaster and Emergency Assistance Policy
- Highlight lessons learnt from best practices in the region, including the prevention and preparedness measures, leadership and coordination, stakeholder participation, and innovative methodologies.

Session 2: How can we innovate?

- Share innovative methodologies of selected ADB's projects for promoting disaster mitigation, protection awareness, and disaster preparedness, especially from perspective of education, stakeholders' participation, and innovative technologies.
- Discuss how innovative methodologies are effectively utilized in the region.

Session 3: Where should we invest more?

- Understand key topics on where we should invest more for managing water-related disaster risks and building resilience.

The discussion topics were as follows:

- Recent water disaster situations including the tsunami disaster caused by the Great East Japan Earthquake.
- Inovative ideas developed by ICHARM for the in-country projects in Indonesia, Bangladesh and Lower Mekong Basin Countries.
- Panel disccussion on flood damage mitigation in the future.

ICHARM also set up a special exhibition booth in the ADB head quarters and showed the flood simulation of the current Chao Phraya River flood and a 3.11 tsunami video. ADB staff showed considerable interest in the exhibiton.

Through the event, ICHARM was able to appeal to participants with the current outputs of TA 7276-REG, and they expressed great appreciation for the ICHARM outputs.

The ADB's Water Learning Week offers an opportunity for Asia's leading water practitioners, researchers, knowledge and funding partners, and ADB staff to share innovative practices and lessons learned. The participants will discuss guidelines for new investments in IWRM in river basins, focusing on water quality, disaster risk, climate change adaptation, and water security. The ADB water week is a yearly event. This time a relatively small group (approximate 100 experts) was invited to join the presentations and discussions. The event was organized at ADB headquarter in Manila. This provided excellent opportunities for networking between the participants and ADB staff.

In between the sessions there were opportunities to discuss with other participants. Most participants originated from government organizations mainly from Lower Mekong, Indonesia, China, India and Bangladesh. Some of them were already working together with Deltares (Dr. Ti Le-Huu of Vietnam and Mr. Isnugroho of Indonesia). An in depth discussion on the Citarum and 6 CI's project in Indonesia was held as case for integrated river basin management. With Mr. Isnugroho we exchanged ideas on how to tackle the problem of conflict of interest (and corruption) in Bangladesh and Indonesia.

Two experts of ICIMOD (Nepal) were also participating. They gave lunchtime lecture on effects of climate change on the water availability in the large rivers from the Himalaya plateau. These rivers are supplying more than 1 billion people with water. Also Mr. Wim

Bastiaanse of Water watch, Wageningen presented his approach to use remote sensing techniques for drought and crop monitoring.

3.1.2 Mapping and stocktaking of initiatives in climate change adaptation

The mapping and stocktaking of initiatives in climate change adaptation are listed in the following Table 3.1.3.

Table 3.1.3 Mapping and Stocktaking of Initiatives in Climate Change Adaptation

S.N.	Project title	Implementing agencies/partners	Country	Status
1	Enabling Activities for the preparation of the Second National Communication of the Bangladesh to the UNFCCC (United Nations Framework Convention on Climate Change)	Department of Environment, Ministry of Environment and Forests (MoEF)	Bangladesh	Ongoing
2	Community Based adaptation to climate change through Coastal Afforestation in Bangladesh	Forests Department, MoEF	Bangladesh	Ongoing
3	Barriers Removal to the Cost Effective Development and Implementation of Energy Efficiency Standards and Labeling Project (BRESL)	UNDP (GEF Regional Project)	Bangladesh	Ongoing
4	Community based Adaptation to Climate Change in Bangladesh	UNDP Regional Project	Bangladesh	Ongoing
5	Clean Air and Sustainable Environment (CASE) Project (Environment Component)	Department of Environment	Bangladesh	Ongoing
6	Bangladesh Climate Change Resilience Fund	Government of Bangladesh, Government of the United Kingdom, Government of Denmark, Government of Sweden, the European Union and the World Bank.	Bangladesh	Ongoing
7	Comprehensive Disaster Management Programme	Ministry of Food and Disaster Management	Bangladesh	Ongoing
8	Sunderbans Environmental And Livelihoods Security (SEALS)	European Union	Bangladesh	Ongoing
9	Increasing Resilience and Reducing Risk of Coastal Communities to Climate Change and Natural Hazards in the Bay of Bengal	European Union	Bangladesh	Ongoing
10	Collective Action to reduce Climate Disaster Risks and enhancing Resilience of the Vulnerable Coastal Communities around the Sundarbans in Bangladesh and India	European Union	Bangladesh	Ongoing
11	Alleviating poverty through disaster risk reduction in North West Bangladesh	European Union	Bangladesh	Ongoing
12	Empowerment of LAs and NSAs in Responding to Economic Development Opportunities and Climate Change and Disaster Vulnerabilities	European Union	Bangladesh	Ongoing

S.N.	Project title	Implementing agencies/partners	Country	Status
13	Improved food and livelihood security in Bagerhat District, Bangladesh in the context of increased disaster risk and climate change (IFLS)	European Union	Bangladesh	Ongoing
14	Improving Klin Efficiency in the Brick Making Industry (Full Project)	Clean Energy Alternatives Inc., Xian Institute of Brick and Roof Building Materials, China	Bangladesh	Upcoming
15	Development of Sustainable Grid-connected Wind Electricity Generation	PDB/Ministry of Power (RBD)	Bangladesh	upcoming
16	Regional Economics of Climate Change	University of Philippines Los Banos, College of Economics and Management (UPLB-CEM) Southeast Asia Regional Center for Graduate Studies in Agriculture (SEARCA) University of Batangas (UB) Palawan State University (PSU) Nha Trang University, Ministry of Marine Affairs and Fisheries	Indonesia, Philippines and Vietnam	Ongoing
17	Wind Hybrid Power Generation (WHyPGen) Marketing Development Initiatives	UNDP, Agency for Assessment & Application of Technology	Indonesia	Ongoing
18	Chiller Energy Efficiency Project	IBRD - The World Bank	Indonesia	Ongoing
19	"Sustainable Tourism through Energy Efficiency with Adaptation and Mitigation Measures in Pangandaran" (STREAM),	UNWTO	Indonesia	Ongoing
20	Capacity Development for Climate Change Strategies	JICA, Ministry of Environment, Indonesia	Indonesia	Ongoing
21	Climate Change Adaptation in the Lower Mekong Basin	International Centre for Environmental Management (ICEM) International Union for Conservation of Nature (IUCN) Southeast Asia START Regional Centre (SEASTAR-RC) Mekong River Committee of the four participating countries	LMB	Ongoing
22	Climate Change Adaptation Planning	MRC	MRC countries	Ongoing
23	Developing an everyday understanding on climate change	MRC	MRC countries	Ongoing
24	Linking people with their environment	MRC	MRC countries	Ongoing
	Downscaling of global climate change scenario climate to Mekong region	MRC, SEA START	MRC countries	Ongoing

S.N.	Project title	Implementing agencies/partners	Country	Status
25	Overview studies of basin vulnerability		MRC countries	Ongoing
26	Overview studies of basin vulnerability	MRC, IWMI and Institute of Environmental Studies	MRC countries	Ongoing
27	Climate and Hydrological modeling for assessing Climate change impacts	MRC, CSIRO and IWMI	MRC countries	Ongoing

3.1.3 Strengthened master's degree

In order to disseminate the lessons learned from the implementation of this ADB TA as far as possible to other countries, a lecture on the CBDRM (Community Based Disaster Risk Management) has been delivered to the Master Course students as well as the participants of JICA Course on "Local emergency operation plan with flood hazard maps" conducted at ICHARM on July 27th, 2011.

The important theme of the lecture was the integration of scientific and local knowledge for effective community based disaster prevention measure. It was discussing about the application of IFAS flood forecasting result or the rain gauge measurement threshold (scientific knowledge) as a flood warning reference and how each local community would utilize this information to perform practical disaster prevention measure that is contextual to their environment (local knowledge).

An example case that was introduced to the students was taken from the implementation of community based evacuation drill demonstration in Bengawan Solo River Basin in Indonesia. By using documented videos and other lecture materials, it was shown many valuable lessons, including parameter tuning of IFAS for local conditions, communicating the concept of flood forecasting advantage in early warning to the local practitioners, educating local residents about the advantage of advance technology, facilitating the local community in making consensus on the suitable standard operation procedure of evacuation operation during flood in their locality, facilitating the development community based flood hazard map, social map and flood evacuation map, and so forth.

This lecture has inspired for the introduction of new module for the Master's Course program. Started from the last year, a lecture on early evacuation of residence has been added.

3.1.4 Pool of regional experts

Pool of regional experts with their expertise is listed in Annex 3. The expertise are categorized into 5 items as "Flood Risk Management (Prevention, Mitigation and Adaptation)", "Flood Disaster Management (Preparedness, Emergency Response and Recovery)", "Flood Forecasting and Early Warning Systems", "Flood Management in Different Climate Conditions and Geographic Zones" and " Others (Flood Risk Index, Training, Indigenous Flood Management Knowledge, etc.)". Totally over 250 experts are listed with category, their country, name and affiliation.

3.1.5 Development of water-related disaster risk index

The framework was developed for Water-Related Disaster Risk Index (WRDRI) and applied for selected ADB-DMCs Nepal and the Philippines. The WRDRI was expressed as a function

of hazards, exposure, vulnerability and capacity. The key indicators on hazards, exposure, vulnerability and capacity were considered in developing risk index. The different types of hazard such as floods, drought and storm surge were considered for developing WRDRI. In each types of hazard, related indicators on hazards, exposure, vulnerability and capacity were identified and were considered to develop WRDRI. The detail descriptions of methodology and results are described in Chapter 4.

3.2 Main outcomes of the in-country projects

3.2.1 Bangladesh component

Based on case studies, field visits and intensive stakeholder consultations an inventory and priority ranking was made for the interventions needed to optimize the Flood Early Warning System (FEWS) in Bangladesh. The main approach of the project comprised three elements:

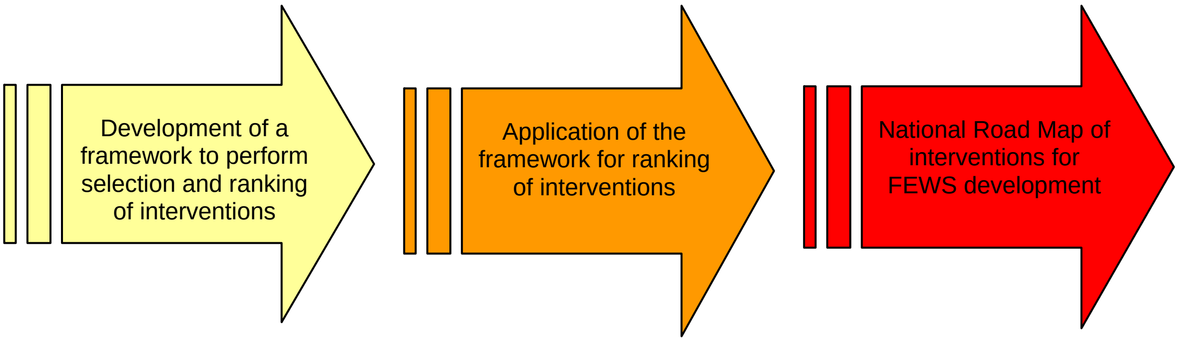


Figure 3.2.1 Framework and approach of National Road Map for flood early warning system in Bangladesh

Through this approach the two main outcomes of the project are to:

- Develop a generic framework for prioritization of interventions in a participatory approach: and
- Prepare a National Road Map (NRM) with a clear portfolio of most feasible interventions including a time line and sequence for implementation

Based on the findings of the TA study the following conclusions and recommendations can be drawn:

- A clear understanding amongst the main stakeholders is presented regarding the urgency of capacity building, dissemination and communication and community response capability;
- FEWS may be differentiated in relation to flood risk zoning;
- Effectiveness of increasing the lead time depends on the demand of the end users;
- Due to lack of communication and dissemination of the flood warnings at regional and local level much of the investment in data acquisition and flood forecasting is ineffective ;
- Use of modern telecom techniques in combination with simple techniques for local dissemination (flag system, rickshaw ‘miking’, mosques) has proved to be a very effective Community Flood Information System (CFIS project);

- Most stakeholders agree upon the urgent need for better dissemination of flood warnings. This includes translation to local level and for specific user groups;
- Subsequent to better dissemination it will be beneficial to create flood hazard maps and damage assessments. Based on such an assessment the dissemination of flood warnings could be more specific for a certain geographic region or end user group. More detailed flood hazard and damage maps per sector would need to be prepared;
- In the review study of 2006 a general cost–benefit analysis per intervention was done. It is recommended to update these cost-benefit analyses for the interventions with the highest priority;
- New, more extensive pilots should be included with a combination of different techniques for communication and dissemination. During one of the field visits the combination of different forecasting and dissemination and communication techniques proved to be very promising and was favored by local stakeholders. It is strongly recommended to continue this experiment on a large scale in different areas.
- Nearly all recommendations of the 2006 review study are still valid so new interventions were identified only in a few cases.

3.2.2 Indonesia component

The Indonesia component of in-country support program contains supports improvements in a) flood forecasting system in the Bengawan Solo river basin shared by the Central and East Java provinces and b) capacity building on local disaster management. The activities to gain the objectives include:

- A demonstration project to improve flood forecasting and warning in the Bengawan Solo river basin through a regional, satellite-supported flood alert system by using Integrated Flood Analysis System (IFAS) with advanced geophysical data integrating satellite and ground observations;
- Training of personnel of the river basin organizations on the local disaster management;
- A community managed flood risk management interventions for selected communities in the Solo River Basin

The integral goal of this TA for Indonesia is the local ownership of the IFAS technology and capacity development of the local river basin organization and the community for the reduction of flood disaster. Thus, the challenge for the present TA implementation in Indonesia is the integration of advance technology and community based disaster management.

The main outcomes of the project in Indonesia are:

- IFAS technology has been transfered to BBWS Bengawan Solo through two main training workshops and three additional intensive trainings.
- A demonstration CBDRM activity has been carried out successfully to educate people awareness on flood disaster preparedness, response and mitigation.
- A new automatic rain gauge has been purchased, installed and calibrated in an upstream village (Pajeng). As a result the lead time for flash flood warning downstream has been increased to approximately 1 hour. According to the local people this is sufficient to safe people, valuables and livestock.

Based on the outcomes the main recommendations are:

- To improve the accuracy of IFAS application in Bengawan Solo River Basin, improvement of parameter (land use, soil data, etc.) with the latest local data and increase number of ground based observation facilities (rain gauge, water level gauge, discharge gauge) are significant.
- A person in charge of IFAS operation and parameter update should be specifically assigned to maintain the sustainability of IFAS operation in Bengawan Solo River Basin.
- The demonstration activities of CBDRM should be followed up by BBWS Bengawan Solo and local government periodically to sustain the awareness and preparedness of the community. This activity should also be tried to implement in other community area to develop local community capacity in disaster management.
- The performance of the rain gauge installed at Kedung Sumber Village for supporting CBDRM activities must be monitored and improved to reach the objective of its installation; the monitoring include: correlation between rainfall intensity and river water level, the alert function of the rain gauge. In this relation operation and maintenance cooperation among stakeholders in Bengawan Solo River Basin should be well coordinated.
- Collaboration with other organizations, such as BMKG, PusAir, PJT-I, etc. are very important towards more effective application of IFAS.

3.2.3 Lower Mekong Basin component

‘In Lower Mekong Basin (LMB), the TA supported the Mekong River Commission Secretariat in developing flood vulnerability indices, which have been identified as a priority requirement for preparing further investment projects in the LMB region. The main objectives were:

(i) Defining flood vulnerability indices relevant to future flood management at the community level (the impact of floods on health, food security, livelihoods, poverty, education, and others), and relating them statistically to the underlying socioeconomic factors.

(ii) Defining and measuring the factors that affect the various flood vulnerability, through supplementary community surveys (at the family level) of flood and impact in flood prone villages where the basic socioeconomic profile has previously been determined by community surveys of other agencies (typically nongovernment organizations).’

The flood vulnerability indices form the most important output of this component and can be used for preparing vulnerability maps:
- ‘Developing a methodology for mapping these indices on a geographic information system (GIS) basis and pilot-testing the mapping.
- Extrapolating the indices across the flood-prone areas by relating the indices and their underlying factors to national socioeconomic statistics.’

ICHARM developed a Hydro-Geo Method, using Satellite Topographical Data as a complement to limited hydrological data sets in the river basin in order to identify flood vulnerable area in Cambodian floodplain. ICHARM technology makes it possible by its hydro-meteorological analysis in combination with careful analysis from past important surveys done by FMMP and others. Water level in the floodplain or flood level is approached

as the river water level at the closest gaging station or by interpolation between two consecutives gaging stations. In ICHARM's grid-based distributed methodology, flood water depth was calculated as difference between flood water level and ground level at 3 arc-second cell (approximately 91.8m×91.8m cell size). A Digital Elevation Model (DEM) of HydroSHEDS which obtained from Shuttle Radar Topography Mission (SRTM) data was used.

The flood vulnerability was defined in terms of amount of potential damages. The agricultural and house damages were considered to identify flood vulnerability indices, because both are major income and stocks in the area. The agricultural damage was defined as the function of flood water depth during the cultivation period and its duration. The maximum daily water depth and their duration for each grid were calculated and agricultural damages in each grid were calculated according to damage curves. The house damage was defined as the function of maximum flood water depth by relating with average year flood level. The household survey data for 2006 flood from Flood Management and Mitigation Programme (FMMP) of Mekong River Commission Secretariat (MRCS) was used to determine damage ratio curve and probability distribution of house value. The calculated house damages were compared with the statistical data of house damages. The Flood Vulnerability Indices (FVIs) were developed for agricultural, houses and total damages by normalizing the calculated values of damages. The FVIs were developed for average flood case and extreme flood case.

3.2.4 Philippines component

In the Philippines component, ICHARM supported to the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) in following:

(a) Application of IFAS in the Cagayan and Pampanga River basins, and

(b) Capacity development of staffs of PAGASA through training programs.

In the Cagayan River basin, IFAS and statistical approaches were applied mainly to identify causes of historical floods in the middle reaches including Tuguegarao City by incorporating satellite-based rainfall data in the southeastern upstream and ground observed hydrological data in the southwestern upstream. In the Pampanga River basin also, IFAS and statistical approaches were applied to identify causes of historical floods in the basin by incorporating satellite-based and ground observed data.

The IFAS developed by ICHARM is a concise flood-runoff analysis system as a toolkit for more effective and efficient flood forecasting in the countries. IFAS provides interfaces to input not only satellite-based but also ground-based rainfall data, as well as Geographical Information System (GIS) functions to create river channel network and to estimate parameters of a default runoff analysis engine and interfaces to display output results. The necessary data such as observed rainfall data, water level data and other data of the Cagayan and Pampanga River basins will be collected from related agencies in the Philippines. By comparing observed and calculated discharge data, the model was calibrated for each river basin. Then IFAS model was applied to simulate the floods.

In the Philippines component, ICHARM organized two training programs (one training program in Metro Manila from 26-28 September 2012 and other training program in Tuguegarao city from 2-4 October 2012) to staffs of PAGASA headquarters and regional offices including Tuguegarao and San Fernando, optimizing their human and technical resources experience. Staffs of government organizations related to flood management were

also invited in the training programs. The training programs were focused on following topics;

(a) Training on identifying causes of historical flood by incorporating satellite-based and ground observed data,
(b) Training on understanding the mechanism of flood in the Cagayan and Pampanga River basins, and
(c) Training on utilizing IFAS in practical work as supplementary information for the existing flood monitoring system.

3.3 Follow up activities

3.3.1 Follow up in Bangladesh

As a follow up a "Follow-up Consultation Workshop on the National Road Map for Floods Early Warning System Development in Bangladesh" on 5th November 2012 at Ruposhi Bangala, Dhaka, Bangladesh.

Participants of the workshop

Total 43 participants from different stakeholders, development partners and related organizations actively joined the workshop. The participants were invited from Bangladesh Water Development Board, Joint River Commission, Institute of Water Modeling, Bangladesh Disaster Preparedness Centre, Center for Environmental and Geographical Information Services, Independent Consultant, Bangladesh Meteorological Department, the Comprehensive Disaster Management Programme-II, Department of Disaster Management, Bangladesh Agricultural Research Council, the Water Resources Planning Organization, Hao Board, JICA Bangladesh, ADB, the World Bank office in Dhaka, UNDP Bangladesh, ICHARM and others.

Outline of the National Road Map

The National Road Map consists of prioritized interventions, their cost estimate, and their timelines for implementation by 2019. The most important interventions are but not limited to: (i) operation and maintenance of the monitoring network; (ii) expanding the range of data acquisition; (iii) national and local level risk assessment; (iv) community preparedness; and (v) FFWC capacity building. These interventions complete flood forecast and early warning cycle filling the major existing gaps in Bangladesh. Implementation of prioritized interventions will lead to (i) increase accuracy and lead time for flood forecasting, (ii) improve flood forecasts to meet demands of end-users, (iii) improve the extent of coverage and the penetration of early warning system to the grassroots level, and (iv) expand coordination among key institutions involved in early warning system.

Objective of the Follow-up Workshop

The main objective of the Follow-up workshop is to: (i) discuss a way forward on the practical and concrete implementation of the National Road Map; (ii) prepare an action plan as realization of discussion; and reach consensus on the ac plan by related organizations in Bangladesh.

Detail Descriptions of Sessions and Discussions

The workshop, chaired by Mr. Md. Sarim Bhuiyan, Chief Planning, BWDB, was attended by 44 participants from 17 government and non-government organizations including development partners such as ADB, World Bank, and Japan International Cooperation

Agency (JICA). Mr. Md. Afzal Hossain, Additional Director General (Planning), BWDB, attended the workshop as the Chief Guest, and Mr. Tetsumi Takahashi, Embassy of Japan in Bangladesh, and Mr. Stefan Ekelund, Deputy Country Director, Bangladesh Resident Mission, ADB, joined the workshop as the Special Guests. Mr. Hisashi Mitsuhashi, the leader of the ADB-ICHARM mission, made welcome remarks. At the first session, Mr. Toshio Okazumi, Team Leader of ICHARM, and Dr. Badri Shrestha, Project Technical Manager of ICHARM, introduced a summary of the Road Map. At the second session, all participants were separated to three groups which comprised participants from various organizations, and provided their opinions to three key questions on implementation of the Road Map facilitated by Dr. Rabindra Osti, Water-Related Disaster Risk Management Specialist, ADB. At the end of the second session, results of discussions in the three groups were shared and summarized as followings:

Outcomes of the workshop

The workshop was successful in having reached consensus among related organizations and development partners on the National Road Map. The outcomes of the workshop are as follows:

- Sharing of the National Road Map for Floods Early Warning System Development in Bangladesh to stakeholders ;
- Building a platform among stakeholders to collaborate in the implementation of the National Road Map for Floods Early Warning System Development in Bangladesh.

The detail descriptions of the workshop are described in Annex 4.

3.3.2 Follow up in Cambodia

Lower Mekong River Basin, which comprises the territories of Lao PDR, Cambodia, Thailand and Viet Nam, has annually been affected by floods. Almost every year, floods take away lives and cause damage to infrastructure, agricultural and industrial production and severely affect socio-economic development. The flood damage observed in the Basin is a significant impediment to a more rapid development.

Vulnerability is the characteristics and circumstances of communities, systems or assets that make them exposed, susceptible and resilient to the damaging effects of a flood hazard. Flood vulnerability indices (FVI) have been developed for the Cambodian floodplains as a rapid and consistent method for characterizing the relative vulnerability of different locations in the floodplains. The ultimate goal of TA intervention is to help Governments prepare and implement flood management investment projects through knowledge and capacity development services that will reduce vulnerability to flood disasters within the Basin.

In this context, training on 'Development and Utilization of Flood Vulnerability Indices in Cambodian' was organized jointly by MRCS, Cambodia National Mekong Committee (CNMC), ADB and ICHARM, from 11-13 December 2012 at MRCS meeting room, Phnom Penh, Cambodia.

Objectives of the training

The main objectives of the training program are to:

(i) Develop the capacity of relevant agencies in Cambodia to prepare FVI maps,

(ii) Discuss on effective utilization of developed FVI as a tool to community people, community leaders, decision makers, policy makers and developers for disaster management,

(iii)Provide orientation on the preparation of guide book on the utilization of FVI for future reference.

The training program on development and utilization of FVI in Cambodian floodplain focused on developing the capacity of flood management to carry out FVI mapping and indexing and to best utilize such results into development practices. The hands on training on the preparation of flood vulnerability maps with GIS tools and methodologies developed by ICHARM were provided to the participants from the relevant agencies in Cambodia. The effective utilization of the developed results of FVI in LMB area is also discussed among the participants leading to the developments of guidebook.

Summary of Training

This training was held at MRCS meeting room, Phnom Penh and 20 participants (excluding guests/ICHARM members/ADB members) joined this training from various related organizations such as Mekong River Commission Secretariat (5 participants), Cambodian National Mekong Committee (2 participants), Ministry of Water Resources and Meteorology (MOWRM) (3 participants), Cambodian Red Cross (CRR) (2 participants), Ministry of Agriculture, Forestry and Fisheries (MAFF) (2 participants), Ministry of Environment (MOE) (1 participant), Ministry of Land Management Urban Planning and Construction (MLMUPC) (1 participant), Ministry of Public Works and Transport (MPWT) (1 participant), National Committee for Disaster Management (NCDM) (2 participant) and Tonle Sap Authority (TSA) (1 participant).

The training program was manly divided into one keynote sessions and three training sessions. Session I was focused on development of flood vulnerability indices. Session II was focused on orientation and preparation of flood vulnerability mapping. Session III was focused on utilization of developed flood vulnerability indices. Session I started with chair of Mr. Toshio Okazumi, ICHARM and this session was focused on methodology for development of flood vulnerability indices. This session was divided into four different parts such as Part I was focused on ICHARM Hydro-Geo Method, Part II was focused on assessment of agricultural damage, Part III was focused on assessment of house damages and Part IV was focused on was focused on development of flood vulnerability indices. Dr. Shigenobu Tanaka, Deputy Director of ICHARM gave a lecture on ICHARM Hydro-Geo method in Part I. Mr. Shigenobu Hibino, Research Specialist of ICHARM gave a lecture on assessment of agricultural damages in Part II. After the lectures of Part I and Part II, a hands-on training of Part I and Part II was held with guidance and instructions of ICHARM members. The participants were divided into four groups and group members were selected from different organization. The training tools were prepared in Microsoft excel with visual basic programming and reference maps. In this hands-on training, participants learned water level interpolation in the river course between two water level stations, and calculation of flood water level and water depth in the floodplain. They also learned identification of transplanting date, water depth and its duration for agricultural damage assessment. By using damage ratio curve, they could learn how to calculate agricultural damages.

In Part III of Session I, Dr. Shigenobu Tanaka, Deputy Director of ICHARM introduced assessment of house damages. After the lecture of house damage assessment, a hands-on training of Part III was held. In this hands-on training, participants learned how to estimate

house damages by using probability distribution of house value, house damage ratio curve and LandScan Population data. Dr. Badri Shrestha, Researcher of ICHARM gave a lecture on development of flood vulnerability indices in Lower Mekong Basin of Cambodian floodplain in Part IV of Session I. The hands-on training of Part IV was combined with hands-on training of Session II.

In session II, Dr. Youngjoo Kwak gave lecture on GIS tools and its application in flood vulnerability mapping. After the lecture on GIS, a hands-on training was held to learn GIS function and its tools to develop maps. A free GIS software Quantum GIS was provided to participants for the practice in hands on training. After the hands-on training of GIS, another hands-on training for development of flood vulnerability indices mapping was held with a guidance of ICHARM members.

In Session III, a lecture of Mr. Toshio Okazumi was focused on flood risk management, which provided basic knowledge on flood risk management to all the participants for their practical works as well as it supported for group discussion on utilization of flood vulnerability indices. Also, in Session III, Dr. Badri Shrestha introduced the results of developed flood vulnerability indices, utilization of flood vulnerability indices and example guidebook as toolkit for community people. After these lectures, a group discussion was carried out and each group made a presentation based on their discussion. The participants were divided into four groups also for group discussion. Then plenary discussion was held with facilitation of Dr. Rabindra Osti, ADB.

Outcomes of the training program

The main outcomes of training program are as follows:

- Sharing methodologies of ICHARM Hydro-Geo Method, agricultural damage assessment, house damage assessment, development of flood vulnerability indices and GIS tools and its application for FVI development.
- Providing hands-on training for participants on water level interpolation, agricultural damage assessment, house damage assessment, FVI development and GIS tools.
- Leveraging knowledge sharing for capacity development.
- Providing knowledge for effective utilization of FVI as a tool to community people, community leaders, decision makers, policy makers and developers for disaster management,
- Providing orientation for preparation of guide book on the utilization of FVI for future reference.

The detail descriptions of the training program are described in Annex 5.

3.3.3 Follow up in Indonesia

As a follow up of Indonesia component, ICHARM Team visited BBWS from 9-11 January 2013 to build the data transfer system between hydrological system (Operated by BBWS) and Auto IFAS as follows.

1. Outline
   Recently, BBWS Solo has implemented real time rainfall gauging stations and real time water level gauging stations. And BBWS Solo requested to combine their real time hydrological observed data and IFAS. Therefore ICHARM has built the real time Flood

Alert system based on real time hydrological observation system and IFAS. And installed rain gauge worked well in the flood situation.

2. Hydrological observation system in Bengawan Solo river basin
At the beginning of ADB TA 7276-REG project, BBWS Solo didn't have so many real time gauging stations in the Bengawan Solo river basin. BBWS Solo has observed rainfall and water level once a day in normal condition. Then BBWS Solo has collected the hydrological data with paper format under the normal condition. But in case of flood, BBWS Solo increased the frequency of hydrological observation once a 3hours, once a 1hour by human observer. BBWS Solo engineers have collected the hydrological data by the phone call every hour. So they are very busy in the flood situation. It was difficult to input real time ground observed data to IFAS in case of flood.

3. Flood Alert System based on IFAS in Bengawan Solo river basin
In the past 2 years, it was difficult to collect observed rainfall data. So ICHARM built Flood Alert System based on IFAS with satellite based rainfall data named GSMaP_NRT (Global Satellite Map of Precipitation _ Near Real Time)
The image of the IFAS is shown in Figure 3.3.1.

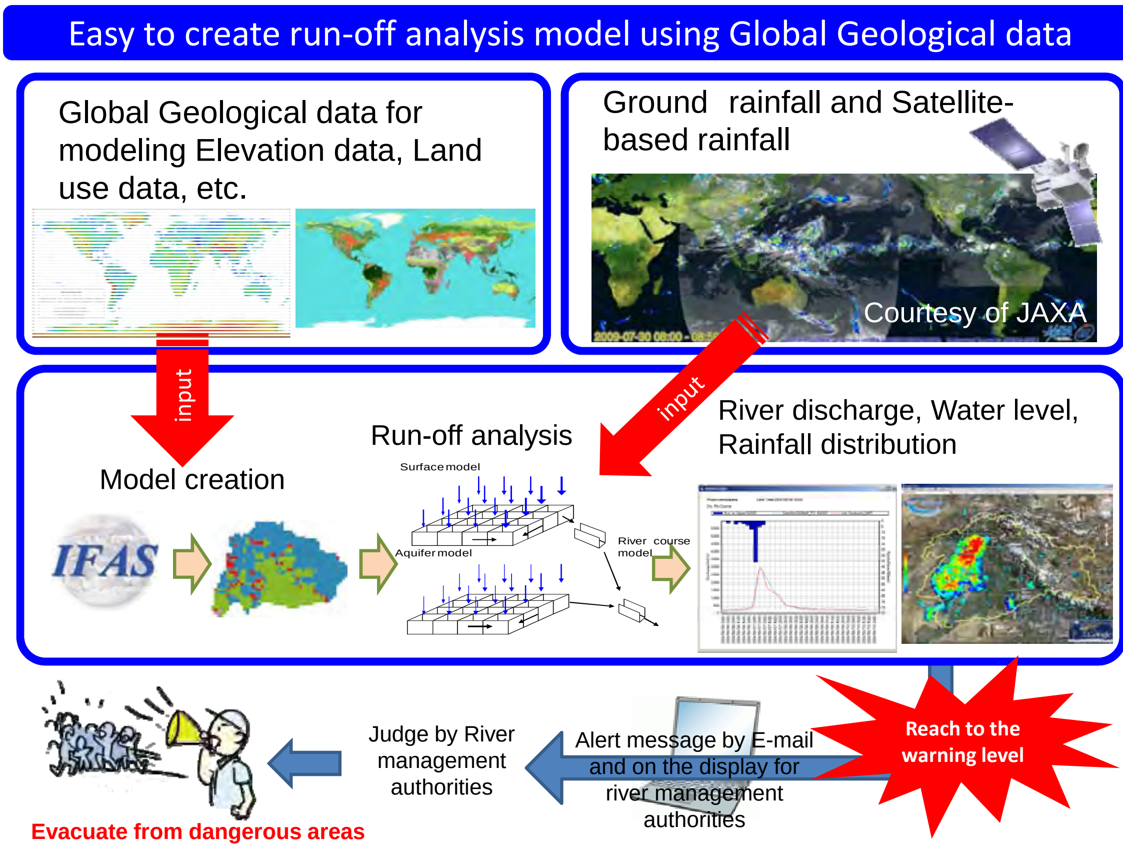


Figure 3.3.1 Procedure of Flood Alert

4. Characteristics of rainfall in Indonesia
The rainfall characteristics in Indonesia are different from typhoon type rainfall. Satellite based rainfall consists of observed data and predicted data. Predicted data is made from rainfall data and cloud movement vector. Unfortunately, Satellite based rainfall does not represent rainfall distribution in Indonesia well. One of the meteorological characteristics of Indonesia is intermittent rainfall such as squalls. This type of rainfall is usually not as heavy as that of typhoons in Japan and does not accompany extremely strong winds,

either. For these reasons, it is difficult to capture accurate distribution of this rainfall type because satellites are designed to estimate rainfall distribution based on the movement of clouds.

5. Characteristics of satellite based rainfall product named GSMaP_NRT
Satellite based rainfall named GSMaP_NRT is produced by JAXA. GSMaP_NRT consists of Microwave Radio Meter observation data and cloud movement vector extracted by Infrared Image data. TRMM (Tropical Rainfall Mesureing Mission) satellite goes along the equator, and other satellites go around earth from pole to pole to measure the rainfall. When the satellites go to other side of the planet, satellites can't send the micro wave observation data. But the number of satellites is lacking to observe the rainfall for whole world every hour. Therefore there is unmeasured area in Microwave observation data. Then JAXA combines microwave observation data and cloud movement vector extracted from Infrared data to make rainfall data for whole world. It takes 3 hours to collect micro wave radio meter observation data, and it takes 1 hour to process global rainfall map. Totally it takes 4 hours to make global rainfall map every hour. Data processing of GSMaP_NRT is shown in Figure 3.3.2.

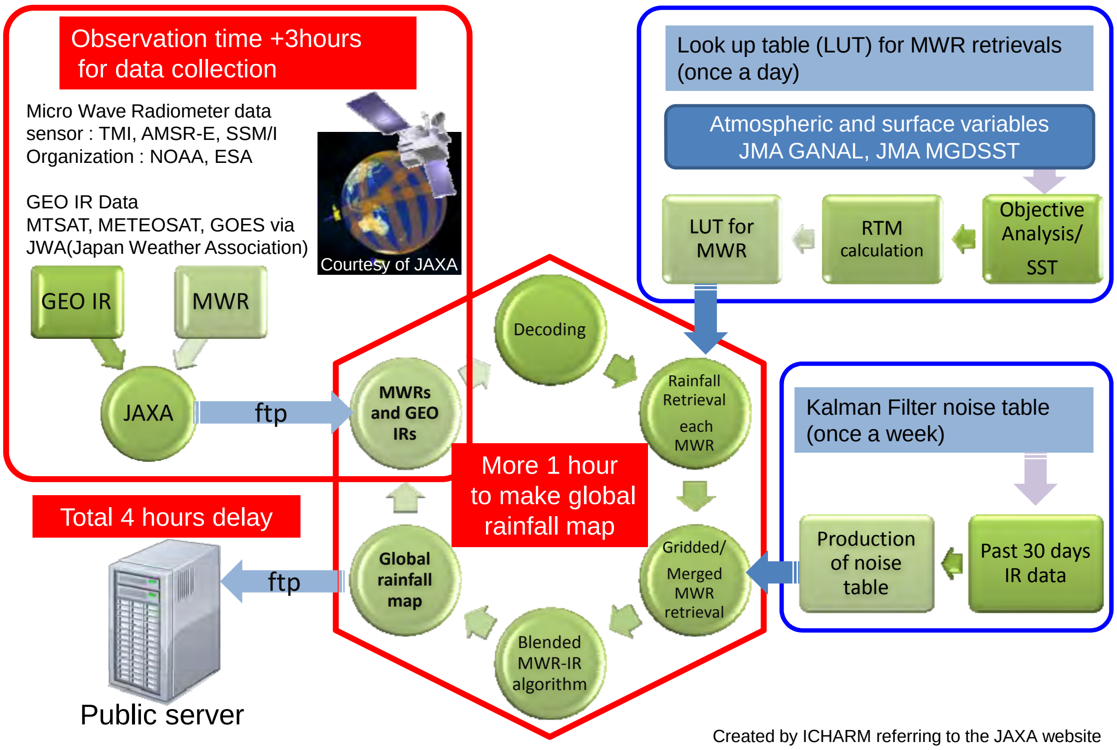


Figure 3.3.2 Data Processing of GSMaP_NRT

6. Development of real-time flood forecasting and warning systems
BBWS Solo Office currently observes rainfall every five minutes, and also sends data from ground observation stations to other public offices every hour by using the SMS (Short Message Service) signal for mobile phones. These five-minute sets of data are stored in a MySQL database and managed by the BBWS office. This way, it is possible to retrieve data by means of MySQL codes and produce various types of data set such as hourly data. The image of the real-time flood alert system is shown in Figure 3.3.3.

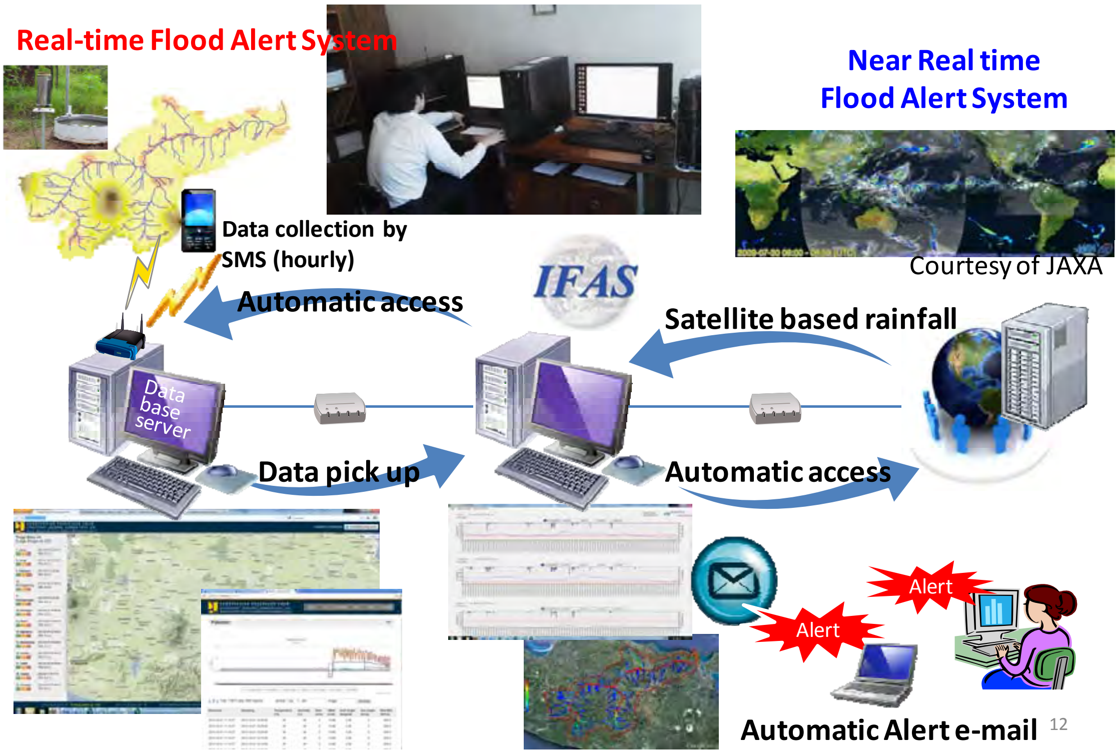


Figure 3.3.3 Real time/Near Real time Flood Alert System based on IFAS

6.1 Observation stations

Figure 3.3.4 shows electricity of SMS system with the observating stations along the Solo River. With a voltage controller controlling solar panels and batteries, the system works on power supplied from solar panels while sunlight is available and from batteries during night or while sunlight is not available. Each observation station is equipped with an SMS system capable of recording data every five minutes and sending 12 sets of data to BBWS Solo office every hour.

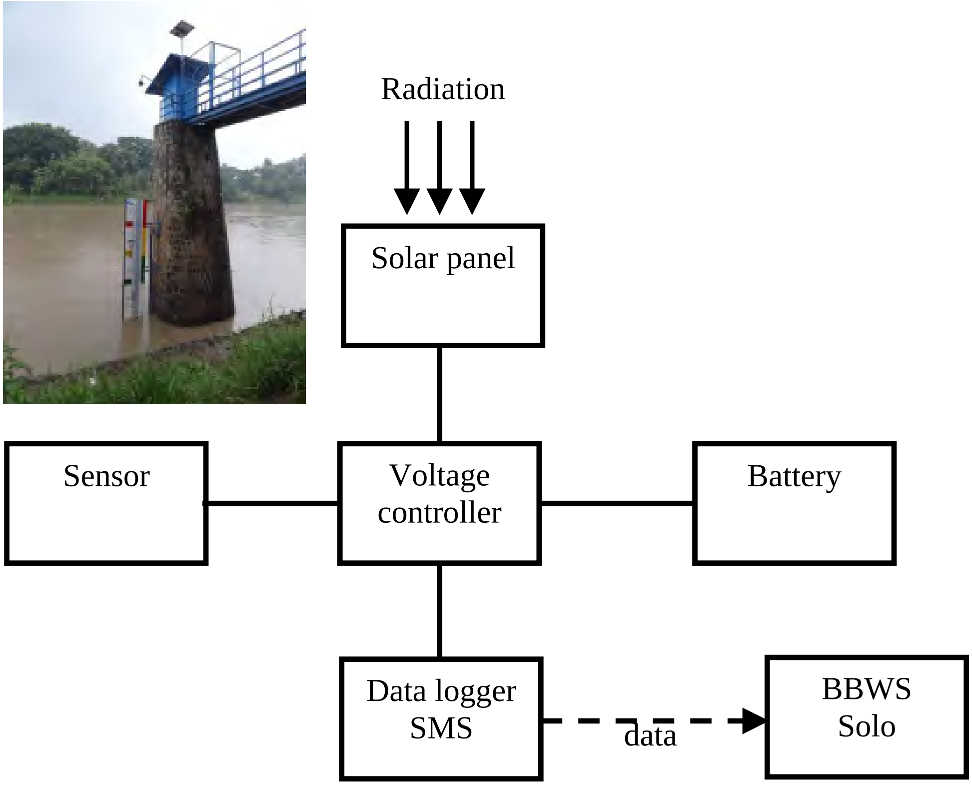


Figure 3.3.4 Electricity of SMS and gauging station

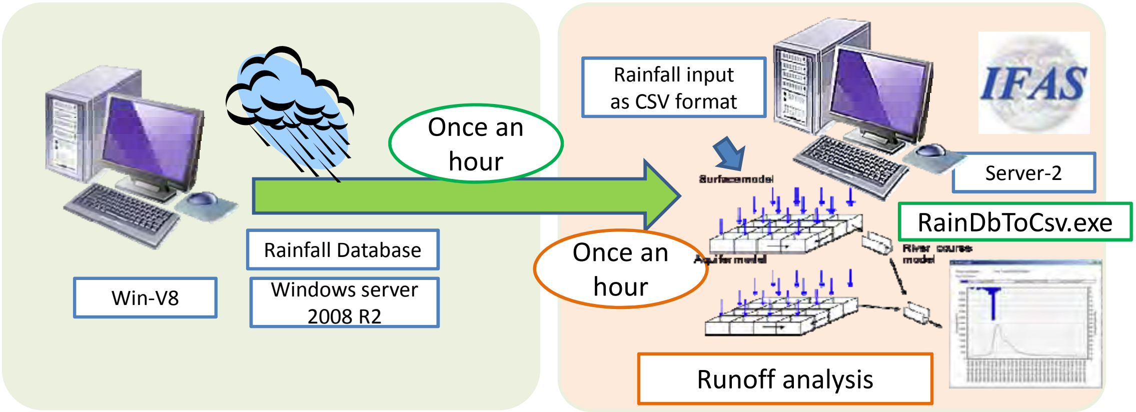
6.2 MySQL database

A MySQL database is used for this project. It stores various data sent from each observation stations by the use of the SMS signal for mobile phones, including rainfall, water levels, water quality and other meteorological measurements. Because this database is based on MySQL, it is possible to retrieve and process data by sending MySQL-based orders to the database.

6.3 Data transfer system

An ‘ini’ file is registered in the data transfer system. In this file is information written in the MySQL code, such as observation stations at which real-time data is stored, the locations of the stations, information on the type of data to be retrieved from the database, and equations for calculation. We developed a system to retrieve certain data from the MySQL database by inputting codes to process orders based on the pre-registered information.

This system enables users to write time-series rainfall data by observation station with location information in CSV format. Users can choose a time period for which they need rainfall data, and the system will produce hourly rainfall data automatically. The image of the data transfer system is shown in Figure 3.3.5.



Program name : RainDbToCsv
Related files : RainDbToCsv.exe（execution file）
MySql.Data.dll（Databese connection library）
settings.config（Setting file）

Database : MySql ver 5.5.16
Environment : Windows7(32bit/64bit),Window XP(32bit,SP3)
Development language : Visual Studio 2010 C#
Framework : .Net Framework3.5

Figure 3.3.5 Data transfer from database server to IFAS

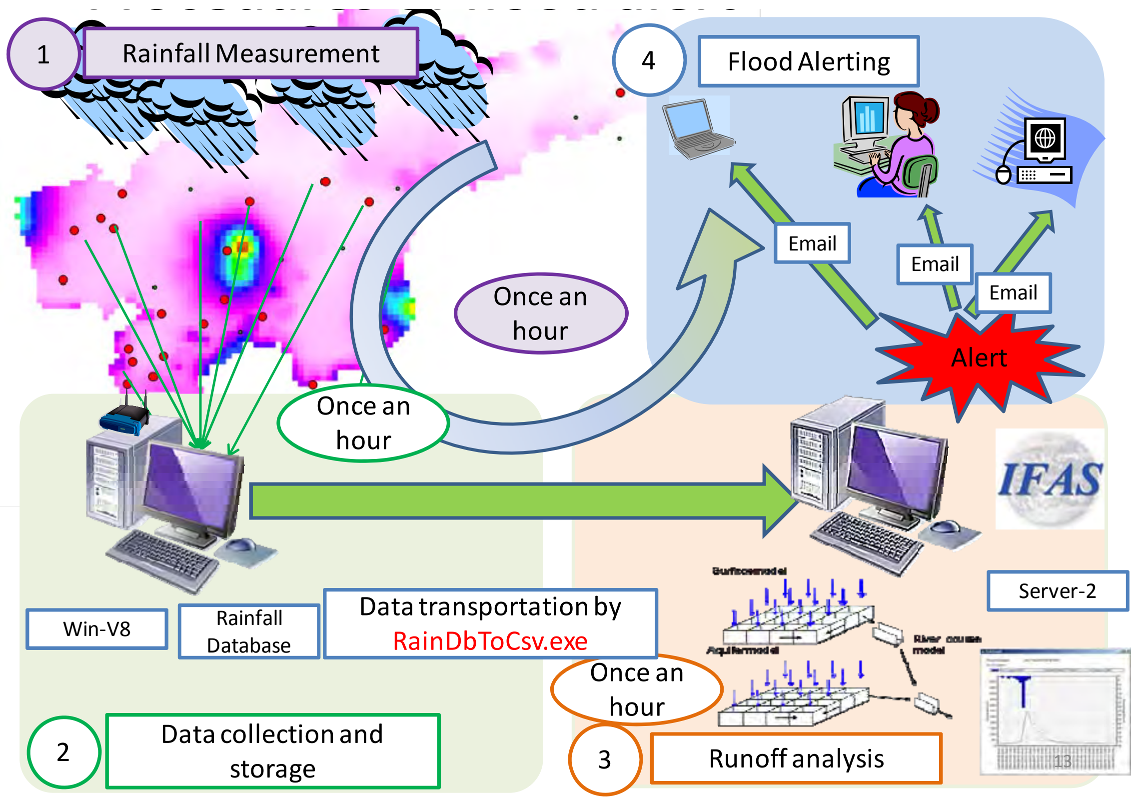


Figure 3.3.6 Real time operation of Flood Alert System

IFAS is designed to retrieve data from the CSV files by using script codes preinstalled in the AutoIFAS component. This function allows IFAS to input the latest hourly data to its runoff analysis model and output a hydrograph after analysis. If the estimated discharge reaches the predetermined threshold, IFAS will

display an alert message and send out an alert mail to registered mail addresses. Figure 3.3.6 shows the real time operation of flood alert system.

7. Conclusion

ICHARM developed Real time/Near real time Flood Alert System in Bengawan Solo river basin. Real time flood forecasting system has more accurate result compared with Near real time flood forecasting system as shown in Figure 3.3.7. But, real time hydrological observation is not conducted every hour. Because the electric power supply is not stable in Indonesia. Therefore, they use solar panel and battery for the power source. This is also the reason of unstable condition. If hydrological observation doesn't work well, BBWS can use satellite based rainfall data, instead of ground rain fall.

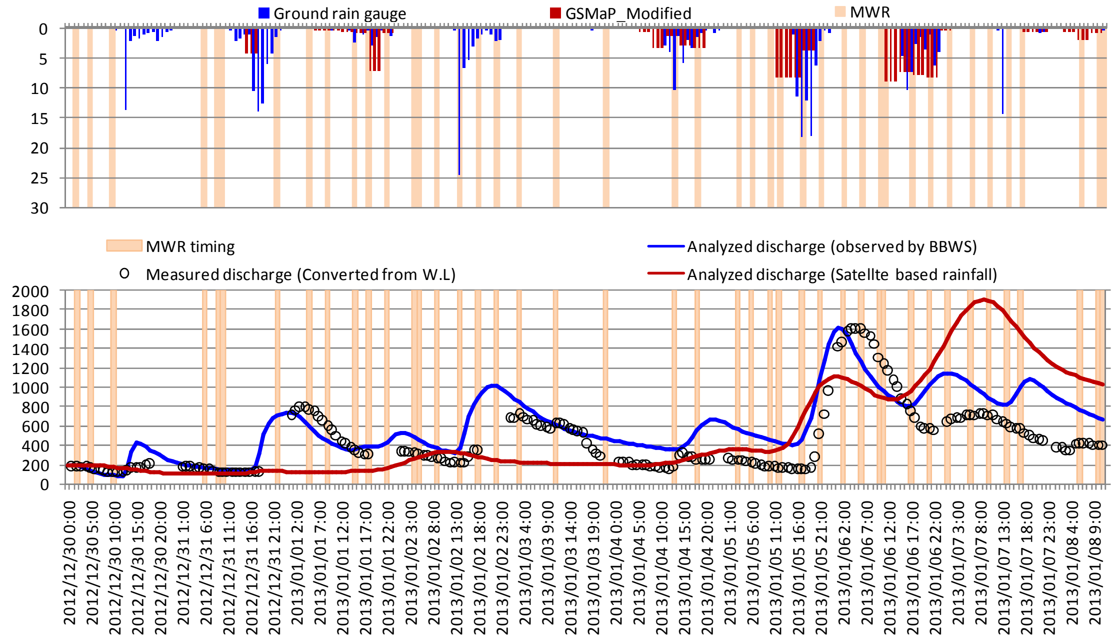


Figure 3.3.7 Analysis result

8. Discussion

ICHARM developed Real time/Near real time Flood Alert System in Bengawan Solo river basin. Followings are recommendations to keep accuracy of the analysis system based on IFAS stored in Flood Alert system.

- Accurate observation of rainfall, water level and discharge
- Collecting Wonogiri dam operation data
- Measurement of cross section and updating H-Q rating curve frequently.
- Electric power supply for gauging station should be maintained.
- Threshold of discharge data should be updated according to the H-Q rating curve revision
- Understanding the feature of satellite based rainfall for flood runoff analysis

And also ICHARM visited Bojonegoro area (KEDUNG SUMBER, SEMEN PINGGIR and BOGO VILLAGES) and the University of Gadjah Mada.

KEDUNG SUMBER
Objective: investigation the recent flash flood situation in relation with flood warning system, emergency response, damages and protection.
Visited Location: Sugihan Sub Village (flash food event location), Village Community Hall (data collection) and Pajeng Village (location of the rain gauge station).
Flood damages due to 4 Dec 2012 flood were investigated and also the performance of automatic SMS alert system were checked.

SEMEN PINGGIR and BOGO VILLAGES
Objective: investigating the recent flood situation and the community based flood disaster management activities.
Visited Location: Semen Pinggir Village and Bogo Village (pilot location of evacuation drill activity, July 2011).
There were no follow up community based flood disaster management after that evacuation drill activity conducted under ADB TA-7276 in July, 2011.

University of Gadjah Mada
Objective: meeting with Prof Legono to inform about the recent flash flood event at Kedung Sumber Village, community response and evacuation action, and discussion on the possible follow up action to maintain the community awareness on disaster management.
Proposal from UGM: to implement the MoU, there must be activities endorsed by both side (UGM and ICHARM) and other stakeholder (BBWS Bengawan Solo) as well.

The field trips mentioned above are reported in Annex 6.

RAIN GAUGE INSTALLED IN PAJENG BOJONEGORO

ICHARM collected information about rain gauge installed in Pajeng as a follow up activities. Pusair and Hydro6 revised the rain gauge system to let the rain gauge system be more effective after receiving rain gauge system from ADB.

1. Outline of rain gauge installed in Pajeng
    a. The rain gauge telemetry equipment which was installed in Pajeng Bojonegoro in July 2011, is for the purpose of supporting community based flood disaster management including capacity development in flood warning and evacuation system, under the arrangement made by ICHARM.
    b. ADB provisionally transferred the operation and maintenance of the rain gauge system equipment to the PUSAIR (Research Center for Water Resource, Ministry of Public Works of Indonesia) via ICHARM.
    c. The PUSAIR received over the authority and responsibility of operation and maintenance of this rain gauge system for two years since the effective date of this transfer. After that this responsibility will be transferred to the BBWS Bengawan Solo Office.

2. Specification of the system

a. Specification of the telemetry equipment:
- Type: Automatic Rainfall Recorder (ARR)
- Brand: Hydrotech Model HRG01
- Pick out area : 200 cm^2
- Pulse Resolution: 0.5 mm
- Sensor : Opto Coupler
- Framework Material: Metal-Stainless Steel
- Dimension: Diameter x b x h (16 cm x 30 cm x 62 cm)
- Type: Tipping Bucket, Compatible with telemetry agent..
- Able to measure the accumulation of precipitation on manually specified duration> 200 mm/day
- Calibrated with a two in one system.

b. Specification of the antenna:
- Type of Antena: YAGI Antenna
- External Modem
- Frequency: 800/900/1800/1900/2100 MHz
- At first, in July 2011, this antenna was installed without a pole, then due to slow news delivery (news received by users in 1 hour), in March 2012 an additional pole was installed, as high as 12 m (news received by users in just 2 minutes).

c. Cellular phone card: by XL-commindo provider

3. Installed area

a. The installation of the ARR in Pajeng village is for the purpose of early warning system to support community based flood disaster management including capacity development in flood warning and evacuation system, particularly for the safety of the Soko, Kedungsumber villagers, who are often devastated by flash floods in the rainy season.

b. Pajeng village is an ideal location to place the ARR, located in the upstream of Soko sub watershed, while it is approximately 5 km from the Soko, Kedungsumber village, which is located close to the Soko River in the downstream.

4. Operation of ARR and flood alert

a. The operator of the ARR is the head of Pajeng village; and the data is recorded automatically and then recorded manually by the operator, every morning at 07:00 AM, written in the daily logbook, and controlled on a monthly basis by PUSAIR.

b. Not only daily data, but also every 5 minutes data is actually received by the server of PUSAIR in Bandung, then processed and the results can be seen as real time data that can be accessed via internet at: http://www.tech4water.com/?cmd=viewlap&postreport=1&reptype=1&locselect=Pajeng&dasslct=B.Solo&wilselect=B.Solo&rainname=Desa%20Pajeng

c. The alarm recipients are:
- ARR operator
- Head of BPBD Bojonegoro
- Mr. Suryanto, Head of Soko Villagers Care for Flood
- 2 (two) other members of Soko Villagers Care for Flood
- Mr. Oky Subrata, PUSAIR Researcher in Bandung.

They receive the alarm message through mobile phone short messages (SMS)

d. The alarm is received when the rainfall more than 40 mm, which is used as a threshold, because the flash floods often occur in these conditions.

5. Threshold level of the rain gauge

The threshold of 40 mm is too high, and better should be lowered, in order to give more time to the villagers to get ready to pack up when they have to evacuate?
The point of 40 mm as a threshold may already be correct. But, setting of the recording and reporting that may should be improved Several times we tried to set the recording and reporting, to find the best one for the security of the villagers against flash floods, as follows:

a. Pusair and Hydro6 applied the settings by the method of "total sum with reset":
- The equipment is setup with a limit of per hour recording.
- In case of rainy days, the equipment will automatically record the amount of rainfall per hour.
- But, the previous hour record will be erased automatically, start with another new records beginning with zero in the next hour.
- At certain times of heavy rains, which could affect the occurrence of flash floods, there may be no SMS of alarm, because the record does not reach 40 mm, due to the previous record has been erased.

b. Pusair and Hydro6 applied the settings by the method of "total sum without reset":
- The equipment is still setup with a limit of per hour recording.
- In case of rainy days, the equipment will automatically record the amount of rainfall per hour.
- Equipment continues to record rainfall from hour to hour automatically.
- At certain times of light rains or drizzle for example in 3 hours duration or more, there may be an SMS of alarm, because the record reaches 40 mm, due to the previous record has not been erased, whereas thereis no incidence of flash floods at all.

c. Pusair and Hydro6 applied the settings by the method of "moving sum":
- The equipment is setup in every half hour, which is then be divided into every 5 minutes.
- The threshold for “each half hour”, determined by 20 mm rainfall.
- Recording is automatically continued to the next half hour, going forward every five minutes, but the earliest 5 minutes record is erased automatically.
- If within half an hour, rainfall reached 20 mm or more, then there will be sent “the first” alarm warning SMS.
- Rainfall continues to be recorded within the next 5 minutes.
- When within the next of half hours, there occurred another rainfall of 20 mm or more, then “the second” warning alarms sms is sent, because the total rainfall in one hour is equal to 40 mm or more, as the real threshold that could cause flash floods .
- However, when the second warning alarm sms is not coming, it means no more heavy rain, and there is no threat of flash floods.
- This “moving sum” method is to let the villagers have a chance an more time to get ready, if they need to evacuate.

3.3.4 Final Workshop on "Supporting Investments in Water-Related Disaster Management"

Objectives of the workshop
The objectives of the workshop are to share among ADB's developing member countries: (i) the outcomes and lessons learned of the TA; and (ii) the leading trends and activities on water-related disaster management in the world. The workshop will also provide a platform to discuss on critical issues as a way forward in water-related disaster risk management.

Participants
The total numbers of the participants were 36. Ms. Iglesias from ADPC and Mr. Mohanty from UN-ISDR were invited as resource persons, Mr. Mitsuhashi (ADB), Dr. Tanaka (ICHARM) and Mr. Yonezawa (Embassy of Japan in Philippines) made opening remarks.
Other participants are from Cambodia, Lao PDR, Thailand, Vietnam, Indonesia, Bangladesh (via TV conference system), Philippines, Tajikistan, Nepal, and ADB staff. List of attendance is attached in the Annex.

Outline
Explanation of Overall TA 7276-REG
The purpose of this presentation is to share the outcomes of TA7276-REG, Detail explanation of ICHARM's advanced technologies were explained in the key inputs of sessions.

Session 1: **Innovative Flood Forecasting**
Session purpose is to share the TA inputs and outcomes in developing a flood forecasting system in target countries and to discuss on their immediate and long-term impacts
As key inputs, ICHARM explained about SWOT-AHP analysis (Bangladesh component), IFAS (Indonesia component and Philippine component)
Panel discussion was made with members from BWDB, BBWS, PAGASA, ADB and ICHARM

Session 2: **Innovative Flood Vulnerability Assessment**
Session purpose is to share the TA inputs and outcomes in developing flood vulnerability indices for Cambodian flood plains and to discuss on their potential roles in development practices.
As key inputs, ICHARM explained about Flood Vulnerability Assessment Method in the case of the Cambodia floodplains.
Panel discussion was made with members of Cambodia, Lao PDR, Thailand, Vietnam, MRCS, ADB and ICHARM.

Session 3: Session purpose is to discuss on diverse problems and challenges of different DMCs and to find ways to share best practices from TA implementation and discuss on the way forward.
As key inputs, ICHARM explained about Water-Related Disaster Risk Indices.
Representative from Nepal and Tajikistan made presentations about recent flood experiences and lessons learnt and Water related disaster risk mitigation.
Panel discussion was made with members of ADPC, UN-ISDR, Nepal, Tajikistan and ADB.

Outcome
- All through the workshop, ICHARM could receive a general consensus that TA outcomes have provided large benefits for recipient countries. Especially, it was apparent

that ICHARM successfully accomplished activities in improving flood early warning systems, supplying innovative methods for community-based disaster risk management interventions, and even building local capacities. Therefore, it was concluded that it is now important to disseminate the obtained know-how to other agencies and more countries.

- Several countries, especially MRCS requested further technical assistances to ADB and ICHARM. The two organizations were then agreed to initiate earnest discussions on the new phase of the project.

- ADB members gave affirmative comments about TA outcomes. They asked ICHARM to submit the final report after taking into account what were discussed in the workshop. Besides, ADB suggested ICHARM’s participation in the Asian Water Week 2013 scheduled in March.

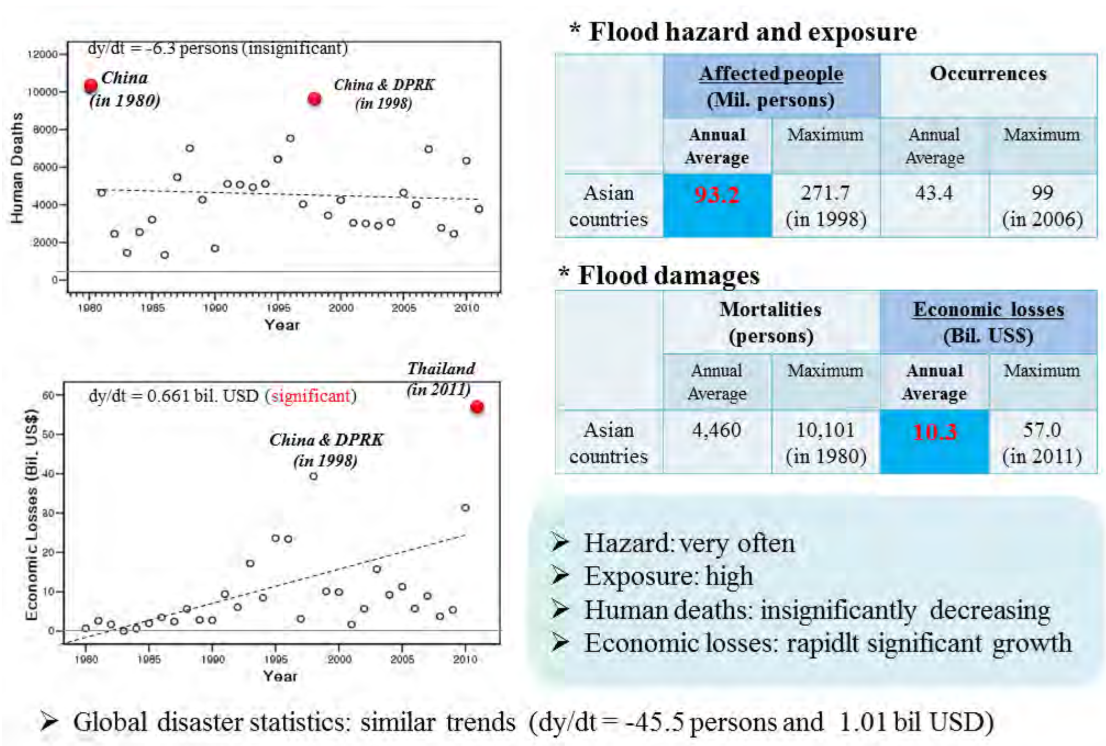
The detail descriptions of this workshop are described in Annex 7.

4. Development of Water-Related Disaster Risk Index

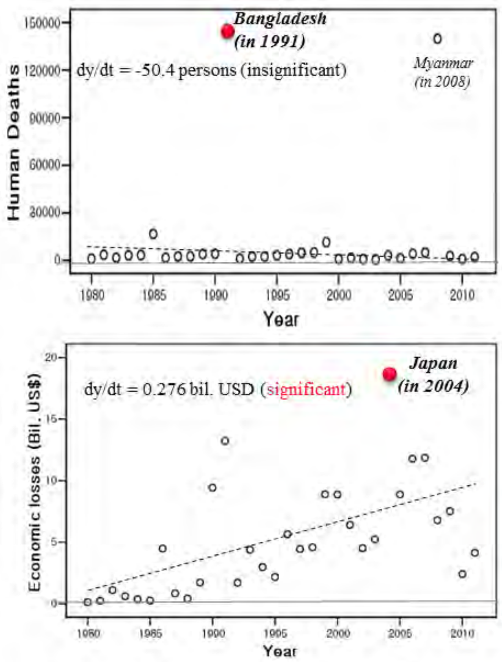
4.1 Introduction

4.1.1 Purpose of WRDRI development

Water-related disasters are the most common and widely distributed natural risks to life and property worldwide. Figure 4.1.1 shows the recent trends of water-related disasters in Asia. There is a strong need to identify countries to be effectively supported for enhancement of their risk management. The development of water-related disaster risk index (WRDRI) is an important pre-requisite for effective water-related disaster risk reduction, which is a one of the key activities enabling decision makers to assess the possible impacts of disasters. The purposes of the TA under this component are the development of better framework for supporting disaster risk management and the development of WRDRI methods for selected target countries. In particular, it should be clearly stated that WRDRI has a special interest in initiating global risk assessment at the national, and watershed basin levels, providing tangible risk indices so that relevant investments can be well guided, as depicted in Figure 4.1.2.



(a) Flood disaster



*** Storm surge hazard and exposure**

	Affected people (Mil. persons)		Occurrences	
	Annual Average	Maximum	Annual Average	Maximum
Asian countries	22.0	109.4	33.0	52.0

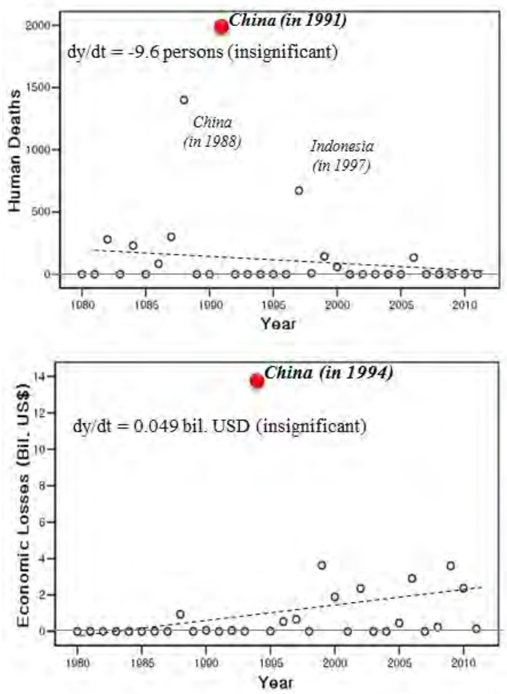
*** Storm surge damages**

	Mortalities (persons)		Economic losses (Bil. US$)	
	Annual Average	Maximum	Annual Average	Maximum
Asian countries	12,117	146,055 (in 1991)	5.15	18.8 (in 2004)

- Hazard: very often
- Exposure: concentrated on coastal regions (but including many big cities)
- Human deaths: largest, showing insignificantly decreasing, trends
- Economic losses: half of flood disasters

- Global disaster statistics: similar trends (dy/dt = -60.4 persons and 1.8 bil USD)

(b) Storm surge disaster



*** Drought hazard and exposure**

	Affected people (Mil. persons)		Occurrences	
	Annual Average	Maximum	Annual Average	Maximum
Asian countries	42.1	371.5 (in 2002)	3.4	13 (in 2000)

*** Drought damages**

	Mortalities (persons)		Economic losses (Bil. US$)	
	Annual Average	Maximum	Annual Average	Maximum
Asian countries	165.9	2,000 (in 1991)	1.1	13.9 (in 1994)

- Hazard: infrequently
- Exposure: widely affecting people if it happens,
- Human deaths: uncommon, except for few countries, showing decreasing trends
- Economic losses: considerable if it happens

- Global disaster statistics: similar trends (dy/dt = -22.0 persons and 0.052 bil USD)

(c) Drought disaster

Figure 4.1.1 Trends of water-related disasters in Asia[1]

1 Data sources: UN-ISDR PreventionWeb

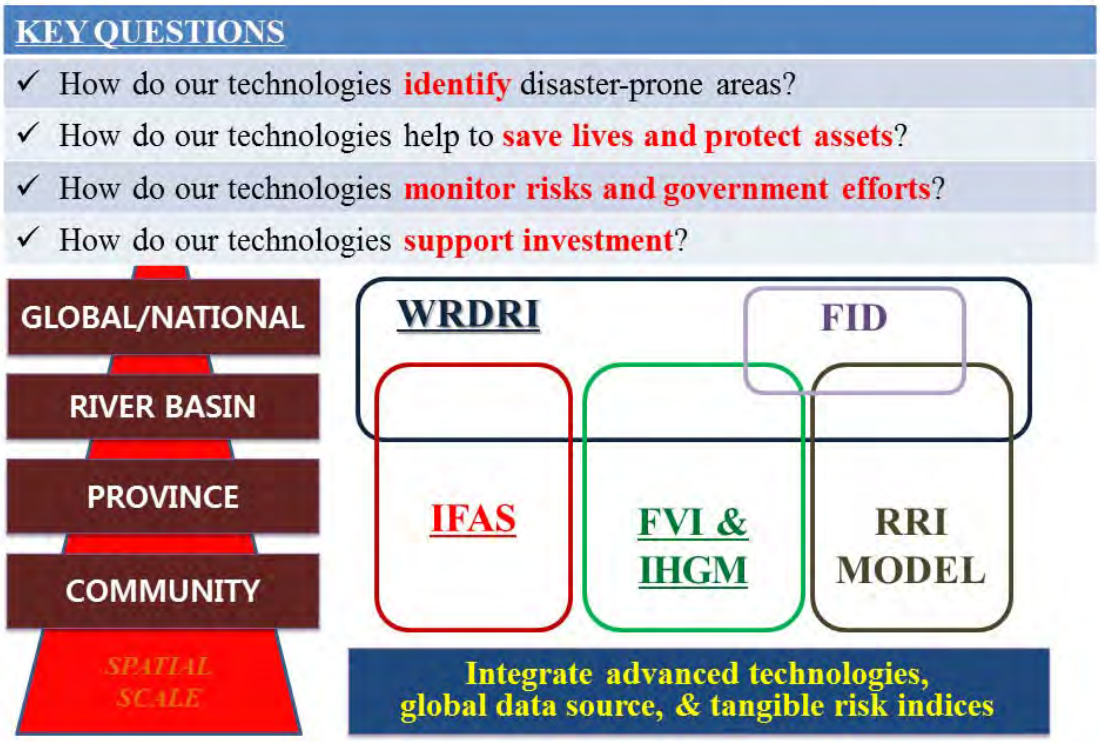


Figure 4.1.2 Summary of purposes

4.1.2 Scope of work

In recent years, numerous dataset and documents concerning disasters are sorted out and compiled, but such activities are often interrupted due to limited availability of country data and historical data of disasters. At present, the four databases such as EM-DAT of CRED, NatCat of Munich Re, Sigma of Swiss Re, and the Global Archive of Large Flood Event of the Dartmouth Flood Observatory, are primarily used when UN organizations or scientists estimate global disaster risk indices. For example, the Global Assessment Report (UN-ISDR, 2009; 2011), the UNEP-GRID Global Risk Data Platform, the World Risk Report (UNU-EHS, 2011), and the Natural Disaster Hotspots: A Global Risk Analysis (World Bank, 2006a; 2006b). Despite many efforts in producing these indices by individual organizations, the figures shown in these indices are not satisfactorily reliable because the used data are neither officially provided by national authorities (UNESCAP and UNISDR, 2010), nor often fully calibrated. No evaluations are available, neither, based on reproduction of flooding, inundation, nor water deficiency events on a basin basis.

4.1.3 ICHARM capability

For development of WRDRI in the TA, ICHARM can reproduce real water disaster situation by newly introducing ICHARM's advanced GIS-based, satellite-based and innovative technologies to overcome data unavailability. ICHARM has actively involved in research, training and information networking in an integrated manner. It promotes a wide range of activities, including local studies to realize an appropriate flood-risk management cycle, the development of a satellite-based flood forecasting system, research on flood risk assessment and adaptation strategies to cope with possible global climate change. ICHARM has a lot of experiences and capacity to develop satellite-based technologies and manipulate the

Geographical Information System (GIS) data for water-related disaster management. It also has a Block-wise TOP (BTOP) model to calculate the river runoff in the river basin globally and also has the Rainfall Runoff Inundation (RRI) model and the Flood Inundation depth (FID) model to identify flood inundation areas with due consideration of geographical attributes. By integrating these advanced technologies, and satellite-based data, flood risk index has been developed for Asia-Pacific Region. Also in Lower Mekong Basin, ICHARM has developed flood vulnerability indices in the Cambodian flood plains, using the ICHARM Hydro-Geo Method (IHGM). In KAKUSHIN project, the climate change impacts on flood disaster risk were conducted over the globe and specific vulnerable areas, and at the same time risk reduction measures were seriously evaluated. All these experiences and capacity of ICHARM are the strengths for development of WRDRI in the effective way.

4.2 Target Countries for WRDRI Development

The Water-Related Disaster Risk Index (WRDRI) has been developed for selected ADB-DMCs. At the beginning, it was intended to develop WRDRI on the basis of five Asian countries including Bangladesh, Cambodia, Indonesia, Nepal, and Philippines. However, due to some difficulties in data collection, ICHARM has just been provided with data of Nepal and Philippines. Thus, the two countries were selected as targets of this study. Nepal and Philippines are commonly in Asian monsoon region. The annual cycle of the Asian monsoon system has been customarily divided into two distinct phases such as wet and dry phases. The Asian monsoon region assumes the most distinct variation of the annual cycle and the alternation of dry and wet seasons which is in contact with the seasonal reversal of the monsoon circulation features (Qian, 2000; Ding and Sikka, 2006). The wet season in general begins from May and ends in October, and the dry season begins from November to April of the next year. However, for different parts of the Asian monsoon region, the durations of dry and wet seasons may be different, depending on their climate regions and the degree of effect of the Asian monsoon (Ding and Sikka, 2006). Thus, the targeted countries for the development of WRDRI are selected from different parts, for example the country Nepal is selected as an inland part and the Philippines is selected as an island part.

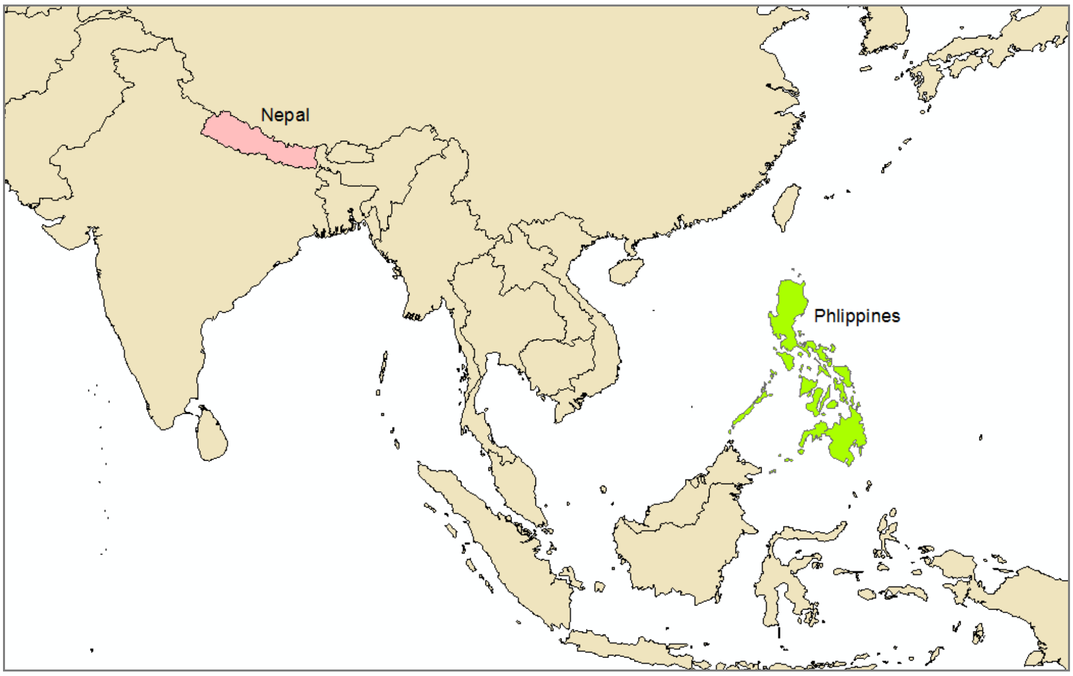


Figure 4.2.1 Locations of Nepal and Philippines

4.2.1 Nepal: an overview

Nepal is a landlocked country situated in South Asia, between China in north and Indian in South. The total area of the country is about 147,181 km^2. The total population of Nepal as of the census date (June 22, 2011) is about 26,494,504[2]. The annual precipitation of the country is about 1,500mm/year[3],and the gross domestic product of the country is about 18.88 billion US$[4]. Nepal has a variety of geographical conditions from the Terai Plain to the Himalayan high mountains, and from very dry to wet areas, and very steep hydraulic conditions (Sharma, 2009). Nepal has heavy monsoonal rain during June to September and relatively weak geological formation. Therefore, water-related disasters are associated with landslides and debris flows in high and mid-mountain areas, sediment deposit and bank erosion in lower mountains and upper plain areas, and bank erosion and flooding in lower plain areas. Figure 4.2.2 shows the major river basins in Nepal. The distribution of mean annual precipitation in Nepal is shown in Figure 4.2.3. Table 4.2.1 and Table 4.2.2 show the biggest water-related disasters on the bases of affected people and economic damage, respectively. In Nepal, floods occur every year and cause catastrophic properties damages and loss of lives. Figure 4.2.4 shows the economic loss and number of affected people in Nepal from 1970-2011. There were also drought and storm disasters in the past. The detail information of past disasters is shown in Annex 8.

[2] Central Bureau of Statistics, Government of Nepal
[3] http://www.fao.org/nr/water/aquastat/data/wbsheets/aquastat_water_balance_sheet_npl_en.pdf
[4] World Bank, http://data.worldbank.org/country/nepal

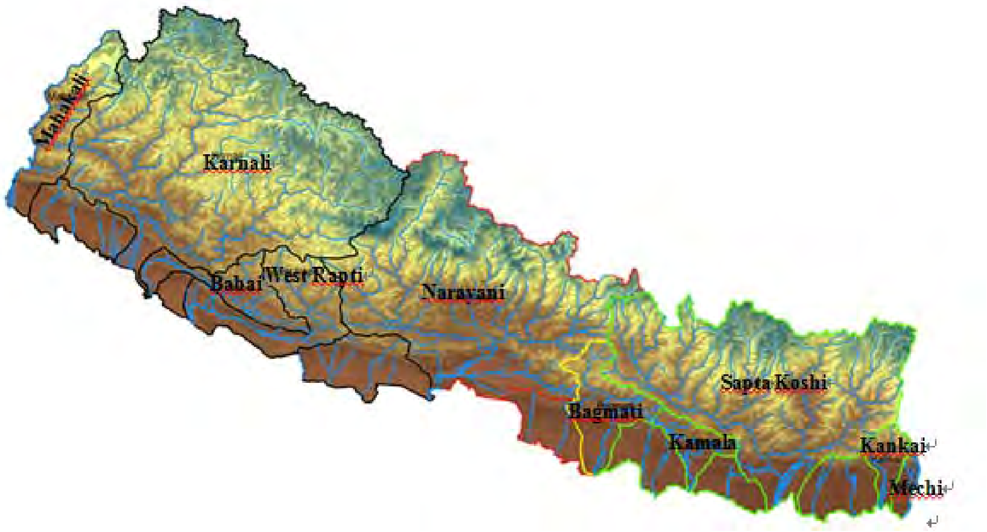
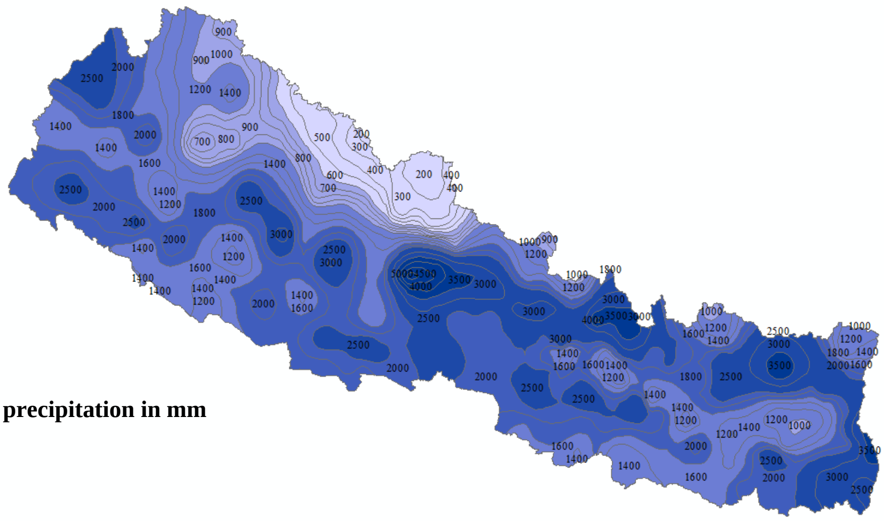


Figure 4.2.2 Major river basins in Nepal[5].



Mean annual precipitation in mm

Figure 4.2.3 Distribution of mean annual precipitation in Nepal.[6]

Table 4.2.1 Biggest water-related disasters shorted based on affected people[7]

Disaster Type	Date	Affected People
Drought	1979	3,500,000
Drought	1972	900,000
Flood	5/7/2004	800,015
Flood	23/07/2007	640,706
Flood	23/08/1993	553,268
Flood	Aug-87	351,000
Drought	2009	303,000
Flood	4/10/2009	257,786

[5] Rajkarnikar, G.: Flood disaster risk management in Nepal, a Knowledge Sharing Workshop on water-related disaster management, Joint Workshop of WECS, DWIDP, ICHARM and ADB, Kathamandu, Nepal, January 2012.

6 Data source: Department of Hydrology and Meteorology, Nepal

7 Data Source: EM-DAT

Table 4.2.2 Biggest water-related disasters shorted based on damage[8]

Disaster	Date	Damage (1000 US$)
Flood	Aug-87	727500
Flood	23/08/1993	200000
Flood	4/10/2009	60000
Flood	4/7/1998	22000
Flood	Sep-83	10000
Drought	1972	10000
Flood	Jun-00	6300

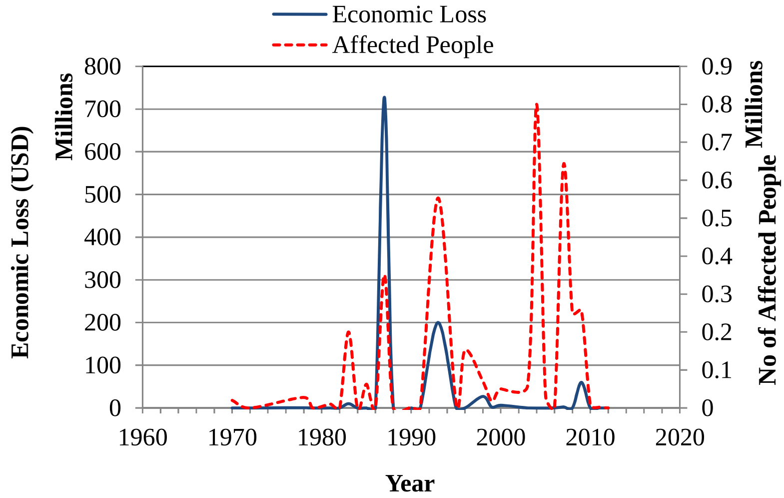


Figure 4.2.4 Economic losses and number of affected people caused by floods in Nepal from (1970 -2011)[9]

4.2.2 The Philippines: an overview

The Philippines is a country composed of about 7,100 islands, and located in the boundary of the Eurasian Plate and the Filipino Plate. The total area of the country is about 299,404 km^2 and the total population of the Philippines as of the census year 2010 is about 92,337,852[10]. The gross domestic product of the country is about 224.8 billion US$[11]. The annual precipitation of the country is about 2,348 mm/year.[12] The Philippines is a typical example of a tectonic zone with very vulnerable geology, showing many volcanos and earthquakes. Besides, the Philippines is very close to the North-West Pacific Ocean where a lot of typhoons are generated every year and is just under the Inter-tropical Convergence Zone with the northeast and southwest monsoons. Therefore, the Philippines, has lots of natural hazard sources, including floods, drought, storm surge, landslides, etc. Figure 4.2.5 shows the major river basins in the Philippines. The season rainfall distributions in the Philippines are shown in Figure 4.2.6. Figure 4.2.7 shows the flood and storm prone areas in the Philippines. Table 4.2.3 and Table 4.2.4 show the biggest water-related disasters based on affected people and damage, respectively. The floods, drought and storm are serious problems in the Philippines and often cause catastrophic properties damages and loss of lives. Figure 4.2.8 and Figure 4.2.9 show the economic loss and number of affected people caused by floods and storm

8 Data Source: EM-DAT
9 Data source: EM-DAT
10 National Statistics Office, Republic of the Philippines
11 World Bank, http://data.worldbank.org/country/philippines
12 http://www.fao.org/nr/water/aquastat/data/wbsheets/aquastat_water_balance_sheet_phl_en.pdf

respectively in the Philippines from 1970-2011. The detail information of past disasters is presented in Annex 8.

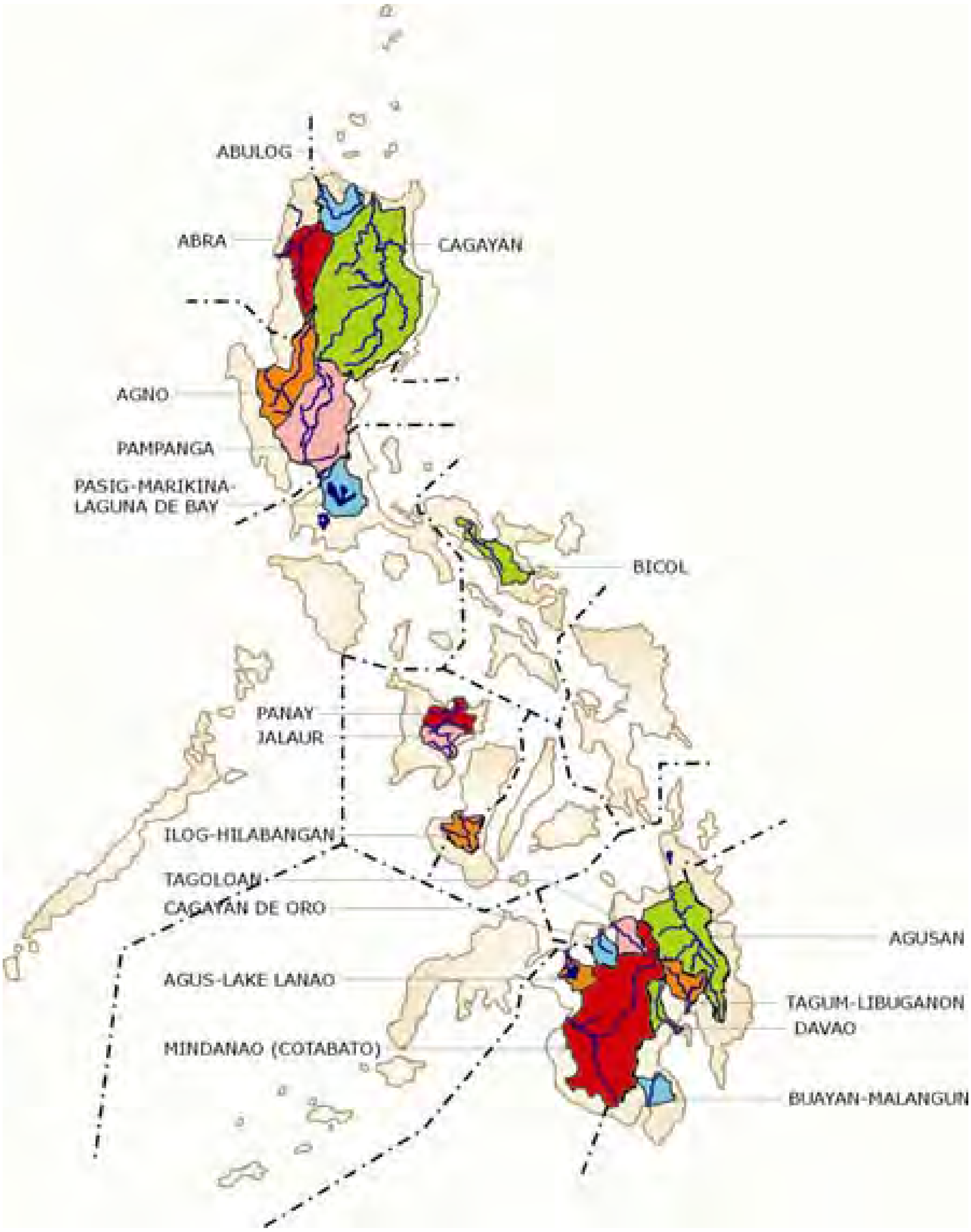


Figure 4.2.5 Major river basins in the Philippines[13].

13 Data source: PAGASA (Philippine Atmospheric, Geophysical and Astronomical Services)

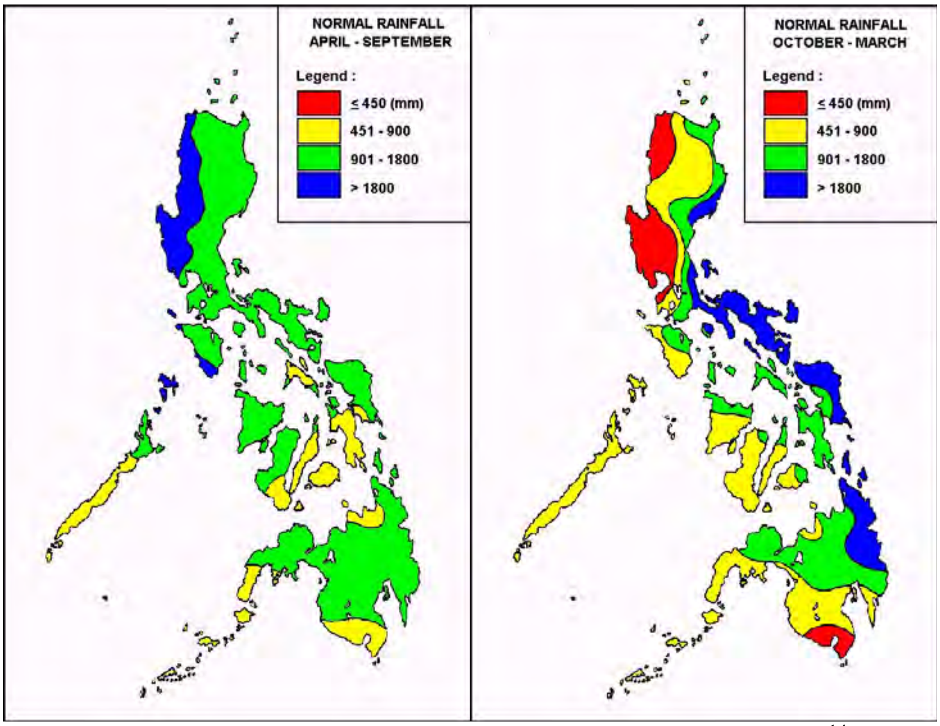


Figure 4.2.6 Season rainfall distribution in the Philippines[14].

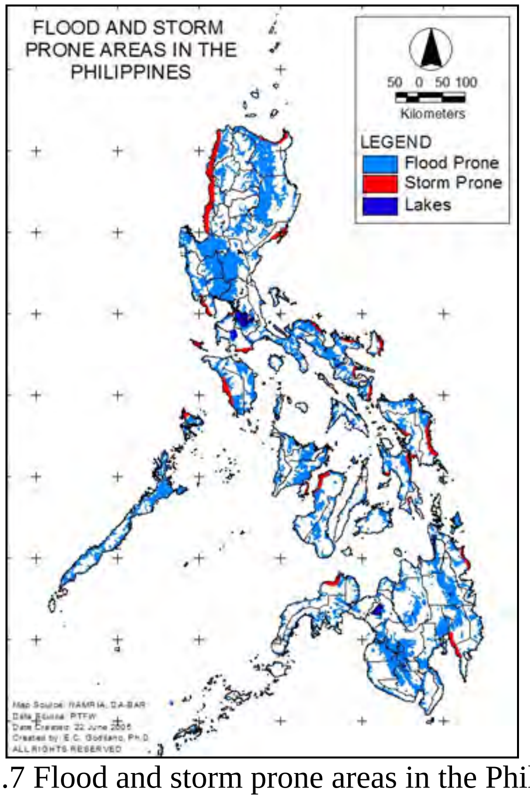


Figure 4.2.7 Flood and storm prone areas in the Philippines[15].

14 Data source: PAGASA (Philippine Atmospheric, Geophysical and Astronomical Services)
15 Data source: PAGASA (Philippine Atmospheric, Geophysical and Astronomical Services)

Table 4.2.3 Biggest water-related disasters shorted based on affected people[16]

Disaster Type	Date	Affected People
Storm	12/11/1990	6,159,569
Storm	24/09/2009	4,901,763
Storm	21/06/2008	4,785,460
Storm	29/09/2009	4,478,491
Flood	6/8/2012	4,451,725
Storm	21/10/1998	3,902,424
Storm	27/09/2006	3,842,406
Storm	20/11/1973	3,400,024
Storm	21/10/1988	3,250,208
Storm	24/09/2011	3,030,846

Table 4.2.4 Biggest water-related disasters shorted based on damages[17]

Disaster Type	Date	Damage (1000 US$)
Flood	4/9/1995	700,300
Storm	29/09/2009	585,379
Storm	12/11/1990	388,500
Storm	24/09/2011	344,173
Storm	21/06/2008	284,694
Storm	18/10/2010	275,745
Storm	3/11/1995	244,000
Storm	21/10/1988	240,500
Storm	24/09/2009	237,489

16 Data source: EM-DAT
17 Data source: EM-DAT

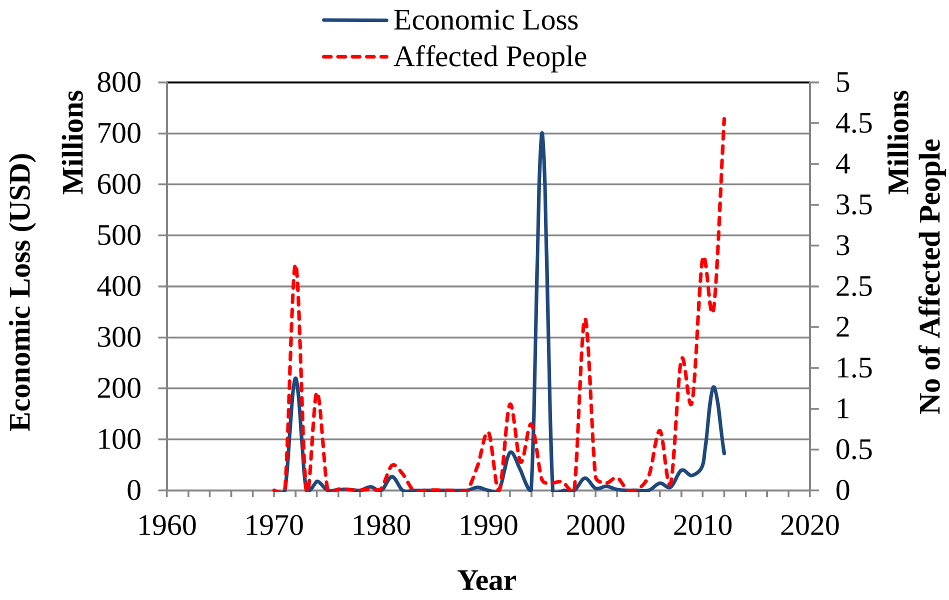


Figure 4.2.8 Economic losses and number of affected people caused by floods in the Philippines from (1970 -2011)

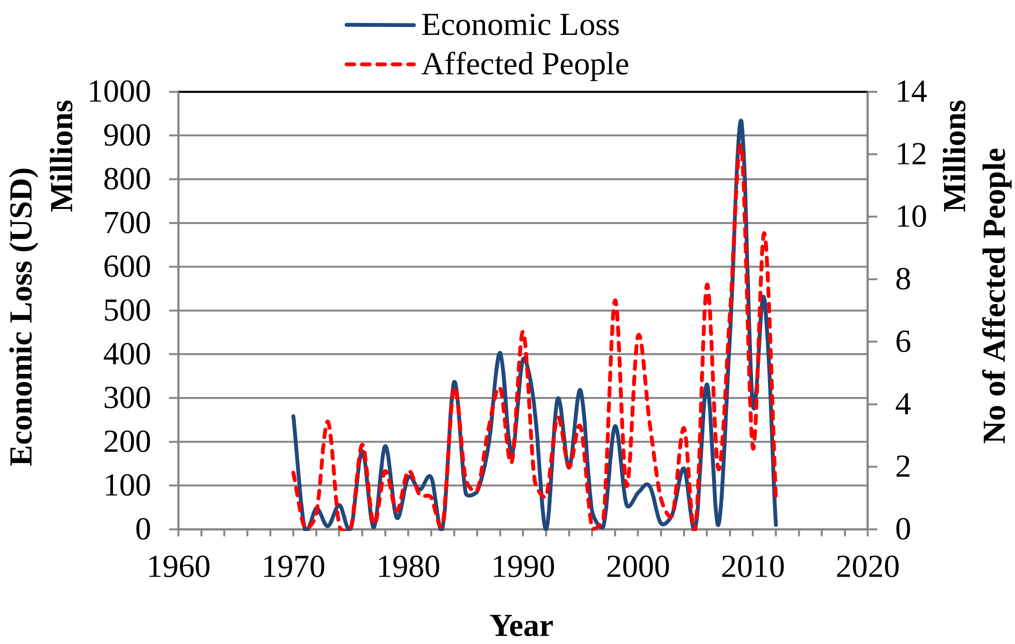


Figure 4.2.9 Economic losses and number of affected people caused by storm in the Philippines from (1970 -2011)

4.3 Previous Studies: Development of WRDRI

From the early of this century, water-related disaster risk reduction has been globally becoming a common goal. Starting from the year 2000, eight Millennium Development Goals (MDGs) were agreed by 191 nations, the UN International Strategy for Disaster Reduction (UN-ISDR) was established as the successor to the United Nations International Decade for Natural Disaster Reduction (UN-IDNDR), which aimed at improving the awareness of

disaster risks, environmental sustainability were seriously discussed in the World Summit on Sustainable Development, held in Johannesburg, 2002. Furthermore, the Hyogo Framework for Action (HFA) was declared by 168 UN-member countries at the World Disaster Reduction Conference in 2005, which have been compiling and updating strategic directions to reduce disaster risks.

Once the inter-governmental organizations and resolutions were established, they largely raised the needs for practical, but policy-neutral sciences. It is because there were no scientifically acceptable methods - including viewpoints, models, data collection, and applications of risk indices. At this moment, most stakeholders and experts feel keenly the necessity of improving those methods. That is mostly because following questions have been suddenly exploding, and thus should be solved before it will be too late.

- How should we identify disaster-prone areas?
- How should we provide information necessary to save lives and project assets?
- How should we provide information necessary to support investment?
- How should we monitor risks and governmental efforts?
- And how should we communicate our knowledge with non-professionals, and so on.

Consequently, great efforts to develop risk indices have been given by a number of organizations including UN-affiliated organizations, international development banks, colleges, and research institutes. Included in such efforts are the Disaster Risk Index (UNDP, 2004), the Synthesis Report of the Natural Disaster Risk Hotspot (World Bank, 2006a; 2006b), the Global Assessment Reports (ISDR, 2009; 2011), the Global Risk Data Platform (UNEP-GRID), the World Risk Report (UNU-EHS, 2011). Table 4.3.1 shows the list of representative disaster risk indices, all of which were commonly developed with a strong ambition of well identifying the disaster risk, and making contributions to solving the above questions[18].

Of course, it is not difficult to find other organizations and individual scientists developing water-related risk indices. Nevertheless, this section only introduces three types of risk indices, as highlighted in the list of Table 4.3.1. It is on the one hand because they adopted prevailing or widely accepted methods to the water-related disaster risk assessment. On the other hand, four indices needed to be reviewed, as they were developed as an attempt to suggest a prototype of the global-scaled risk assessment methods. Thus, each report has its own ideas, at the global scale, about how to generalize viewpoints, risk assessment models, data collection, and applications of risk indices.

18 In fact, ICHARM also developed a global-scale risk assessment index through the Asian Water Development Outlook 2010 – Key Dimension 5, supported by the ADB. however, the results were not officially published yet, and thus this study does not review the index

Table 4.3.1 List of representative water-related disaster risk indices

Development year	Main organization	Index (or project) name	Hazards of concern
2004	UNDP Bureau for Crisis Prevention and Recovery	Disaster Risk Index “World Vulnerability Report”	Earthquake, cyclone, flood, & drought
2005	Global Water System Project	Water Wealth Index	Water (in)security
2006	World Bank	Natural Disaster Risk Hotspots	Cyclones, flood, drought, landslide, earthquake, & volcano
2009	UNISDR	“2009 Global Assessment Report”	(1) Weather-related hazards: cyclones, floods, landslides, etc. (2) Other hazards: earthquakes, drought, tsunamis, fires
2011	UNISDR	“2011 Global Assessment Report”	(1) Weather-related hazards: cyclones, floods, landslides, etc. (2) Other hazards: earthquakes, drought, tsunamis, fires
2011	UNU-EHS	World Risk Report 2011	Earthquakes, storms, floods, droughts and see level rise

* The highlighted indices were chosen for literature review in this section.

4.3.1 UNDP: Disaster Risk Index (DRI)

(1) Backgrounds

The UNDP has played a central role in implementing the International Strategy for Disaster Reduction (UN-ISDR). Especially, it seeks to improve the current development process, addressing the chronic problem that disaster loss continues to jeopardize the achievement of the Millennium Development Goals (MDGs). In 2000, the UNDP and many groups of experts thus came together for in-depth discussions on integration of the disaster reduction and MDGs. After a series of extensive studies, they finally published a global synthesis report in 2004, which introduced its risk assessment model and collected data, showed global-scaled applications, and further suggested the future disaster risk reduction strategies from the MDGs context. Purposes of this report are expressed, as follows:

- Create a quantitative measure allowing for comparison of disaster risk between countries exposed to selected hazards – using the generally acceptable methods
- Additionally, investigate the way the current development influences disaster risk and vulnerability

In spite of growing demands to integrate development policy and disaster risk management, large methodological challenges remain to be addressed. Of a special concern was how to

build the DRI in order to demonstrate how the current development contributes to the configuration of risk and vulnerability. It was expected that the DRI could illuminate the reorientation of development policy and planning, and make great contribution to disaster risk reduction and management. As a conclusion, it is well acknowledged that the UNDP team and a group of scientists made a successful first step toward the development of the risk assessment method. In particular, the suggested method, DRI, is generally viewed as scientifically acceptable, and receives relatively high confidences. It should be also noted that the DRI was proposed as a prototype. As mentioned by the team, it showed unsatisfactory performances in evaluating drought disaster risk, and raised many further studies, mainly to incorporate more human-induced risk drivers into the model.

(2) Selected hazard types and study sites

The DRI was developed to analyze earthquake, cyclone, flood, and drought risks. According to the first purpose, i.e. comparison of disaster risk between countries, DRI was assessed at the national level.

(3) Basic concepts of global risk assessment

The report assumed that risk is measured in terms of the probable mortalities, and a function of physical exposure, and vulnerability. It was also strongly stated that the relation of risk components should be validated statistically, rather than presumed normatively as in many other studies.

$$R = f(PhExp, V) = PhExp \times V \quad (1)$$

R the number of persons killed by a certain type of hazard (persons)

PhExp the physical exposure, implying population living in exposed areas multiplied by the frequency of occurrence of the hazard (persons)

V vulnerability index (dimensionless)

Physical exposure was viewed as the average number of people in a country who are affected by a natural hazard. The physical exposure was first estimated at the smaller level, i.e. watershed or grid-scaled level. Then, it was aggregated to the national level, using the following equation.

To seriously consider the different characteristics in the different hazards, it was necessary to use the different ways to estimate physical exposure at the smaller level, between flood and drought. Hence, physical exposures of flood and drought were individually calculated as follows:

Physical exposure – flood

i) Identify the watershed basins affected for the period 1980-2000 (in the EM-DAT database), and their frequencies.
ii) Disaggregate the watershed to follow country borders, and then calculate affected population.
iii) Multiply the population by the event frequency.
iv) Aggregate the results to country level, i.e., an annual average of physical exposure of a country to a flood.

Physical exposure - drought

i) Presume that drought occurs in the grid when the amount of precipitation accumulated over 3 months is less than 50% of the median, i.e., a simplified indicator of Standardized Precipitation Index (SPI).
ii) Compute, for each calendar month, the median precipitation for all grid points over the base period 1979-2001 (using the IRI data library).

iii) Compute, for each grid point, the percent of the long-term median precipitation for every month for the period 1980-2000.
iv) Compute, for each grid point, the total number and frequency of events during the period 1980-2000, using the assumed drought criteria.
v) Calculate, for each grid point, the population multiplied by frequency (using the population data of GPW ver.2)
vi) Aggregate the results to country level, i.e., an annual average of physical exposure of a country to a drought

To gain the insights about integration of disaster risk reduction (DRR) and Millennium Development Goals (MDGs), the UNDP team attempted to analyze vulnerability index and its factors (or risk drivers) in a rigorous and stepwise way. To this end, the DRI methods were divided into the relative vulnerability (one-dimension vulnerability) model and the multi-dimension vulnerability model. In the one-dimension vulnerability model, risk assessment has a focus on empirically inferring the magnitude of vulnerability that each country has for a certain hazard. Therefore, vulnerability index was simply estimated by dividing the number of people killed (mortalities) by the number of people exposed (physical exposure).

$$R = PhExp \times V \quad \leftrightarrow \quad V = R / PhExp \qquad (2)$$

In the multi-dimension vulnerability model, the UNDP team attempted to identify a set of human-induced risk drivers influencing vulnerability index. the UNDP formulated the logarithmic multi-regression models, and tried to incorporate many socio-economic proxies, known as relevant to vulnerability, into the model. Especially 10 and 19 proxies were respectively used for drought and flood risks, and analyzed for statistical significances. Finally, this stepwise approach was illustrated to be useful in obtaining risk assessment models that include human-induced risk drivers in the scientifically acceptable manner.

$$R = C \times (PhExp)^{\alpha} \times V_1^{\alpha_1} \times V_2^{\alpha_2} \times \cdots \times V_p^{\alpha_p} \qquad (3)$$

C the multiplicative constant

V_i the socio-economic variable

α_i the exponent of Vi , which is positive, or negative

For the one-dimension vulnerability, the number of people killed (EM-DAT records) and the number of people exposed (estimated using the hydrological database) were compared for each country. For flood vulnerability, it was easily found that there is a certain trend line between the number of people killed and the number of people exposed. This means that many of countries have the relatively similar vulnerability to flood hazards. The exceptions are Venezuela, which was shown as the country with highest vulnerability, and Germany and other highly developed countries, which were viewed as very successful in controlling flood risks. For drought vulnerability, many of countries have a slope of zero in the graph where the horizontal axis is the number of people exposed and the vertical axis is the number of people killed. This implies that fatal accidents did not well occur during drought events. Of course, these results might be attributed to low vulnerability of many countries. However, deaths were manifested, mostly in the African countries where people are suffered from serious conflicts, wars, dictatorship, or poor governance, not simply from drought. Therefore, the results are showing the clear evidence that meteorological drought does not necessarily lead to human deaths even in developing countries. After a series of statistical analyses, the multi-dimension vulnerability model resulted in the following equations for flood and drought risk assessments, respectively.

- Flood risk calculation equation:

$$\ln(R) = 0.78\ln(PhExp) + 0.45\ln(GDP_{cap}) - 0.15\ln(D) - 5.22 \qquad (4)$$

GDP_{cap} the normalised Gross Domestic Product per capita

D local population density

- Drought risk calculation equation:

$$\ln(R) = 1.26\ln(PhExp) - 7.58\ln(WAT_{TOT}) + 14.4 \qquad (5)$$

WAT_{TOT} % of population with access to improved water supply

As a whole, it was well illustrated that the model structure and risk drivers were properly selected to build statistical risk models, in that the coefficients of determination are relatively high, R-Sq of 0.69 and 0.78. Moreover, it was clearly shown that flood vulnerability is dependent on economic capabilities (GDP per capita) and population density, while drought vulnerability is closely related to provision of water supply infrastructure.

4.3.2 World Bank: Natural Disaster Hotspot

(1) Backgrounds

The World Bank voluntarily initiated discussions on a global-scale, multi-hazard risk analysis, after establishing the Center for Hazards and Risk Research (CHRR) at Columbia University. To implement the Global Natural Disaster Risk Hotspots project, the World Bank organized the umbrella of the ProVention Consortium including the World Bank, the Columbia University, the Center for International Earth Science Information Network (CIESIN), the International Research Institute for Climate Prediction (IRI), and the Lamont-Doherty Earth Observatory (LDEO). Moreover, this project was provided with technical supports by the Norwegian Geotechnical Institute (NGI), the U.S. Geological Survey (USGS), and many UN organizations such as UNDP, UNEP, OCHA, WFP, and ISDR. The purposes were mentioned, as follows:

- Identify key hotspots, i.e., highly disaster-prone areas
- Draw a world map of hotspot

Using the disaster-risk map, the World Bank team was planned to take actions to improve disaster preparedness and prevent economic losses.

(2) Selected hazard types and study sites

The natural disaster risk hotspots were investigated with respect to earthquake, cyclones, flood, drought, landslide, and volcano risks. Also, they were assessed at the grid level (cell size: 2.5 x 2.5 km^2) and over all populated areas in the world.

(3) Basic concept of the risk assessment model

It was supposed that any risk is represented as both mortalities and economic losses, but the risk in a grid cell is commonly a function of hazard, exposure, and vulnerability, as follows:

$$R = H \times E \times C_{jk} \quad (6)$$

R	the number of persons killed or values of assets lost from the hazard (persons or US$)
H	occurrences of a defined level of the hazard (dimensionless)
E	the exposure coefficient; population density for physical exposure, and GDP density for economic exposure (persons or USD)
C_{jk}	the vulnerability coefficient for continent j and wealth status k (dimensionless)

In defining flood occurrences in each grid cell, the Dartmouth Flood Observatory data were applied to calculate flood occurrences for the period 1980-2000. Even though this data source was known as poor records in some areas, and in early 90s, the team reluctantly endured the possibility of inaccurate results. For measuring occurrences of drought, the Weighted Anomaly Standardized Precipitation (WASP) was used which the IRI library calculated with average monthly precipitation data for the period 1980 – 2000. Then, a simple criteria approach was adopted to identify the grid cells affected by droughts: i.e. ascertaining, for each grid cell, how many times rainfalls over the 3 months are less than 50% of the median for the period.

To consider how largely each grid cell is exposed to the hazard, the calculated hazard occurrences were multiplied by exposure coefficients, i.e., population density for physical exposure, and GDP density for economic exposure. Population density was easily calculated by using the GPW ver. 3 of the CIESIN. Differently, GDP density was measured with three variations; the GDP from economic activities, the GDP from agricultural activities, and road density (using the grid-level data of World Bank DECRG and VMAP(0)). Since the hazard occurrence probability and density data were collected at the grid level, physical and economic exposure could be estimated, as follows:

For a grid cell,

$$\text{Physical exposure} = \text{probability} \times \text{exposure coefficient}$$

$$= (\text{dimensionless}) \times (\text{population}) \quad (7)$$

$$\text{Economic exposure} = \text{probability} \times \text{exposure coefficient}$$

$$= (\text{dimensionless}) \times (\text{USD}) \quad (8)$$

Despite the fact that the risk is highly related to human-induced factors, the questions “how seriously or why people or assets in a grid cell are vulnerable to the hazard” were not addressed directly. Instead, vulnerability in a grid cell was simply determined by the surrounding country and Continent. This is underlain by the viewpoint that susceptibility and coping capability in a grid cell depend on wealth-related attributes at the national or international level. Grid cells was categorized, according to deciles, i.e. ten groups of approximately equal number of cells, based on the magnitude of each individual risk.

Unlike the flood risk, it was found that the spatial patterns differ greatly, depending on whether the risk is represented as mortalities or economic losses. The outcomes showed that mortalities arise mainly in the areas suffering from severe political conflicts, saying again that even serious droughts do not necessarily lead to deaths. It was therefore said that the mortality-related droughts result significantly from human-induced risk drivers.

4.3.3 UNU-EHS: World Risk Report

(1) Backgrounds

As an alliance of German development and relief agencies, the Bündnis Entwicklung Hilft (BEH) launched a risk assessment project in 2011. Through the project, BEH collaborated with the United Nations University Institute for Environment and Human Security (UNU-EHS) in Bonn, Germany. Then, they attempted to publish the World Risk Report in order to reveal the real shape of current disaster risk at the global level, and advise decision-makers of future strategies for the aid program, and relevant policies.

In the report, the term World Risk Index indicates the tendency that a country or a region will be influenced by a disaster. Of special concern was vulnerability attributes. The central questions to evaluating the disaster risk were fourfold:

- How likely are natural hazards to affect countries?
- How vulnerable are the countries to natural hazards.
- To what extent are societies able to cope with severe and immediate disasters?
- Does our society take precautionary measures against anticipated future natural hazards?

(2) Selected hazard types and study sites

The report deals with five natural hazards such as earthquakes, storms, floods, droughts and see level rise. The country level was the frame of reference for the analysis. Besides, due to data unavailability problems, the index was calculated for 173 among a total of 192 countries.

(3) Basic concept of the risk assessment model

Natural disasters can do harms to a variety of entities including people, resources, infrastructure, production, goods, services, ecosystems, and even coupled social- ecological systems. Among such entities, this report considers people as the only element at risk. Risk was also defined as the interaction between exposure to natural hazard events and the vulnerability of the exposed element or society. Here, the first was measured as the number of people exposed to a natural hazard (physical exposure), while the latter focuses on dimensionless characteristics of societies and social actors. Since this report had a special interest in going into details about vulnerability, this concept was divided into susceptibility (likelihood of suffering harm), coping capacities (capacities to reduce negative consequences), and adaptive capacities (capacities for long-term strategies for societal change), although such classification and terminologies are not universally accepted. Finally, risk was defined as a function of exposure to a natural hazard, susceptibility, coping capacities, and adaptive capacities, as follows.

$$R = E \times V = E \cdot \{(0.33 \times S) \cdot (0.33 \times C) \cdot (0.33 \times A)\} \qquad (9)$$

R the qualitative risk term
E the number of people exposed to a natural hazard (in a fraction of exposed people in the country)
S the qualitative susceptibility (in rank, re-scaled over the range 0-1)
C the qualitative coping capacities (in rank, re-scaled over the range 0-1)
A the qualitative adaptive capacities (in rank, re-scaled over the range 0-1)

Each risk component was conceptualized as follows. Values of the calculated risks were grouped into five classes by the Quantile Classification Method of the ArcGIS software. Then, each class was named: “very high”, “high”, “medium”, “low”, and “very low”. Exposure is defined as the potential average number of individuals exposed and prone to be affected by selected hazards, which simply referred to physical exposure data contained in UNEP’s Global Risk Data Platform called the PREVIEW. Exposure to each hazard is added to calculate total physical exposure, and divided by the population of their country. Thus, the calculated exposure is interpreted as a fraction of exposed people in the country.
Based on the general definition (i.e., likelihood of suffering harm and damage at a certain level of a natural hazard), susceptibility was separated into five sub-categories related to “surrounding conditions”: (i) public infrastructure condition, (ii) housing condition, (iii) nutrition, (iv) poverty and dependencies, (v) economic capacity and income distribution.
Coping capacities denoted the “short-term capacities” to avert damage. Thus, for this indicator, it is important to know how sufficiently direct actions and resources are prepared to minimize negative impacts of hazards. The following five sub-categories were chosen to quantify this component: (i) government and authorities, (ii) disaster preparedness and early warning, (iii) medical services, (iv) social networks, and (v) material coverage (many indicators for each sub-category were selected, and then converted into the range 0-1). Unlike coping capacities being focused on the short-term damage mitigation, Adaptive capabilities were referred to as “abilities to adapt to the long-term or permanent changes”. It was also assumed to have five sub-categories including (i) education and research, (ii) gender equity, (iii) protection of environmental status and ecosystem, (iv) adaptation strategies, and (v)

investments. Three vulnerability-related indicators, susceptibility, coping capacities, and adaptive capabilities, were commonly applied for all types of disaster risks. This is underlain by the viewpoint that vulnerability is equally relevant to all natural hazards. It should be noted that in this risk assessment model, vulnerability indicators are expressed in the dimensionless coefficients. This means that vulnerability indicators equally map physical exposure into the risk.

As a result of combining three vulnerability indicators, Africa, and South and Southeast Asia were found to be hotspots of vulnerability. It is worth noting that these regions are the places where since the last 20th century; much attention has been paid to building human capacity and providing infrastructure for basic services. The vulnerability is a more important factor to determine the disaster risk. This originated largely from the fact that exposure, reported in UNEP's data platform, has smaller variations than vulnerability. For example, exposure of Afghanistan to the hazards was relatively low. However, due to its highest vulnerability, it was chosen as one of the 15 countries with the highest risk. Besides, it should be noted that our target countries, Nepal and Philippines, were included in global hotspots (the 3rd, and 6th, globally). The two countries were found to be very high in both exposure and vulnerability.

4.3.4 Current limitations in disaster risk assessments

In talking about pros and cons of the existing risk assessment models, it would be better to avoid excessively technical discussions. Any of disaster risk assessments cannot be perfect, especially if they have wide study scopes, as in this study. Rather, it is more important how their methods are useful in achieving the "purposes of the disaster risk assessment". To ascertain our purposes, it is necessary to think over backgrounds of developing these methods again, especially having 8-MDGs, the UN-ISDR, the Hyogo Framework for Action (HFA) in mind. Coming up to the HFA, our key question was not snapshotting natural hazards, which indeed could be evaluated with the conventional tools in the disaster risk management and hydrological communities. Rather, it has been our belief that for effective disaster risk management, relevant policies and options should be planned with due consideration of risk patterns at a variety of scales. To realize our belief, the risk assessment methods were required to urgently address various questions with practical, but policy-neutral sciences. For example, the ISDR (2003) mentioned methodological challenges from the sentence "risk reduction requires risk assessments in order to determine which areas are at highest risk of disaster and why, so that appropriate and cost-effective mitigation measures can be identified, adapted, and implemented." The World Bank (2005) also pointed out the current limitations, saying "the underlying rationale for risk assessment is that it reveals where investments in risk reduction are most needed and likely to have the biggest payoff in terms of reduced losses. Much remains to be learned, however, about how to use this type of information to best advantage, including the institutions, policies, cost/benefit analyses, mitigation measures, and resource allocation decisions needed to convert risk information to disaster reduction."

In practical attempts to analyze and reduce global disaster risks, many questions remained to be unsolved due to methodological limitations. Thus, purposes of developing the risk assessment models should be found in such questions, and they might be separated into the followings:

- P1: clarify how seriously natural disasters are **doing harm** to various spatial levels, from local to global scale
- P2: **monitor trends** of exposure and vulnerability to natural hazards
- P3: help **stakeholders understand** how current development and disaster risk reduction contribute to achieving the long-term goals such as MDGs and HFA

- P4: demonstrate that it is effective to **invest** local/national/international resources in a certain set of strategies, policies, and technical options

For each purpose, risk assessment models are necessary to satisfy various methodological requirements, as summarized in Table 4.3.2. Besides, it was anticipated that all requirements should be met, if the models are to be applied for P4, i.e. decision upon DRM-related investments.

As aforementioned, this section is not much interested in technical problems of the existing risk assessment models. Instead, using Table 4.3.2, it is discussed whether or not each model is useful to address four purposes, and if not, why it is improper. As a conclusion, it will be explained that UNDP's DRI gains a remarkable superiority over other risk assessment models. However, this model will be found to have many shortcomings in achieving the purposes, as well. Watchable is just that there remain a lot to be done to improve methods including viewpoints, models, data collection, and usages.

Table 4.3.2 Methodological requirements

Purpose	Methodological requirements
P1	➢ It should provide clear insights about the current risk. ➢ Risk should be identified based on proper scale and resolution. ➢ It should offer high confidence in quantified risks. ➢ Risk can be assessed periodically.
P2	➢ It should provide clear insights about the current exposure (either physical or economical) and vulnerability. ➢ It should offer high confidence in quantified exposure and vulnerability. ➢ Exposure and vulnerability can be assessed periodically.
P3	➢ It should consider controllable and human-induced risk drivers as vulnerability factors. ➢ It should be reliable in anticipating the risk in the future. ➢ From the model, it should be possible to clearly understand contributions of such risk drivers to the risk.
P4	➢ It should evaluate all risk components at a variety of spatial scales. ➢ It should provide clear insights about risk, exposure, and vulnerability. ➢ It should consider controllable and human-induced risk drivers as vulnerability factors. ➢ It should be reliable in estimating effectiveness of DRM actions.

4.3.4.1 UNDP Disaster Risk Index

(1) Can this method clarify how natural disasters are doing harm to local, national, regional, and global scales?

- Risk was clearly expressed in human deaths, which were also based on empirical evidences.
- Through a series of statistical analyses, the calculated risk was linked to historical records accumulated in the global disaster Data Base. However, as admitted in the report, the drought risk was not sufficiently accurate, and showed excessive dependency on accessibility of improved water services which seems to overwhelm contributions of other risk components to risk.
- In spite of the fact that risk was assessed at the country level, it is possible to update water-related risk maps continuously, since it requires easily accessible statistical data for exposure and vulnerability.

(2) Can this method monitor trends of physical or economic exposure and vulnerability to natural hazards?

- Physical exposure was measured in terms of population in the affected area and annual frequency of occurrence, i.e., the probable number of affected people. This is very practical in figuring out the exposure level. Despite the fact that vulnerability was the dimensionless index (mentioned as the relative or one-dimension vulnerability), this was directly calculated from empirical and practical measures, i.e., the ratio of mortalities and the number of affected people. Thus, it facilitates the evaluation of the magnitude of vulnerability in the unambiguous way. However, this method is not interested in economic exposure.
- Through a systematic validation test, it was illustrated that the DRI-oriented model is useful in quantifying physical exposure and its vulnerability to flood hazards. Yet, it was not feasible to quantify them to drought hazards, which was because occurrences of drought were evaluated from the meteorological standpoint; i.e. whether the amount of precipitation accumulated over 3 months is less than 50% of the median. In reality, as highlighted in the Global Assessment Report (UN-ISDR, 2011), exposure to drought is complicatedly driven by water stresses, complicatedly combined by meteorological drought, economic activities, residents' life-styles, regional water allocation, local water distribution, and so on. Regarding drought risk components, therefore, the results cannot receive sufficient confidences.
- In measuring exposure and vulnerability, this method makes use of data opened in the EM-DAT, IRI data library, and MDG-related indicators, which all are annually announced or can be easily updated.

(3) Can this method help stakeholders understand how current development and disaster risk reduction contribute to achieving the long-term goals?

- In the multi-dimension vulnerability assessment, the UNDP attempted to relate various potential risk drivers with vulnerability index. As a result, key risk drivers and their contributions to risk were identified. However, due to

methodological strictness and inflexibility of the multi-regression method, most risk drivers were excluded from the model. Accordingly, it is hard to trace causes of vulnerability with the remaining drivers like population density, GDP per capita, and the percentage of people with access to improved water supply. The first two risk drivers do not tell about easy ways for MDGs and DRM, and even if major DRM actions are made, the DRI model is likely to fail in reflecting their effectiveness. Besides, the risk assessment model for drought disaster was not statistically bad, but the magnitude of risk is excessively dominated by the level at which people are provided with water supply services. This problem might arise from other risk drivers being important, but excluded from the model.

(4) Can this method demonstrate whether it is effective to invest local/national/international resources in a certain set of strategies, policies, and technical options?
- Obviously, the DRI seems to be a success at the country level in making all risk components quantifiable and communicable, in the scientific way. For applications at the different scales, great efforts should be given to dis-aggregating the disaster records and socio-economic indicators into the grid cell, and improving accuracy of exposure to drought hazards. This might be technically feasible within few years.
- The multi-regression method was also found to be improper to incorporate various controllable and human-induced risk drivers into the DRI model. This is also a technical problem, and seems to be solved by using more flexible methods like machine learning techniques.
- Nevertheless, it is obvious that the current DRI model does not help to address value judgment problems, previously required to invest in the DRM actions.

4.3.4.2 WORLD BANK Natural Disaster Hotspot

(1) Can this method clarify how natural disasters are doing harm to local, national, regional, and global scales?
- Based on empirical evidences, risk was expressed as both human deaths and asset damages. However, how well the risk assessment model explains historical records was not explicitly stated. The World Bank also stated that the calculated drought risk can be misleading, and the results should be used for limited purposes.
- It would be technically possible to assess risks periodically after analyzing newly changing hazards, and evaluating physical and economic exposure. It is also apparent to provide insights about the risk for various spatial units, from grid-sized to global level.

(2) Can this method monitor trends of physical or economic exposure and vulnerability to natural hazards?
- The method might be able to adequately measure the magnitudes of exposure and vulnerability at various spatial levels. However, in addition to well-known inaccuracies about exposure to drought, it is an unavoidable limitation that the resolution of vulnerability is much lower than that of exposure.
- As a vehicle for monitoring vulnerability, this method has a serious problem. Vulnerability is determined by the national wealth level, and Continental

tendency related to disaster consequences. Thus, the calculated vulnerability coefficients are too superficial, less discriminable, and static yardsticks for vulnerability. Risk is viewed as more static than those calculated with other risk assessment methods. Even if any DRM actions are made, it is impossible to anticipate and monitor their effectiveness. This shortcoming will certainly impede periodic evaluations.

(3) Can this method help stakeholders understand how current development and disaster risk reduction contribute to achieving the long-term goals? Highly doubtful
- Risk drivers are not embodied in the risk assessment model. It cannot be used to shed light on broad issues such as DRM and MDGs.

(4) Can this method demonstrate whether it is effective to invest local/national/international resources in a certain set of strategies, policies, and technical options?
- Risk drivers are not embodied in the risk assessment model, and thus risk drivers and counter-measures cannot be analyzed at the same time.

4.3.4.3 UNU-EHS World Risk Report

(1) Can this method clarify how natural disasters are doing harm to local, national, regional, and global scales?
- The calculated risk index does not have physical meanings such as moralities or economic losses. Rather the UNU-EHS made it as a yardstick, i.e. the rank saying which countries are relatively well prepared for disaster risk.
- Because of poor physical meanings, and the artificially presumed model structure, it is difficult to attach high confidence to the results.
- However, risk can be updated annually from the merit of using easily accessible data.

(2) Can this method monitor trends of physical or economic exposure and vulnerability to natural hazards?
- The calculated ranks about exposure and vulnerability seem to be plausible. However, the two components do not have the physical meanings. In addition, the problem was not unsolved that the data from the UNEP DEWA/GRID-Geneva are not reliable to delineate drought exposure.
- The vulnerability index has the triple-layer hierarchy. Hence, it is very important to determine the weighting factors between indicators, and between sub-categories in order to calculate the index accurately. Indeed, there were no comments about which indicators and sub-categories are more significant than others.
- To cover the full range of risk drivers, the UNU-EHS classified vulnerability in detail. It does not seem terminologically problematic to separate vulnerability in the suggested manner. The real problem is that this classification does not help in operationalizing vulnerability at all. Conceptual ambiguity, arising from the classification, exists between all categories: for example, susceptibility and coping capacity are not clearly separated in that early warning systems should be accompanied by relevant public infrastructure; coping capacity and adaptive capacity are not clearly separated in that long-term investments are needed to build social network and improve medical services; susceptibility and adaptive

capacity are also unclearly separated, in that gender equity is more often a system setting related to hazards, as well as the ability to adapt. Therefore, the report had to admit that "(p.16) based on the definitions of susceptibility and coping capacity, it can be seen both components are closely interlinked, and that a clear separation in practice is thus often impossible."

- Of course, it will be possible to update exposure and vulnerability annually, because easily accessible data are used for the calculation.

(3) Can this method help stakeholders understand how current development and disaster risk reduction contribute to achieving the long-term goals?

- The most strength might be that a variety of risk drivers are considered in the vulnerability index. However, since the model was not sufficiently proved to have validity and usefulness, it seems very dangerous to draw insights about DRM and MDGs actions by using this method.
- Because many indicators were considered in the vulnerability index, it is possible to recognize key risk drivers of a risk-prone country. Still, answering the practical question "how sensitive vulnerability and risk are to such risk drivers" will be misled by the untested model structure.

(4) Can this method demonstrate whether it is effective to invest local/national/international resources in a certain set of strategies, policies, and technical options?

- At the country level, and inter-country level, risk components are readily evaluated, and risk drivers are well identified. Nevertheless, lack of physical meaning will impede the method from addressing value judgment problems like cost-effectiveness evaluation. It can be said that this method is irrelevant to practical discussion upon the DRM action.

Table 4.3.3 Results of comparison between methods

Purpose	**Methodological usefulness**		
	UNDP DRI	**WORLD BANK NDRH**	**UNU-EHS WRR**
P1	Useful	Useful	Doubtful
P2	Useful	Highly doubtful	Doubtful
P3	Doubtful	Highly doubtful	Highly doubtful
P4	Doubtful	Highly doubtful	Highly doubtful

4.4 Methodology of WRDRI Development

4.4.1 Fundamental strategies

The WRDRI is developed as an attempt to solve methodological challenges in global- or national-level risk assessment activities. According to the current challenges, its fundamental strategies were made as follows:

(1) WRDRI should prefer adopting advanced technologies to overcome data unavailability: For implementing risk assessment on spatially large scale, most challenging factors are data unavailability problems. In particular, many developing countries open very limited data list, and available data are often lack of data quality including accuracy, consistency, and length. To solve these problems, it is very important to concert all available potentials together. In this regard, this study intends that WRDRI sheds light on the way to

integrate ICHARM's advanced technologies (BTOP model, FID model, and ATLM), and global data sources (APHRODITE, LandscanTM, and other global statistics and development indicators) that are now constructed separately.

(2) WRDRI should reflect reproduction of real disaster situations, and then damages of people and assets should be expressed separately: Many water-related disaster statistics say that economic damages are rapidly increasing in the Asian-Pacific region, irrespective of hazard types. That implies that the current efforts to reduce economic damages are not effective, and thus better management tools should be made in order to protect assets. Therefore, both of people and assets are considered seriously as risk elements of the WRDRI framework.

(3) WRDRI should identify disaster-prone areas in the scientifically acceptable way, and provide tangible and validatable risk indices: As shown in reviewed literature, many organizations and individual scientists have been identifying disaster-prone areas in a variety of way. For this purpose, some studies rank countries according to subjectively selected proxies, and other studies attempt to calculate values of conceptual indices without any effort to operationalize the PAR model. However, as far as those approaches are adopted, nobody can be convinced of risk information, because they neither present communicative terms, nor contain sufficient knowledge on actual risk causes. WRDRI is therefore developed to be tangible, validatable, and eventually useful in supporting decisions and investments on disaster risk reduction. To this end, it seems essential that WRDRI reproduces real disaster situations like human deaths, or economic losses.

(4) WRDRI should be a good tool for monitoring government efforts so that countries can be fully convinced of the need for their risk management programs.

4.4.2 General framework: risk definition

As risks are specified according to the aspects of people and assets, it is necessary to make two-dimensional definitions, i.e. one definition for people and another definition for assets. One of the most common and simple conceptual model to define the risk is the Pressure and Release Model (PAR model), which is based upon the equation as follows (Wisner et al., 2004).

Risk (people) = Hazard x Vulnerability (people)

Risk (assets) = Hazard x Vulnerability (assets) (10)

Based on the above concept of risk, WRDRI definition was extended to find more chances to measure governments' efforts for risk reduction. Therefore, risk is considered as a function of hazard, exposure, vulnerability and capacity, as follows.

$$Risk\ (people) = Hazard\ \times Exposure\ (people) \times \frac{Vulnerability\ (people)}{Capacity\ (soft + hard)}$$

$$Risk\ (assets) = Hazard\ \times Exposure\ (assets) \times \frac{Vulnerability\ (assets)}{Capacity\ (soft + hard)}$$

(11)

In fact, all terminologies, in Eq.(11), are not newly developed. They appear in every risk assessment and communication, and heated arguments have been made to reach consensus on the meaning of each terminology in the UN-affiliated organizations (e.g., UNU-EHS, 2006)

and also scientific community (e.g. Cutter, 1996; Pau, 2011) for the last several decades. If new terminologies are proposed again at this moment, it will be possible to cause confusion in communication. Therefore, it is briefly mentioned that the WRDRI basically follows the UN-ISDR guideline (as presented in Table 4.4.1), and it just classifies coping capacity into two types, i.e., soft coping capacity and hard coping capacity in order to systematically categorize governments' efforts. As well-known, soft coping capacity is the ability of people, organizations and systems to face disasters, and essentially it is naturally or purposefully increased by non-structural efforts such as community power, early warning systems, disaster-related education, and good governance. On the contrary, hard coping capacity is confined to the ability purposefully increased by structural efforts like dam, dike, and reservoirs.

Table 4.4.1 Definition of some terminologies based on UN-ISDR Terminology-2009

Terminology	Definition
Disaster	A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.
Risk	The combination of the probability of an event and its negative consequences.
Hazard	A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.
Vulnerability	The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.
Exposure	People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.
Coping Capacity	The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters.

Regarding the Eq.(11), it should be also mentioned that all mathematical notations in the above equations are still conceptual. The equations simply imply that risk of an area can differ, depending on hazard, exposure, vulnerability, and coping capacity. It is also said that risk increases with growing hazard, exposure, and vulnerability, while it decreases with growing coping capacities. Yet, nobody can reveal full shapes of vulnerability and coping capacity since these risk components are concepts complicatedly related to countless settings in the areas. As an alternative, many scientists have thus been defining them with important proxies. Therefore, a complete risk definition requires risk components and their proxies for all types of hazards.

- **Flood risk definition for people:** in general, hazard is recognized as a probabilistic term related to occurrences of extreme hydrological events. However, WRDRI is interested in analyzing a specific level of the extreme events. Thus, it is assumed that flood hazard is a flood event of the 50-year return period, and its impact is quantified by inundation areas. Table 4.4.2 summarizes the results that were made after in-depth

discussions through internal seminars, and official workshops, which show examples of selecting proper proxies.

- **Flood risk definition for assets**: likewise, it is assumed that flood hazard is a flood event of the 50-year return period, and its impact is quantified by inundation areas. However, asset exposure is rather different from people exposure. In this case, WRDRI considers two types of risk elements. The first is house exposure. Floods often break down houses, or fill them with water, and finally yield serious damages in property. The latter is productivity exposure. Especially, WRDRI is intended to measure the economic values of agricultural and industrial productivities affected to flood, based on inundation areas. For vulnerability and coping capacity, proxies in Table 4.4.3 were selected after internal seminars, and official workshops.
- **Storm surge risk definition for people:** considering risk consequences of storm surge, storm surge risk definition was made very similar to flood risk definition. However, storm surge hazard is a storm surge occurring in the LECZ, i.e., the low elevation coast zones where elevation is below 10 meters. Hence, people exposure was also defined as the number of persons in the LECZ. Table 4.4.4 shows what proxies for vulnerability and coping capacity were selected through internal seminars, and official workshops.
- **Storm surge risk definition for assets:** like asset exposure in flood risk definition, WRDRI considers house exposure, and productivity exposure. For productivity exposure, WRDRI measures economic values of agricultural and industrial activities affected to storm surge, after identifying LECZ areas. For vulnerability and coping capacity, proxies in Table 4.4.5 were selected after internal seminars, and official workshops.
- **Drought risk definition for people:** regarding drought risk, it is possible to select various definitions. This is, drought can be meant by lack of precipitation, soil moisture, or discharge, depending on study purposes. WRDRI is especially focused on drought leading to disaster damages like human deaths or significant economic losses. Therefore, drought hazard is here regarded as a drought event of the 50-year return period. Its impact is quantified by water deficiency volumes, which are important to know how drought is socio-economically hazardous.
- **Drought risk definition for assets:** likewise, it is assumed that drought hazard is a drought event of the 50-year return period, and its impact is quantified by water deficiency volumes. Asset exposure is focused on agricultural and industrial productivities, which arise from given fractions of water deficiency volumes. Table 4.4.7 summarizes the results that were made after in-depth discussions through internal seminars, and official workshops, which show examples of selecting proper proxies.

Table 4.4.2 Flood risk definition for people

Risk components	sub-components	Selected proxies
Risk	-	Human deaths (persons per 1,000 km^2)
Hazard	-	Flood events of the 50-year return period (Impact: inundation area)
People Exposure	-	Number of persons in the area where the impact happens (persons per 1,000 km^2)
Basic Vulnerability[19]	Critical people	Age dependency ratio (%) – defined as the fraction of dependents (people younger than 15 or older than 64) to working-age population
	Population growth	Population growth rate (% per year)
	Deforestation	Deforestation rate (%)
Soft Coping Capacity[20]	Early warning systems	Score of ISDR HFA Priority 2[21] (1-5 scale; 5=best) – measuring risk awareness and early warning
	Past experiences on hazards	Number of total disaster events per capita – calculated based on natural disasters happened for the period from 1980 to 2010
	Community power	Score of ISDR HFA Priority 1 (1-5 scale; 5=best) – measuring a strong institutional basis for implementation and community participation
	Good governance	WGI[22] (0-100 scale; 100=best)
Hard Coping Capacity[23]	Dam	effective flood control capacity per capita (m^3 per capita)
	Dike	Dike length (%)

19 For proxies of vulnerability, data were collected from the sources, World Development Indicators (The World Bank), UN data (United Nations Statistics Division), and AQUASTAT (FAO).

20 For proxies of soft coping capacity, data were collected from the sources, PreventionWeb (UN-ISDR), EM-DAT (CRED), and Worldwide Governance Indicators (World Bank).

21 Since 2007, UN-ISDR has reviewed national reports for HFA progress. It then calculated scores for five Priorities. Especially scores of Priorities 1 and 2 are closely related to, and considered the only official data for, early warning systems and community power

22 In fact, World Bank opens 6 types of governance indicators including i) voice and accountability, ii) political stability and absence of violence, iii) government effectiveness, iv) regulatory quality, v) rule of law, and vi) control of corruption. Among these indicators, this study selects only one after conducting correlation analysis. It is because governance usually has close ties with disaster risk management, but this point can instead restrict importance of other important proxies.

23 This study could not consider proxies for hard coping capacity as data were unavailable.

Table 4.4.3 Flood risk definition for assets

Risk components	sub-components	Selected proxies
Risk	-	Economic losses (US$ per 1,000 km^2)
Hazard	-	Flood events of the 50-year return period (Impact: inundation area)
Asset Exposure	House exposure	Number of houses in the area where the impact happens (# per 1,000 km^2)
	Productivity exposure	Economic values of agricultural and industrial productivities in the area where the impact happens (US$ per 1,000 km^2)
Basic Vulnerability[24]	Urbanization	Urbanization rate (% per year)
	Deforestation	Deforestation rate (%)
Soft Coping Capacity[25]	Past experiences on hazards	Number of total disaster events per capita – calculated based on natural disasters happened for the period from 1980 to 2010
	Community power	Score of ISDR HFA Priority 1 (1-5 scale; 5=best) – measuring a strong institutional basis for implementation and community participation
	Good governance	WGI (0-100 scale; 100=best)
Hard coping capacity[26]	Dam	effective flood control capacity per capita (m^3 per capita)
	Dike	Dike length (%)

24 For proxies of vulnerability, data were collected from the sources, World Urbanization Prospects (United Nations), and AQUASTAT (FAO).

25 For proxies of soft coping capacity, data were collected from the sources, EM-DAT (CRED), PreventionWeb (UN-ISDR), and Worldwide Governance Indicators (World Bank).

26 This study could not consider proxies for hard coping capacity as data were unavailable.

Table 4.4.4 Storm surge risk definition for people

Risk components	sub-components	Selected proxies
Risk	-	Human deaths (persons per 10 km of coastline)
Hazard	-	Storm surge events under the LECZ condition
People Exposure	-	Number of persons in the LECZ (persons per 10 km of coastline)
Basic Vulnerability[27]	Critical people	Age dependency ratio (%) – defined as the fraction of dependents (people younger than 15 or older than 64) to working-age population
	Population growth	Population growth rate (% per year)
Soft Coping Capacity[28]	Early warning systems	Score of ISDR HFA Priority 2 (1-5 scale; 5=best) – measuring risk awareness and early warning
	Past experiences on hazards	Number of total disaster events per capita – calculated based on natural disasters happened for the period from 1980 to 2010
	Community power	Score of ISDR HFA Priority 1 (1-5 scale; 5=best) – measuring a strong institutional basis for implementation and community participation
	Good governance	WGI (0-100 scale; 100=best)
Hard Coping Capacity[29]	Dike (coastline)	Dike and sea wall length (%) - constructed along the coastline

27 For proxies of vulnerability, data were collected from the sources World Development Indicators (The World Bank), and UN data (United Nations Statistics Division),

28 For proxies of soft coping capacity, data were collected from the sources, PreventionWeb (UN-ISDR), EM-DAT (CRED),), and Worldwide Governance Indicators (World Bank).

29 This study could not consider this proxy as data were unavailable.

Table 4.4.5 Storm surge risk definition for assets

Risk components	sub-components	Selected proxies
Risk	-	Economic losses (US$ per 10 km)
Hazard	-	Storm surge events under the LECZ condition
Asset Exposure	House exposure	Number of houses in the LECZ (# per 10 km)
	Productivity exposure	Economic values of agricultural and industrial productivities in the LECZ (US$ per 10 km)
Basic Vulnerability[30]	Urbanization	Urbanization rate (% per year)
Soft Coping Capacity[31]	Past experiences on hazards	Number of total disaster events per capita – calculated based on natural disasters happened for the period from 1980 to 2010
	Community power	Score of ISDR HFA Priority 1 (1-5 scale; 5=best) – measuring a strong institutional basis for implementation and community participation
	Good governance	WGI (0-100 scale; 100=best)
Hard Coping Capacity[32]	Dike (coastline)	Dike and sea wall length (%) - constructed along the coastline

30 For proxies of vulnerability, data were collected from the source World Urbanization Prospects (United Nations)

31 For proxies of soft coping capacity, data were collected from the sources, EM-DAT (CRED), PreventionWeb (UN-ISDR), and Worldwide Governance Indicators (World Bank).

32 This study could not consider this proxy as data were unavailable.

Table 4.4.6 Drought risk definition for people

Risk components	sub-components	Selected proxies
Risk	-	Human deaths (persons per 1,000 km^2)
Hazard	-	Drought events of the 50-year return period (Impact: water deficiency volumes)
People Exposure	-	Number of persons who may experience water deficiency (persons per 1,000 km^2)
Basic Vulnerability[33]	Critical people	Age dependency ratio (%) – defined as the fraction of dependents (people younger than 15 or older than 64) to working-age population
	Population growth	Population growth rate (% per year)
Soft Coping Capacity[34]	Early warning systems	Score of ISDR HFA Priority 2 (1-5 scale; 5=best) – measuring risk awareness and early warning
	Efficiency of water supply	Revenue water rate (%) - measured as the volumetric fraction of water reaching customers to the total water [35]
	Past experiences on hazards	Number of total disaster events per capita – calculated based on natural disasters happened for the period from 1980 to 2010
	Community power	Score of ISDR HFA Priority 1 (1-5 scale; 5=best) – measuring a strong institutional basis for implementation and community participation
	Good governance	WGI (0-100 scale; 100=best)
Hard Coping Capacity[36]	Dam	Dam storage (m^3 per capita)
	Water supply systems	Water service coverage (%)

33 For proxies of vulnerability, data were collected from the sources, World Development Indicators (The World Bank), and UN data (United Nations Statistics Division)

34 For proxies of soft coping capacity, data were collected from the sources, PreventionWeb (UN-ISDR), IBNET online database, EM-DAT (CRED), and Worldwide Governance Indicators (World Bank).

35 For proxies of hard coping capacity, data were collected from the sources, AQUASTAT (FAO), and IBNET online database.

36 For the water supply field, it is common to use ‘non-revenue water rate’ in evaluating water supply efficiencies. However, the reason this study uses revenue water rate is that coping capacity is defined as governments’ efforts reducing risks.

Table 4.4.7 Drought risk definition for assets

Risk components	sub-components	Selected proxies
Risk	-	Economic losses (US$ per 1,000 km^2)
Hazard	-	Drought events of the 50-year return period (Impact: water deficiency volumes)
Asset Exposure	-	Economic values of agricultural and industrial productivities which may be influenced by water deficiency (US$ per 1,000 km^2)
Basic Vulnerability[37]	Urbanization	Urbanization rate (% per year)
	Water withdrawal	Annual water withdrawal increment rate (% per year)
Soft Coping Capacity[38]	Efficiency of water supply	Revenue water rate (%) - measured as the volumetric fraction of water reaching customers to the total water
	Past experiences on hazards	Numbers of total disaster events per capita – calculated based on natural disasters happened for the period from 1980 to 2010
	Community power	Score of ISDR HFA score 1 – measuring a strong institutional basis for implementation and community participation
	Good governance	WGI (0-100 scale; 100=best)
Hard Coping Capacity[39]	Dam	Dam storage (m^3 per capita)
	Water supply systems	Water service coverage (%)

37 For proxies of vulnerability, data were collected from the sources, World Urbanization Prospects (United Nations), and AQUASTAT (FAO).

38 For proxies of soft coping capacity, data were collected from the sources, IBNET online database, EM-DAT (CRED), Preventionweb (UN-ISDR), and Worldwide Governance Indicators (World Bank).

39 For proxies of hard coping capacity, data were collected from the sources, AQUASTAT (FAO), and IBNET online database.

4.4.3 General framework: general procedures

This study has a purpose of suggesting WRDRI as a prototype. Hence, all tasks for WRDRI were fitted to general risk assessment procedures. The whole procedures can be divided into preliminary data arrangement and risk assessment. At the preliminary data arrangement procedure, huge data were collected from a variety of global data sources, and then carefully analyzed for availability and adequacy. At the risk assessment procedure, this study started with hazard assessment. The three types of hazard impacts, i.e. inundation areas for flood, LECZ areas for storm surge, and water deficiency volumes for drought, were identified by concerting various technologies and data including APHRODITE data, the BTOP model, the FID model, and the Applied Threshold Level Method (ATLM). Then, exposure assessments were conducted, which aimed to identify people exposure, house exposure, and productivity exposure. To this end, it was necessary to use spatially-distributed population data, Landscan™, in order to accurately estimate people exposure, and reduce the errors occurring in examining house exposure. Global statistics, development indicators and national statistics were also used to calculate various coefficients, which were needed to calculate productivity exposure. Proxies for basic vulnerability and coping capacity were then calculated, and all proxies were statistically combined into risk indices for people and assets.

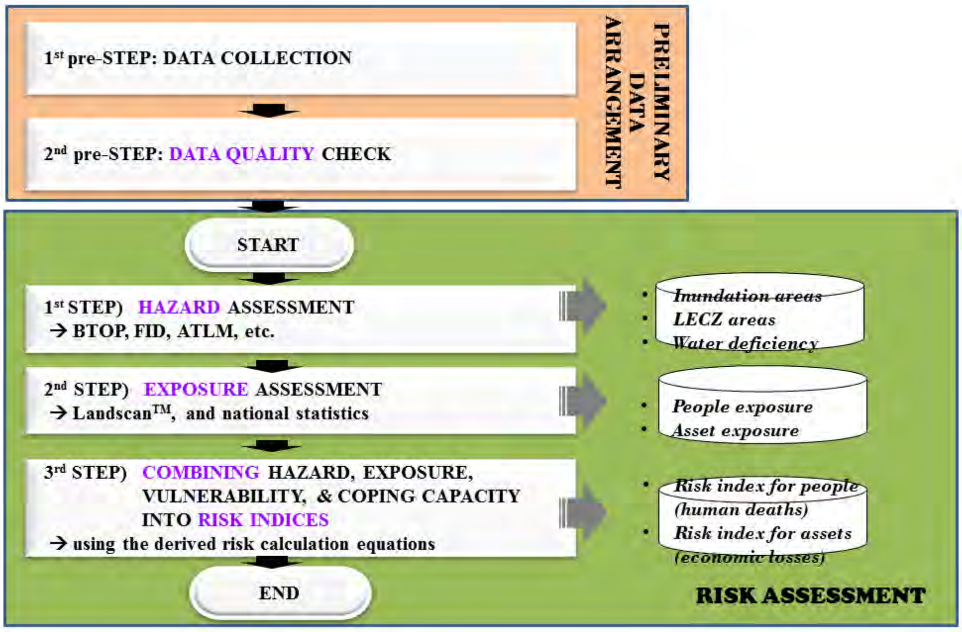


Figure 4.4.1 General procedures of WRDRI

4.4.4 Methods

4.4.4.1 Preliminary data arrangement

In this study, three types of risk (flood, storm surge, and drought) were defined from two aspects (people and assets), which then required various proxies to be included. To calculate those proxies, it was necessary to endeavor to gather huge data. Therefore, this study planned three strategies for data collection. The three strategies can be summarized, as follows:

(1) Data collection

(a) ADB's participation

- Though the field surveys, the ADB (with a hired international consultant) investigated hydrological characteristics and collected time-series data for target countries (Nepal and Philippines). This support ICHARM in well calibrating and validating hydrological models used for hazard assessment.
- Though the field surveys, the ADB collected data about economic activities and dwelling for target countries so that ICHARM could conduct exposure assessment, especially in calculating asset exposure.
- The ADB provided information about global data sources so that ICHARM could calculate proxies for vulnerability and coping capacity.
- The ADB cooperated with ICHARM to discuss validity of risk assessment results.

(b) Analysis of advanced data sources

- The satellite-based image data and geographical information system (GIS) data were extensively utilized by ICHARM's techniques.
- These data sources helped in well considering geographical attributes of target countries, accurately identifying people exposure, and eventually increasing reliabilities of hazard assessment and exposure assessment.

(c) Investigation of global statistical data

- Various socio-economic data were required to calculate proxies related to vulnerability and coping capacity. Great efforts were also paid to investigate reliable global data sources, and check their usefulness. Moreover, this study necessitated risk calculation equations in order to integrate selected proxies into tangible risk indices. The equations were built from statistical data of 15 countries in South Eastern and Southern Asia, which demanded more data to be collected from global statistical databases.

After comparing data from various sources, this study constructed the data list as presented in Table 4.4.8.

Table 4.4.8 Representative data sources for WRDRI method

Data sources	Organizations	Data
Field survey	ADB	• Hydrological characteristics and historical data of target countries • Economic activities and dwelling of target countries
APHRODITE	Japanese MOE	• Global precipitation data
HydroSHEDS	USGS	• SRTM DEM (15s)
Landscan^{TM}	US Dept. of Defence	• Global population distribution
EM-DAT	CRED	• Past records on mortalities, economic losses, people exposure (affected people), and house exposure (affected houses)
AQUASTAT	UN FAO	• Deforestation; Dam storage; Water withdrawal

ISDR HFA Priority Score	UN-ISDR (PreventionWeb)	• Early warning systems • Community power
World Urbanization Prospects	United Nations	• Urbanization rate
UN data	United Nations Statistics Division	• Population growth rate • National statistics
World development indicators	World Bank	• Critical people
Worldwide Governance Indicators	World Bank	• Voice and accountability • Political stability and absence of violence
Online database	IBNET	• Efficiency of water supply (revenue water rate) • Water service coverage

(2) Data quality check

(a) Data availability check

Data quality was checked in two ways: data availability check and data correlation check. First, this study ascertained which proxies could be covered by available data sources. Then, it was found that all proxies cannot be considered in assessing defined risk. For example, it was impossible to investigate dam flood control capacity, and dike length, because of limited resources. Therefore, WRDRI was imperfect in measuring hard coping capacity. Therefore, the number of used proxies was not the same as that in risk definition.

Table 4.4.9 Results of data availability check

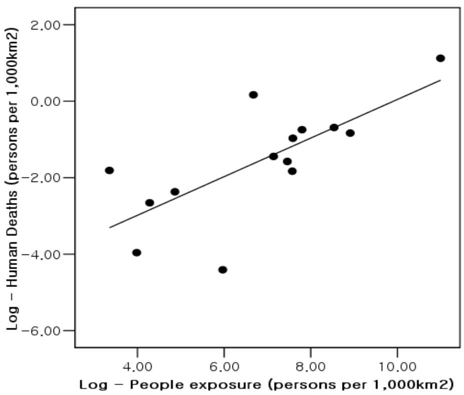
	Number of proxies in risk definition		Number of proxies after data availability check	
	People	Assets	People	Assets
Flood risk	10	9	8	7
Storm surge risk	8	7	7	6
Drought risk	10	9	10	9

(b) Data correlation check

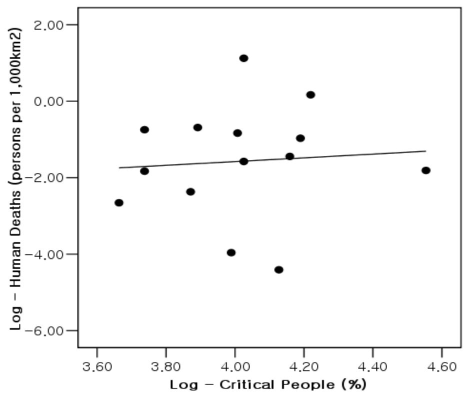
WRDRI was intended to reproduce real disaster situations. Therefore, although the proxies, selected in risk definition, are conceptually correct, they cannot be used without evidences in target countries. Therefore, this study had to calculate all remaining proxies for 15 countries[40] in South Eastern and Southern Asia. Then, it excluded some proxies from risk assessment if they were wrongly correlated to disaster records such as human deaths and economic losses over the countries. For example, Figure 4.4.2 shows the results of analyzing correlation between proxies and human deaths due to flood. The correlations of five proxies, as depicted in Figure 4.4.2(a) to (e), accord with risk definition. It thus seems likely that human deaths would be large when people exposure (Pearson r = 0.73), critical people (Pearson r = 0.08),

[40] The countries include Afghanistan, Bangladesh, Cambodia, India, Indonesia, Iran Islam Rep, Lao P Dem Rep, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, Viet Nam. Even though Bhutan, Brunei Darussalam, Maldives, Singapore, and Timor-Leste belong to the Continents, they were excluded for poor data, or outliers.

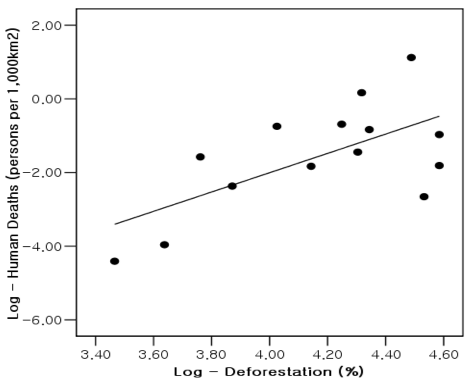
and deforestation (Pearson r = 0.64) increases, and when early warning systems (Pearson r = -0.16) and good governance (Pearson r = -0.19) are poor. However, regarding population growth, past experiences on hazard, and community power, this study could not find out correct correlations, as shown in Figure 4.4.2 (f) and (h). In spite of two proxies selected for vulnerability and coping capacity, individually, the Pearson r values were found to be negative and positive towards human deaths over the 15 countries.



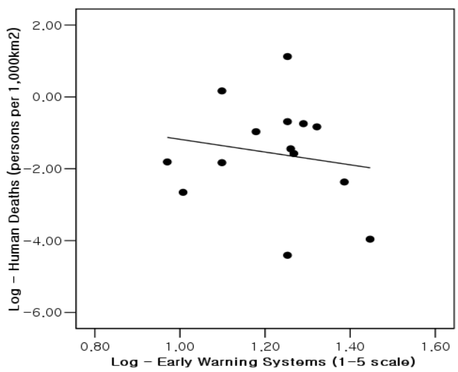
(a) People exposure



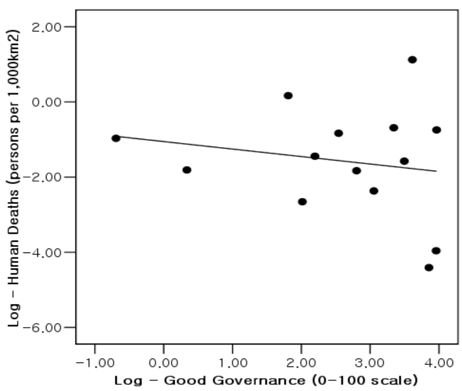
(b) Critical people



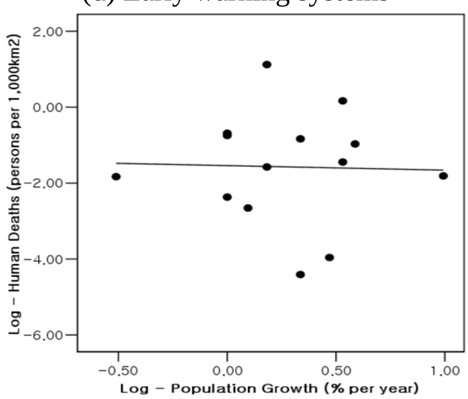
(c) Deforestation



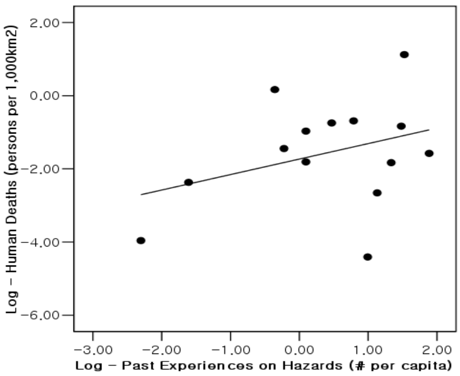
(d) Early warning systems



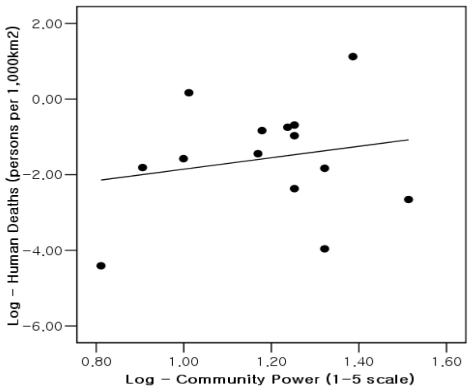
(e) Good governance



(f) population growth



(g) Past experiences on hazards



(h) Community power

Figure 4.4.2 Example of data correlation check: proxies for flood risk (people)

After a series of correlation checks, it was found that the following proxies well satisfy real disaster situations of the Asian counties, and thus can be considered importantly.

- Flood risk assessment (people): people exposure, critical people, deforestation, early warning systems, and good governance (political stability and absence of violence)
- Flood risk assessment (assets): house exposure, productivity exposure, deforestation and good governance (voice and accountability)
- Storm surge risk assessment (people): people exposure, critical people, and good governance (political stability and absence of violence)
- Storm surge risk assessment (assets): house exposure, productivity exposure, urbanization, and good governance (political stability and absence of violence)
- Drought risk assessment (people): people exposure, good governance (political stability and absence of violence), dam (dam storage), and water supply systems (water supply coverage)
- Drought risk assessment (assets): productivity exposure, and good governance (voice and accountability)

4.4.4.2 Hazard assessment and exposure assessment

(1) Flood

Figure 4.4.3 presents the whole procedures for flood hazard assessment and exposure assessment. Impacts of flood hazard were identified by using the GIS-oriented flood inundation depth (FID) model. This model was originally developed to calculate the relative DEM (REM) and the maximum river water depth based on Manning's steady, uniform flow resistance formula, as presented below:

$$H_{max} = \{ Q_{max} \times n_0 / (B_f \times I_f^{1/2}) \}^{0.6} \qquad (12)$$

$$FID = H_{max} - REM \qquad (13)$$

In Eq.(13), REM is calculated as a difference of height between river and land on the basis of DEM. Also, the DEM data were abstracted from the Shuttle Elevation Derivatives at multiple Scale, usually abbreviated to the HydroSHEDS, produced by the NASA's Shuttle Radar Topography Mission (SRTM). Hmax was set as the maximum river water depth used the Manning's roughness coefficient (n0), the local channel slope (If) , width (Bf) and the maximum daily river discharge (Qmax). For data for Qmax, the BTOP model41 was simulated with the grid-based APHRODETE Monsoon Asia (version V1003R1) having a daily time step for 57 years (1951-2007). Based on the simulation outputs, the river discharges for 50-year flood were calculated over vast areas covering two countries. Hence, the FID indicates the potential flood inundation depth of a given cell42 when the difference between Hmax and the REM of that cell is more than 0.1 meter. In the case when the difference is below 0.1 meter, it is natural to consider that no flooding would occur over such cells, as flood might cause relatively negligible inconveniences. Figure 4.4.4 illustrates how FID was derived for cells around a given river channel cell. It is assumed that the floodwater flows into the neighboring cells, looking for the lowest REM. Then, this FID model evaluates inundation depth continuously. Finally, the GIS tool identifies locations and areas of all selected cells. It was recently found that this GIS-oriented approach effectively simplifies the complexity between hydrological and topological variables, and it can provide considerable merits in carrying out global-scale risk assessments (Kwak et al., 2011; Kwak et al., 2012).

For exposure assessment, the geographic population distributions were picked out on the flood inundation area identified by FID model. This work was conducted by using the Landscan[TM] (Global Population Database at 30 arc seconds, developed by the Oak Ridge National Laboratory for the United States Department of Defense), and produced number of people in the inundation areas, i.e. people exposure. Then, the data, including inundation areas and people exposure, were again used to calculate house exposure and productivity exposure. Especially, when estimating productivity exposure, this study only considered agricultural and industrial activities.

41 The BTOP model was developed with the Muskingum-Cunge method (Cunge, 1969) by Takeuchi et al. (1999).

42 For the FID model, a grid cell has the 15 arc-second resolution (approximately 500 meters at the equator).

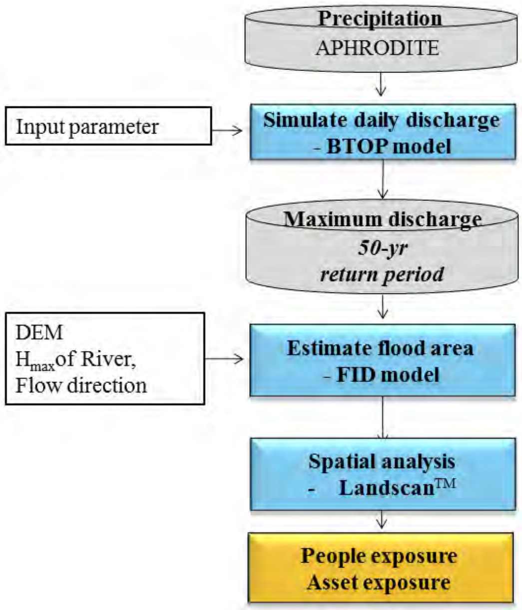


Figure 4.4.3 Schematic diagram for flood hazard assessment and exposure assessment

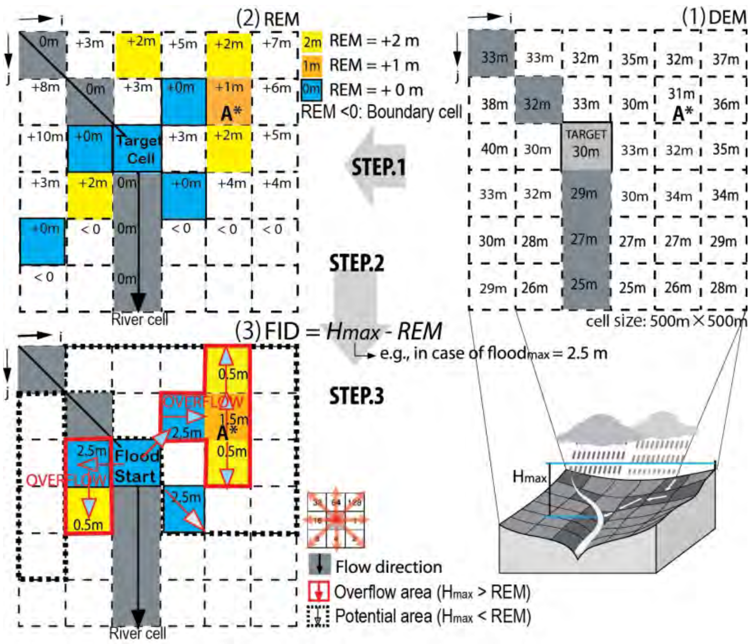


Figure 4.4.4 Schematic diagram of the GIS-based flood inundation depths (FID) model

(2) Storm surge

According to risk definition, impacts of storm surge hazard are measured in terms of storm surge area. Hence, this study attempted to examine the low elevation coastal zone (LECZ) where elevation is below 10 meters above mean sea level along the coastal line, and then directly estimate people exposure. Figure 4.4.5 presents the whole procedures for storm surge hazard assessment and exposure assessment.

- Identify the LECZ in Philippines: the elevation layer, i.e., DEM, was made with a combination of the original SRTM-3 and the digital terrain elevation data (DTED-1) of SRTM at 15 arc-second resolution. Then, the DEM was used to investigate locations and areas of LECZ. Therefore, it should be mentioned that in calculating

the impacts in hazard assessment, dikes and seawalls, often constructed along the coastal line from the storm surge, were not considered.

- Assess persons, houses, and productivities affected to storm surge: for exposure assessment, the geographic population distributions were extracted from the storm surge area identified by the GIS-oriented LECZ analysis. Like the flood exposure assessment, this work was focused on calculating people exposure in the storm surge areas, using the Landscan™. Then, the data, including storm surge areas and people exposure, were again used to calculate house exposure and productivity exposure. Also, it was assumed that productivities consist of agricultural and industrial activities. Therefore, in order to calculate productivity exposure, this study used several coefficients such as per area agricultural productivity (US$ per 1km^2) and per employee industrial productivity (US$ per an industrial employee), which had been previously calculated by national statistics.

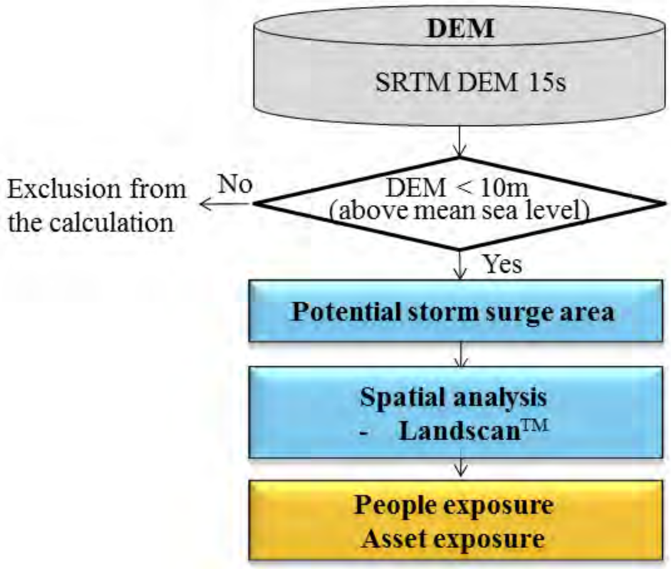


Figure 4.4.5 Schematic diagram for storm surge hazard assessment and exposure assessment

(3) Drought

(a) Past studies on drought definition

For the developing countries, socio-economic drought, causing real drought disasters, is problematic due to unavailability of water demand information. Therefore, the water demand needed to be approximated by a threshold level of physical parameter such as river discharge and historical drought records. The threshold level method (TLM) defines any drought as a deviation of system parameters (e.g., precipitation, soil moisture, river discharge) below a selected threshold level (Van Loon and Van Lanen, 2012; Van Huijgevoort et al., 2012). The threshold level can be constant or time-dependent for drought characterization on global and local scale. Huijgevoort et al. (2012) used both constant and variable TLM for any drought type characterization at global scale. Van Loon and Van Lanen (2012) adopted variable TLM for drought simulations at five river basins in the European Union. For the hydrologic drought, the 20th percentile of the monthly duration curve was used by Huijgevoort et al. (2012) and Van Loon and Van Lanen (2012). Smakhtin (2001) identified a range between 10th and 30th percentile for perennial rivers. In the absence of the long-term data, the

droughts are evaluated using TLM with simulated river discharge from a hydrologic model (Van Loon and Van Lanen, 2012).

(b) The Applied Threshold Level Method (ATLM)

Improving the past studies, the following procedures for the ATLM were designed in order to estimate water deficiencies for the 50 year return period drought, which were defined as drought impacts.

- Simulate river discharge using the BTOP model with APHRODITE data.
- Verify water deficiencies against historical drought records: the simulated 50-year river discharge with the selected threshold level was calibrated against historical drought records from the EM-DAT.
- Ascertain which level of percentiles, ranging from 1% and 30%, fit the past records, and choose the threshold level value: the percentile value was defined as the threshold level deciding on drought of the river basin.
- Determine water deficiency volumes for the 50-year return period drought.

Once the threshold level and 50-year impact were confirmed, exposure was estimated by dividing water deficiency volumes with water demand per water use unit. This is, people exposure was estimated by using existing information of water consumption per capita, while productivity exposure was calculated by using existing information of water demand per agricultural and industrial productivities. For this calculation, this study previously calculated coefficients such as agricultural productivities per agricultural water consumption (US$ per 1 m^3), industrial productivities per industrial water consumption (US$ per 1 m^3), and the fractions of various water consumption over total amounts, based on UN-water and national statistics.

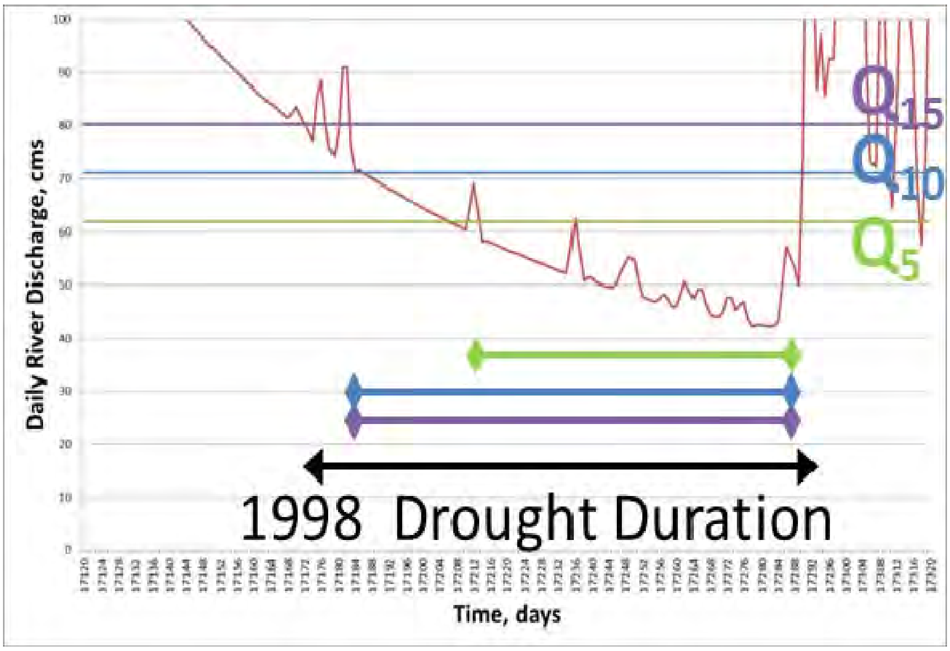


Figure 4.4.6. Example of comparing historical drought duration and river discharge simulated with BTOP model: in the Pampanga river, Philippines

4.4.4.3 Combining hazard, exposure, vulnerability, and coping capacity into risk indices

WRDRI was developed for tangible risk indices. Therefore, risk cannot be calculated without knowledge about how all proxies influence human deaths and economic losses. However, since such knowledge is very intuitive, descriptive, or site-specific, it is very difficult to express it in the widely acceptable way. On the top of this, it is not feasible to conduct field surveys in order to get damage curves for all proxies. Therefore, UNDP and recent scientists recommend that risk calculation equations should be statistically obtained, in the fact that under the situation when researchers do not have full knowledge, the best way is embodying empirical facts only, while excluding researchers' subjective. As suggested by them, this study decided to derive risk calculation equations out of data of the 15 Asian countries. Also, for the same reason, this study included the proxies, proved to be certainly correlated to disaster situations, in risk calculation equations, rather than considered all proxies. These all were attempted to avoid the cases where plausible results for unknown reasons were obtained.

(1) Risk calculation equations

In order to derive risk calculation equations using statistical methods, two procedures were designed. First, in cases when there were many proxies available, the factor analysis method was conducted to eliminate scales of proxies and effectively integrate proxies into a dimensionless score. Also, it is known as minimizing possibilities of excluding proxies reluctantly in building statistical equations for the multi-collinearity problem (for more information, see the Annex 9). Second, the logarithm multiple regression method was used to examine the relation of proxies and risk indices. It helped build optimum mathematical equations after trials and errors. Based on two procedures, optimum model structure and model parameters were obtained. As a conclusion, it is stated that all derived equations describe risks of the sample countries in a very plausible way, and especially this approach seemed to be very useful in identifying the flood risk index for people, and examining relevant DRR strategies.

(a) Flood risk index for people

$$\log R_p = -5.19 + 0.53 \times \log E_p + 0.64 \times FS \qquad [r^2 = 82.7\%]$$
$$FS = 0.12 \times CP + 0.37 \times DE - 0.35 \times EWS - 0.37 \times GG \qquad (14)$$

where R_p = flood risk index for people (persons/1,000 km^2); E_p = people exposure (persons/1,000 km^2); FS = a factor score (#); CP = standardized value of critical people (%); DE = standardized value of deforestation (%); EWS = standardized value of the early warning systems (1-5 scale); GG = standardized value of good governance (political stability and absence of violence, 0-100 scale).

- General comments: as a whole, the Eq.(14) seems very useful, in that explanatory power is satisfactory over the 15 countries, and it contains relatively many proxies, i.e. people exposure, two proxies for basic vulnerability, and two proxies for soft coping capacity. This result reveals the possibility that the flood risk index for people would be very successfully estimated using these methods, if the data for hard coping capacity could be collected.
- Meanings of included proxies: regarding the relation of proxies and human deaths, Eq.(14) implies that human deaths would be increased with people exposure,

physically weak people, and urbanized or spoiled land uses. At the same time, human deaths are found to be decreased by establishing early warning systems, and politically stabilizing the government. These all are well met by the DRR directions.

(b) Flood risk index for assets

$$\log R_a = 4.50 + 0.33 \times \log E_{a1} + 0.33 \times \log E_{a2} + 0.27 \times GG \quad [r^2 = 68.0\%] \quad (15)$$

where R_a = flood risk index for assets (US$ /1,000 km^2); E_{a1} = house exposure (#/1,000 km^2); E_{a2} = productivity exposure (US$/1,000 km^2); GG = standardized value of good governance (voice and accountability, 0-100 scale).

- General comments: Eq.(15) moderately shows explanatory power over the 15 countries. However, it turns out that Eq.(15) needs to improve its performance more for reliable risk assessment, and just include few proxies, i.e. house exposure and productivity exposure, and a single proxy for soft coping capacity. Hence, it is thought that Eq.(15) should be derived again once it is possible to consider hard coping capacity.
- Meanings of included proxies: regarding the relation of proxies and economic losses, Eq.(15) presents that the flood risk index for assets would be increased with house exposure, and productivity exposure. Also, it means that the flood risk index for assets could be largely mitigated if the government carefully listens to citizens' voices. The results are satisfied by common expectations. However, it should be noted that insights about governance do not necessarily lead to practical DRR strategies. Thus, it is found that Eq.(15) does not provide many merits, except for calculating the relevant risk.

(c) Storm surge risk index for people

$$\log R_p = -5.56 + 0.67 \times \log E_p + 0.97 \times CP \quad [r^2 = 92.7\%] \quad (16)$$

where R_p = storm surge risk index for people (persons/1,000 km^2); E_p = people exposure (persons/1,000 km^2); CP = standardized value of critical people (%).

- General comments: it is remarkable that Eq.(16) very accurately explains human deaths over the 15 countries only with people exposure and a single proxy for basic vulnerability. This is mostly because human deaths have very high correlation (i.e. the Pearson R was more than 0.7) with people exposure. Hence, it is strongly supposed that the storm surge risk index for people is predominated by 'physical conditions', exposure, rather than 'socio-economic conditions', vulnerability and coping capacity.
- Meanings of included proxies: regarding the relation of proxies and human deaths, Eq.(16) implies that the storm surge risk index for people would be increased with people exposure, and physically weak people. These all are well met by common expectations, which, however, shows that the risk might not be easily lowered without reducing exposure.

(d) Storm surge risk index for assets

$$\log R_a = 16.90 + 0.34 \times \log E_{a1} + 0.28 \times \log E_{a2} - 0.27 \times GG \quad [r^2 = 96.7\%] \quad (17)$$

where R_a = storm surge risk index for assets (US$ /1,000 km^2); E_{a1} = house exposure (#/1,000 km^2); E_{a2} = productivity exposure (US$/1,000 km^2); WGI = standardized value of good governance (political stability and absence of violence, 0-100 scale).

- General comments: similarly, economic losses are found to absolutely depend on exposure, i.t. how many houses and productivities are placed in the LECZ. As a result, Eq.(17) very accurately explains the storm surge risk index over the 15 countries only with two proxies for asset exposure, and a single proxy for soft coping capacity.
- Meanings of included proxies: regarding the relation of proxies and economic losses, Eq.(17) clarifies intuitive knowledge, saying that the risk index for assets would be increased by house exposure and productivity exposure, and decreased by politically stabilizing the government. This result seems to suggest that effective DRR strategies should tackle on exposure. Nevertheless, it should be noted that this study does not consider hard coping capacity like dike. Excessive conclusions should not be made.

(e) Drought risk index for people

$$\log R_p/E_p = -9.61 + 29.58 \times FS_2 + 27.22 \times FS_1 \times FS_2 \quad [r^2 = 85.7\%]$$

$$FS1 = -0.09 \times GG + 0.09 \times DAM - 0.99 \times WS$$

$$FS2 = -0.57 \times GG - 0.58 \times DAM - 0.01 \times WS \quad (18)$$

where R_p = drought risk index for people (persons/1,000 km^2); E_p = people exposure (persons/1,000 km^2); FS_1 and FS_2 = factor scores (#); GG = standardized value of good governance (political stability and absence of violence, 0-100 scale); DS = standardized value of dam storage (m^3/person); WS = standardized value of water supply systems (%).

- General comments: above all, it should be understood that Eq.(18) was built out of five countries where people have ever been killed by drought. This fact hints that it is hard to put much importance to explanatory power, and it is very dangerous to apply Eq.(18) to other countries where drought has never caused mortalities. Regarding the relation of proxies and human deaths, it turns out that mortality-related drought is a very complicated phenomenon. Conceptually, it is not adequate to perfectly separate people exposure and human deaths, since people exposure does not show sufficient correlation so that it is not well regarded as an independent variable for human deaths. Therefore, Eq.(18) has usefulness in examining the differences between people exposure and human deaths, and their reasons, rather than calculating drought risk. Also, since this type of drought is complex, Eq.(18) contains an interaction term between proxies, which usually make interpretations difficult. Based on these results, it is found out that in order to better build the drought risk calculation equation for people, more sufficient data, more delicate proxies, and more flexible methods are essential to handle this complicated disaster.[43]
- Meanings of included proxies: from Eq.(18), it is well supposed that if the government is politically stable, and basic needs are satisfied by sufficient dams and water supply systems, the differences between people exposure and drought risk index will be increased. This information well satisfies common expectations, especially raising the need for water resources infrastructure as a DRR strategy.

(f) Drought risk index for assets

$$\log R_a = 3.81 + 0.44 \times \log E_a - 0.70 \times GG \quad [r^2 = 69.6\%] \quad (19)$$

[43] For similar reasons, UNDP and ISDR could not clarify the results of global drought risk assessments

where R_a = drought risk index for assets (US$ /1,000 km^2); E_a = productivity exposure (US$/1,000 km^2); GG = standardized value of good governance (voice and accountability, 0-100 scale).

- General comments: as a whole, Eq.(19) does not look problematic in explaining economic losses over the 15 countries, yet it just includes productivity exposure and a single proxy for soft coping capacity. For better risk calculation, therefore, other efforts should be given again to include many proxies and increase explanatory power further.
- Meanings of included proxies: regarding the relation of proxies and human deaths, Eq.(19) implies that the drought risk index for asset would be increased with productivity exposure, and decreased if the government carefully listens to citizens' voices. These results are equal to those in the storm surge risk index for assets. However, in this drought case, it is possible to greatly increase explanatory power, while adding new proxies continuously. Therefore, the results should be differently interpreted: for example, the results do not directly lead to practical DRR strategies, and Eq.(19) does not have much meaning, except for calculating the relevant risk.

(2) Limitations of risk calculation equations

Apparently, several attentions should be paid to using the risk calculation equations. The current equations are imperfect yet. It is partly because statistical methods were methodologically strict to incorporate many proxies into the equations, but mostly because many assumptions were needed to overcome data unavailability (simultaneously these researchers might have to test other methods and data sources to solve identified problems continuously). Among the matters that require attentions, the five following limitations should be clarified and fully understood.

- Assumption with hazard intensity (for more detail, see the Annex 10)
- Imperfection in data collection: Data for calculating proxies were not perfectly collected. If more data become available, these equations should be derived again. Especially, it should be noted that any proxies for hard coping capacity were not included in the flood and storm surge equations.
- Methodological limitations: regression methods have considerable limits in incorporating less significant proxies. Especially, in the case of storm surge, exposure is an absolutely predominating proxy over risk. In result, risk calculation equations contain critical people and good governance only. Several proxies, e.g., early warning systems, and community power, were slightly correlated to risk, but these proxies were incompatible with exposure. This can be a technical limit of this statistical method.
- Small sample used to derive the drought risk calculation equation: drought, causing human deaths, is very exceptional in Asia. Thus, the equation was just built using five countries where there have been drought-induced mortalities for the last 50 years. In this regard, the risk calculation equation, relating people exposure with human death due to drought, should be applied only to the five countries, i.e. Afghanistan, India, Indonesia, Pakistan, and Philippines. For other countries, it would be adequate to simply say that human death levels are zero, irrespectively of calculated values of people exposure. The countries did not show human deaths even if they had been suffered from extremely serious droughts.

- Attentions arising from usage of data from the EM-DAT: in deriving these equations, the most important data are exposure, and damages, i.e. how many people were affected, and killed in a country, and how seriously economic losses occurred then. Those data were obtained from the Emergency Events Database (EM-DAT) that the CRED has since 1988 developed. CRED's efforts to organize and count disaster-related statistics must be priceless in implementing most disaster studies. However, it has been often said that data of EM-DAT largely underrate the current disaster situations. Two important features of the database thus need to be enumerated (for more detail, see the Paul (2011)): (i) strict criteria is used in identifying a disaster event (more than 10 fatalities, more than 100 affected people, a call for international assistance, or official declaration of emergency); (ii) strict criteria is used in identifying affected people (only the persons who require immediate assistance are included).

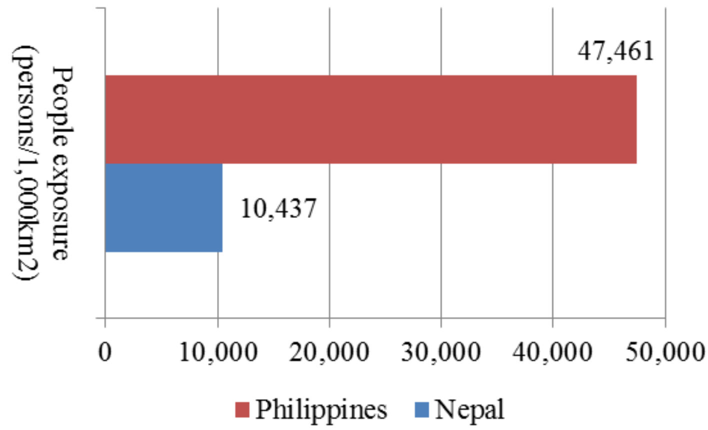
4.5 Results and Discussions

Using the methodologies introduced above, risks were estimated for the extreme hydrological conditions. In cases of flood and drought, it was assumed that hazards have 50-year return periods on the basis of simulated daily discharges. Storm surge hazard was assumed to follow the LECZ definition: i.e., the one influencing low elevation coastal zones where elevation is below 10 meters. Besides, it should be noted that Nepal does not have any storm surge risk since it is an inland country.

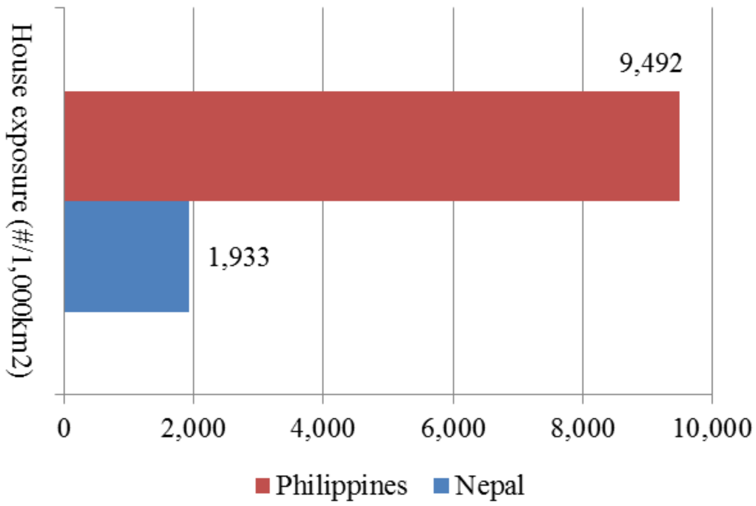
4.5.1 Flood

Results of flood hazard assessment and exposure assessment are summarized, as follows:

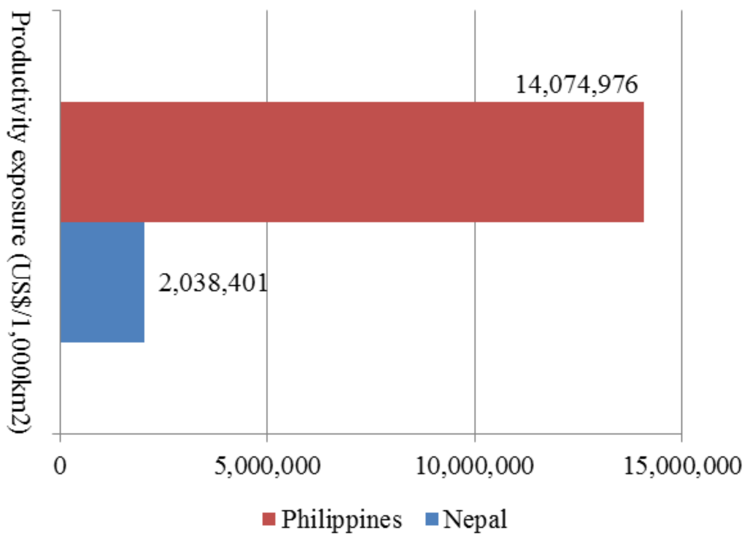
- People exposure: on the basis of the same area (1,000 km^2), people exposure of Nepal and Philippines is, respectively, 10,437 persons and 47,461 persons. This is, people in Philippines is 4.5 times more exposed to flood than that in Nepal, which are attributed to larger inundation areas (the magnitude of hazard impact), and higher population density.
- Asset exposure: from the assets viewpoint, the difference becomes more dramatic. The productivity exposure, including agricultural and industrial activities, in Philippines reaches about 7 times that in Nepal. It is of course because economic activities of Philippines are relatively compact within the same area.
- However, exposure in Nepal should not be disregarded. The calculation implies that productivity exposure is related to 3.6% of national GDP, if 50-year flood occurs.



(a) People exposure



(b) Asset exposure (house exposure)



(c) Asset exposure (productivity exposure)

Figure 4.5.1 Comparison of flood exposure between two countries

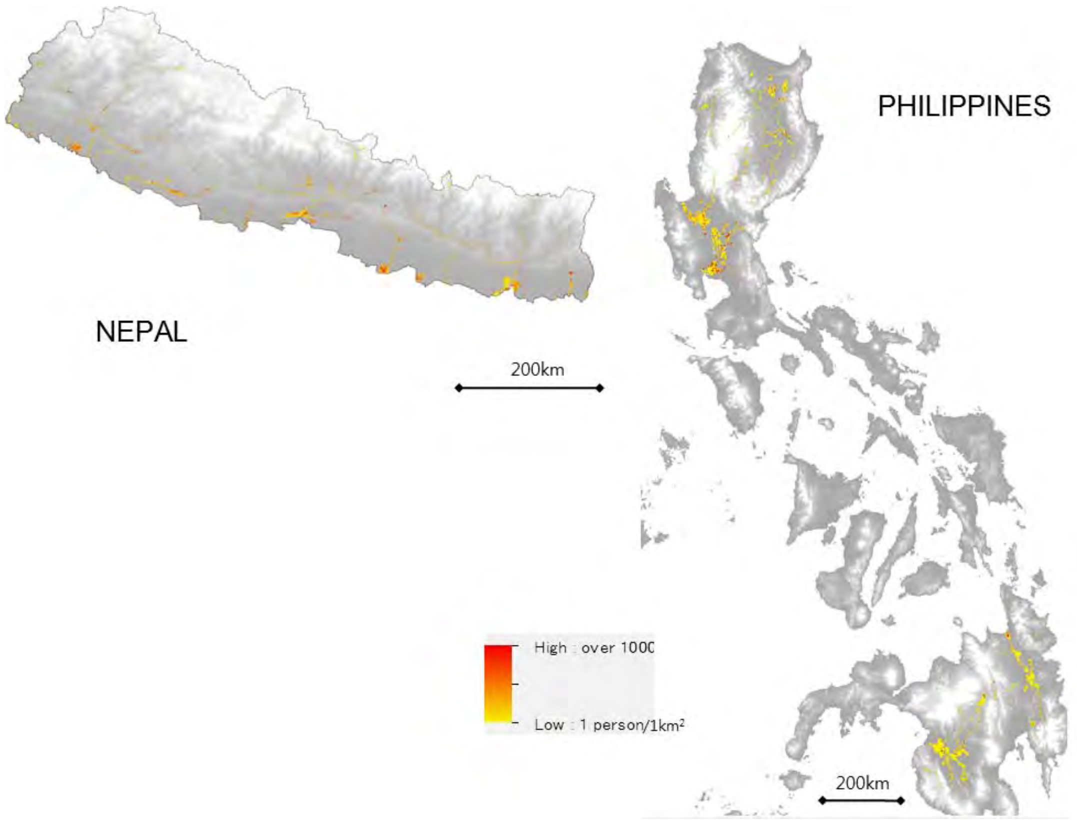
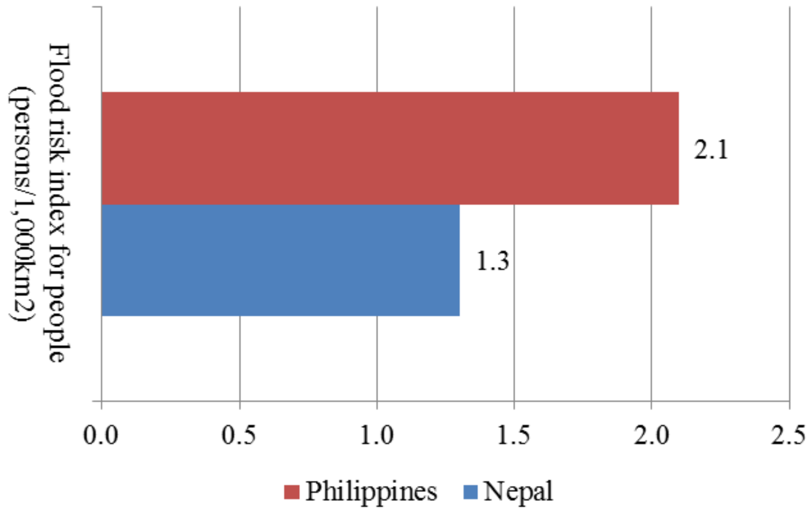


Figure 4.5.2 Result of flood exposure assessment

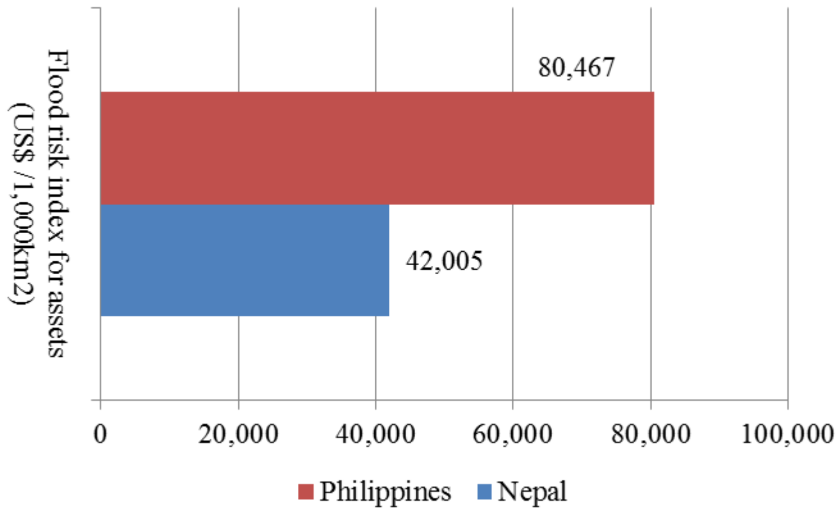
Using the risk calculation equations, all proxies for exposure, basic vulnerability, and coping capacity were combined into risk indices. The results are summarized, as follows (Figure 4.5.3):

- Flood risk index for people: on the same area 1,000 km^2, the calculated values of the index of Nepal and Philippines are 1.3 and 2.1 persons, respectively. It is found that risk of Philippines is about 60% larger that of Nepal. Note that the difference in people exposure was more dramatic: i.e. exposure of Philippine was 4.5 times as many as that of Nepal. This means that Philippines have largely reduced flood risk due to some reasons. Based on proxies included in the risk calculation equation, the reasons are low vulnerability (low percentages of critical people, and low percentages of deforestation), and high soft coping capacity (high early warning systems, and good governance). In other words, Nepal has much room to reduce this risk index greatly through better flood risk management programs.
- Flood risk index for assets: this index value of Philippines is about double that of Nepal. However, it should be noted again that the differences in productivity exposure and house exposure between the two countries were much bigger. In our calculation, good governance was regarded as a very important proxy for soft coping capacity. It was expected that higher governance score of Philippine would mitigate economic losses pretty much.
- As a whole, it is apparent that Philippines have more flood risk within the same area. This is complicatedly attributed to larger inundation areas, higher population density, and more compact economic activities. However, Philippines were analyzed to have the relative superiority in vulnerability (critical people, and deforestation) and coping

capacity (early warning systems, and good governance), which help to avoid much larger risks.



(a) Flood risk index for people



(b) Flood risk index for assets

Figure 4.5.3 Comparison of flood risk between two countries

4.5.2 Storm surge

For Philippines, results of storm surge hazard assessment and exposure assessment are summarized, as follows (Table 4.5.1):

- People exposure: every 10 km of coastline, people exposure amounts to 5,121 persons, which is very noticeable. If the exposure is converted into the national coastline, it corresponds to about 20% of total population, i.e. 18.6 million persons. As in Figure 4.5.4, this large value of exposure results from the fact that many big cities including Manila and Cebu are located along the coastline.
- Asset exposure: affected productivities, including agricultural and industrial activities, amount to 4.3 million US$ per 10 km, which also comes up to 12% of national GDP.
- Irrespectively of people or assets, it is easily perceived that exposure to storm surge is

more than that to flood or drought. Therefore, storm surge seems very likely to be a threat, generating the largest exposure, to Philippines.

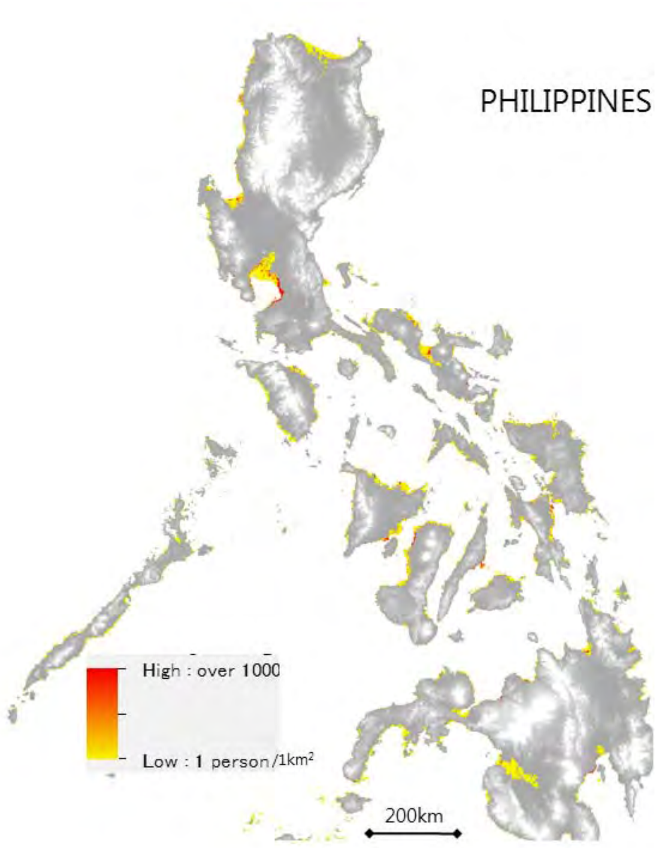


Figure 4.5.4 Result of storm surge exposure assessment

Table 4.5.1 Storm surge exposure of the Philippines

People exposure (persons/10km)		5,121
Asset exposure	House exposure (#/10km)	1,024
	Productivity exposure (US$/10km)	4,351,936

In the case of storm surge, it should be first understood that exposure is an absolutely predominant factor over the risk (thus, two risk calculation equations could not contain various proxies for vulnerability and coping capacity, yet they could reproduce risk indices very well). Using the risk calculation equations, the calculated values of exposure, critical people, and good governance were combined into risk indices. The results are summarized, as follows (Table 4.5.2):

- Storm surge risk index for people: if the extreme events like the LECZ definition happen in Philippines, human deaths would be likely to be 1.5 persons in every 10 km. This figure means that 0.03% of people exposure would be killed, or 5,443 persons would be killed countrywide. This result is 8.7 times higher than that in the flood risk index for people, and thus storm surge seems to be a tremendous threat to Philippines.
- Storm surge risk index for assets: if extreme events happen, economic losses are

estimated to be very significant. The calculated value of the risk index, 213,104 US$ per 10 km, is equivalent to 773 million US$ over the whole coast lines, and corresponds to 0.6 % of national GDP. It is obvious that this risk would temporally paralyze residents' lives and governments' functions, and also hamper economic growth for a long period.

- All these results clearly show that storm surge is the biggest water-related threat to Philippines. In reality, ISDR PreventionWeb lists top 10 natural disasters in Philippines, saying that storm surge generated 8 of top 10 serious events in both of mortalities, and economic losses. Also, our risk index properly describes records on historical maximum events; 5,956 persons killed (1991) and 585 million US$ lost (2009).

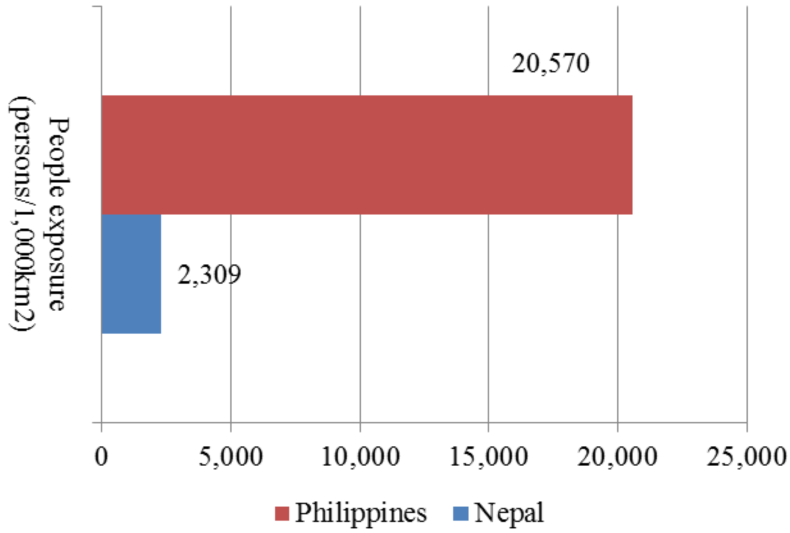
Table 4.5.2 Storm surge risk of the Philippines

Storm surge risk index for people (persons/10km)	1.5
Storm surge risk index for assets (US$/10km)	213,104

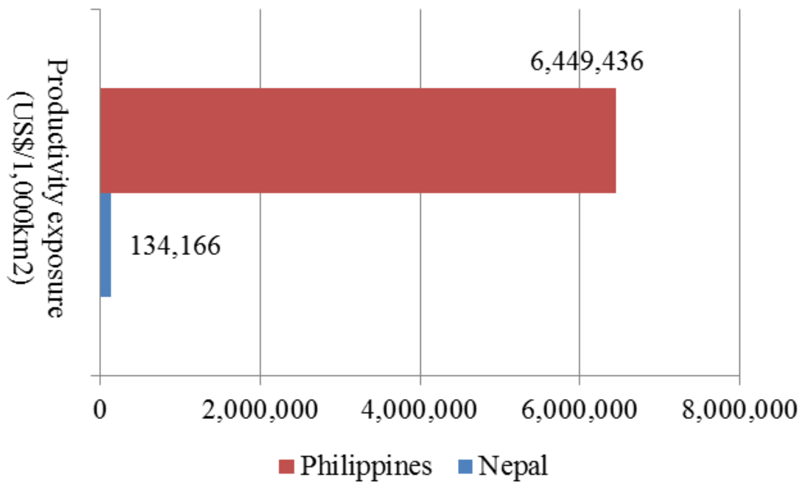
4.5.3 Drought

The results of drought hazard assessment and exposure assessment are summarized, as follows (Figure 4.5.5):

- People exposure: on the basis of the same area (1,000 km^2), people exposure of Nepal and Philippines is, respectively, 2,309 persons and 20,570 persons. This is, people in Philippines is about 9 times more exposed to drought than that in Nepal. This seems to be mainly attributed to larger water deficiency volumes (the magnitude of hazard impact), arising from unbalance between water availability and water demand requirements. However, it should be noted that for both countries, exposure to drought is not much high, compared to that to flood. People exposure to drought in Nepal and Philippines is merely 22% and 43% of that to flood, respectively.
- Asset exposure: for both countries, exposure to drought is not relatively high as well. Productivity exposure to drought in Nepal and Philippines is, individually, 6.6% and 45.8% of that to flood (besides, houses are not affected to drought). Hence, it is found that for these countries, water deficiency is not the impact generating relatively serious exposures.



(a) People exposure



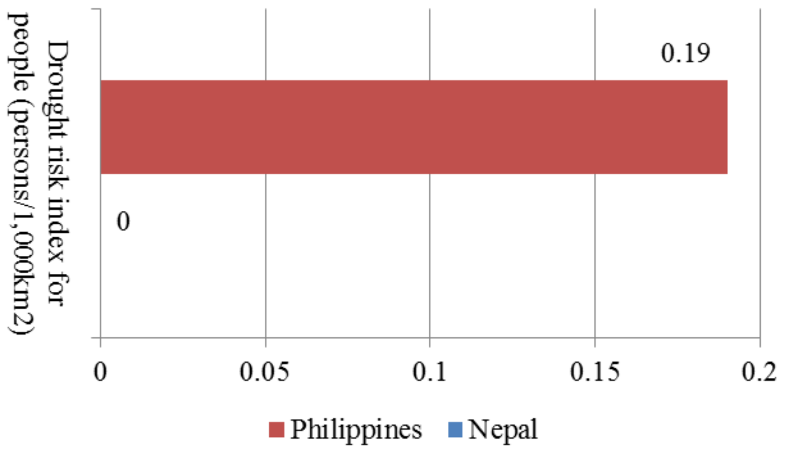
(b) Asset exposure (productivity exposure)

Figure 4.5.5 Comparison of drought exposure between two countries

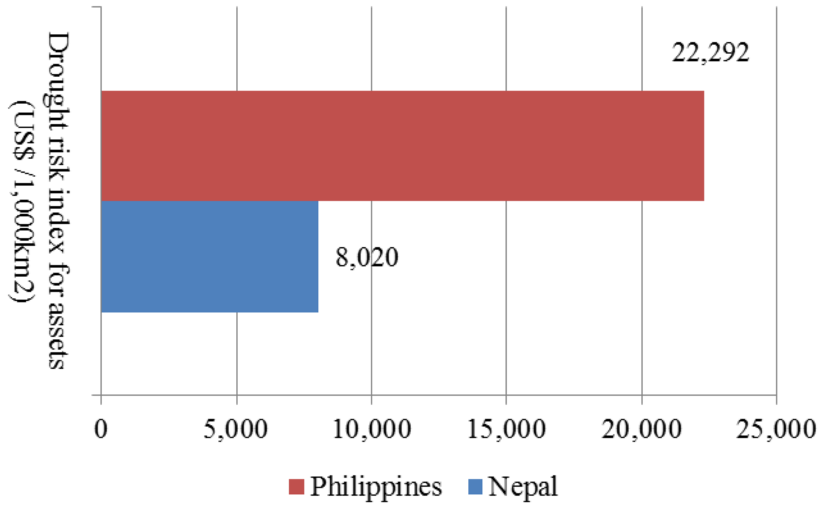
Using the risk calculation equations, all proxies for exposure, basic vulnerability, and coping capacity were combined into risk indices. The results are summarized, as follows (Figure 4.5.6):

- Drought risk index for people: as a result of calculating risk at the extreme drought event, it is found that human deaths due to drought are very uncommon. On the same area 1,000 km^2, the calculated index value of Nepal were 0.29 persons. This corresponds to 42 persons countrywide. However, it should be noticed that in Nepal, drought has never led to human deaths for the last 50 years, and thus Nepal could not be used in deriving the risk calculation equation. Unlike the calculation, it would be better to, for Nepal, consider the calculated value of drought risk index for people to be meaningless. For Philippines, the index value amounts to 0.19 persons per 1000 km^2, which correspond to 57 persons killed countrywide. In reality, disaster records (ISDR PreventionWeb) show that 8 persons died from drought in 1998. Our calculation warns Philippines that more human deaths could arise without any measures to increase soft coping capacity (good governance), and hard coping capacity (dam storage. and water supply coverage).

- Risk indices for assets in Nepal and Philippines are 8,020 and 22,292 US$ per 1,000 km2, respectively, saying that drought risk of Philippines is about 8 times that of Nepal. However, it should be stated that Nepal has much room to reduce drought risk, in the fact that the difference in productivity exposure between the two countries was much larger. Based on the risk calculation equation, it is possible to recommend that risk of Nepal can be largely mitigated by improving governance (and especially in the way to listen carefully to residents' voices and better fulfill governments' accountability regarding drought risk management).



(a) Drought risk index for people



(b) Drought risk index for assets

Figure 4.5.6 Comparison of drought risk between two countries

In summary, the case studies clearly indicate that Philippines are a water-related disaster-prone country. First, storm surge, not threatening Nepal at all, was analyzed to yield the biggest risk to Philippines. Second, on the same area (1,000 km^2), flood and drought risk indices were found to be larger than those of Nepal, which pertains to high hazard impacts, high population density, and more compact economic activities. Nonetheless, it should be noted that in all cases, the difference in risk is small, compared to that in exposure. On the whole, Nepal shows higher vulnerability and lower coping capacity. It is emphasized again that well-planned governments' efforts would be very likely to reduce the current risk levels to a great extent

4.6 Conclusions

4.6.1 Limitations and solutions

It can be contended that ICHARM's advanced technologies largely helped satisfy data requirement, and then showed the possibility of assessing global risk for various water-related disasters. Current limits of WRDRI might be summarized as follows:

- **Find more useful data sources to specify local attributes**: Unlike hazard assessment and exposure assessment, proxies for vulnerability and coping capacity were calculated mainly by using global statistics. The problem is that most of these data are announced at the country level, and thus averaged over the wide areas. This is, accuracy of WRDRI is excessively limited by resolutions of those proxies. In particular, floods are disasters occurring in relatively narrow areas with large impacts. For measuring flood risk in the areas better, it is necessary to downscale proxies for vulnerability and coping capacity to the finer scale such as the catchment basin level at least. It can be therefore said that WRDRI should be able to utilize satellite image information and GIS data sources more. Among all used proxies, critical people, deforestation, dam storage, and water supply coverage are those having special needs for localization.

  Moreover, the sample size, needed to conduct statistical analyses, has to be increased. Considering that Philippines and Nepal respectively belong to South Eastern and Southern Asia, this study selected 15 countries after excluding several outliers. However, the sample size was not sufficient, especially to build drought risk calculation equations. In the countries of consideration, droughts resulting in mortalities are very exceptional, and thus only five countries were used to find the relation of proxies and human deaths due to drought. This might be an important reason if drought risks are overestimated or underestimated.
- **Measure governments' efforts better (for hard coping capacity)**: In WRDRI, all proxies of hard coping capacity and soft coping capacity were selected with a special interest in quantifying governments' efforts. However, through two case studies, it was found that there were unexpected difficulties in handling both coping capacity.

  For hard coping capacity, the biggest efforts should be paid to data collection. This study could not access to data such as dam flood control capacity and dike length, which are crucial factors in the conventional flood and storm surge management. Although reservoir capacity is important to reduce drought damage, this was alternatively measured in terms of dam storage per capita, one of MDG indicators. When thinking of importance of these data, these researchers contend that digital water atlas projects, being currently and individually conducted by UN-Water, FAO, and the Global Water System Project (GWSP), will provide very valuable data sources. WRDRI certainly needs to be advanced in the way to adopt such data sources.
- **Measure governments' efforts better (for soft coping capacity)**: For soft coping capacity, many available data have been biennially produced by the UN-ISDR HFA Monitor's endeavors since 2009. However, the scores, officially announced by HFA, were analyzed to be rough estimates still. More seriously, they are autonomously estimated by each country, and thus it is often questionable whether the scores talk about governments' efforts objectively. Therefore, it can be said that it is important to newly develop objective proxies on the basis of national reports that have been submitted to the ISDR.

  Moreover, in WRDRI risk definition, a proxy for past experiences on hazards was

selected under the hypothesis that past experiences would be helpful to overcome current disasters. Yet, over the 15 Asian countries, the high value of this proxy did not mean low risk. As the result, this proxy certainly needs to be re-examined. In our opinions, the original hypothesis should be changed: for example, "past experiences would be helpful to overcome current disasters only when learning conditions are well met." Thus, it seems more important to measure learning conditions, not simply past experiences.

- **Find better risk calculation equations**: after literature review, UNDP's study was chosen as a best practice in deriving risk calculation equations. In fact, the equations, suggested by this study, look more useful than UNDP' in that explanatory powers are higher, and selected proxies are more closely related to risk drivers and disaster management. Nevertheless, there is apparently much room for improving the current equations.

  First of all, the risk calculation equations were built out of annual average data, opened in EM-DAT, over 15 Asian countries. Regarding whether it is proper to use these equations to calculate the 50-year return period risks, theoretical adequacy should be discussed seriously. To solve this problem, risk calculation equations need to be derived, based on exposure and damages with return periods satisfying research purposes.

  Furthermore, the logarithm regression method was too strict to successfully incorporate many proxies into the equations. This study partly solved the technical problem, while integrating proxies into a dimensionless score. Still, the equations do not include proxies sufficiently. It is thus expected to test more flexible, but still acceptable, methods, e.g. pattern recognition techniques or causality-related system models, for this purpose.

4.6.2 Conclusions

In spite of further studies suggested, this study definitely provided countless benefits. Among them, the following benefits are especially highlighted.

- **The important framework was established as a prototype of the global risk assessment.** This study made clear definition of risk and relevant terminologies, and systemized WRDRI methodologies. Besides, it showed high possibility that the current data unavailability problem would be largely solved by integrating advanced technologies and global data sources.
- **The strategies for collecting data were certainly established.** This study identified the current data availability and requirement clearly, and suggested solutions for reducing the gap so that reliable risk assessments can be implemented in the near future. At the same time, this study emphasized importance of data collection in each country to the disaster risk management.
- It was confirmed that **the WRDRI method helps to identify disaster prone countries in the widely acceptable way, and provides communicative and tangible risk indices**, i.e. probable mortalities and probable economic losses. Therefore, it will make great contributions to investments on disaster risk reductions. Moreover, this method was anticipated to be able to have finer resolutions, i.e. the watershed level, if additional improvements are made (for more details, see the Annex 11).
- **All used methods effectively simplify high complexities related to hazard, exposure, and risk, and significantly lower global data requirements**. Especially, at the extreme conditions of hydrological events, risk calculation results would be very plausible and realistic. Therefore, WRDRI method was expected to be applicable to set up disaster risk reduction strategies: for example, 'Halve the population without access to the basic early warning for extreme hydro hazards'.

Undoubtedly, the biggest gain from this project is that ICHARM and ADB had valuable chances to discuss global risk assessment framework together with various stakeholders, and continuously tried to fill strong wishes and diverse voices in WRDRI. These researchers carefully, but strongly, suggest that all outcomes including WRDRI framework, methodologies, data, and obtained know-how should be sustained, and advanced further.

5. Overall Conclusions and Recommendations

5.1 Overall Conclusions

The overall conclusions of the TA are described as follows.

In-country project support component:

- In Bangladesh, the TA helped the Bangladesh Water Development Board (BWDB) prepare a National Road Map for Flood Early Warning System by developing a method which can indicates priority of actions proposed by wide range of stakeholders.
- In Indonesia, the TA helped the Balai Besar Wilaya Sungai (BBWS) Solo improve their capacity on flood forecast in the Solo River basin by applying ICHARM's GIS-based integrated flood analysis system (IFAS) which can forecast floods by combining precipitation data obtained by satellites with topographic data. Training programs for the river basin organization in the Solo River basin were also conducted.
- In the Lower Mekong basin, the TA helped the Mekong River Commission Secretariat (MRCS) develop a methodology to assess flood vulnerability in Cambodian floodplains, especially for houses and agriculture.
- In Philippines, the TA helped the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) develop their capacity through training programs to identify flood causes in the Pampanga and the Cagayan River basins by applying IFAS to historical floods.

Program quality support component:

- A methodology to estimate indices for water-related disaster risk was proposed based on socio-economical and hydrological data in several Asian countries.
- Workshops and training programs were conducted to improve knowledge networking and regional cooperation of ADB's developing member countries.

5.2 Way Forward

The interaction between in-country components of the project created large added value. Transfer of knowledge and exchange of ideas, experiences and information on flood risk management between the different stakeholders proved to be very effective. For example the development of flood vulnerability indices for Lower Mekong Basin of Cambodian floodplain may prove to be vastly useful in the floodplains of other countries such as the Lao PDR, Vietnam, Bangladesh, Indonesia and the Philippines.

Next the project also addressed the need for localized flood information systems and the involvement of the local community for increased preparedness and flood risk management. The approach developed in Indonesia component by integrating advanced technology such as application IFAS for flood forecasting system and community based flood disaster risk management may be also useful in other river basins. The setup and experience of the community evacuation drill may prove to be of value for similar (flash flood) situations in other countries.

In Bangladesh component the project gained experience with the development of a SWOT-AHP approach to prioritize different interventions and measures in the setup of flood early warning systems. The outcomes were presented in form of a National Roadmap for FEWS

development in Bangladesh so that other projects and donor agencies may apply the approach in similar decision making processes. The developed national road map is very useful for stakeholders and donor agencies in project implementation and investments.

The methodology of the Philippines component to identify causes of historical flood based on ground-observed and satellite based information is also useful in other river basins.

The transfer of knowledge related to IFAS was very successful. It proved that real time flood early warning systems could be developed in data deprived circumstances. The training on IFAS concentrated in Indonesia and the Philippines and but also experts from Bangladesh and Cambodia received introduction courses on IFAS.

Overall the project showed the use of a more science and technology driven approach for flood analysis, forecasting and flood modeling and the (community based) disaster management that requires an insight in the perception of risk, the costs and benefits of mitigating measures etc. The project also helped to develop a capacity of the counterpart institutions of the targeted countries by organizing various capacity development training, knowledge sharing workshop and exchange visit programs.

5.3 Recommendations

Based on the outcomes of the project the main recommendations are:

- More effort needs to be given to close the gap between local knowledge on flooding and the development of flood early warning systems.
- Capacity building (hardware, software and expertise) is a key factor in the successful operation of any FEWS. Special attention is needed to maintain sufficient staff capacity at the FFWC in Bangladesh.
- Exchange of results from the in-country projects might be intensified and extended to other flood prone regions in Asia.
- IFAS flood early warning system could be further developed and introduced in other Asian countries as supplementary information.
- Developed flood vulnerability indices in Lower Mekong Basin of Cambodian floodplain can be useful for decision makers, planners, and local government to establish the policies required for reducing the vulnerability. The developed methodology of flood vulnerability indices can be expanded to other area.
- Developed framework of WRDRI can be introduced in other countries for validation and other perspective.

More detailed recommendations are described in the in-country reports.

Acknowledgement

This final report Main Volume is prepared under program quality support of Asian Development Bank, Technical Assistance for Supporting Investments in Water-Related Disaster Management (TA7276). We, International Centre for Water Hazard and Risk Management (ICHARM), Public Works Research Institute (PWRI), Japan, would like to express our gratitude to Bangladesh, Indonesia, Philippines, Nepal and other DMCs which contributed to this project. We also express sincere gratitude to MRCS, JICA, JAXA, UNESCAP and other organizations who supported to implement this project

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Annex 1: Workshop report: Nepal (15-18 January 2012)

Report of Knowledge Sharing Workshop on Water-Related Disaster Risk Management (15-18 January 2012), Lalitpur, Nepal:

Background

The international Centre for Water Hazard and Risk Management (ICHARM) has been implementing Capacity Development Technical Assistance for Supporting Investments in Water-related Disaster Management (R-CDTA7276) under the flagship of Asian Development Bank (ADB)-ICHARM partnership agreement. This ICHARM-ADB joint project has implemented different types of national and regional- level interventions mainly through the application of Integrated Flood Analysis System (IFAS) to the Solo River basin in Indonesia, pilot implementation of community-based flood management approaches in Indonesia, national road mapping of early warning system in Bangladesh, development of flood vulnerability indices in the Lower Mekong Basin, and capacity development by practical training and knowledge-sharing programs for target as well as other countries in the region.
The main aim of implementing knowledge sharing activities among member countries under the program quality support component of TA 7276 is to share know-how and lessons learned in the field of water-related disaster risk management. In line with this objective, a knowledge sharing workshop on Water-related Disaster Risk Management was planned on 15-18 January, 2012 in Nepal. The workshop mainly focused on sharing international experiences and best practices on flood forecasting and early warning system inviting participation from regional member countries such as India, Bangladesh, Bhutan and Nepal as well as experts from other Asian countries from Indonesia, the Philippines and Cambodia. The countries in the basins of Ganges and Brahmaputra rivers, which have been playing a significant role in socio-economic development but also often put a major set-back in the development due to massive annual floods, can be benefited from this knowledge sharing workshop. The knowledge sharing on best practices of disaster risk management is one of the key activities prioritized in the framework. In the workshop, the outcomes of TA 7276 related to flood forecasting and early warning such as implementation of IFAS based flood forecasting and early warning and community based flood risk management in Indonesia, national road mapping on flood forecasting and early warning system in Bangladesh together with experiences from Lower Mekong Basin floods of 2011 as well as floods in South Asian region were shared.

Dates and Venue

This Workshop was held on 15-18 January, 2012 at Hotel Himalaya in Kathmandu, Nepal.

Organizers

International Centre for Water Hazard and Risk Management (ICHARM), Japan
Asian Development Bank (ADB), the Philippines
Water and Energy Commission Secretariat (WECS), Nepal
Department of Water Induced Disaster Prevention (DWIDP), Nepal
With supported by Deltares, the Netherland

Participants of the workshop

About 44 participants including ICHARM, ADB and Deltares members actively joined the workshop. The participants were invited from India, Bangladesh, Bhutan and Nepal as well as experts from other Asian countries provisionally such as from Indonesia, Cambodia and the Philippines. About 11 participants from Nepal joined the workshop as guests.

Content

The contents of the workshop are presentation by resource persons, presentation by ICHARM, presentation by participants, review, panel discussion, field site survey, flood simulation game by Deltares, the Netherland.

Detail Descriptions of Sessions and Discussions

1st day of the workshop (15th January 2012)
Session I: Activities of ADB's Technical Assistance 7276

- To understand activities of ADB's regional capacity development technical assistance 7276 for *Supporting Investments in Water-Related Disaster Management* (the TA);
- To recognize innovative activities of the TA; and
- To share reflection from three piloted countries/areas (Bangladesh, Indonesia, and the Lower Mekong Basin), and their activities on how to link with ADB's activities.

Chair: Dr. Ravi Sharma Aryal, Joint Secretary, Water and Energy Commission Secretariat (WECS)
Co-chair: Dr. Rabindra Osti, Asian Development Bank (ADB)
Facilitator: Dr. Badri Shrestha, International Centre for Water Hazard and Risk Management (ICHARM)

Speaker: Mr. Toshio Okazumi, ICHARM, Japan
'Activities of ICHARM and ADB TA 7276-REG Project'

Main points and remarks

- Floods in Asia
  - Economic loss from water-related disasters in Asia and the Pacific has been increasing tremendously in recent 30 years
  - Two-thirds of the flood-related disaster fatalities in 1980-2011 were in Asia.
  - Flood vulnerability is increasing in Asia because of population growth, economic development, urbanization, and economic globalization.
- Introduction of ICHARM
  - ICHARM is the Asia-Pacific Water Forum's Regional Water Knowledge Hub on disaster risk reduction and flood management from June 2008.
- Overview of the TA
  - The objective of the TA is to help preparation and implementation of flood management projects through knowledge and capacity development that will reduce vulnerability to water-related disasters.
  - The TA has three in-country components and one regional component: (i) a national roadmap on flood forecasting and early warning system development in Bangladesh, (ii) a satellite-based flood warning system (IFAS) in the Solo River basin in Indonesia and community-based flood management approaches in Indonesia, (iii) development of flood vulnerability indices in the Lower Mekong Basin (LMB), and (iv) capacity development through practical training and knowledge-sharing programs for target as well as other countries in Asia and the Pacific.
  - Since flood is different in each river basin (e.g. meteorological, hydrological, topographical, socio-economical), the TA finds and creates new innovative and appropriate approaches based on the philosophy of ICHARM's 'localism' to mitigate flood damage in river basins.

Speaker: Dr. Lam Hung Son, Mekong River Commission Secretariat, Cambodia
'Best practices on water-related disasters in Lower Mekong Basin'

Main points and remarks

- Outline of MRC's Flood Management and Mitigation Programme (FMMP)
  - FMMP provides technical and coordination services to the four countries in LMB to prevent, minimize or mitigate the civil and socio-economic losses due to floods, while preserving the environmental benefits of floods.

- o There are five components in FMMP: (i) regional FMM Center, (ii) structural measures and flood proofing, (iii) enhancing cooperation, (iv) flood emergency management strengthening, and (v) land management.

Speaker: Ms. Gemala Suzanti, Bengawan Solo River Basin Organization, Ministry of Public Work, Directorate General of Water Resources, Republic of Indonesia
'Reflection on ADB TA 7276-REG activities in Indonesia and activities of BBWS in flood related disasters' (Supported by **Dr. Mamoru Miyamoto, ICHARM**)

Main points and remarks

- Outline of the Solo River basin
  - o The Solo River basin, located in Central and West Java, has a catchment area of 19,800km^2 and has population of about 16 million. Its annual average rainfall is about 2,100mm: the wet season is from November to April, and the dry season is from May to October.
  - o The factors that cause flooding in the Solo River basin are large amount of rainfall, hydrological watershed condition, physical condition of the river, topography, influence of tides, and residential areas in the flood plain and depression.
  - o The government of Indonesia takes comprehensive measures to mitigate flood damage in the Solo River basin. There are several hurdles to achieve the goal: for structural measures, cost of investment, social and environment problem, and difficulty with relocation, and for non-structural measures, automation of monitoring stations, use of models for forecasting floods, quick exchange and transfer of data, information for the local authorities, and raising awareness of populations to the risks.
- Application of IFAS to the Solo River basin
  - o IFAS is a concise flood-runoff analysis system as a toolkit for effective and efficient flood forecasting by using hourly global rainfall maps observed from satellites which are provided via internet about four hours after observation. IFAS provides interfaces to input not only satellite-based but ground-based rainfall data, as well as GIS functions to create river channel network and to estimate parameters of a default runoff analysis engine and interfaces to display output results.
  - o IFAS will be applicable for flood analysis in the mainstream as a second opinion to the ground observatory system, which has 18 automatic water level stations and 36 automatic rainfall stations.
  - o Several things remain to be developed for the practical use of IFAS in the Solo River basin: (i) development of an automated rainfall data transfer system from the ground observatory system to IFAS, (ii) calibration of rainfall data obtained by satellites, (iii) modification of warning messages to residents from email to short message service, and (iv) capacity development of BBWS-BS staffs.
- Community based disaster risk management
  - o Evacuation drills were conducted in two villages in Bojonegoro district in July 2011.
  - o BBWS-BS is planning to do some replication of the training in the other areas by adopting the local value and improving methodology.

Speaker: Mr. Md. Enamul Islam, Executive Engineer, Surface Water Processing Branch, Bangladesh Water Development Board, People's Republic of Bangladesh
'Flood Forecasting and Warning services in Bangladesh: A Way Forward in the Early Warning System'

Main points and remarks

- Overview of natural disasters in Bangladesh
  - o Bangladesh is in the biggest delta in the world formed by sedimentation of the three great river systems: Ganges, Brahmaputra, and Meghna. It receives runoff from a

catchment of 1.72 million km^2. About 50% of the country is within 6-7m of MSL. Its annual average rainfall is 2,300mm.
    - Floods: Floods occur regularly in Bangladesh. About 25-30% of its land is inundated every year, and 68% of which was flooded in 1998. There are four kinds of floods: monsoon floods from the major rivers, flash floods in the eastern and northern areas, floods due to storm surge in the coastal area, and local floods due to high intensity rainfalls.
    - Water shortage: about 25% of the country suffers water stress in dry season.
    - River erosion: 8,700ha agricultural land is eroded and 64,000 inhabitants are displaced every year.
    - From 1996 to 2000, average annual loss due to natural disaster is $23.614 million.
    - The government of Bangladesh takes structural and non-structural measures for disaster mitigation. For the early warning, the national water policy states that "through its responsible agencies, the government will develop early warning and flood proofing systems to manage natural disasters like flood and drought."
- Objectives and findings of the TA Bangladesh in-country component
    - The main objective of the component is to prepare analytical input and prepare project portfolios and pre-feasibility studies to enhance the existing early warning system including flood forecasting system operated by the Flood Forecast and Warning Center (FFWC), BWDB.
    - There are three elements of early warning system: (i) forecasting, (ii) dissemination, and (iii) response to forecast and warnings.
- Flood Forecasting Services in Bangladesh
    - From 1972, the government of Bangladesh has been developing flood forecasting services. Now, 86 real time water level and 56 real time rainfall stations, 85 flood monitoring stations and 46 flood forecasting stations are operated.
    - FMMC routinely collects real time hydro-meteorological data, enters data to the model, runs the model, formulates flood forecast, prepares daily flood bulletin, and disseminates it to the President, the Prime Minister, Ministers, heads of different departments, and mass communications.
    - Forecast performance is satisfactory, but there is a need to increase the lead time to more than 3 days.
- Regional cooperation for flood forecasting
    - International Centre for Integrated Mountain Development (ICIMOD) and the World Meteorological Organization (WMO), supported by the US Department of State (Regional Environmental Office of South Asia), US Office for Foreign Disaster Assistance, and DANIDA, organized a high level consultative meeting on 'Developing a Framework for Flood Forecasting and Information Exchange in the Hindu Kush Himalayan Region' in Kathmandu in May 2001.
    - ICIMOD and WMO have initiated the development of the South Asian Floods (SAF) website.
    - Through the website, Bangladesh receives hydro meteorological river data from People's Republic of China, India and Nepal. During monsoon period, it is effective to Bangladesh for flood forecasting.
- Regional and international cooperation and coordination along with structural and non-structural measures is essential for mitigation or reduction of disasters and hazards of flood.

Session II: Knowledge Sharing on Flood Disaster Management Experiences

- To recognize flood disaster situation in Regional Member Countries (RMCs)
- To share experience on Flood Disaster Management in RMCs from various perspectives

Chair: Mr. Kamal Prasad Regmi, DWIDP
Co-chair: Dr. Rabindra Osti, ADB
Facilitator: Dr. Badri Shrestha, ICHARM

Speaker: Dr. Ramesh Vaidya, ICIMOD, Nepal
'Changing Perspective on a strategic flood risk management framework for the Himalayan region'

Main points and remarks
- Focus on the transfer from science to policy
- Addressing the knowledge gap in policy and decision making
- Very often the local stakeholders are not involved
- Pure engineering solutions deliver unwanted (by the stakeholders) results
- ICIMOD recommends to invest in communication in the last mile to reach grass root level
- ICIMOD will conduct a session at the WWF 6 in Marseille, France 15th March. They uploaded their experience on the WWF website

Speaker: Mr. Gautam Rajkarnikar, WECS, Nepal
'Flood Disaster Risk Management in Nepal'

Main points and remarks
- Nepal is a country of large extreme due to water related disasters
- Temperature ranges from tropical (+ 40 degrees) to Alpine (- 50 degrees)
- Dry areas (250 mm/year) wet areas (6000 mm/year)
- Precipitation 80% during monsoon season
- Regular flood events (most recent is Koshi river flood in 2008)
- Nepal prepared National Water Plan in 2005

Speaker: Mr. Mamoru Miyamoto, ICHARM, Japan
'IFAS and other innovative activities of ICHARM'

Main points and remarks
- ICHARM has three pillars: research, training and information networking
- Integrated Flood Analysis System (IFAS) is an easy to use flood forecasting and warning system
- The different aspects of IFAS in early flood warning activities were highlighted and how the model can be used effectively
- It is based on web based freely available data such as Digital Elevation Model (90x90 meter), Satellite rainfall data, Land use

Speaker: Dr. Susan Espinueva, PAGASA, the Philippines
'History of flood forecasting activities and technology and the way forward in the case of the Philippine'

Main points and remarks
- Number of casualties and damage increased over the years due to flooding
- Extreme weather events are adding to this
- Damage cost between 3 – 24% of the Gross Domestic Product (GDP)
- Due to awareness raising the number of casualties is decreasing whereas the damage is increasing
- Preparedness and awareness are most important factors in Community Based Flood Early Warning Systems (CBFEWS)

2nd day of the workshop (18th January 2012)

Session III Flood Simulation Game
- To refresh and solicit flexible perspective for Flood Disaster

- To increase awareness for International River Basin Management

Moderator/Commentator: Dr. Badri Shrestha, ICHARM
Speaker and game leaders: Mr. Dick van den Bergh, Mrs. Maaike Maarse, Deltares, the Netherlands

Main points and remarks

- The simulation game was performed in an active, friendly and open atmosphere
- All participants were actively involved
- The groups were made out of experts form different countries in the Ganges-Brahmaputra-Meghna (GBM) basin and from outside (LMB, Philippines and Indonesia)
- The ICHARM and ADB staff were involved as observers
- The Bangladesh participants were playing the mid-stream country role
- The participants form India were playing the downstream role

Remarks per sub-Group

Panthania or Upstream

- They negotiated the cost for the hydro power dam project with downstream countries
- The process for obtaining permits from the central ministry/authority took a long time

Aquareiha or Mid – Stream

- They enjoyed the set up with multiple actions and multiple actors
- They considered the non-structural measures as the most easy pickings or low hanging fruits. So they concentrated on that
- Not all engineering measures were feasible (budget constraints)
- They realized they had to start negotiations with both up-stream and downstream countries
- The second round gave little more insight in the effects of the measures

Fluviarheia or Down - Stream

- They concentrated on a mix of structural and non-structural measures.
- Dike displacement and land use planning were within the total budget
- Furthermore no approval from the ministry was needed and that was seen as big advantage
- For all long term structural measures Ministry approval was needed. For instance the overall by pass cost 380 Million and needed also subsidy and clearance from the ministry
- Discussion with the upstream countries on the hydro power project was seen as very useful. Also the ministry expressed their favor of those options
- In all cases for decision on measures consensus was needed

The Ministry of Water Resources

- Coordination of the whole process was needed
- Due to time constraints they could not perform optimal
- In the setup of the game a provision for Environmental Impact Assessment (EIA) of measures (up-stream and down-stream effects) was missing
- For approval of measures overview is needed
- So the capacity (only two staff members) was deemed to limited
- Money was never a (big) constraint

Overall conclusions and recommendations

- All participants like the simulation game and were eager to participate
- At the start of the process the Ministry staff was sitting idle whereas later on they were flooded with request so that the sub-regions had to wait long time
- Because of this the implementation of measures was also not spread over time. As a result the impacts of individual measures could not be visualized sufficiently

- The participants were all water management experts. They quickly realized the advantage of making cooperation agreements between up-stream and down-stream regions
- The ministry acted somewhat isolated. Only later they realized they could take measures on their own.
- It was striking no use was made of the option to hire external advice
- When the simulation game is played in somewhat longer time period more results may come out
- The documentation was not completely correct (some cost figures on the forms were different)
- The simulation game may be greatly improved if real world names and measures are being used. In other words to make it more dedicated to the river basin of the participants

Session IV: Leveraging Knowledge Sharing for Capacity Development

- To understand present activities in our river basin
- What type of innovative tools will be needed in our river basin?
- How can ICHARM and ADB support in our river basin?
- Case study, success story and innovative approaches

Chair: Mr. Toshio Okazumi, ICHARM
Facilitator: Dr. Mamoru Miyamoto, ICHARM

Speaker: Dr. Badri Shrestha, ICHARM, Japan
'Recent flood disasters in our river basin'

Main points and remarks

- Climate change is having effect on glacier melt, increased run off, decreased run off, sea level rise
- Flood events in India, Nepal account for 50% the casualties of natural disasters
- In Bangladesh this is 75%

Speaker: Mr. Ananta Kumar Gajurel, DWIDP, Nepal
'Role of DWIDP in Disaster Risk Management'

Main points and remarks

- Nepal is classified in 2005 by the World Bank as 'natural disaster hotspot'
- The disaster mitigation program is focusing at awareness raising and hazard mapping
- There is also disaster control program consisting of a master plan and point specific projects
- In the Koshi river there is an emergency rehabilitation project
- Outcome of that program is: flood forecasting system for the Koshi river and an assessment of potential risks and recommendations for prevention package

Speaker: Mr. Rocky Talchabhadel, Department of Hydrology and Meteorology (DHM), Nepal
'Flood forecasting in Nepal – Role of DHM and introduction to ongoing projects'

Main points and remarks

- Flood forecast and early warning are becoming more important in Nepal
- Data collection is partly manual (3x daily) partly automated and based on remote sensing
- All data is published on website www.hydrology.gov.np
- MIKE11 is used for modeling in cooperation with IWM Bangladesh.
- Modeling is validated with real time on the ground
- Based on the model outcome warnings are prepared for community based flood early warning
- ICIMOD is preparing a real time flood information system for the whole Hindu Kush-Himalayan region

- In the Koshi River disaster there was a lack of early warning information. ICIMOD is currently preparing a FEWS for the Koshi river basin

Speaker: Mr. Munni Lal, CWC, India
'Success stories on flood related disaster management from India'

Main points and remarks

- 12% of the area of India is flood prone most of it in the Ganges basin
- Flood plain zoning and flood warning are very effective to prevent or decrease flood impacts
- CWC publishes data on flooding on their website www.india-water.com/ffs/index.htm
- Mass media are also important in dissemination of flood warnings
- Improving warning time is deemed important
- Data (also rainfall data) is exchanged on 3x daily basis with neighboring countries (Nepal, Bhutan and Bangladesh)
- Lessons learned from the Koshi River. Appropriate and timely coordination of organizations in both countries is very much needed

Speaker: Mr. Pashupati Sharma Dahal, Hydrology Division, Department of Hydro-Met Services, Bhutan
'Installation of Glacial Lake Outburst (GLOF) Early Warning System in Punaka – Wangdi valley, Kingdom of Bhutan'

Main points and remarks

- Bhutan has many water induced disasters
- Landslides are the biggest challenge
- Himalaya mountains are very steep and unstable due to young geology
- Bhutan is also monitoring GLOF's
- In the Punakha-Wangdi valley an automated early warning system is being set up
- Siren systems are installed in all villages
- There are following system components; 4 AWLS stations at the lake in Lunana, 3 siren stations of the 3 small villages in Lunana, 14 siren stations in the Punakha-Wangdi Valley, 2 AWS/A/AWLS stations (one in Dngsa and one in Thanza) and 1 control center in Wangdi.

Speaker: Mr. Md. Enamul Islam, BWDB, Bangladesh
'Success stories on flood related disaster management from Bangladesh'

Main points and remarks

- There are natural and manmade disasters
- More than 50% of Bangladesh area is prone to flooding
- Normal 'flooding' affects 25-30% of Bangladesh area
- In extreme cases up to 60% of Bangladesh can be flooded
- International data exchange is deemed important
- Operation & maintenance is done by the BWDB

Bangladesh:
24 hours warning is possible now, it is efficient but they are trying 10 days or 7 days warning.

What about the flash floods in the north eastern part?
Coastal parts no observation, no possible warning, flash floods there is no warning in earstern and southern part. Information exchange with India upstream part of river basin is sufficient and enough for three days.

Bhutan: Data sharing is very important, Bhutan is on upper site, sharing with India.

India: Data sharing with Bangladesh, thankful to Nepal and Bhutan, they help sharing in a timely manner, now it is ok, no problem.

Nepal: data sharing is most important part, continuously sharing database and this should be continued. Telemetry stations are very important.

ICIMOD: ICIMOD is focused on capacity building on flood forecasting in member countries. Data sharing needs to be further developed on bi-lateral and multi-lateral base. Bangladesh wants increased warning lead time up to 7 or 10 days.

Panel Discussion: Way forward for our River Basins' International Activities by Innovative Flood Disaster Management

Chair: Dr. Keshav Sharma, Department of Hydrology and Meteorology (DHM)
Moderator/Commentator: Mr. Dick van den Bergh, Deltares, the Netherlands
Facilitators: Dr. Badri Shrestha

How to leverage knowledge sharing?
How to achieve more or less?
How can we innovate?
What can we do better for managing our river basin?
How to apply innovative knowledge into other countries?
What is the role of ICHARM to help other countries to understand innovative knowledge, accept, and adapt?

Panelists:
Mr. Toshio Okazumi, ICHARM
Mr. Hisashi Mitsuhashi, ADB
Dr. Lam Hung Son, MRCS
Dr. Keshav Sharma, DHM
Ms. Gemala Suzanti, BBWS
Dr. Susan Espinueva, PAGASA
Dr. Ramesh Vaidya, ICIMOD
(5mins presentation/explanation by each panelist)

Panel Discussion:
Dr. Keshav Sharma, DHM:

- Leverage knowledge sharing
- How to achieve more or less

Mr. Toshio Okazumi, ICHARM:

- Appreciates the workshop and the involvement of the participants
- IFAS is innovative but this is not the final solution, each river basin has it's characteristics, so this takes time to customize the system
- High Tech alone is not the final solution
- Support from ADB expected for more projects
- Science is available but how to allocate the money
- What can be done better

Mr. Hisashi Mitsuhashi, ADB:

- Expresses his gratitude and satisfaction to gather the countries of the river basin in one workshop and share expectations
- ADB has large workshop experience focused on guidelines or technology, in this case there was a focus on the whole basin
- this workshop is very much specific for these basins and this is one of the best examples for knowledge sharing, we want to cooperate with ICHARM
- Request the participants to continue with this kind of knowledge sharing

Mr. Md. Enamul Islam, Bangladesh:

- Very important workshop for knowledge sharing,
- Due to climate change Bangladesh is facing many challenges: flood, drought, sea level rise, salinity, and cyclone. It is the challenge to improve the state of the infrastructure; we need each other to face this issue
- He enjoyed the different presentations and workshop activities
- He would be happy to further explore regional cooperation with ICHARM

Dr. Lam Hung Son, MRCS:

- He offered support and cooperation from MRC for other river basins
- LMB is also concerned to get support from ADB
- He indicates that there should not be too much focus on individual countries
- He is happy to intensify cooperation with ICHARM. He indicates that MRC and ICHARM signed a MoU for more cooperation recently
- Application of IFAS in LMB could be very interesting
- The national coordinator of MRC can give support.
- A real time flood management tool would be helpful

Ms. Gemala Suzanti, BBWS:

- Knowledge sharing needs to include cooperation with local staff
- Each river basin has its own physical and social context
- What can be done better? ➔ listen to the demands of the stakeholders
- A roadmap for IWRM would be helpful
- Connect high- tech with local indigenous knowledge
- Work together, the expert should have a counterpart, find out what is the specific problem and situation to improve.

Dr. Susan Espinueva, PAGASA:

- Share knowledge through workshops, achieve more with data sharing. Best practices and lessons learnt.
- Apply the available data, remote sensing and GIS. In that way we can show to the stakeholders the impact and people learn to appreciate. For better management of river basins.
- We haven't thought about economics, not only about structural measures, sometimes nonstructural measures are better. One dollar investment can lead to 7 dollar benefits; this is very hard to explain.
- Economy is key factor
- Involvement of stakeholders is important
- ICHARM is doing a great deal with implementing IFAS in some of our river basins. Despite all this knowledge we have to make the community understand, providing information to the public, very localized and simple.
- IFAS is nice example of innovation through GIS/RS for improvement of flood forecasting
- How to reach the communities? Public information needs to be made accessible and understandable for people in the villages

Dr. Ramesh Vaidya, ICIMOD:

- Initiatives made by ADB on river basins are very good; we are very much excited because ICHARM is partner.
- ICHARM and ICIMOD are already partners.
- The fund for disaster management is low, only after the event, some of the money should become before the disaster.
- Use the money for data sharing. With new modeling techniques, the scientists and policy makers should reduce the vulnerability of the communities.
- Science is developing but how to allocate money. How can we better manage our river basins?
- How to achieve more with less? He refers to HYCOS project on development of regional information system for hydrological and metrological information and flood risk management. Data sharing has great potential.
- After disasters funds are flowing but also attention for more long term measures is needed.
- The same amount of budget could be more effective in prevention of damage (hazard maps, FEWS, communication).
- A lot of knowledge is already available but how to allocate the funds to projects?
- The planning commission in Nepal could work in a more holistic way.

Reflection from audience:

Mr. Mahendra Singh Varma, India

- Most of discussion has the focus on Koshi Embankment.
- Many aspects were covered, one thing was missing: the causes of the disaster to happen
    - Raise of riverbed
    - Deforestation upstream
- Preventing disaster is more an economical problem than a technical problem.
- What can be done to prevent similar events in member countries?
- Flood forecasting should be in the local language, should be displayed on boards in local areas.

Mr. Munni Lal, India:

- Information needs to be shared with local stakeholders in the language they understand
- Livelihood is very important, do not just focus on casualties
- Policy makers need be liberal in approving schemes realizing that loss of lives cannot be valued for money
- Sharing of flood information amongst the basin countries is very important for mitigating flood losses and needs to be reviewed periodically to check as if the system requires any improvement, and the executing level officials responsible for flood forecasting in these countries need be more interactive with their counter parts
- Backup system needed for exchange of data. If no information received, be active in requesting.

Mr. Shreekamal Dwivedi, Nepal

- More attention should be given to the suffering and the economy of the local people, they are often neglected after the disaster.
- During the repair of the embankment large suffering occurred, many people were affected and there was a disruption of the society
- Not just the event area , also the indirect effect should be taken into account

Mr. Rabinath Babu Shrestha, Nepal

- If we are prepared and local people are aware then a lot can be achieved
- Data sharing is important

- Modern mechanisms to share information
- Techniques for data acquisition need to be improved

Response from panel

Reaction of Dr. Ramesh Vaidya, ICIMOD: He agreed with India/Nepal. Standard cost-benefits analysis is not enough; there is a new concept where they try to compare the value of the benefits of the information system with the costs of creating the information system. However you cannot put a value on a human life.

Reaction of Dr. Mandira Shrestha, ICIMOD: we need to upgrade our meteorological network, use these advanced technologies in addition to what we already have.

Reaction of Mr. Dick van den Bergh, Deltares: A closer relation between spatial planning and flood risk management is very important. Vulnerability is something we can influence by identifying the risks with flood hazard maps and adjust spatial planning.

Chair:

- Many initiatives for regional cooperation
- Knowledge is shared
- It is very good to expand towards MRC, Indonesia and the Philippines to share their experiences
- The whole region is under the challenge of monsoon,
    - Too much water -> flooding
    - Too little -> drought
- Technology access is now more affordable and available (mobile phones, satellite data)

- mapping (hazards)
- websites (downloads_
- meteorological predictions -> seasonal forecast of drought

- Awareness campaign and insurance companion
  How to reach the communities -? NGO's are successful in this
  Community gets the advantage
- Integrated disaster management model needed on flood, draught, landslide, fires and earthquake
- Internet is bringing all of us together, please use it

- In 2001 there was 1 automated water level station, in 2012 there were 60 automatic water level stations and we are aiming at 200 real time stations
- Data will be on the internet, it is free for all

Outcomes of the workshop

The knowledge sharing workshop was very much fruitful to share international experiences and best practices on flood forecasting and early warning at policy and operational levels. Also, it was helpful for way forward for our River Basins' management by innovative flood disaster methodologies. Further main outcomes of the workshop are as follows:

- learning of lessons from the implementation of water related disasters, flood forecasting and early warning practices from around Asia.
- sharing of innovative methodology and results from ADB TA 7276-REG mainly IFAS application in Indonesia, national road mapping of flood early warning in Bangladesh, risk mapping in LMB and bring discussions to promote know-how and application in the region,
- sharing and discussion of the experiences on flood forecasting and early warning among countries,
- learning of best practices and quick responses of Koshi Flood 2008.

List of Participants of Nepal workshop

SN	Name	Country	Position	Organization
1	Dr. Ramesh Ananda Vaidya	Nepal	Senior Advisor	Internal Centre for Intregated Mountain Development (ICIMOD)
2	Mr. Sriranjan Lacoul		Joint Secretary	Water and Energy Commission Secreary (WECS)
3	Mr. Gautam Rajkarnikar		Senior Division Engineer	Water and Energy Commission Secreary (WECS)
4	Mr. Rocky Talchabhadel		Hydrologist Engineer	Department of Hydrology and Meteorology (DHM)
5	Mr. Ananta Kumar Gajurel		Senior Division Engineer	Departmnet of Water Induced Disaster Prevention (DWIDP)
6	Mr. Shreekamal Dwivedi		Engineeering Geologist	Departmnet of Water Induced Disaster Prevention (DWIDP)
7	Mr. Manohar Rijal		Division Chief	Departmnet of Water Induced Disaster Prevention (DWIDP)
8	Mr. Sunder Prasad Shama		Soil Conservation Officer	Departmnet of Water Induced Disaster Prevention (DWIDP)
9	Mr. Rabinath Babu Shrestha		Senior Divisional Engineer	Department of Irrigation (DOI)
10	Mr. Manik Lal Kalu Shrestha		Regional Director	Department of Irrigation (DOI)
11	Mr. Mitra Baral		Senior Division Engineer	Department of Irrigation (DOI)
12	Anil Pokhrel		Disaster Risk Management Specialist	Disaster Risk Management Section, WBN
13	Mr. Md. Enamul Islam	Bangladesh	Executive Engineer	Bangladesh Water Development Board (BWDB)
14	Mr. Md. Ansar Ali Mian		Chief Engineer of Hydrology	Bangladesh Water Development Board (BWDB)
15	Mr. Md. Azizur Rahman		Assistant Director	Bangladesh Meteorological Department (BMD)
16	Mr. Md. Manzoor Alam Bhuiyan		Director (Administrative)	Disaster Management Bureau (DMB)
17	Mr. Pashupati Sharma Dahal	Bhutan	Deputy Executive Engineer	Department of Hydro-met Services, Ministry of Economic Affairs
18	Mr. Sherub Phuntsho		Engineer	Department of Hydro-met Services, Ministry of Economic Affairs
19	Ms. Tshewang Lhamo		Environment Officer	Water Resource Coordination Division, The National Environment Commission
20	Ms. Gemala Suzanti	Indonesia	Manager for Operation and Maintenance Planning	Bengawan Solo River Basin Organizations
21	Dr. Lam Hung Son	Cambodia	Programme Coordinator	Flood Management and Mitigation Programme, Mekong River Commission Secretariat (MRCS)
22	Dr. Susan R. Espinueva	Philippines	Chief, Hydrometeorology Division	Philippine Atmosheric, Geophysical and Astronomical Services Administration (PAGASA)
23	Mr. Om Prakash	India	Technical Officer	Ministry of Home Affairs
24	Mr. Mahendra Singh Varma		Deputy Commissioner (Ganga)	Ministry of Water Resources
25	Mr. Munni Lal		Superintending Engineer	Central Water Commission

Participation of Guests and others

1	Mr. Bishwa Prakash Pandit	Nepal	Secreatary	Water and Energy Commission Secreary (WECS)
2	Mr. Hari Prasad Iswar	Nepal	Joint Secretary	Water and Energy Commission Secreary (WECS)
3	Dr. Ravi Sharma Aryal	Nepal	Joint Secretary	Water and Energy Commission Secreary (WECS)
4	Mr. Kamal Prasad Regmi	Nepal	Director General	Departmnet of Water Induced Disaster Prevention (DWIDP)
5	Mr. Shishir Koirala	Nepal	Senior Divisional Engineer	Water and Energy Commission Secreary (WECS)
6	Mr. Dinakar Khanal	Nepal	Senior Divisional Engineer	Water and Energy Commission Secreary (WECS)
7	Dr. Keshav Sharma	Nepal	Deputy Director General	Department of Hydrology and Meteorology (DHM)
8	Dr. Mandira Shrestha	Nepal	Water Resources Specialist	Internal Centre for Intregated Mountain Development (ICIMOD)
9	Ms. Hira Giri	Nepal	-	Water and Energy Commission Secreary (WECS)
10	Ms. Sita Karki	Nepal	-	Departmnet of Water Induced Disaster Prevention (DWIDP)
11	Mr. Deepak B. Singh	Nepal	-	ADB NRM

Participation of ICHARM members

1	Mr. Toshio Okazumi	Japan	Chief Researcher	International Centre for Water Haward and Risk Management (ICHARM)
2	Dr. Badri Bhakta Shrestha	Japan	Researcher	International Centre for Water Haward and Risk Management (ICHARM)
3	Mr. Mamoru Miyamoto	Japan	Research Specialist	International Centre for Water Haward and Risk Management (ICHARM)
4	Ms. Yuri Suzuki	Japan	Administrative Staff	International Centre for Water Haward and Risk Management (ICHARM)

Participation of ADB members

1	Mr. Hisashi Mitshuhashi	Phillipines	Water Resources Specialist	International Centre for Water Haward and Risk Management (ICHARM)
2	Dr. Rabindra Prasad Osti	Phillipines	-	International Centre for Water Haward and Risk Management (ICHARM)

Participation of Deltares members

1	Mr. Benedictus Paulus Johannes van den Bergh	Netherland	Senior policy advisor	Deltares
2	Ms. Maaike Marse	Netherland	-	Deltares

Detail Final Program Agenda and Schedule

Date	Time	Description
15-Jan-12	09:30-10:30	Registration
	10:30-11:00	**Opening Session**
	(5 mins)	Welcome Address by **Mr. Sriranjan Lacoul**, Joint Secretary, WECS
	(5 mins)	Remarks: **Mr. Kamal Prasad Regmi**, Director General, DWIDP
	(5 mins)	Remarks : **Mr. Toshio Okazumi**, ICHARM
	(5 mins)	Remarks: ADB NRM Representative
	(5 mins)	Concluding Remarks and Session Close by Chairperson, **Mr. Bishwa Prakash Pandit** Secretary, WECS
	11:00-11:30	Self-Introduction from all participants, Group Photo
	11:30-11:50	Tea/Coffee Break
		Session I : ADB Technical Assistant 7276 Activities - **To understand ADB's activities on its effectiveness.** - **To recognize ICHARM's activities on its innovativeness** - **Reflection from recipient members, and their activities on how to link with ADB's activities** **Chair: Dr. Ravi Sharma Aryal, Joint Secretary, WECS** **Co-chair: Dr. Rabindra Osti, ADB** **Facilitator: Dr. Badri Shrestha, ICHARM**
	11:50-12:20	Speaker: **Mr. Toshio Okazumi**, ICHARM "Activities of ICHARM and ADB TA 7276-REG project"
	12:20 -12:40	Speaker: **Dr. Lam Hung Son**, Mekong River Commission Secretariat (MRCS), Cambodia "Best practices on flood management and mitigation; and water-related disasters in Lower Mekong Basin"
	12:40 -13:10	Speaker: **Ms. Gemala Suzanti**, Bengawan Solo River Basin Authority (BBWS), Indonesia "Reflection on ADB TA 7276-REG activities in Indonesia and activities of BBWS in flood related disasters" (Supported by **Dr. Mamoru Miyamoto**, ICHARM)
	13:10-13:30	Speaker: **Mr. Md. Enamul Islam**, Bangladesh Water Development Board (BWDB), Bangladesh "Flood forecasting and warning services in Bangladesh - A way forward in early warning system"
	13:30-14:00	Discussion
	14:00-14:45	Lunch break
		Session II: Knowledge Sharing on Flood Disaster Management Experiences - **To recognize flood disaster situation in regional member countries (RMCs)** - **To share experience on Flood Disaster Management in RMCs from various perspectives** **Chair: Mr. Kamal Prasad Regmi, Director General, DWIDP** **Co-chair: Dr. Rabindra Osti, ADB** **Facilitators: Dr. Badri Shrestha, ICHARM**
	14:45-15:10	Speaker: **Dr. Ramesh Vaidya**, ICIMOD "Changing perspective on a strategic flood risk management framework for the Himalayan region"
	15:10-15:35	Speaker: **Mr. Gautam Rajkarnikar**, WECS "Flood Disaster Risk Management in Nepal"

Date	Time	Description
	15:35-15:55	Coffee/Tea break
	15:55-16:10	Speaker: **Dr. Mamoru Miyamoto**, ICHARM "IFAS and other innovative activities of ICHARM"
	16:10-16:35 16:35-17:05	Speaker: **Dr. Susan Espinueva**, Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), the Philippines "History of flood forecasting activities and technology, and way forward in the case of the Philippines" Discussion
	17:05-17:20	Short presentation on "**Field visit program: Site Survey in flood affected areas in the lower Koshi Basin**" By **Dr. Badri Shrestha,** ICHARM
	17:30-	Reception Dinner
16-17 Jan-12		Site survey at flood affected area (please refer to enclosed sheet for details)
18-Jan-12	10:00-12:15 Tea/Coffee Break)(11:00-11:15)	**Session III Flood Simulation Game** - **To refresh and solicit flexible perspective for Flood Disaster** Speaker: **Mr. Dick van den Bergh and Mrs. Maaike Maarse** , Deltares, Netherland "Flood Simulation 'SAMA' game"
	12:15-13:15	**Lunch break**
	          13:15-13:30 13:30-13:45 13:45-14:00 14:00-14:15 14:15-14:30 14:30-14:45 14:45-15:15	**Session IV: Leveraging Knowledge Sharing for Capacity Development** - **To understand present activities in our river basin** - **What type of innovative tools will be needed in our river basin?** - **How can ICHARM and ADB support in our river basin?** - **Case study, success story/innovative approaches** **Chair by Mr. Toshio Okazumi, ICHARM** **Facilitators: Dr. Mamoru Miyamoto, ICHARM** Speaker: **Dr. Badri Shrestha**, ICHARM "Recent flood disasters in our river basin" Speaker: **Mr. Rocky Talchabhadel**, Department of Hydrology and Metrology (DHM) "Flood Forecasting in Nepal - Role of DHM and introduction to ongoing project" Speaker: **Mr. Ananta Kumar Gajurel**, DWIDP "Role of DWIDP in Disaster Risk Management" Speaker: **Mr. Munni Lal**, CWC, **Mr. Mahendra Singh Varma**, Ministry of Water Resources "Success story on flood related disaster management from India" Speaker: **Mr. Pashupati Sharma Dahal**, Hydrology Division, Department of Hydro-Met Services, Bhutan "Installation of Glacial Lake Outburst(GLOF) Early Warning System in the Punakha -Wangdi valley, Kingdom of Bhutan" Speaker: **Mr. Md. Enamul Islam**, BWDB "Success story on flood related disaster management from Bangladesh" Discussion
	15:15-15:30	Coffee/Tea break
	15:30-16:30	**Panel Discussion: Way forward for our River Basins' International Activities by Innovative Flood Disaster Management** **Chair: Dr. Keshav Sharma, DHM** **Co-chair: Mr. Dick van den Bergh, Deltares, Netherlands** **Facilitator: Dr. Badri Shrestha, ICHARM**

Date	Time	Description
		How to leverage knowledge sharing? **How to achieve more or less?** **How can we innovate?** **What can we do better for managing our river basin?** **How to apply innovative knowledge into other countries?** **What is the role of ICHARM to help other countries to understand innovative knowledge, accept, and adapt?** **Panelists:** Mr. Toshio Okazumi, ICHARM Mr. Hisashi Mitsuhashi, ADB Mr. Md. Enamul Islam, BWDB Dr. Lam Hung Son, MRCS Ms. Gemala Suzanti, BBWS Dr. Susan Espinueva, PAGASA Dr. Ramesh Vaidya, ICIMOD **Reflection from audience**
	16:30-16:45	**Closing Session** **Chairperson Mr. Bishwa Prakash Pandit, Secretary, WECS** Closing Remarks by **Mr. Hisashi Mitsuhashi,** ADB Closing Remarks by **Mr. Kamal Prasad Regmi,** DWIDP Vote of Thanks by **Mr. Sriranjan Lacoul**, **Joint Secretary**, WECS Closing the session with remarks by **Mr. Bishwa Prakash Pandit, Secretary,** WECS
	17:00-	Friendly dinner Appreciation by **Mr. Toshio Okazumi,** ICHARM

Site Survey in flood affected areas in the lower Koshi Basin

Date	Time	Description
16-Jan-12	07:20	Meeting at Lobby Hotel Himalaya
	07:30	Depart from Hotel Himalaya to airport
	09:00	Depart flight time from airport
	09:40	Arrival at Biratnagar airport
	10:20	Arrival at Hotel (4km) (Hotel Swagatam)
	10:30-11:20	Lunch at Hotel
	11:20	Depart for Koshi river barrage and flood affected site (50km, 2hrs from Biratnagar)
	13:30	Visit Koshi River flood disaster areas and barrage
	17:00	Depart to Hotel
	19:00-19:30	Presentation on emergency rehabilitation works in the Koshi River Basin, by **Mr. Babu Ram Adhikari,** Team Leader, Project Management Support Consultants' Team - PCO
	19:30-	Dinner at Hotel Swagatam
17-Jan-12	10:00-11:30	Listening to Local government such as DOI, DWIDP Presentation of from DWIDP staffs and discussions
	11:30-12:30	Lunch
	12:30	Depart to Biratnagar airport
	14:00	Depart for Kathmandu
	14:40	Arrival in Kathmandu
	15:30	Arrival in Hotel Himalaya

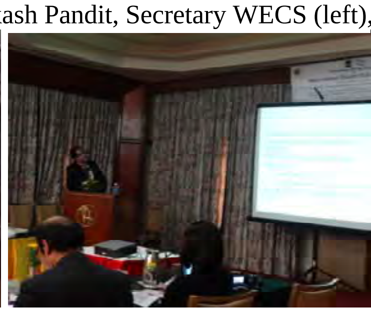
Some Photographs of the Workshop

Group photograph of participants of the workshop

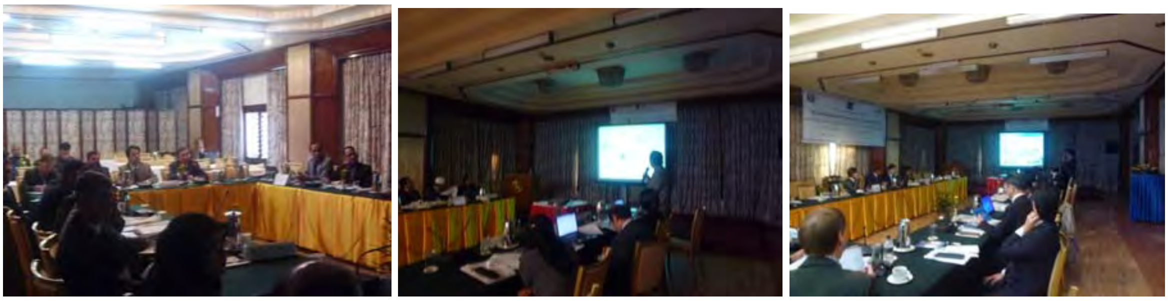
Glimpse of 1st Day of the Workshop

Opening session and speech by Mr. Okazumi, ICHARM (left), Inauguration by Mr. Bishwa Prakash Pandit, Secretary WECS (right)

Opening speech by Mr. Bishwa Prakash Pandit, Secretary WECS (left), participants of the workshop (right)



Photographs of Session I (presentation and participants)



Photographs of Session II (presentation and participants)

Glimpse of 2nd Day of the Workshop

Photographs during flood Simulation SAMA game (Session III)

Photographs of Session IV

Photographs of Panel Session

Annex 2: Workshop report: Cambodia (9-10 February 2012)

Report of Knowledge Sharing Workshop on Flood Vulnerability Assessment in Cambodian Flood Plains (9 – 10 February 2012), Phnom Penh, Cambodia:

Objectives of the workshop

The objectives of this knowledge sharing workshop on flood vulnerability assessment in Cambodian flood plains are as follows:

- Learning the Mekong River Flood last year and present status of Mekong river basin.
- Clear definition of vulnerability etc. in general as well as in ICHARM methodology.
- Understanding of hydro-meteorological, topographical, societal and economical characteristics in flood damage in each river basin
- Learning basic functionality and efficiency of satellite information, GIS and Hydro-meteorological analysis
- Learning mechanism of house and crops damage through household survey and its resilience
- Attempt to apply ICHARM methodology to each basin through learning , exchange experience and discussion, and find out necessary further steps.

Dates and Venue

This workshop was held on 9-10 February at Hotel Cambodiana, Phnom Penh, Cambodia.

Organizers

International Centre for Water Hazard and Risk Management under the auspices of UNESCO (ICHARM), Japan
Asian Development Bank (ADB), the Philippines
Mekong River Commission Secretariat (MRCS), Cambodia
Cambodia National Mekong Committee (CNMC), Cambodia
With supported by Deltares, the Netherland

Participants of the workshop

24 participants including ICHARM (6), ADB (1) and Deltares (2) joined the workshop. The participants were invited from Cambodia (6), Vietnam (2), Lao PDR (2), Bangladesh (3) and Indonesia (2).

Contents of the workshop

The contents of the workshop were presentations by resource persons, presentations by ICHARM, presentation by Deltares, group discussions (three groups), presentations by each group, and plenary discussion.
The sessions of the workshop program is as follows

Session I:	ADB TA7276-REG Activities and linkages to Mekong River Flood Risk management
Session II:	Understanding Vulnerability, hazard and risk
Session III:	Innovative ICHARM Hydro-Geo Method
Session IV:	Way forward for Vulnerability by Socio-economic and Physical Approach
Session V:	Flood Vulnerability Assessment in Your River Basin
Session VI:	Supporting Investment on Water-related Disaster Management by Innovative Methodology

Outcomes of the workshop

The outcomes of the workshop are as follows:

- Sharing of innovative methodology and results from ADB TA7276-REG, mainly the method of flood vulnerability assessment in Cambodian flood plains.
- Sharing and discussions of the experiences on flood vulnerability, flood risk, etc. among participants' countries.
- As the results of the group discussions, the situation and availability to apply the ICHARM

Hydro-Geo method were described.

Program Agenda of the Workshop

Program on 9 February, 2012 (1st Day)

Session	Time	Description
Registration	8:30 - 9:00	Responsible: Ms. Momoe Nakamura, Mr. Shigenobu Hibino
Opening Session Moderator: ICHARM		
	9:00 - 9:20	Welcome Address by **CNMC (TBD)**
		Remarks: **Dr. Lam Hung Son, MRC**
		Remarks: **Dr. Shigenobu Tanaka, ICHARM**
Session I: ADB TA 7276-REG Activities and Its Linkages to Mekong River Flood Risk Management Chair: Deltares		
	9:20 - 9:55	"Scope and objective of ADB TA 7276-REG and its outcomes" Speaker: **Mr. Toshio Okazumi, ICHARM/ Mr. Dick van den Bergh, Deltares**
	9:55 - 10:20	"Report on flood situation 2011 and presentation about the results of MRC/FMMP projects on flood disaster management" Speaker: **Dr. Lam Hung Son, MRC**
	10:20 - 10:30	**(Break)**
Session II: Understanding Vulnerability, Hazard and Risk Chair: MRC		
	10:30 - 11:00	"Definition of vulnerability, and relationships among risk, and hazard". Speaker: **Mr. Toshio Okazumi, ICHARM**
	11:00 - 11:10	Guidance for group discussions Speaker: **Mr. Shigenobu Hibino, ICHARM**
	11:10 - 11:50	Group discussions about the vulnerability. ● What is the mechanism of flood damages? ● What is the most serious impact by flood? In your river case
	11:50 - 13:30	**(Lunch Break)**
Session III: Innovative ICHARM Hydro-Geo Method Chair: CNMC		
	13:30 – 14:00	"Basic understanding on satellite information and GIS technology ● Introduction of Satellite information, ● how to use the GIS data Speaker: **Dr. Kwak Youngjoo, ICHARM**

Session	Time	Description
	14:00 – 15:00	"Overall procedure of ICHARM Hydro-Geo method and crops damages" Speaker: **Mr. Toshio Okazumi, ICHARM**
	15:00 – 15:40	Group discussions on damage of crops
	15:40 – 16:00	**(Break)**
Session IV: Way Forward for Vulnerability by Socio-economic and Physical Approaches Part 1 Chair: Deltares		
	16:00 - 16:40	"General explanation of socio-economy and vulnerability, presentation of household survey results" Speaker: **Dr. Marcel Marchand, Deltares**
	16:40 - 17:00	Group discussions on results of household survey

Program on 10 February, 2012 (2nd Day)

Session	Time	Description
Session IV: Way Forward for Vulnerability by Socio-economic and Physical Approaches Part 2 Chair: Deltares		
	9:00 - 9:30	"House damages from flood in Cambodian plains" Speaker: **Dr. Ai Sugiura and Dr. Shigenobu Tanaka, ICHARM**
	9:30 - 10:10	Group discussions about household damages from flood in each river basin
	10:10 - 10:30	**(Break)**
Session V: Flood Vulnerability Assessment in Your River Basin Chair: ICHARM		
	10:30 - 11:30	"Integrated vulnerability assessment and way forward to resilience and recovery" Speaker: **ICHARM**
	11:30 - 12:30	Group discussions about how to apply this IHGM to your river basin ● findings ● understandings ● difficulties ● necessary actions ● next steps, etc.
	12:30 - 13:30	**(Lunch Break)**
	13:30 - 15:00	"Presentations by each group" Group A: Group B: Group C: Group D: Discussion
	15:00 - 15:20	**(Break)**

Session	Time	Description
Session VI: Supporting Investment on Water-related Disaster Management by Innovative Methodology Chair: ADB		
	15:20 -16:10	**Plenary Discussion** "Discussion about how to use this methodology for investment" (e.g. setting a new system to obtain accurate water level and rainfall, construction new dyke, installing gate for Irrigation) **Wrap up by Chair**
Closing Session Moderator: CNMC		
	16:10 - 16:20	Comments by **Dr. Lam Hung Son, MRC** Closing address by CNMC

Photographs of the workshop

All participants

Group discussion

Plenary discussion

Explanation of ICHARM method

Annex 3: Pool of experts

Country	Name		Affiliation
Category 1: Flood Risk Management (Prevention, Mitigation and Adaptation)			
Australia	Dr.	Mark Jempson	BMT WBM PTY LTD
Austria	Dr.	Clemens Neuhold	UNIVERSITY OF NATURAL RESOURCES AND LIFE SCIENCES - BOKU
Austria	Dr.	Stefan Kienberger	CENTRE FOR GEOINFORMATICS (Z_GIS) - UNIVERSITY OF SALZBURG, AUSTRIA
Bangladesh	Mr.	Md.Rakibul Hassan Khan	CENTRE FOR ENVIRONMENT AND GEOGRAPHI INFORMATION SERVICES(CEGIS)
Brunei	Mr.	K B M Shafiuddin	Department of Civil Engineering Institute of Technology Brunei
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China	Dr.	Jian Fang	ACADEMY OF DISASTER REDUCTION AND EMERGENCY MANAGEMENT, BEIJING NORMAL UNIVERSITY
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China	Dr.	Wang Zili	Yellow River Institute of Hydraulic Research(YRCC)
China	Ms.	Wang Jingjing	STATE KEY LABORATORY OF HYDROLOGY-WATER RESOURCES AND HYDRAULIC ENGINEERING OF HOHAI UNIVERSITY
China	Prof.	Xiang Fu	WUHAN UNIVERSITY
China	Prof.	Xiaotao Cheng	CHINA INSTITUTE OF WATER RESOURCES AND HYDROPOWER RESEARCH (IWHR)
China	Prof.	Yugang Tian	COLLEGE OF INFORMATION ENGINEERING CHINA UNIVERSITY OF GEOSCIENCES
China	Dr.	Zhang Xingqi	NANJING UNIVERSITY
France	Dr.	Andre Paquier	CEMAGREF
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India	Dr.	Pramodkumar Hire	ARTS AND COMMERCE COLLEGE, INDIA
India	Prof.	Subashisa Dutta	IIT GUWAHATI
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Taiwan	Dr.	Keh-Chia Yeh	FLOOD AND DROUGHT DISASTERS REDUCTION DIVISION OF NCDR
Taiwan	Dr.	Kwan Tun LEE	National Taiwan Ocean University
Taiwan	Dr.	Yu-Chi Wang	TAIWAN TYPHOON AND FLOOD RESEARCH INSTITUTE, NATIONAL APPLIED RESEARCH LABORATORIES
Thailand	Mr.	S.H.M Fakhruddin	REGIONAL INTEGRATED MULTI-HAZARD EARLY WARNING SYSTEM (RIMES)
Turkey	Prof.	Arda Sorman	ANADOLU UNIVERSITY, DEPARTMENT OF CIVIL ENGINEERING, ESKIŞEHIR, TURKEY
Turkey	Dr.	Aynur Sensoy	ANADOLU UNIVERSITY, ESKISEHIR, TURKEY
UK	Mr.	Frazer Rhodes	ENVIRONMENT AGENCY
USA	Mr.	Mark Tepper	SONTEK/YSI, SAN DIEGO, USA
USA	Prof.	Mustafa Altinakar	National Center for Computational Hydroscience and Engineering, The University of Mississippi
Category 4: Flood Management in Different Climate Conditions and Geographic Zones			
Bhutan	Mr.	Ugyen Wangda	Department of Geology and Mines, Ministry of Economic Affairs
China	Prof.	E Youhao	CHINESE ACADEMY OF METEOROLOGICAL SCIENCES
China	Prof.	Huo Zhiguo	CHINESE ACADEMY OF METEOROLOGICAL SCIENCES
China	Dr.	Jianming Ma	CHINA INSTITUTE OF WATER RESOURCES AND HYDROPOWER RESEARCH
China	Dr.	Jingshi Liu	INSTITUTE OF TIBETAN PLATEAU RESEARCH, CAS, CHINA
China	Prof.	Liang Zhongmin	STATE KEY LABORATORY OF HYDROLOGY-WATER RESOURCES AND HYDRAULIC ENGINEERING OF HOHAI UNIVERSITY
China	Dr.	Peng Zhang	ACADEMY OF DISASTER REDUCTION AND EMERGENCY MANAGEMENT, MINISTRY OF CIVIL AFFAIRS & MINISTRY OF EDUCATION
China	Mr.	Ren Yushan	member of Association for Hydro-engineering in China
China	Dr.	Xingzhang Chen	SOUTHWEST UNIVERSITY OF SCIENCE AND TECHNOLOGY
France	Mr.	Julian Eleutério	UNIVERSITY OF STRASBOURG
France	Mr.	Pierre-Henri Bazin	CEMAGREF, FRANCE

Country	Name		Affiliation
India	Dr.	Anand Bhole	INSTITUTE FOR SUSTAINABLE DEVELOPMENT & RESEARCH , ISDR, INDIA
India	Prof.	Kapil Gupta	INDIAN INSTITUTE OF TECHNOLOGY BOMBAY, MUMBAI
India	Prof.	Rao Bhaskar	SAARC DISASTER MANAGEMENT CENTRE, NEW DELHI, INDIA
Japan	Dr.	Hiroshi Takebayashi	DISASTER PREVENTION RESEARCH INSTITUTE, KYOTO UNIVERSITY
Japan	Prof.	Ichiro Fujita	DEPARTMENT OF CIVIL ENGINEERING, GRADUATE SCHOOL OF ENGINEERING, KOBE UNIVERSITY
Japan	Dr.	Junko Mimaki	NATIONAL MUSEUM OF ETHNOLOGY
Japan	Prof.	Kazumi Matsuo	KUMAMOTO UNIVERSITY
Japan	Dr.	Mikio Ishiwatari	JAPAN INTERNATIONAL COOPERATION AGENCY
Japan	Mr.	Mohd Remy Rozainy M.A.Z	DISASTER PREVENTION RESEARCH INSTITUTE (DPRI), KYOTO UNIVERSITY, JAPAN
Japan	Ms.	Roxana Hoque	TOKYO METROPOLITAN UNIVERSITY
Japan	Prof.	Satoru Oishi	KOBE UNIVERSITY
Japan	Prof.	Tetsuro Tsujimoto	DEPARTMENT OF CIVIL ENGINEERING, NAGOYA UNIVERSITY
Korea	Mr.	Don Namgung	Hanyang University, Department of Korea
Nepal	Mr.	Gautam Rajkarnikar	WATER AND ENERGY COMMISSION SECRETARIAT
Netherland	Mr.	Bob Pengel	STOWA FOUNDATION FOR APPLIED WATER RESEARCH
Netherland	Mr.	Brenden Jongman	INSTITUTE FOR ENVIRONMENTAL STUDIES, VU UNIVERSITY AMSTERDAM
Netherland	Dr.	Ferdinand Diermanse	DELTARES
Netherland	Ms.	Kim Anema	UNESCO-IHE
Pakistan	Mr.	Ahmed Kamal	NATIONAL DISASTER MANAGEMENT AUTHORITY(NDMA) ISLAMABAD, PAKISTAN
Pakistan	Prof.	Amir Nawaz Khan	CENTRE FOR DISASTER PREPAREDNESS AND MANAGEMENT (CDPM), UNIVERSITY OF PESHAWAR, PAKISTAN
Pakistan	Mr.	Asjad Imtiaz Ali	OFFICE OF THE CHIEF ENGINEERING ADVISOR/ CHAIRMAN, FEDERAL FLOOD COMMISSION, ISLAMABAD, PAKISTAN
Poland	Mr.	Adam Chorynski	INSTITUTE FOR AGRICULTURAL AND FOREST ENVIRONMENT, POLISH ACADEMY OF SCIENCES
Taiwan	Dr.	Ming-Young Jan	DEPARTMENT OF CIVIL ENGINEERING, I-SHOU UNIVERSITY
Taiwan	Dr.	Szu-Hsien Peng	CHIENKUO TECHNOLOGY UNIVERSITY
Taiwan	Mr.	Yu-Hsin Liu	Department of Harbor and River Engineering
Thailand	Mr.	Aslam Perwaiz	ASIAN DISASTER PREPAREDNESS CENTER, THAILAND
USA	Ms.	Karen Durham-Aguilera	U.S. ARMY CORPS OF ENGINEERS, UNITED STATES
Category 5: Others (Flood Risk Index, Training, Indigenous Flood Management Knowledge, etc.)			
Australia	Ms.	Miriam Middelmann-Fernandes	GEOSCIENCE AUSTRALIA, AUSTRALIA
Canada	Ms.	Tamsin Lyle	NORTHWEST HYDRAULIC CONSULTANTS LTD.

Country	Name		Affiliation
Chile	Mr.	Alejandro Lara	UNIVERSITY OF GIRONA
China	Dr.	Changzhi Li	CHINA'S INSTITUTE OF WATER RESORCES AND HYDROPOWER RESEARCH
China	Prof.	Chunchang Huang	DEPARTMENT OF GEOGRAPHY, SHAANXI NORMAL UNIVERSITY, CHINA
China	Prof.	Fei Mao	INSTITUTE OF ECOTOPE AND AGROMETEOROLOGY, CHINESE ACADEMY OF METEOROLOGICAL SCIENCES
China	Mr.	Hantao Wang	COLLEGE OF WATER RESOURCES AND HYDROPOWER, SICHUAN UNIVERSITY
China	Prof.	Jiming Kong	INSTITUTE OF MOUNTAIN HAZARDS AND ENVIRONMENT, CHINESE ACADEMY OF SCIENCES AND MINISTRY OF WATER CONSERVANCY
China	Dr.	Jinfeng Liu	INSTITUTE OF MOUNTAIN HAZARDS AND ENVIRONMENT, CHINESE ACADEMY OF SCIENCES
China	Dr.	Song Yuqin	SCHOOL OF ENVIRONMENTAL SCIENCES AND ENGINEERING, PEKING UNIVERSITY, CHINA
China	Mr.	Xian Luo	NANJING UNIVERSITY
China	Dr.	Yonggang Ge	INSTITUTE OF MOUNTAIN HAZARDS AND ENVIRONMENT, CHINESE ACADEMY OF SCIENCES,CHIA
France	Dr.	Flora Branger	CEMAGREF LYON FRANCE
France	Dr.	Frédéric Grelot	UMR G-EAU, CEMAGREF
India	Dr.	Joseph Paimpillil	CENTER FOR EARTH RESEARCH AND ENVIRONMENT MANAGEMENT
India	Ms.	Kalpana Chaudhari	SARDAR VALLABHBHAI NATIONAL INSTITUTE OF TECHNOLOGY , SURAT, INDIA
Indonesia	Dr.	Masimin	DEPT. OF CIVIL ENGINEERING SYIAH KUALA UNIVERSITY, BANDA ACEH, INDONESIA
Indonesia	Mr.	Noerdin Basir	BENGKALIS POLYTECHNIC, INDONESIA
Japan	Prof.	Keiichi Toda	DISASTER PREVENTION RESEARCH INSTITUTE, KYOTO UNIVERSITY
Japan	Mr.	Kengo Hanajima	GRADUATE SCHOOL OF ENGINEERING, KYOTO UNIVERSITY, KYOTO, JAPAN
Japan	Mr.	Koji Mori	GEOSPHERE ENVIRONMENTAL TECHNOLOGY CORP. JAPAN
Japan	Mr.	Kotaro Takemura	Foundation for Riverfront Improvement and Restoration, Japan] [2 Hitachi, Ltd, Japan], [3Geosphere Environmental Technology Corps, Japan
Japan	Mr.	Makoto Hada	FORUM8 CO., LTD.
Netherland	Prof.	Dimitri Solomatine	IHE
Netherland	Prof.	Jaap De Heer	VU UNIVERSITY AMSTERDAM
Netherland	Ms.	Joanne Vinke-De Kruijf	UNIVERSITY OF TWENTE
Netherland	Mr.	Jurjen Wagemaker	HKV CONSULTANTS
Netherland	Ms.	Marja Segers	PROVINCE NOORD-BRABANT
Netherland	Mr.	Rien Van Zetten	RIJKSWATERSTAAT
Netherland	Dr.	Sebastiaan Jonkman	DELFT UNIVERSITY, THE NETHERLANDS
Netherland	Dr.	Stefan Uhlenbrook	UNESCO-IHE, Institute for Water Education, The Netherlands
Pakistan	Mr.	Arslan Muhammad	COLLEGE OF EARTH AND ENVIRONMENTAL SCIENCES

Country	Name		Affiliation
Philippine	Mr.	Jessie Felizardo	PMO-FLOOD CONTROL AND SABO ENGINEERING CENTER, DPWH
Serbia	Dr.	Biljana Radojevic	UNESCO
Sweden	Mr.	Guoyi Han	STOCKHOLM ENVIRONMENT INSTITUTE
UK	Prof.	Ian Cluckie	College of Engineering, Swansea University, UK,
UK	Ms.	Meghan Alexander	FLOOD HAZARD RESEARCH CENTRE, MIDDLESEX UNIVERSITY, UK
UK	Prof.	William Allsop	COASTAL STRUCTURES GROUP, HR WALLINGFORD, HOWBERY PARK, WALLINGFORD, OX10 8BA, UK
USA	Prof.	Michael H Glantz	CONSORTIUM FOR CAPACITY BUILDING (CCB), UNIVERSITY OF COLORADO, DIRECTOR, USA
USA	Mr.	Pete Rabbon	U.S. ARMY CORPS OF ENGINEERS, UNITED STATES
USA	Ms.	Stephanie Bray	U.S. ARMY CORPS OF ENGINEERS, UNITED STATES

Annex 4: Follow up activities report: Bangladesh workshop (5 November 2012)

Report on Follow-up Consultation Workshop on the National Road Map for Floods Early Warning System Development in Bangladesh (5th November, 2012), Dhaka, Bangladesh:

Background
The international Centre for Water Hazard and Risk Management (ICHARM) has been implementing Capacity Development Technical Assistance for Supporting Investments in Water-related Disaster Management (TA 7276) under the flagship of Asian Development Bank (ADB)-ICHARM partnership agreement. This ICHARM-ADB joint project has implemented different types of national and regional-level interventions mainly through the application of Integrated Flood Analysis System (IFAS) to the Solo River basin in Indonesia, pilot implementation of community-based flood management approaches in Indonesia, national road mapping of early warning system in Bangladesh, development of flood vulnerability indices in the Lower Mekong Basin, application of IFAS in Pampanga and Cagayan river basins of the Philippines and capacity development by practical training and knowledge-sharing programs for target as well as other countries in the region.

In order to identify key interventions to improve the flood forecasting and early warning system in Bangladesh, a baseline study was conducted in 2006 by the Government of Bangladesh with support of the Asian Development Bank (ADB). The result of the baseline study was 22 interventions recommended to the Government. The Government showed keen interest on this recommendation, but there was a concern that several recommended measures have already been implemented / planned during and after the baseline study. Therefore, the Government, the Government requested ADB in 2009 to provide additional support to review and update those recommended measures based on case studies and stakeholders' interests under the regional capacity development technical assistance project TA 7276, which resulted in the National Road Map on Flood Forecasting and Early Warning System Development in Bangladesh.

Date and Venue
This Workshop was held on 5th November, 2012 at Marble Room, Ruposhi Bangla Hotel, Dhaka, Bangladesh.

Organizers
Bangladesh Water Development Board (BWDB), Bangladesh
Asian Development Bank (ADB), the Philippines
International Centre for Water Hazard and Risk Management (ICHARM), Japan

Participants of the workshop
Total 43 participants from different stakeholders, development partners and related organizations actively joined the workshop. The participants were invited from Bangladesh Water Development Board, Joint River Commission, Institute of Water Modeling, Bangladesh Disaster Preparedness Centre, Center for Environmental and Geographical Information Services, Independent Consultant, Bangladesh Meteorological Department, the Comprehensive Disaster Management Programme-II, Department of Disaster Management, Bangladesh Agricultural Research Council, the Water Resources Planning Organization, Hao Board, JICA Bangladesh, ADB, the World Bank office in Dhaka, UNDP Bangladesh, ICHARM and others.

Outline of the National Road Map
The National Road Map consists of prioritized interventions, their cost estimate, and their timelines for implementation by 2019. The most important interventions are but not limited to: (i) operation and maintenance of the monitoring network; (ii) expanding the range of data acquisition; (iii) national and local level risk assessment; (iv) community preparedness; and (v) FFWC capacity building. These

interventions complete flood forecast and early warning cycle filling the major existing gaps in Bangladesh. Implementation of prioritized interventions will lead to (i) increase accuracy and lead time for flood forecasting, (ii) improve flood forecasts to meet demands of end-users, (iii) improve the extent of coverage and the penetration of early warning system to the grassroots level, and (iv) expand coordination among key institutions involved in early warning system.

Objective of the Follow-up Workshop
The main objective of the Follow-up workshop is to: (i) discuss a way forward on the practical and concrete implementation of the National Road Map; (ii) prepare an action plan as realization of discussion; and reach consensus on the ac plan by related organizations in Bangladesh.

Detail Descriptions of Sessions and Discussions
The workshop, chaired by Mr. Md. Sarim Bhuiyan, Chief Planning, BWDB, was attended by 44 participants from 17 government and non-government organizations including development partners such as ADB, World Bank, and Japan International Cooperation Agency (JICA). Mr. Md. Afzal Hossain, Additional Director General (Planning), BWDB, attended the workshop as the Chief Guest, and Mr. Tetsumi Takahashi, Embassy of Japan in Bangladesh, and Mr. Stefan Ekelund, Deputy Country Director, Bangladesh Resident Mission, ADB, joined the workshop as the Special Guests. Mr. Hisashi Mitsuhashi, the leader of the ADB-ICHARM mission, made welcome remarks. At the first session, Mr. Toshio Okazumi, Team Leader of ICHARM, and Dr. Badri Shrestha, Project Technical Manager of ICHARM, introduced a summary of the Road Map. At the second session, all participants were separated to three groups which comprised participants from various organizations, and provided their opinions to three key questions on implementation of the Road Map facilitated by Dr. Rabindra Osti, Water-Related Disaster Risk Management Specialist, ADB. At the end of the second session, results of discussions in the three groups were shared and summarized as followings:

Key Question 1: What are the major gaps and challenges in achieving goals recommended in the Road Map and what are the probable solutions? The Road Map focuses on flood forecasting and early warning system for flash floods and riverine floods, which is under the mandate of the Flood Forecasting and Warning Center (FFWC) of BWDB. However, Bangladesh has other types of floods which need equal attention: storm surge, tidal floods, cyclone induced floods, and pluvial floods. The Road Map should be developed in the future to cover these floods which require different forecast systems. Currently, the mandates of forecast for different types of floods are under different organizations[44], which lead to the fact that there is always a chance of overlapping and duplication. Therefore, enhancing the coordination and cooperation among organizations should be considered.

The capacity of FFWC needs to be urgently improved as suggested by the Road Map. However, its capacity development does not only mean to provide hardware nor improve the capacity of forecasters and forecasting tools including models but also to institutionally reform FFWC so that FFWC has well-functioning teams with clear roles and mandates. The characteristics of floods have been found to change annually due to the change in river flow condition, demography, and river morphology as well as due to the impact of artificial control over the river flow conditions. This has made difficult not only in flood forecasting but also in estimating the danger levels for flood warning in each river. It has been unclear whether existing flood forecasting system can manage such complexities. Besides, short term (one week), medium term (15 days) and seasonal flood forecasting is required for various purposes though it has always been a challenging task. Usually, frequent need assessments at both local and institutional levels are required to identify the purposes for those short, medium or long-term forecasts.

As recommended by the Road Map, the information dissemination system in Bangladesh is still weak in terms of both hardware and software. There is a lack of mechanism to interpret the forecast

[44] (i) Flash flood: Bangladesh Space Research and Remote Sensing Organization (SPARRSO), BWDB, and Bangladesh Meteorological Department (BMD), (ii) Riverine Flood: BWDB (iii) Storm Surge and Cyclone: Storm Warning Centre (SWC/BMD), (iii) Coastal Flooding: BMD, (iv) Cyclone: BMD.

information into warning information at different levels of uses so that it has always been difficult for them to judge the right time for issuing evacuation advisories and orders. This can be improved by clearly mentioning the forecast provisions and mandates in the Standing Orders on Disaster (SOD), which has no link to any resources gap at present.

Key Question 2: How do you implement/contribute the Road Map by participants' organizations, roles, and positions? The most important thing to establish reliable flood forecasting and early warning system is to develop an accurate database, which is possible by timely sharing the different types of data by relevant organizations. To enhance flood forecasting, each organization should provide available database to the FFWC whenever required. The two way communication among forecaster and users should be maintained, and coordination among organizations should be enhanced in the coming years. Specialized organizations and institutions, such as the Bangladesh University of Engineering & Technology (BUET), the Institute of Water Modeling (IWM), the Centre for Environmental and Geographic Information Services (CEGIS), can provide significant input to improve the existing flood forecasting system by introducing cutting edge methodology and technologies. Most of the participating stakeholders agreed to share available data with FFWC. To assure all stakeholders' ownership, coordination and cooperation, there is a need of additional commitments from the organizations to prepare at least 10-15 years development plan with clear financial and other resources obligations.

Key Question 3: What are the on-going or pipeline interventions (projects), which are in-line with the Road Map? In the last two years, many projects have been initiated by relevant organizations to improve the flood forecasting and early warning in Bangladesh as followings.

- BWDB has been developing a data collection model with its own resources.
- The Comprehensive Disaster Management Programme-II (CDMP II) supported by the United Nations Development Programme (UNDP) has committed to increase the forecast lead time from existing 3 days to 5 days. This will be possible by increasing the observation stations within Bangladesh and by incorporating the data from upstream basin.
- The Regional Integrated Multi-Hazard Early Warning System (RIMES) in support from CARE International is helping FFWC to produce 10 days probabilistic flood forecast, which will be possible by expanding the boundary of the hydrological model, which is currently being set at boarder within Bangladesh territory.
- The Bangladesh Haor and Wetland Development Board (BHWDB) has newly established a flood information dissemination system to support Haor area in north eastern part of Bangladesh to produce a reliable localized flood forecast.
- The World Bank has come up with an idea to help BWDB automate all manual rainfall and water gauge stations and increase the number of hydrological observation stations under the project named Hydro-Met.
- The Hindu Kush Himalaya-HYCOS project jointly initiated by the International Centre for Integrated Mountain Development (ICIMOD) and the World Meteorological Organization (WMO) will establish a regional hydrological data observation and dissemination system so that each participating country including Bangladesh can get benefit from the system.
- JICA has been providing training programs to the staff of BWDB, BMD and the Department of Disaster Management (DDM) continuously.
- There is also a proposed Haor area development master plan, if this is realized more region focused initiative for hydrological monitoring and forecasting will be established.
- ADB has two projects on flood risk management which contribute to the implementation of the Road Map. The first project is the Main River Flood and Bank Erosion Risk Management Program. This Program aims to sustain incomes and livelihoods of people along the three main rivers Jamuna, Meghna, and Padma. There are two anticipated outputs from this Program. The first output is enhanced integrated flood and riverbank erosion disaster risk mitigation measures. The measures will consist of (i) non-structural and structural measures for selected priority river reaches, (ii) effective measures to sustain infrastructures involving local communities, (iii) support for enhancing local communities flood/erosion disaster risk management capacity in the subproject areas, and (iv) livelihood enhancement for project zone of influence. The second output is a strengthened flood and river erosion risk management system, including an improved

knowledge base and institutional performance in sustainable operation and maintenance and long-term river erosion management. The second project is the Regional Capacity Development Technical Assistance for Applying Remote Sensing Technology in River Basin Management. The project will collaborate with CDMP II to extend flood warning lead time by providing remote sensing data in the upper basin of main rivers observed by satellites. In addition, the project will support a localized flood forecasting model at union-level, and a localized flood warning dissemination system in pilot areas by utilizing cell phone technologies, in cooperation with BWDB and DDM, and other organizations.

Representatives from development partners also provided their remarks on the discussed issues. They highlighted the importance of ownership on the road map as well as the cooperation and coordination among stakeholders in the implementation. The sustainability is a prime issue for each and every intervention to be implemented. There are agencies like JICA that has accumulated vast experience globally in both technical and non-technical aspects of flood forecasting and early warning system development can be best utilized in the contexts of Bangladesh.

At the end of the workshop, Mr. Tetsumi Takahashi, Embassy of Japan in Bangladesh, Mr. Stefan Ekelund, Deputy Country Director, Bangladesh Resident Mission, ADB, and Mr. Md. Afzal Hossain, Additional Director General (Planning), BWDB, made remarks. The workshop was concluded by the closing remarks from the Chairperson Mr. Md. Salim Bhuiyan. Mr. Bhuiyan said that BWDB has owned the Road Map and will implement it. He appreciated the comments and suggestions from participating organizations and development partners.

Outcomes of the workshop

The workshop was successful in having reached consensus among related organizations and development partners on the National Road Map. The outcomes of the workshop are as follows:

- Sharing of the National Road Map for Floods Early Warning System Development in Bangladesh to stakeholders ;
- Building a platform among stakeholders to collaborate in the implementation of the National Road Map for Floods Early Warning System Development in Bangladesh; a

Detail Final Program Agenda and Schedule

Chairperson: Mr. Md. Salim Bhuiyan, Chief Planning, BWDB, Dhaka
Chief Guest: Mr. Md. Afzal Hossain, Additional Director General (Planning), BWDB, Dhaka
Special Guests: Mr. Tetsumi Takahashi, Embassy of Japan in Bangladesh
Mr. Stefan Ekelund, Deputy Country Director, Bangladesh Resident Mission, ADB

9:30-10:00	**Registration**
10:00-10:10	Welcome Address by **Mr. Hisashi Mitsuhashi**, ADB
10:10-10:45	**Session 1**: Introduction of the National Road Map for Floods Early Warning System Development in Bangladesh **Speaker**: **Mr. Toshio Okazumi** and **Dr. Badri Shrestha**, ICHARM.
10:45 – 11:00	**Tea Break**
11:00-12:30 12:30-12:50 12:50-13:00	**Session 2:** Discussion about Implementation of the National Road Map for floods Early Warning System Development in Bangladesh Facilitator: **Dr. Rabindra Osti**, ADB Discussion Plenary discussion and session summary

13:00-13:10	**Remarks from Special Guest: Mr. Tetsumi Takahashi**, Embassy of Japan in Bangladesh
13:10-13:20	**Remarks from Special Guest: Mr. Stefan Ekelund**, Deputy Country Director, Bangladesh Resident Mission, ADB
13:20-13:30	**Remarks from Chief Guest: Mr. Md. Afzal Hossain**, Additional Director General(Planning), BWDB, Dhaka
13:30-13:45	**Closing Remarks by the Chair**: **Mr. Md. Salim Bhuiyan**, Chief Planning, BWDB, Dhaka
13:45	**Lunch**

Some Photographs of the Workshop

Starting of Workshop from BWDB and participants of the workshop

Welcome remarks given by Mr. Hisashi Mitsuhashi, ADB (left) and Presentation given by Mr. Toshio Okazumi, ICHARM (right)

Group Photo of workshop

Group discussion (participants were divided into 3 groups)

Remarks given by Chief Guest Mr. Md. Afzal Hossain, Additional Director General (Planning), BWDB (left) and closing remarks given by Chair of workshop Mr. Md. Salim Bhuiyan, Chief Planning, BWDB (right)

Annex 5: Follow up activities report: FVI Training in Cambodia (11-13 December 2012)

Report of Training on Development and Utilization of Flood Vulnerability Indices in Cambodian Floodplain (11-13 December 2012), Phnom Penh, Cambodia:

Background

Lower Mekong River Basin, which comprises the territories of Lao PDR, Cambodia, Thailand and Viet Nam, has annually been affected by floods. Almost every year, floods take away lives and cause damage to infrastructure, agricultural and industrial production and severely affect socio-economic development. The flood damage observed in the Basin is a significant impediment to a more rapid development.

The International Centre for Water Hazard and Risk Management (ICHARM), an implementing partner of Asian Development Bank (ADB) for the Technical Assistance (TA7276) named Supporting Investments in Water-Related Disaster Management, has recently mapped the flood vulnerability situations in the Cambodian flood plains. The TA has been implemented to support the Mekong River Commission Secretariat (MRCS) in developing flood vulnerability indices in the Lower Mekong Basin.

Vulnerability is the characteristics and circumstances of communities, systems or assets that make them exposed, susceptible and resilient to the damaging effects of a flood hazard. Flood vulnerability indices (FVI) have been developed for the Cambodian floodplains as a rapid and consistent method for characterizing the relative vulnerability of different locations in the floodplains. The ultimate goal of TA intervention is to help Governments prepare and implement flood management investment projects through knowledge and capacity development services that will reduce vulnerability to flood disasters within the Basin.

In this context, training on 'Development and Utilization of Flood Vulnerability Indices in Cambodian' was organized jointly by MRCS, Cambodia National Mekong Committee (CNMC), ADB and ICHARM, from 11-13 December 2012 at MRCS meeting room, Phnom Penh, Cambodia.

Objectives of the training

The main objectives of the training program are to:

(iv) Develop the capacity of relevant agencies in Cambodia to prepare FVI maps,
(v) Discuss on effective utilization of developed FVI as a tool to community people, community leaders, decision makers, policy makers and developers for disaster management,
(vi) Provide orientation on the preparation of guide book on the utilization of FVI for future reference.

The training program on development and utilization of FVI in Cambodian floodplain focused on developing the capacity of flood management to carry out FVI mapping and indexing and to best utilize such results into development practices. The hands on training on the preparation of flood vulnerability maps with GIS tools and methodologies developed by ICHARM were provided to the participants from the relevant agencies in Cambodia. The effective utilization of the developed results of FVI in LMB area is also discussed among the participants leading to the developments of guidebook.

Summary of Training

This training was held at MRCS meeting room, Phnom Penh and 20 participants (excluding guests/ICHARM members/ADB members) joined this training from various related organizations such as Mekong River Commission Secretariat (5 participants), Cambodian National Mekong

Committee (2 participants), Ministry of Water Resources and Meteorology (MOWRM) (3 participants), Cambodian Red Cross (CRR) (2 participants), Ministry of Agriculture, Forestry and Fisheries (MAFF) (2 participants), Ministry of Environment (MOE) (1 participant), Ministry of Land Management Urban Planning and Construction (MLMUPC) (1 participant), Ministry of Public Works and Transport (MPWT) (1 participant), National Committee for Disaster Management (NCDM) (2 participant) and Tonle Sap Authority (TSA) (1 participant).

The training program was begun with opening ceremony and Mr. Nicolaas Bakker, Chief Advisor of Flood Management and Mitigation Progrmme (FMMP)/MRC, Mr. Hisashi Mitsuhashi, Water Recourses Specialists of ADB and H. E. Mr. Kol Vathana, Deputy Secretary General of CNMC made opening remarks. In keynote session which chaired by Mr. Toshio Okazumi, Chief Researcher of ICHARM, Mr. Nguyen Tien Kien, Operational Meteorologist of MRCS gave keynote lecture on a general overview of flood risk approaches under FMMP 2004-2010 and FMMP 2011-2015 and Dr. Shigenobu Tanaka, Deputy Director of ICHARM gave keynote lecture on past activities related to flood risk management and overview of methodology for developing flood vulnerability indices.

This training program was manly divided into 3 sessions. Session I was focused on development of flood vulnerability indices. Session II was focused on orientation and preparation of flood vulnerability mapping. Session III was focused on utilization of developed flood vulnerability indices. Session I started with chair of Mr. Toshio Okazumi, ICHAMR and this session was focused methodology for development of flood vulnerability indices. This session was divided into four different parts such as Part I was focused on ICHARM Hydro-Geo Method, Part II was focused on assessment of agricultural damage, Part III was focused on assessment of house damages and Part IV was focused on was focused on development of flood vulnerability indices. Dr. Shigenobu Tanaka, Deputy Director of ICHARM gave a lecture on ICHARM Hydro-Geo method in Part I. Mr. Shigenobu Hibino, Research Specialist of ICHARM gave a lecture on assessment of agricultural damages in Part II. After the lectures of Part I and Part II, a hands-on training of Part I and Part II was held with guidance and instructions of ICHARM members. The participants were divided into four groups and group members were selected from different organization. The training tools were prepared in Microsoft excel with visual basic programming and reference maps. In this hands-on training, participants learned water level interpolation in the river course between two water level stations, and calculation of flood water level and water depth in the floodplain. They also learned identification of transplanting date, water depth and its duration for agricultural damage assessment. By using damage ratio curve, they could learn how to calculate agricultural damages. The major key points of this hands-on training of agricultural damage assessment are as follows.

- ◎ How to get water level in river channel by interpolation
- ◎ How to set “iso-flood band”(same water level area)
- ◎ How to identify the transplanting date
    - ➢ Thiessen Polygon setting
    - ➢ How to get Cumulative rainfall
- ◎ How to use rice damage curve for a location
- ◎ How to estimate agricultural damage

In Part III of Session I, Dr. Shigenobu Tanaka, Deputy Director of ICHARM introduced assessment of house damages. After the lecture of house damage assessment, a hands-on training of Part III was held. In this hands-on training, participants learned how to estimate house damages by using probability distribution of house value, house damage ratio curve and LandScan Population data. The major key points of this hands-on training of house damage assessment are as follows.

- ➢ How to get House value distribution
- ➢ How to get house damage curve
- ➢ How to calculate house damage distribution with HV distribution and damage curve
- ➢ How to calculate house damage with LandScan 30 sec data

Dr. Badri Shrestha, Researcher of ICHARM gave a lecture on development of flood vulnerability indices in Lower Mekong Basin of Cambodian floodplain in Part IV of Session I. The hands-on

training of Part IV was combined with hands-on training of Session II.

In session II, Dr. Youngjoo Kwak gave lecture on GIS tools and its application in flood vulnerability mapping. After the lecture on GIS, a hands-on training was held to learn GIS function and its tools to develop maps. A free GIS software Quantum GIS was provided to participants for the practice in hands on training. After the hands-on training of GIS, another hands-on training for development of flood vulnerability indices mapping was held with a guidance of ICHARM members.

Session III was started with a lecture of Mr. Toshio Okazumi, Chief Researcher of ICHARM. The lecture of Mr. Okazumi was focused on flood risk management, which provided basic knowledge on flood risk management to all the participants for their practical works as well as it supported for group discussion on utilization of flood vulnerability indices. Also, in Session III, Dr. Badri Shrestha introduced the results of developed flood vulnerability indices, utilization of flood vulnerability indices and example guidebook as toolkit for community people. After these lectures, a group discussion was carried out and each group made a presentation based on their discussion. The participants were divided into four groups also for group discussion. Then plenary discussion was held with facilitation of Dr. Rabindra Osti, ADB. The key points of group and plenary discussion are as follows.

1. What are major flood problems in Cambodian floodplain?

2. How can these flood vulnerability indices maps help to solve those problems?

3. What kind of information to be added in flood vulnerability indices maps and guidebook of utilization of flood vulnerability indices?

4. What is your action plan after this training?

The summary of the group discussion on four key points are as follows.
Key point 1: Major flood problems are damages in agricultural and infrastructures, health problem, loss of life, food shortage, lack of medicine, drinking water problem, difficulty in transportation accessibilities, electricity and sanitation problems and damages of assets and livestock, high flood depth and duration can cause big damages, onset and offset flood problems.

Key point 2: The flood vulnerability indices maps help to provide information, useful for evacuation and also to decision maker, for planning (high risk and damage areas, population density), damage estimation assessment, useful for responses (food, health treatment), and for restoration and rehabilitation plan, for risk reduction, recovery and preparedness, useful for quick assessment of flood damage areas, local decision – making process and dentifying the priority area for implementation of disaster-related project.

Key point 3: The necessary information to be added in flood vulnerability indices maps and in guide book are: nearest safety area, emergency contacts, contact phone number of focal point of Commune Committee for Disaster Management (CCDM), evacuation routes, specific infrastructures (school, pagoda, health center, food center), preparedness actions (before, during, after), translation into local language, simple and clear definition of disaster terminology, socio-economic information, coping capacity of community

Key point 4: After the training their action plan are as follows:

- Apply ICHARM Hydro-Geo Method to other area for development of flood vulnerability indices.
- Distribute a developed flood vulnerability indices maps to community.
- Share knowledge to their colleague
- Share information to local community and vulnerable locations and stakeholders.

- Cooperating and sharing the methodology to colleagues in offices in MAFF, MOWRAM, MPWT and NGOs working at local level.

Satisfactory from participants

All the participants actively participated in the training. About 53% participants of the training have less than 5 years experiences on river-related work. About 86.6% participants felt that they could understand on the philosophy of development of ICHARM Hydro-Geo Method. About 86.7% participants understood assessment of agricultural and house damages. All the participants stated that they could understand flood vulnerability indices and all of them expressed that FVI maps are very useful for flood risk management. About 85.7% understood the usage of GIS software for their working activities. About 93% participants expressed that this training would be helpful for the flood management. All the participants actively participated in all keynote and lectures session, hands on training of water level interpolation and agricultural damage assessment, house damage assessment, FVIs mapping and GIS. As a result, all participants got helpful technology and knowledge for flood risk management through the training.

Outcomes of the training program

The main outcomes of training program are as follows:

- Sharing methodologies of ICHARM Hydro-Geo Method, agricultural damage assessment, house damage assessment, development of flood vulnerability indices and GIS tools and its application for FVI development.
- Providing hands-on training for participants on water level interpolation, agricultural damage assessment, house damage assessment, FVI development and GIS tools.
- Leveraging knowledge sharing for capacity development.
- Providing knowledge for effective utilization of FVI as a tool to community people, community leaders, decision makers, policy makers and developers for disaster management,
- Providing orientation for preparation of guide book on the utilization of FVI for future reference.

Agenda of Training Program

Date	Time	Descriptions
2012-12-11 (Tuesday) (1st Day)	8:00-8:30	**Registration** ICHARM
	8:30-9:00	**Opening Ceremony** **Chair: MRCS** Remarks: Mr. Nicolaas Bakker, Chief Technical Advisor, FMMP/MRC Remarks: Mr. Hisashi Mitsuhashi, ADB Remarks: H.E Mr. Kol Vathana, Deputy Secretary General of Cambodia National Mekong Committee
	9:00-9:05	**Group Photo**
	9:05-11:20	**Keynote Session:** **Chair: MRCS** A general overview of flood risk approaches under FMMP 2004-2010 and FMMP 2011-2015 Speaker: Mr. Nguyen Tien Kien, Operational Meteorologist/Flood Forecaster, Regional Flood Management and Mitigation Centre, MRC (30) **Tea/Coffee Break (15)** Past activities related to flood risk management and overview of methodology for development of flood vulnerability indices Speaker: Dr. Shigenobu Tanaka, Deputy Director, ICHARM (Past activities related to flood risk management and overview of methodology for development of flood vulnerability indices) (30) Questions and Answers
	11:20-12:00	**Session I: Development of Flood Vulnerability Indices** **Part I: ICHARM Hydro-Geo Method** General of ICHARM Hydro-Geo Method and Hydro-Meteorological Analysis (40) Speaker: Dr. Shigenobu Tanaka, ICHARM
	12:00-13:00	**Lunch Break**
	13:00-15:20	**Session I:** **Part I: ICHARM Hydro-Geo Method (Continued) (140)**
	15:20-15:40	**Tea/Coffee Break**
	15:40-16:10	**Part II: Assessment of Agricultural Damage** Methodology of agricultural damage calculation (30) Speaker: Mr. Shigenobu Hibino, ICHARM
	16:10-17:30	**Hands on Training of Part I and Part II (80)** Instructors: ICHARM Team

	17:30-17:35	**Closing by MRCS**
	18:30-	**Welcome dinner**
2012-12-12 (Wednesday) (2nd Day)	8:30-9:00	**Registration**
	9:00-10:00	**Session I (Continued)** **Part III: Assessment of House Damage** Methodology of house damage calculation (60) Speaker: Dr. Shigenobu Tanaka, ICHARM
	10:00-10:20	**Tea/Coffee Break**
	10:20-11:20	**Hands on Training of Part III (60)** Instructors: ICHARM Team
	11:20-12:00	**Part IV: Development of Flood Vulnerability Indices** Development of Flood Vulnerability Indices in Lower Mekong Basin of Cambodian Floodplain (40) Speaker: Dr. Badri Shrestha, ICHARM
	12:00-13:00	**Lunch Break**
	13:00-13:40	**Session II: Orientation and Preparation of Flood Vulnerability Indices Maps** **Part I: GIS tools and its application in flood vulnerability mapping** Introduction of GIS and its application in flood vulnerability mapping (40) Speaker: Dr. Youngjoo Kwak, ICHARM
	13:40-15:00	**Part II: Flood vulnerability indices mapping** Hands on training of Part IV and flood vulnerability indices mapping (80) Instructors: ICHARM Team
	15:00-15:20	**Tea/Coffee Break**
	15:20-17:00	Hands on training (**Continued**) (100) Instructors: ICHARM Team
	17:00-17:05	**Closing by MRCS**
2012-12-13 (Thursday) (3rd Day)	8:30-9:00	**Registration**
	9:00-9:40	**Session III: Utilization of developed flood vulnerability indices** Lecture on Flood Risk Management (30) Speaker: Mr. Toshio Okazumi, ICHARM Questions and Answers (10)
	9:40-10:10	Utilization of flood vulnerability indices maps (30) - Example Guidebook Speaker: Dr. Badri Shrestha, ICHARM

	10:10-10:30	**Tea/Coffee Break**
	10:30-12:00	Group discussion on how to utilize developed flood vulnerability indices for the local community and decision makers (4 Groups) Focused on necessary information for following recipients: - Community people - Decision makers/policy makers - Developers
	12:00-13:00	**Lunch Break**
	13:00-13:30	Group discussion (Continued) (30) Presentation from each Group
	13:30-14:45	**Plenary discussion** (60) Facilitator: Dr. Rabindra Osti, ADB Plenary discussion summary (15)
	14:45-14:55	**Wrap up of the overall training and workshop** (10) Speaker: Mr. Hisashi Mitsuhashi, ADB
	14:55-15:10	**Closing Ceremony** **Chair: MRCS** Remarks: Mr. Toshio Okazumi, Team Leader of project, ICHARM Remarks: Dr. Lam Hung Son, FMMP Coordinator, FMMP/MRCS

List of participants

Participants list (as of 13-Dec)

Registrate No.	Group No.	Organization	Mr./Ms.	Family name	First Name	Province	1st day	2nd day	3rd day	Certificate
1	G-1	CNMC (Cambodia National Mekong Committee)	Mr.	Sakhon	Pory	Phnom Penh	●	●	●	◎
2	G-3	CRC (Cambodian Red Cross)	Mr.	Kieng	Vaddanak	Phnom Penh	●	_	●	◎
3	G-1	MAFF (Ministry of Agriculture, Forestry and Fisheries)	Mr.	Tan	Chan Tara	Phnom Penh	●	●	●	◎
4	G-3	MOE (Ministry of Environment)	Mr.	Phin	Rady	Phnom Penh	●	●	●	◎
5	G-4	MLMUPC (Ministry of Land Management Urban Planning and Construction)	Mr.	Reuy	Nga	Phnom Penh	●	●	●	◎
6	G-1	MPWT (Ministry of Public Works and Transport)	Mr.	Lim	Sopheak	Phnom Penh	●	●	●	◎
7	G-2	MRCS (Mekong River Comission Secretariat)	Dr.	Varoonchotikul	Pichaid	Phnom Penh	●	●	●	◎
8	G-3	MRCS (Mekong River Comission Secretariat)	Dr.	Phung	Katry	Phnom Penh	●	●	●	◎
9	G-4	MRCS (Mekong River Comission Secretariat)	Mr.	Nguyen	Tien Kien	Phnom Penh	●	●	●	◎
10	G-1	MRCS (Mekong River Comission Secretariat)	Mr.	Nuon	Kunthea	Phnom Penh	●	●	●	◎
11	G-2	MRCS (Mekong River Comission Secretariat)	Mr.	Khim	Vandy	Phnom Penh	●	●	●	◎
12	G-3	MOWRAM (Ministry of Water Resources and Meteoroloy)	Ms.	Chhun	Sokunth	Phnom Penh	●	●	●	◎
13	G-4	MOWRAM (Ministry of Water Resources and Meteoroloy)	Mr.	Yin	Savuth	Phnom Penh	●	_	_	_
14	G-1	MOWRAM (Ministry of Water Resources and Meteoroloy)	Ms.	Pot	Peou	Phnom Penh	●	●	●	◎
15	G-2	NCDM (National Committee for Disaster Management)	Mr.	Lorn	Trob	Phnom Penh	●	●	●	◎
16	G-3	NCDM (National Committee for Disaster Management)	Mr.	Hak	Minea	Phnom Penh	_	●	●	◎
17	G-4	Tonle Sap Authority	Mr.	Tang	Karaney	Phnom Penh	●	●	●	◎
18		MOWRAM (Ministry of Water Resources and Meteoroloy)	Mr.	Veng	Sithy	Phnom Penh	●	●	●	◎
19		MOWRAM (Ministry of Water Resources and Meteoroloy)	Mr.	Im	lay	Phnom Penh	●	●	●	◎
20		MRCS (Mekong River Comission Secretariat)	Mr.	Le	Tuan Nghia	Phnom Penh	●	_	_	_

Photographs of training program

 

Opening remarks given by H. E. Mr. Kol Vathana, Deputy Secretary General of CNMC and photo during opening session

All participants of training program

 

Keynote lecture given by Mr. Nguyen Tien Kien, Operational Meteorologist (left) and participants of the training (right)

 

Keynote lecture and lecture on ICHARM Hydro-Geo Method (Session I: Part I) given by Dr.

Shigenobu Tanaka, Deputy Director of ICHARM

Photographs show the hands-on training of Part I and Part II of Session I

Annex 6: Follow up activities report of Indonesia

VISIT TO SOLO RIVER BASIN – BOJONEGORO AREA (KEDUNG SUMBER, SEMEN PINGGIR AND BOGO VILLAGES) AND VISIT TO THE UNIVERSITY OF GADJAH MADA (UGM)

I. VISIT TO KEDUNG SUMBER VILLAGE

1.1 Date of visit: 26 January 2013

1.2 Objective: investigating the recent flash flood situation in relation with flood warning system, emergency response, damages and protection works

1.3 Visited Location: Sugihan Sub Village (flash food event location), Village Community Hall (data collection) and Pajeng Village (location of the rain gauge station). Fig.1 shows the map of visited location.

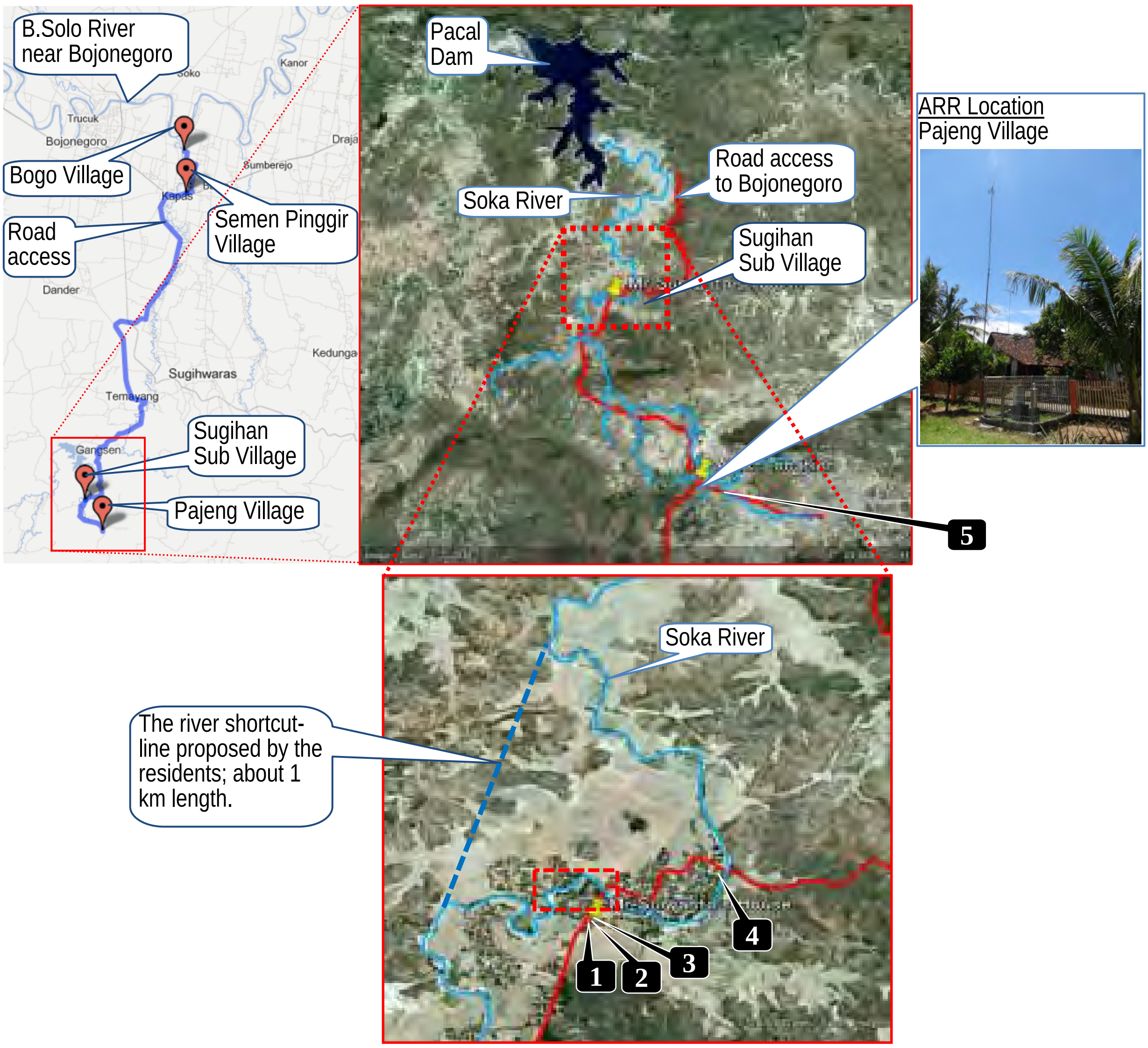

Fig.1 Map of visited location Kedung Sumber and Pajeng Villages); the blue dotted line in the bottom picture is the proposed river shortcut line by the residents; the number labels (1 to 5) indicate the location of damages shows in Fig.2

1.4 Visited person: Mr Suryanto (the Community Leader) and several people of Sugihan Sub Village; Mr Dedi (the Leader of Pajeng Village); the Secretary of Kedung Sumber Village.

1.5 Main Damages: See Fig.2

a. One old house (about 6 x 4 m2) made of wood board and woven bamboo wall was fully collapsed
b. A fence (made of bricks) was collapsed
c. A houses was inundated inside about 110cm depth; the soil floor was destroyed
d. The foundation of a house were destroyed
e. Ten sheeps were died few days after the flood
f. Many hens were floated and missing by the flood

Fig.2 Main damages due to Dec 4th, 2012 flash flood in Sugihan Sub Village; refer to number label in Fig.1 for the location of each damaged point.

1.6 Protection works after the flood: See Fig.3

a. Several sandbags were placed as temporary foundation
b. Settlement of sandbags at several places surrounding houses (funded by BPDP and executed by the residents)
c. Improvement of earth-soil embankment (provided by the Bojonegoro Office of Public Works)
d. Gabion protection to protect river embankment erosion (not yet constructed; provided by BBWS Bengawan Solo).

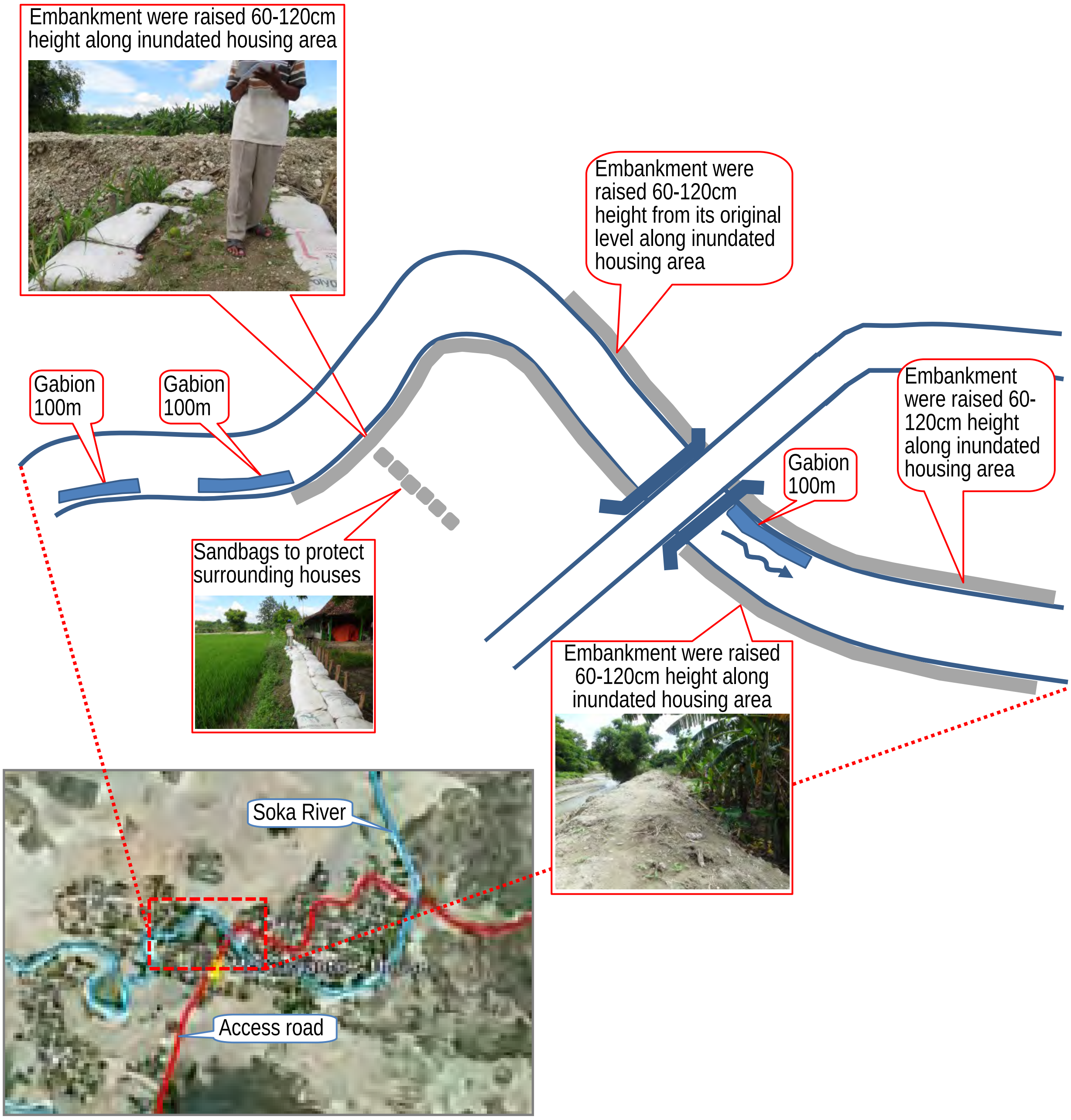

Fig.3 Protection works after the Dec 4th, 2012 flashflood

1.7 House materials in Sub Village Sugihan (according to Mr Suryanto explanation): See Fig.4

a. Number of houses with stone foundation: 50% of total houses; the remaining are directly laid on the earth.
b. Number of houses with the wall combination of bricks (60cm heigh from the foundation) and wood board: 20% of total houses
c. Number of houses with the wall made of wood board and or woven bamboo: 80% of total houses
d. Number of houses which are fully made of bricks wall are very few.
e. Most all of the houses roof are made of traditional baked clay (tile)

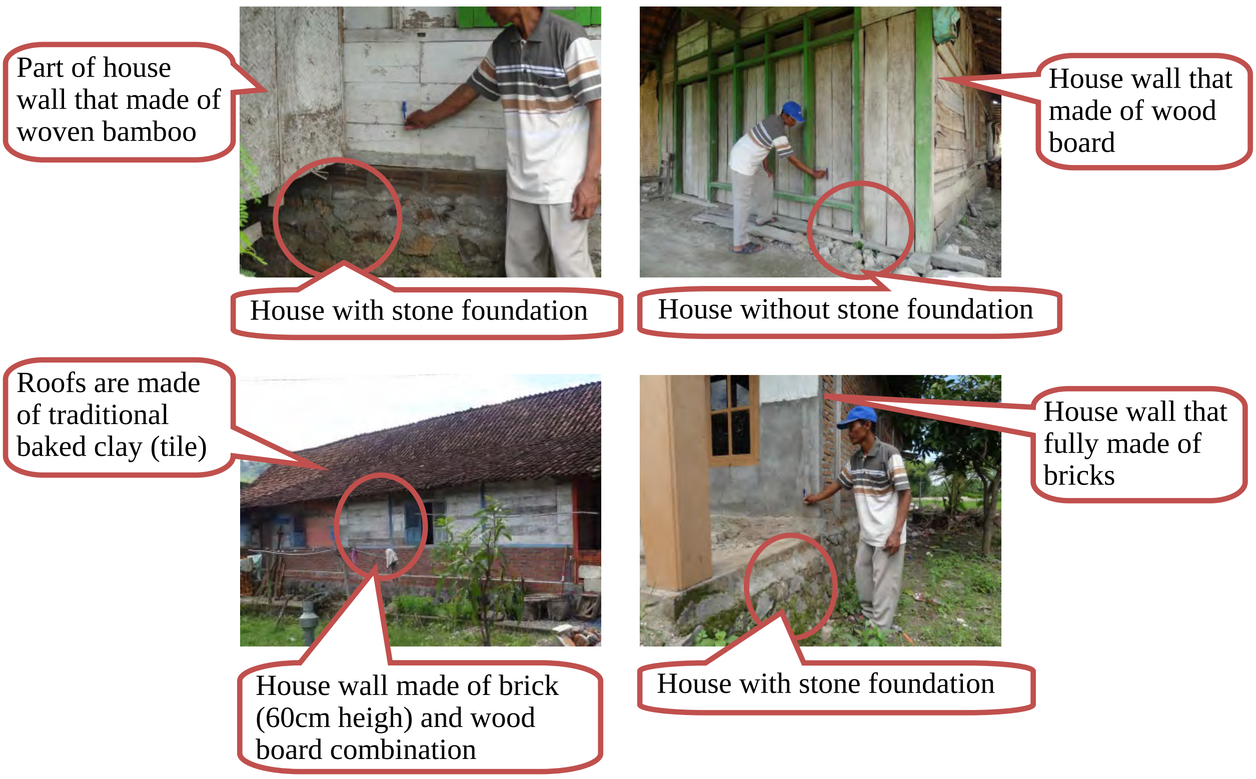

Fig.4 House materials in Bojonegoro, Kedung Sumber Village, Sub Village Sugihan

1.8 Community proposal for flood countermeasure: See Fig.4

a. Embankment gives protection, but many times were overflowed and destroyed by flash flood and eventually generated more damages.
b. The village residents prefer and propose the shortcut of the river (Soko River) to let water flow out bypassing the village.

1.9 Performance of automatic SMS alert from the ARR installed at Pajeng Village (ADB TA-7276

a. Mr Dedi (Pajeng Village Leader) informed that the rain-gauge was not recording for ten days in August, 2012 because of the loose cable connection of battery. It works normal again after reparation; In November, 2012 the antenna pole was bent because of very strong wind, but it was immediately repaired and works normally again.
b. Mr Suryanto informed that the automatic SMS alert from Pajeng ARR works normally;

   Alert message were received several times during rainy season, i.e. Nov 25th, 2012 (25mm); Dec 4th, 2012 (first 24mm, second 50.50mm, flashflood event); Dec 17th, 2012 (22mm).

   After receiving these SMS alert, Mr Suryanto immediatey always conveyed the message to the residents following the standard operation procedure of flood warning and evacuation.

   Note: unfortunately, the record of these automatic SMS messages have no longer available (have been deleted) in the mobile phone of Mr Suryanto.

c. The same automatic SMS alerts were also received well by Mr Dedi (Pajeng Village Leader).

d. Situation flowchart of flood alert and warning on the Dec 4th flash flood in Sugihan Sub Village as narrated by Mr Suryanto (the Community Leader of Sugihan Sub Village) is shown in Fig.5

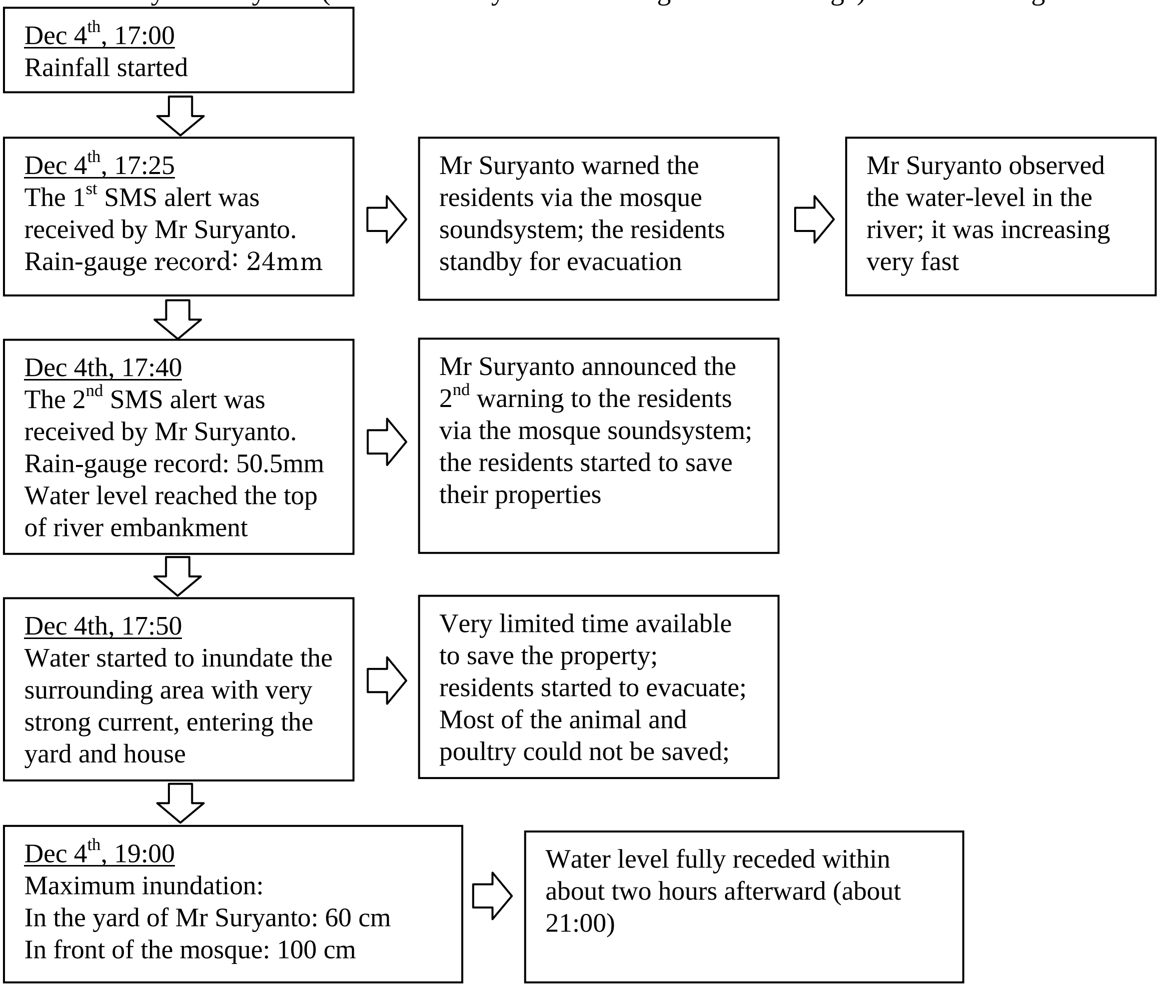

Fig.5 Situation of flood alert and warning on the Dec 4th, 2012 flash flood in Sugihan Sub Village

II. VISIT TO SEMEN PINGGIR VILLAGE AND BOGO VILLAGE

2.1 Date of visit: 27 January 2013

2.2 Objective: investigating the recent flood situation and the community based flood disaster management activities.

2.3 Visited Location: Semen Pinggir Village and Bogo Village (pilot location of evacuation drill activity, July 2011). Fig.6 shows the map of visited location.

2.4 Visited person: Village Leader of Semen Pinggir Village and Deputy Leader of Bogo Village.

2.5 Situation of recent flood and the community based flood disaster management activities in Semen Pinggir Village (as narrated by the Village Leader):

a. There is no follow up community based flood disaster management after that evacuation drill activity conducted under ADB TA-7276 in July, 2011.

b. A flood disaster emergency response drill was carried out at the village by the local Search and Rescue Agency, but had not included the direct participation of the community.

c. One representative of the Village was assigned to participate in an evacuation training workshop held by BPDP Bojonegoro in Dander Village (November, 2012).

d. At the beginning of Januari, 2013, the overflow from Pacal River inundated the house yard of about 40% area and 70% area of agriculture field for two days; the inundated area included only

e. At the beginning of Januari, 2013, the overflow from Pacal River inundated the house yard of about 40% area and 70% area of agriculture field for two days; the inundated area included only the area at the river side of the main access road.

f. In general, the residents mentioned that a flood will be a benefit in term of forcing rats out of the rice field only if the flood inundation is at the level of about 20 cm depth in the rice field and lasting for about 10-12 hours.

2.6 Situation of recent flood and the community based flood disaster management activities in Bogo Village (as narrated by the Village Deputy Leader):

a. There is no follow up community based flood disaster management after that evacuation drill activity conducted under ADB TA-7276 in July, 2011.
b. One representative of the Village was assigned to participate in an evacuation training workshop held by BPDP Bojonegoro in Dander Village (November, 2012).
c. At the beginning of Januari, 2013, the overflow from Pacal River inundated the house yard of 87 household (from total 338 household), about 5 cm depth from the house floor for 4 days; the inundated area included only the area at the right side of the main access road.
d. In general, the residents mentioned that a flood will be a benefit in term of forcing rats out of the rice field only if the flood inundation is at the level of about 20 cm depth in the rice field and lasting for about 10-12 hours.
e. House material: about 80% of houses in this village are made of bamboo

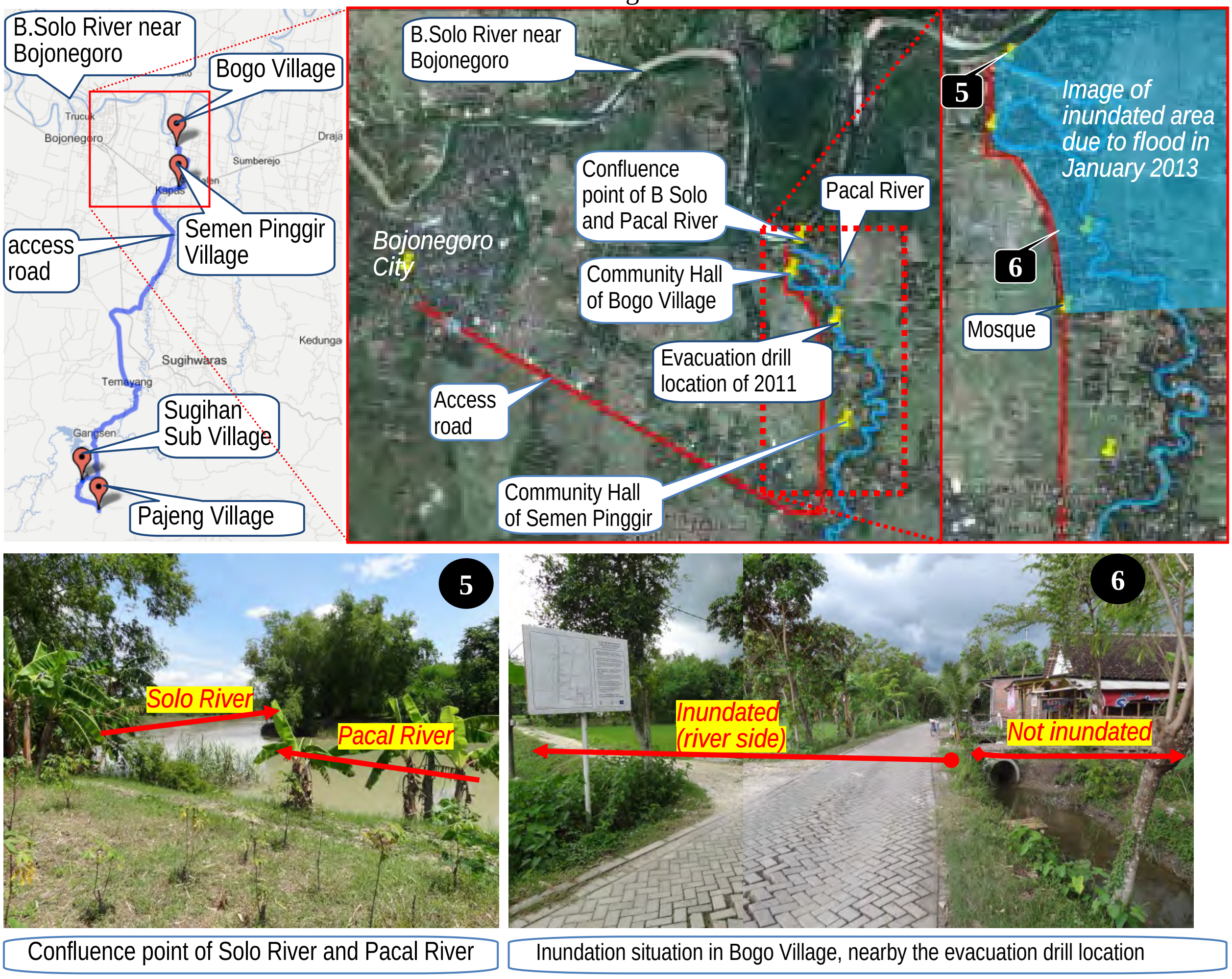

Fig.6 Map and pictures of visited location in Semen Pinggir and Bogo Villages;

III. VISIT TO THE UNIVERSITY OF GADJAH MADA (UGM)

3.1 Date of visit: 28 January 2013

3.2 Objective: meeting with Prof Legono to inform about the recent flash flood event at Kedung Sumber Village, community response and evacuation action, and discussion on the possible follow up action to maintain the community awareness on disaster management.

3.3 Minutes of meeting:

a. Proposal from UGM: to implement the MoU, there must be activities endorsed by both side (UGM and ICHARM) and other stakeholder (BBWS Bengawan Solo) as well;

b. Target, output and time frame must be clearly determined together to measure the progress of the activity.

c. Funding for the program activities can be shared among ICHARM, UGM and BBWS Solo based on and connected to the available ongoing research project in each institution.

d. Prof Legono proposed a tentative theme of "Community based small catchment development, Case of Pacal River"; this theme is considered flexible to include many topics such as study on Solo River flood effect to the backwater caused flood at Pacal River Basin (IFAS/RRI implementation and SOSEI's damage calculation (ICHARM); Community based flood disaster management development at Kedung SUmber Village based on automatic SMS alert by ARR (UGM); and Development of standard data collection of flood disaster damage in Solo River Basin (BBWS Solo)

e. Pilot location: Kedung Sumber Village and Semen Pinggir Village;

f. Prof Legono will write an initial proposal for this activity and initiate contact with Ms Lilik Cahyadiningsih (BBWS Solo) in this regard.

g. Discussion and consultation on the possible collaboration implementation will be done based on the above proposal;

Annex 7: Workshop report: ADB headquarters (4 February 2013)

TA7276-REG Final Workshop on Supporting Investments in Water-Related Disaster Management
–from Innovation to Investment

Purposes of the Final Workshop. ADB and ICHARM opened this workshop with following purposes:

- *Review of TA7276-REG activities*
  ADB and ICHARM invited representatives of seven countries to the workshop. Then, sharing information about technologies, activities, and experiences, they attempted to make in-depth discussions about effectiveness and feasibility of TA outcomes. All collected opinions will be seriously considered in improving project outcomes and complementing the final report.
- *Investigation of further chances to aid developing countries in implementing flood risk management.*
  The workshop was expected to receive new applications from participants, and explore the chances to extend ADB and ICHARM's supports
- *Reflection of critical issues as a way forward in water-related disaster risk management*
  Participants had opportunities to discuss effective strategies for disaster risk reduction.

II. ORGANIZATION OF THE FINAL WORKSHOP

1. **Date and Venue:** 4 February 2013 at the Asian Development Bank Headquarters in Manila, Philippines

2. **Participants** (invited): a total of 36 persons

- Invited speakers: 3 persons from ADPC, UN-ISDR, and embassy of Japan
- ADB-member countries: 20 representatives from 7 countries
- ICHARM (host): 7 persons
- ADB (venue): 6 persons

3. **Workshop programs:**

Program Agenda

8:30-9:00	**Registration**
9:00-9:15	**Opening Session** Welcome and Opening Remarks: **Mr. H. Mitsuhashi, ADB** (5) Opening Remarks: **Dr. S. Tanaka, ICHARM** (5) Opening Remarks: **Mr. A. Yonezawa, Embassy of Japan in Philippines** (5)
9:15–10:25	**Keynote Lecture** Keynote Lecture: **Dr. S. Tanaka**, **ICHARM** (30) **Invited Lectures**

	Invited Lecture: **Ms. Gabrielle Iglesias, ADPC** (20) Invited Lecture: **Mr. Sujit Kumar Mohanty, UNISDR** (20)
10:25-10:40	**Group Photo and Coffee Break**
10:40-11:00	Overall Introduction of TA7276-REG:**Mr. T. Okazumi, ICHARM** (20)
11:00-12:20	**Session 1: Innovative Flood Forecasting** Key inputs: **Dr. M. Miyamoto ICHARM** (30) Panel Discussion (50) BWDB (Via TV conference), BS-BBWS, PAGASA, ADB, ICHARM (TBC)
12:20-13:20	**Lunch**
13:20-14:40	**Session 2: Innovative Flood Vulnerability Assessment** Key inputs: Dr. S. Tanaka ICHARM (30) Panel Discussion (50) Cambodia, Viet Nam, Lao PDR, Thailand, MRCS, ADB, ICHARM (TBC)
14:40-15:10	**Session 3: Water-Related Disaster Risk Management and a Way Forward to Supporting-Investment** Key inputs: **Dr. Y. Kwak** and **Dr. S. Lee, ICHARM** (30)
15:10:15:30	**Coffee Break**
15:30:17:10	Panel Discussion (100) Keynote Speaker, Invited Speakers, Representatives from Tajikistan, Representatives from Nepal, ADB (TBC)
17:10-17:25	**Closing Session** Closing Remarks: **Dr. S. Tanaka, ICHARM** (10) Closing Remarks: ADB (5)

III. LECTURES

1. **Keynote lecture.** Dr Tanaka delivered a keynote lecture on “Global Trend and Importance of Risk Indices – for Post HFA and SDGs”. He first briefed participants on important components of TA 7276 – REG, and introduced the trend of water-related disaster. Then, he noticed three major international events (SDGs, post-HFAs, and post-Kyoto protocol) that will be opened in 2015. Recalling all situations to mind, He emphasized that international organizations and countries should clarify goals, and this can be effectively achieved if risk is measured and

monitored by using standardized methods. Finally, he added that ICHARM has a special interest in supporting local practices, and developing related technologies.

2. Invited lectures. Ms. Iglesias (ADPC) gave an invited lecture with the title of "Water Disaster Risk Management: Initiatives, Innovations, and Beyond." She said that reducing the impact of disaster and climate risk in the Asia-Pacific region is also of great concern to ADPC. Then, she emphasized an innovative way to overcome the current water-related disasters, i.e. integrating disaster risk management and climate change adaptation. Then, she advocated "urban climate resilience" as an integrated frame, and explained how to understand vulnerability and build resilience under this frame. The second invited lecture was given by Mr. Mohanty (UN-ISDR) who talked about "Global Process Towards the Post-2015 Framework on Disaster Risk Reduction". After reminding participants of three disaster management processes (SDG, Post-2015 HFAs, and Post-MDGs), he commented on importance of HFA progress reports. After then, he unfolded ISDR's challenges for development of a post-2015 HFA framework.

IV. SESSIONS

1. Overall introduction of TA7276 was provided by Mr. Okazumi. He first said that ICHARM was established to take a role as a regional knowledge hub for water-related disaster management. Then he explained goals and strategies to be addressed by the partnership and TA7276-REG. He disclosed implications of all activities related to TA7276-REG, as follows:

- In order to advance global disaster risk management, it is important to have full capabilities of identifying risks on multiple scales.
- Especially, IFAS applications (session I) and FVI assessment (session II) were made to support risk management activities on the spatial scale from community to the river basin
- WRDRI method (session III) is also expected to make contributions to broadening our visions for global disaster risk assessment, while effectively tackling on data unavailability using advanced technologies and data sources.

Putting developed technologies and outcomes together, he described how three sessions were organized.

2. Session I. Dr. Miyamoto provided key-inputs about the topic "Innovative Flood Forecasting" which were related to Bangladesh, Indonesia, and Philippines components. For the Bangladesh component, he showed the results of establishing the national road map for flood early warning systems. For the Indonesia component, he talked about IFAS performances as an early warning system, and its potentials for community-based disaster risk management interventions. For the Philippines component, he illustrated flood forecasting capabilities of IFAS with two application studies, and reported experiences of conducting training programs. After then, three short presentations were given by panelists. The Bangladesh representative informed participants of ongoing projects for development of early warning systems. The Indonesia representative shared his experiences of using IFAS as a flood forecasting system. Especially, he mentioned that more accurate hydrological data should be available in order to make practical use of IFAS in Indonesia. The Philippines representative showed the results of conducting IFAS training programs and applying IFAS to two river basins. After heated discussions, panelists came to several conclusions, as follows:

- TA outcomes, related to IFAS applications and training programs, have offered considerable benefits to recipient countries, stimulating many positive changes.
- It is necessary to transfer obtained "know-how" to other organizations and more countries.
- Still, much effort should be paid to understanding the characteristics of each river basin, collecting more data and building capacity of other agencies.

3. Session II. This session started with Dr. Tanaka's key-input presentation, "Innovative Flood Vulnerability Assessment". He first introduced definition and philosophies of the flood vulnerability index (FVI) and the ICHARM Hydro-Geo Method (IHGM), and then illustrated how

to assess agricultural and house damage using FVI and IHGM. Furthermore, he concluded that those methods are useful to draw spatially-detailed damage distribution maps, showing the results of the Lower Mekong Basin component. Regarding localized flood risk management, the Cambodia representative commented difficulties of sending flood alerts to the local community. Also, he argued that more capacity-building programs are needed to improve current situations. In the panelists' discussions, the following consensuses were made:

- The Lower Mekong Basin component well illustrated that TA outcomes, related to FVI and IHGM, are useful in assessing flood vulnerability at the local level.
- However, a few technical requirements need to be improved. Especially, those methods should allow for different flood situations according to topography, water level, and spatial complexity.
- In order to enlarge this activity, ADB and ICHARM are requested to conduct more extensive cooperation with MRCS member countries, not simply with relevant agency of Cambodia. MRCS greatly wished to continue to receive technical supports at the next project.

4. Session III. Key-inputs of session III were given by Dr. Kwak and Dr. Lee, who jointly delivered the presentation "Water-Related Disaster Risk Management and a Way Forward to Support Investment". Dr. Kwak elucidated trends of water-related disasters for the period from 1980 to 2010, and contended that economic damages in Asia are rapidly increasing. Considering the disaster trends, he listed ICHARM's challenges and technical supports. Then, he explained advanced technologies and their possibilities in identifying hazard and exposure. Dr. Lee presented the framework and operational procedures of the water-related disaster risk indices (WRDRI) which were developed to assess flood, storm surge, and drought risks at national and watershed levels. Also, he showed possibilities of WRDRI with two case studies, Nepal and Philippines. Two panelists, the Nepal representative and Tajikistan representative, individually introduced present status of water-related disasters and challenges in disaster management practices. Then, Mr. Mohanty (UN-ISDR) summarized "The Asia-Pacific Disaster Report 2012: Reducing Vulnerability & Exposure to Disasters", revealing how and why urban growth affects water-related disaster risk in Asia-Pacific region. As a result of panel discussions, all participants reached the following conclusions:

- As a whole, ICHARM's advanced technologies are expected to be useful for hazard and exposure assessments.
- It should be however noted that risk is a combination of exposure and vulnerability, and hence, more socio-economic factors should be incorporated into risk assessment in order to consider site-specific vulnerability attributes well.
- Risk assessment methods should identify how to reduce exposure and vulnerability, separately, which would lead to effective disaster risk reduction actions.

V. CONCLUSION

1. All through the workshop, ICHARM could receive a general consensus that TA outcomes have provided large benefits for recipient countries. Especially, it was apparent that ICHARM successfully accomplished activities in improving flood early warning systems, supplying innovative methods for community-based disaster risk management interventions, and even building local capacities. Therefore, it was concluded that it is now important to disseminate the obtained know-how to other agencies and more countries.

2. Several countries, especially MRCS requested further technical assistances to ADB and ICHARM. The two organizations were then agreed to initiate earnest discussions on the new phase of the project.

3. ADB members gave affirmative comments about TA outcomes. They asked ICHARM to submit the final report after taking into account what were discussed in the workshop. Besides, ADB suggested ICHARM's participation in the Asian Water Week 2013 scheduled in March.

V. ACKNOWLEDGEMENTS

The mission wishes to convey its appreciation to representatives of the Embassy of Japan, ADPC, UN-ISDR, Bangladesh (BWDB), Cambodia (MRCS, CNMC, and MOWRAM), Indonesia (BS-BBWS), Laos PDR (Ministry of Natural Resources and Environment) Nepal (Department of Water Induced Disaster Prevention), Philippines (PAGASA, and DOST), Tajikistan (Executive Office of the President), Thailand (TNMCS), and Viet Nam (VNMC) for their close cooperation and insight technical suggestions.

Photographs of the workshop

Group photo and opening remarks

Participants and panelist of session 1

Panelists of session 3 and closing remarks

List of participants

TA7276-REG Final Workshop on Supporting Investments in Water-Related Disaster Management

–from Innovation to Investment

4 February, 2013

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Annex 8: Past Disaster Data of Nepal and Philippines

Table A8.1 Nepal: water-related disaster damages (Data Source: EM-DAT)

Year	Estimated Damage due to Drought (1000 USD)	Estimated Damage due to Flood (1000 USD)	Estimated Damage due to Storm (1000 USD)	Total Damage (1000 USD)
1981	0	0	0	0
1982	0	0	0	0
1983	0	10000	0	10000
1984	0	0	0	0
1985	0	0	0	0
1986	0	0	3600	3600
1987	0	727500	0	727500
1988	0	0	0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	200000	0	200000
1995	0	1200	0	1200
1996	0	0	0	0
1998	0	27000	0	27000
1999	0	2000	0	2000
2000	0	6300	0	6300
2003	0	0	0	0
2004	0	0	0	0
2005	0	0	0	0
2006	0	0	0	0
2007	0	2400	0	2400
2008	0	29	0	29
2009	0	60000	0	60000
2010	0	0	0	0
2011	0	0	0	0

Table A8.2 Nepal: number of affected people (Data Source: EM-DAT)

Year	Affected People due to Drought	Affected People due to Flood	Affected People due to Storm	Total number of affected people
1981	0	10000	0	10000
1982	0	0	0	0
1983	0	200050	0	200050
1984	0	0	0	0
1985	0	62557	0	62557
1986	0	0	0	0
1987	0	351000	0	351000
1988	0	0	0	0
1990	0	2500	0	2500
1991	0	482	165	647
1993	0	553268	0	553268
1995	0	13000	0	13000
1996	0	152382	19	152401
1998	0	70000	0	70000
1999	0	18068	0	18068
2000	0	50070	0	50070
2003	0	59254	0	59254
2004	0	800015	0	800015
2005	0	31600	0	31600
2006	200000	0	0	200000
2007	0	640706	0	640706
2008	0	250003	0	250003
2009	303000	257786	0	560786
2010	0	8000	0	8000
2011	0	1858	0	1858

Table A8.3 Philippines: water-related disaster damages (Data Source: EM-DAT)

Year	Estimated Damage due to Drought (1000 USD)	Estimated Damages due to Flood (1000 USD)	Estimated Damage due to Storm (1000 USD)	Total Damages (1000 USD)
1980	0	0	118391	118391
1981	0	27000	90384	117384
1982	0	60	118605	118665
1983	0	3	4320	4323
1984	0	0	336490	336490
1985	0	0	83033	83033
1986	0	56	86460	86516
1987	0	0	193700	193700
1988	0	0	403016	403016
1989	0	6000	171085	177085
1990	64000	43	388500	452543
1991	0	1300	275000	276300
1992	0	74200	0	74200
1993	0	39600	297442	337042
1994	0	4142	140813	144955
1995	0	700942	317494	1018436
1996	0	0	42150	42150
1997	0	76	7500	7576
1998	0	0	235437	235437
1999	0	24000	56487	80487
2000	0	4080	83464	87544
2001	0	8000	99061	107061
2002	453	1842	13534	15829
2003	0	0	35302	35302
2004	0	0	138867	138867
2005	0	515	2000	2515
2006	0	14157	330921	345078
2007	0	6600	10215	16815
2008	0	39577	441625	481202
2009	0	29314	932703	962017
2010	0	50589	284420	335009
2011	0	202787	527238	730025

Table A8.4 Philippines: number of affected people (Data Source: EM-DAT)

Year	Affected People due to Drought	Affected People due to Flood	Affected People due to Storm	Total number of affected people
1980	1002100	25980	1866965	2895045
1981	0	307622	1101545	1409167
1982	0	201085	1019615	1220700
1983	1691060	1835	170530	1863425
1984	0	0	4535206	4535206
1985	0	5444	1603974	1609418
1986	0	615	1242736	1243351
1987	1002100	0	3237632	4239732
1988	0	0	4517505	4517505
1989	0	307511	2136865	2444376
1990	254282	712736	6319583	7286601
1991	0	823	1571865	1572688
1992	0	1053832	1046294	2100126
1993	0	348084	3581327	3929411
1994	0	811583	1991217	2802800
1995	0	129185	3276812	3405997
1996	0	96000	37628	133628
1997	0	105000	366770	471770
1998	2600000	0	7322999	9922999
1999	0	2105016	1387290	3492306
2000	0	165643	6187431	6353074
2001	0	91300	3450437	3541737
2002	0	155567	982194	1137761
2003	0	3500	466261	469761
2004	0	21694	3241278	3262972
2005	0	193046	20011	213057
2006	0	732509	7821808	8554317
2007	0	86747	1922309	2009056
2008	0	1602889	6851979	8454868
2009	0	1083276	12221663	13304939
2010	0	2846935	2595545	5442480
2011	0	2218828	9468676	11687504

Annex 9: Factor Analysis Method and an Example

(1) Purposes of the factor analysis method: it is widely used to integrate the large number of proxies into one or the small number of dimensionless factor scores, and minimize manipulations and losses of information in original proxies.

(2) Basic concepts of the factor analysis method: it is very remarkable that this method integrates proxies without any value judgments. In doing this, it is underlain by the premise that the best integration of proxies is using their roots, rather than grouping proxies according to subjective judgments. However, **t**he roots are inherent features, and often impossible to observe. Therefore, dimensionless factor scores, which are regarded as the roots, are statistically calculated out of variances of proxies.

(3) How to determine factor scores: the general way to calculate factor scores might be enumerated, as follows (also, see the example of applying this method to integrate proxies for the flood risk index for people. This example presents how the Eq.(14) was derived):

a) Standardize all proxies: the factor analysis method has an assumption that variances of all proxies are equal. Thus, it is essential to use standardized proxies such that variances can be equally one.

b) Calculate correlations of all proxies, and define the correlation matrix: Table A9.1 shows the correlation matrix calculated by using the proxies selected for the flood risk index for people.

Table A9.1 Calculated correlation matrix

	critical people	deforestation	early warning systems	good governance
critical people	1.000	.137	-.061	-.267
deforestation	.137	1.000	-.679	-.742
early warning systems	-.061	-.679	1.000	.636
good governance	-.267	-.742	.636	1.000

c) Extract few factor scores from the matrix: selecting and using the small number of factors (or roots) will be convenient. However if excessively few factors are selected, it is possible to have the limit in properly explaining original proxies. Therefore, it should be always noted that regarding the selection of factors, there is the trade-off between convenience and explanatory power. For this reason, some criteria are usually applied to determine factor scores. The respective criterion is to select factor scores of which eigenvalues are more than one. The eigenvalue is conceptually meant by the degree to which each factor explains variances of all proxies. Hence, this criterion requires all important factors to be included, from the viewpoint of all proxies. Figure A9.1 shows that there are four factors available, and only the factor score 1 has the eigenvalue more than one. Hence, this criterion may use the factor score 1 in integrating proxies (as below), and regards other factors as less important

$$FS_1 = 0.12 \times CP + 0.37 \times DE - 0.35 \times EWS - 0.37 \times GG \qquad (20)$$

where FS_1 = factor score 1 (#); CP = standardized value of critical people (%); DE = standardized value of deforestation (%); EWS = standardized value of early warning systems (HFA score 2, 1-5 scale); GG = standardized value of good governance (political stability and absence of violence, 0-100 scale).

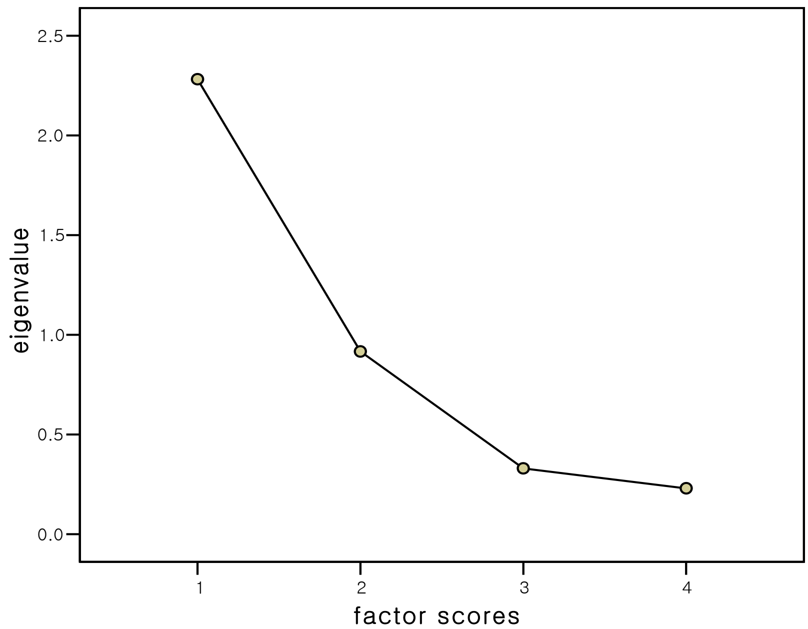


Figure A9.1 Eigenvalues of factor scores for the selected proxies

d) Rotate the factor scores: if multiple factors are selected, it is technically possible to increase correlations with proxies. For this, the factor scores are rotated, which means that, say, using the VARIMAX method, the correlation matrix are transformed in order to have values, known as factor loading, to be closer to +1, -1, or 0. However, in the example, the single factor score was selected, and thus this study did not need to transform the correlation matrix. Finally, this study found out factor scores, integrating four proxies, for all countries, which is listed in Table A9.2.

Table A9.2 Results of calculating the factor score for the flood example

Country	Factor Score 1	Country	Factor Score 1
Afghanistan	-1.85006	Nepal	-.90263
Bangladesh	-.03911	Pakistan	-1.20684
Cambodia	.69648	Philippines	-.40139
India	-.14488	Sri Lanka	.15006
Indonesia	.76029	Thailand	-.30322
Iran Islam Rep	-1.17512	Timor-Leste	.55455
Lao P Dem Rep	1.09607	Viet Nam	1.04356
Malaysia	1.72222		

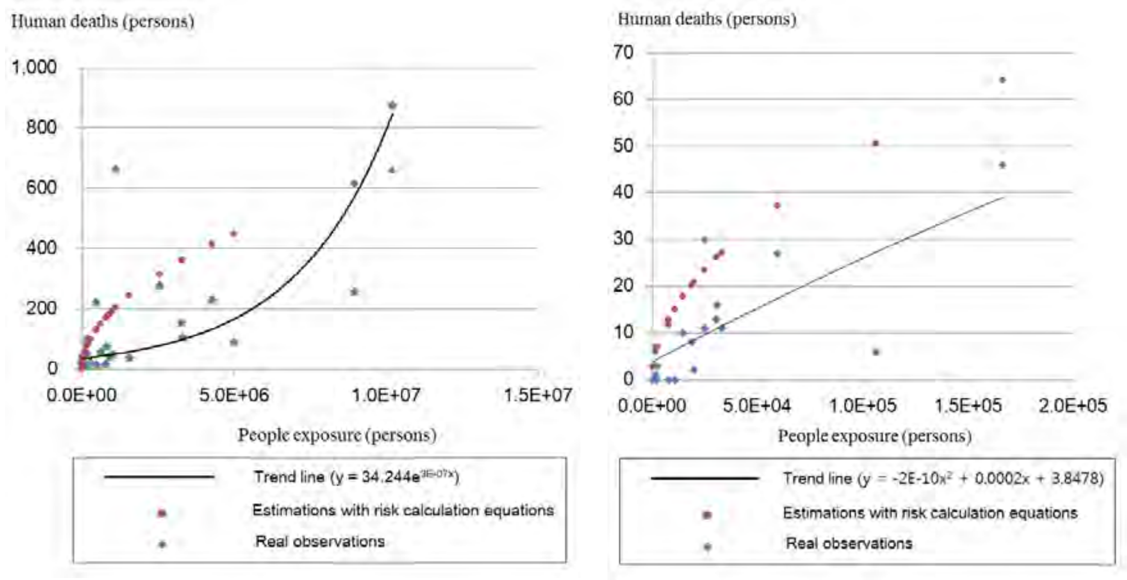
(4) Advantages of the factor analysis method: Above all, this method encourages further statistical methods. Factor scores are those obtained from integration and refinement of proxies. Hence, many of random errors inherent in values of proxies are excluded while factor scores are calculated. Also, since the large number of proxies is changed into the small number of factor scores, this method helps in overcoming multi-collinearity problems, and thus employing many proxies into the regression models. Moreover, this method improves our understanding about proxies. Calculating factor scores is the procedure to find out the roots of proxies. Especially, obtained factor scores help think of the reasons many proxies are correlated

Annex 10: In-depth Discussion on Hazard Intensity and Risk Calculation Equations

This study had to quantitatively know how seriously damages would occur, provided that a country had specific levels of exposure, vulnerability, and coping capacity. To this end, after selecting 15 countries as samples, these researchers obtained annual averages (from 1980 to 2010) of exposure and damages for each type of risk from EM-DAT, and collected data of vulnerability and coping capacity from various data sources. This way helps in estimating changes of damages over the range of hazard intensity (or exposure value). However, it should be noted that the estimation is based on other countries' experiences, especially of which hazards commonly have 2-year return period, as annual averages are used. In other words, it is still questionable if the equations, derived from annual averages of various countries, can be used to analyse damages for a country with hazards of the 50-year return period. This seems to be the most fundamental assumption pertaining to the whole procedures, and theoretical adequacy needs to be fully discussed (hence, ANNEX 10 handles this assumption seriously).

In general, it is anticipated that as hazard intensity increased from 2 years to 50 years, damages of the country would be heightened exponentially or explosively. Let's suppose that 10,000 persons reside in the space having area of 1,000 km2, and only 100 persons are exposed to flood because hazard intensity is not large (say, 2-year return period). In this case, it might be possible to expect that human deaths are very few (say, 2 persons). The two persons would be considered as physically weak. Let's now assume that very extreme flood (say, having 50- year return period) occurs in the space, and 5,000 persons get exposed to the flood. This case might lead to the expectation that some of physically good and healthy persons would die because of high exposure, and thus the total deaths due to flood would be highly increased (say, 1,000 persons). In summary, this example hints that for a country, damages might be increased highly nonlinearly with hazard intensity and exposure (from 2 persons among 100 persons at the 2-year return period to 1,000 persons among 5,000 persons at the 50-year return period). However, our risk calculation equations describe that damage would increase with exposure, but might not show such 'damage sensitivities to exposure' for a country.

In these regards, this study needed to ascertain if the equations, derived from annual average data of various countries, have sufficient, or insufficient, damage sensitivities to exposure for a country. Above all, it was found that in many countries, damages are not highly sensitive to exposure, compared to the expectation. As an example, Figure A10.1 shows the relations between affected people and human deaths due to flood. Figures A10.1 (a) and (b) present many events that happened, for the period from 1980 to 2011, in Thailand and Malaysia, respectively. In the Thailand case, Figure A10.1(a) says that it is possible to define the sensitivity with an exponential trend line, according to the expectation. However, it was also found that the estimation is not a failure even when derived equations are used (for real observation data, explanatory power was slightly decreased from 45.2% to 39.7%. The Malaysia case shows totally different results. Figure A10.1(b) says that any ever-accelerating (or highly increasing) trend lines are not proper to define the sensitivity, and instead, the sensitivity can be defined with ever-diminishing trend lines. In this case, the derived equations are found to explain the sensitivity quite well with rather overestimation.

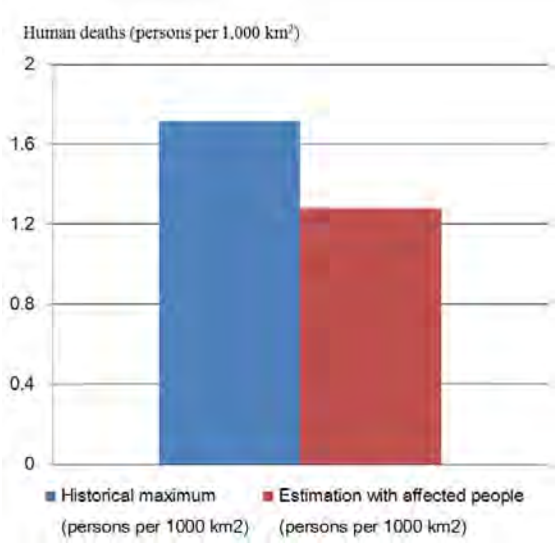


(a) Thailand (b) Malaysia

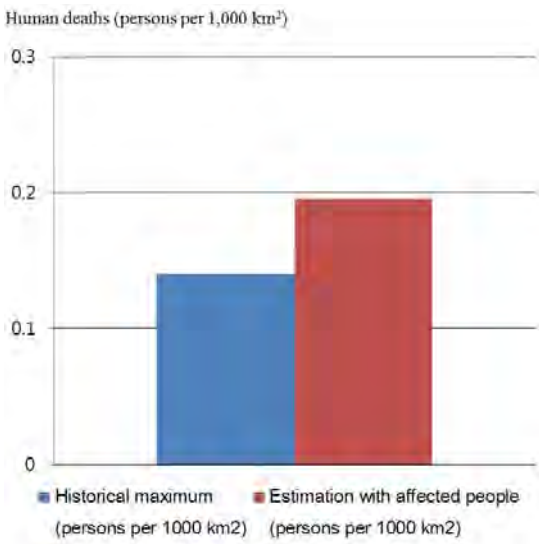
Figure A10.1 Sensitivity of human deaths to flood exposure for each country

From the whole results, it is stated that if human deaths clearly has nonlinear sensitivity to hazard intensity or exposre, the derived equations can lead to large errors in estimating damage of a country, but these sensitivities do not exist in all countries. Rather, when assessing risks of various countries at a time, the derived equations seem not to make big biases, compared to previously selecting a certain type of 'hazard intensity curve'. Thus, it is hard to say that a serious problem arized from deriving risk calculation equations from annual average data of various countries.

Also, Figure A10.2 presents the results of applying the equations to calculate flood risks in the cases when the two countries had historically maximum damages after 1980 (namely, flood hazard intensities are close to the 50-year return period). For the same reason, it might be possible to anticipate that the equations would underestimate human deaths. The Thailand case, as in Figure A10.2(a), says that actually the equations resulted in 1.3 deaths per 1,000 km2, which is lower than 1.7 deaths per 1,000 km2 that was recorded at those days. However, The Malaysia case, as in Figure A10.2(b), reveals that for the historical extreme, the derived equations could overestimate human deaths due to flood, from 0.14 to 0.20 persons per 1,000 km2. Considering that these equations should be applied to many countries, it is important to say that they neither necessarily underestimate, nor overestimate the risk. In this regard, the derived equations do not seem to be much dangerous. However, it is clearly said that theoretical adequacy problems cannot be certainly solved with these empirical discussions. To solve them more fundamentally, risk calculation equations will have to be derived again on the basis of exposure and damages with return periods satisfying research purposes.



(a) Thailand (for flood event in 2011)



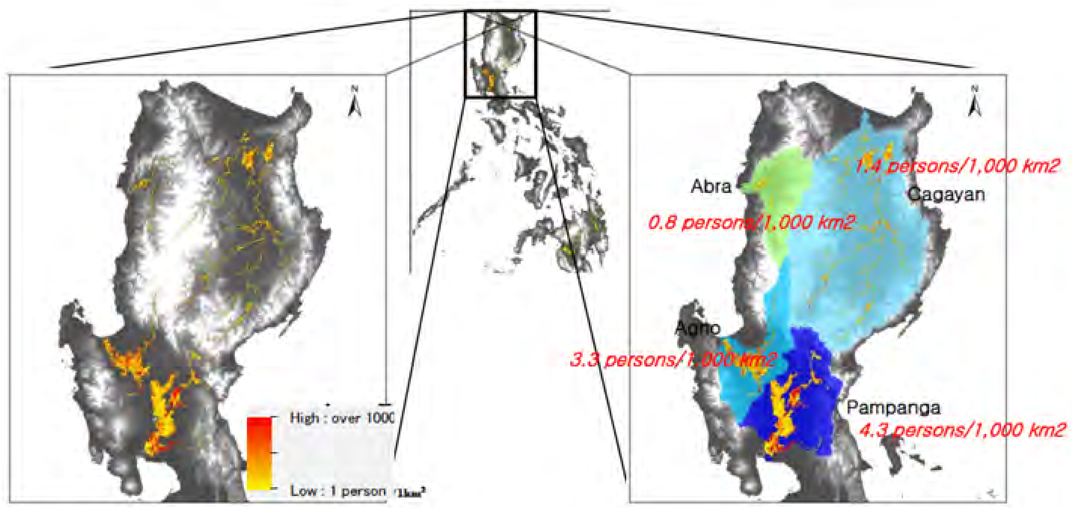
(b) Malaysia (for flood event in 2007)

Figure A10.2 Comparison of historical maximum human deaths and calculated human deaths

Annex 11: Flood Risk Assessment at the Watershed Basin Level

This study examined the possibility of using WRDRI as a flood risk assessment tool at the watershed basin level. For this, the northern region in Philippines was selected as study sites, which consist of four basins, namely, Pampanga, Agno, Cagayan, and Abra. Then, the whole procedures, including hazard assessment, exposure assessment, and WRDRI calculation equations, were used to count flood risk indices for people at the 50-year return period.

On the basis of the same area (1,000 km2), Pampanga and Agno are highly affected to this extreme flood, compared to other basins. Because of hydrological, and demographic features, people exposure in Pampanga (173,364 persons per 1,000 km2) reach 25 times as many as that in Abra (6,874 persons per 1,000 km2). In fact, people exposure in Pampanga and Agno correspond to 29.1% and 22.9% of total population, respectively. Using the flood risk calculation equation, Eq.(14), all proxies for exposure, basic vulnerability, and coping capacity were combined to calculate flood risk indices for people. The results are summarized in Figure A11.1, saying that Pampanga and Agno (4.3 and 3.3 persons killed per 1,000 km2, respectively) are still risk hotspots in the northern region, Philippines. It is also remarkable that among the watershed basins, the difference in human deaths is much lower than the difference in people exposure. As stated before, the difference in people exposure between Pampanga and Abra was tremendous. However, as a result of calculating risk, it was found that flood risk indices for people in Pampanga would be around 10 times as many as those in Abra. The reason the differences decrease seems to be that exposure is a part of risk, and other parts (vulnerability and coping capacity) were fixed with national estimates.



(a) People exposure (b) Flood risk index for people

Note: National average of flood risk was 2.1 persons killed per 1,000 km^2

Figure A11.1 Result of flood risk assessment for northern regions in Philippines

However, it should be noticed that the following results are proposed as an example. Data used for vulnerability and coping capacity are national estimates, and the question about whether risk calculation equations, made at country level, are applicable to the watershed basin levels was not addressed. For the watershed level assessment, other challenges remain to be solved: for example, how to downscale proxies of vulnerability and coping capacity.

Asian Development Bank

Technical Assistance
for
Supporting Investments in Water-Related Disaster Management
(TA7276)

Final Report
(Volume 2)
Bangladesh Component

September 2012

International Centre for Water Hazard and Risk Management
under the auspices of UNESCO (ICHARM)

Public Works Research Institute (PWRI)

Structure of Reports

(TA 7276 for Supporting Investments in Water-Related Disaster Management)

The reports of TA 7276 for Supporting Investments in Water-Related Disaster Management are divided into following volumes:

Volume 1: Main Volume

(i) Development of Index for Water-Related Disaster Risk Management
(ii) Organization of regional knowledge sharing workshops, exchange visit program and capacity development trainings, etc.

Volume 2: Bangladesh Component

(i) Technical support for improvement of current early warning system
(ii) Capacity building of engineers and managers

Volume 3: Indonesia Component

(i) Satellite-based flood alert system
(ii) Capacity building on local disaster management
(iii) Implementation of community based flood disaster risk management

Volume 4: Lower Mekong Basin Component

(i) Supporting Mekong River Commission Secretariat in developing flood vulnerability indices

Volume 5: Philippines Component

(i) Applying Integrated Flood Analysis System (IFAS) to the river basins
(ii) Identifying causes of historical floods
(iii) Training on utilization of IFAS as supplementary information of the existing flood monitoring systems

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Asian Development Bank

Technical Assistance
for
Supporting Investments in Water-Related Disaster Management
(TA7276)

Final Report
(Volume 2)
Bangladesh Component

September 2012

International Centre for Water Hazard and Risk Management under the auspices of UNESCO (ICHARM)

Public Works Research Institute (PWRI)

Abbreviations

ADB	Asian Development Bank
AHP	Analytical Hierarchy Process
CBA	Cost-Benefit Analysis
CDMP	Comprehensive Disaster Management Program
CFAB	Climate Forecast Application in Bangladesh
CNRS	Center for Natural Resources Studies (NGO)
CSFFWS	Consolidation and Strengthening of Flood Forecasting and Warning Services project
DEM	Digital Elevation Model
EMIN	Environmental Monitoring Information Network
FEWS	Flood Early Warning Systems
FHM	Flood Hazard Map
ICHARM	International Centre for Water Hazard and Risk Management (Tsukuba, Japan)
IFFWS	Improvement of Flood Forecasting and Warning Services
MOFDM	Ministry of Food and Disaster Management
MOWR	Ministry of Water Resources
MSL	Mean Sea Level
NAP	National Adaptation Programme Action
NGO	Non-Governmental Organization
NRM	National Road Map
O & M	Operation & Maintenance
SOD	Standing Orders for Disaster
SMS	Short Message Service
TA	Technical Assistance
TA7276	Regional Capacity Development Technical Assistance for Supporting Investments in Water-Related Disaster Management
TRAM	Tasks, Responsibilities, Activities and Mandate
USAID	United States Agency for International Development
WFP	Water Financing Program 2006–2010

Bangladesh Component Specific Abbreviations

AHP	Analytical Hierarchical Process
BWDB	Bangladesh Water Development Board
BRIC	Bangladesh River Information and Conservation project
BMD	Bangladesh Meteorological Department
BUET	Bangladesh University of Engineering & Technology
CDMP-2	Comprehensive Disaster Management Program – II
CEGIS	Centre for Environmental and Geographic Information Services
CFIS	Community Flood Information System
DMB	Disaster Management Bureau
EW/EWS	Early Warning (System)
EEWS	Flood Early Warning System
FFWC	Flood Forecasting Warning Centre
IWFM	Institute of Water & Flood Management
IWM	Institute of Water Modelling
JRC	Joint Rivers Commission, Bangladesh

JAXA	Japan Aerospace Exploration Agency
MCA	Multi Criteria Analysis
SWOT	Strengths Weakness Opportunities Threats
UNISDR	United Nations International Strategy for Disaster Reduction
WARPO	Water Resources Planning Organization

List of Glossaries

Mouza	A type of administrative district in Bangladesh
Upazila	Sub district unit in Bangladesh
Union	Smallest local government unit in Bangladesh

Summary

Bangladesh is located in part of the world's most dynamic hydrological system. The river flow and the rainfall, with their distribution in different seasons and variations from year to year pose a formidable challenge and water-related disasters. The development, implementation, operation, and maintenance of Flood Early Warning Systems (FEWS) can help decrease the number of casualties and socio-economical damages in flood affected areas. A good working FEWS, combined with structural measures, can further reduce vulnerability to water-related disasters.

The Flood Forecasting and Warning Centre (FFWC) under the Bangladesh Water Development Board (BWDB) has been developing and operating a FEWS for over a decade. In order to assess the need for further improvement of the FEWS in Bangladesh, a technical assistant was implemented under ADB's regional capacity development technical assistance for Supporting Investments in Water-Related Disaster Management (TA7276).

Based on interaction with the key stakeholders, a proposal was made to develop a National Road Map for early warning system development under the TA. The Road Map is expected to be useful to guide the preparation of long term national planning and can be used by the government agencies and donor agencies for screening and ranking of investments on FEWS development projects in Bangladesh.

The two main outcomes of the project are:

- A generic framework for prioritization of interventions in a participatory approach: and
- A National Road Map (NRM) with a clear portfolio of most feasible interventions including a time line and sequence for implementation

Based on case studies, field visits and intensive stakeholder consultations an inventory and priority ranking was made for the interventions needed to optimize the Flood Early Warning System (FEWS) in Bangladesh. The study assessed the needed interventions and performed a priority ranking of interventions based on a participatory stakeholder approach. By evaluating the Strength-Weakness-Opportunities-Threats (SWOT) of each short-listed intervention and weighing the importance of each intervention through an Analytical Hierarchical Process (AHP) a validated selection could be made.

This approach may prove to be valuable for parallel projects in which selection and priority ranking of interventions is requested. Therefore, the methodology is presented as generic approach in Annex I 'National Road Mapping for Early Warning System development in Bangladesh'.

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1 Introduction

1.1 Background

Bangladesh lies approximately between 20^0 30’ and 26^0 40’ North latitude and 88^0 03’ and 92^0 40’ East longitude. India borders the country in north, east and west. The southern part of the country lies on the coastal belt of the Bay of Bengal, while Myanmar borders part of the South-Eastern area. Bangladesh is administratively divided into 7 divisions, 64 districts and 482 sub-districts. Bangladesh occupies one of the biggest deltas in the world. The country is extremely flat with low land relief with only a few hills in the southeast and the northeast part of the country. Generally, ground slopes of the country extend from the north to the south and the elevation ranges from 1 m to 60 m above Mean Sea Level (MSL) at the boundary at Tentulia and at the coastal areas in the south. Besides, Bangladesh is very densely populated. With a total population of nearly 150 million people and a land surface of 147,570 km^2 the overall population density is nearly 1,015 persons/km^2 [1]. In case of natural disasters it is likely that large groups of people will be affected.

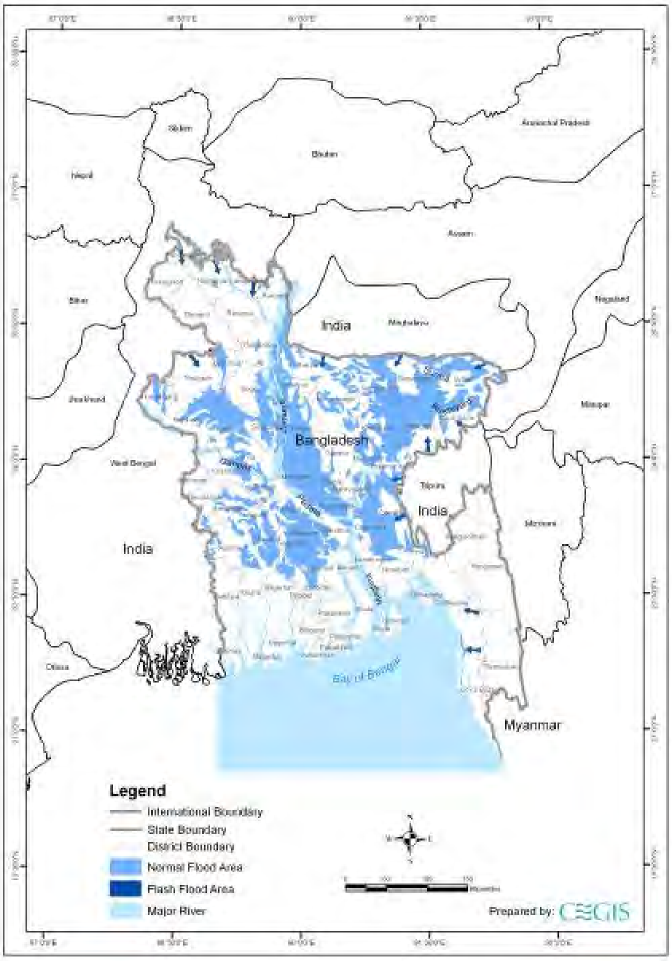

Figure 1.1 Overview of main features and location in Bangladesh (Source: CEGIS)

It has a sub-tropical monsoon climate and experiences an annual average of 2,300 mm precipitation, varying from as little as 1,200 mm in the west to over 5,000 mm in the east. There are 230 rivers in total, including 57 international rivers of which three are major rivers (Ganges, Meghna and Jamuna). Their total catchment area is approximately 1.6 million km^2 of which only

[1] *Bangladesh Bureau of Statistics*

about 7.5% lies in Bangladesh and the rest, 92.5% lies outside the territory. It is assumed that an average flow of 1,009 Billion m^3 passes through these river systems during the monsoon season. Monsoon flood inundation of about 20% to 25% area of the country is assumed beneficial for crops, ecology and environment, inundation of more than that cause direct and indirect damages and considerable inconveniences to the population (Source: FFWC Annual Flood Report 2011[2]).

The river flow and the rainfall, with their distribution in different seasons and variations from year to year pose a formidable problem of floods, drought and water scarcity in almost every year. The main river system carries huge volumes of run-off from the upper catchments. The geographical location is also responsible for cyclonic disaster in the country. In other words, water related disasters causing threat to human lives, property and damages to the national economy are frequent natural phenomena in the country. Table 1.1 and Table 1.2 show the major water-related disaster in Bangladesh shorted based on total number of affected people and damages, respectively.

Table 1.1 Major water-related disaster in Bangladesh based on total number of affected people
(Data Source: EM-DAT)

Disaster	Date	Total Affected People
Flood	June-1988	45000000
Flood	July-1974	38000000
Flood	20/06/2004	36000000
Flood	May-1984	30000000
Flood	22/07/1987	29700000
Drought	July-1983	20000000
Flood	July-1968	15889616
Storm	11/5/1965	15600000
Storm	29/04/1991	15438849
Flood	5/7/1998	15000050

Table 1.2 Major water-related disaster in Bangladesh based on damages
(Data Source: EM-DAT)

Disaster	Date	Damage (in 1000 US$)
Flood	5/7/1998	4300000
Storm	15/11/2007	2300000
Flood	20/06/2004	2200000
Flood	June-1988	2137000
Storm	29/04/1991	1780000
Storm	15/05/1995	800000
Flood	August-1987	727500
Flood	July-1974	579200
Flood	September-2000	500000

[2] Processing & Flood Forecasting Circle, BWDB, Annual Flood Report 2011, FFWC

In flood management, Bangladesh has taken many structural and non-structural measures. One of the main non-structural measures is the flood forecasting and warning system. Flood forecasting in Bangladesh is the responsibility of the Flood Forecasting and Warning Centre (FFWC) of the Bangladesh Water Development Board (BWDB), the Ministry of Water Resources (MOWR). FFWC was established in 1972 and is fully operative in the flood season, from 1 April to 31 October each year, as directed by the Standing Orders for Disaster (SOD) of the Government of Bangladesh which was renewed in April 2010.

The objectives of flood forecasting and warning are to enable and persuade people and organizations to be prepared for floods and take action to increase safety and reduce damage. Its goal is to alert the ‘combat’ agencies to enhance their preparedness and to motivate vulnerable communities to undertake protective measures. In Bangladesh, several main types of (river) flooding are differentiated:

- Riverine flood (in upstream area);
- Flash floods (Particular in North East region);
- Rainfall floods (in floodplain).

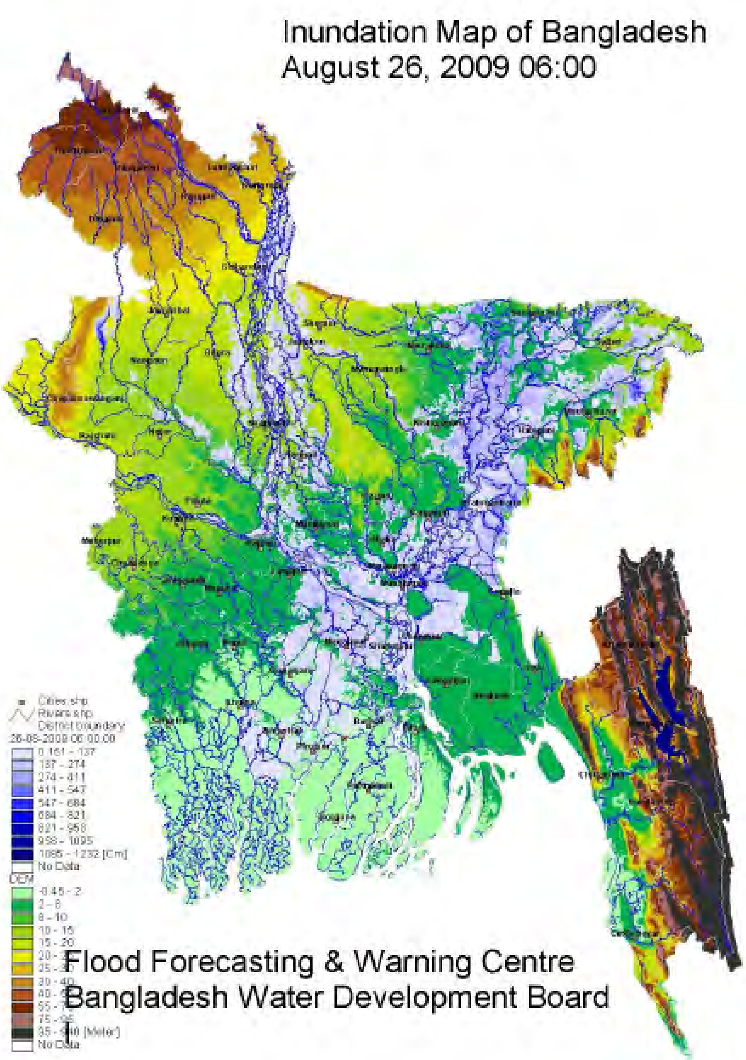

Figure 1.2 Example of national flood forecast map, (derived from Annual Flood report 2009, FFWC, Dhaka)

The lead-time for early warning and adaptation measures may vary between 12 - 24 hours for flash floods and cyclones, to several days for riverine floods related to upstream events.

1.2 Objectives

The main objective of the Technical Assistance (TA) for "Supporting Investments in Water-Related Disaster Management" is to help prepare and implement flood management investment projects through knowledge and capacity development services that will reduce vulnerability to water-related disasters with in-country and regional assistance. The TA has two components: i) in-country project support and ii) program quality support through regional cooperation.

In Bangladesh component, main objectives of the TA are as follows:
(i) Technical review of early warning systems currently being practiced in Bangladesh and recommendation for improvement, and
(ii) Capacity building of engineers and managers, who are responsible to look after disaster management projects and programmes in Bangladesh.

The national component focused on the review of an ADB study of 2006 on the status of FEWS in Bangladesh. In Annex B, a summary of recommendations of the '2006 study' is presented. The project has produced an update on the status of the recommendations and priorities for the different stakeholders in relation to other projects and initiatives (Comprehensive Disaster Management Program – II (CDMP-II), Asian Development Bank-Japan Aerospace Exploration Agency (ADB-JAXA), Bangladesh River Information and Conservation project (BRIC)). So that Government of Bangladesh can plan a way forward for strategic implementation of recommended interventions. The main beneficiaries will be the BWDB. The project focused on early warning systems for riverine and rainfall floods. The prioritized interventions for FEWS are drafted in the form of National Road Map for Flood Early Warning System Development in Bangladesh.

The second objective of the project is capacity building of engineers and managers who are responsible to look after disaster management projects and programs in Bangladesh. In Bangladesh three workshops were organized (in December 2010, March 2011 and January 2012 (Annex J)), which helped to build a capacity of engineers and managers of related organizations of Bangladesh in identification and prioritization of interventions for FEWS and in development of effective FEWS. Also under program quality support program of the TA, engineers and managers of related organizations of Bangladesh were invited in outside of Bangladesh to participate in exchange visit program, trainings on flood management and workshop related to water-related disaster management. The detail descriptions of program quality support of the TA are described in Main Volume report of the TA.

1.3 Previous studies on flood early warning systems

In Bangladesh, a considerable number of studies and projects related to the development of flood early warning systems have been undertaken in recent years. All these projects and studies produced valuable background information on the development and improvement of FEWS. Some key projects are:

Environmental Monitoring Information Network (EMIN) (2000-2007)

The project is an information network that facilitates planning and management of water and land resources in flood and erosion monitoring. The purpose of the project is to implement an information network to facilitate the planning and management of water and land resources as it relates to flood and erosion monitoring among national stakeholders and relevant agencies in the Brahmaputra-Jamuna rivers region.

Improvement of Flood Forecasting and Warning Services (IFFWS)

The feasibility study for the Improvement of Flood Forecasting and Warning Services was funded by the Government of Bangladesh and the Japan International Cooperation Agency (JICA). The study was aimed at:

- Formulating improvement plan of the flood forecasting and warning system in Bangladesh in order to mitigate flood damage focusing particularly on improvement of the data communication system;
- Conducting a feasibility study of the selected optimal scheme; and
- Transferring technology to Bangladesh counterpart personnel in the course of the Study.

Community Flood Information System (CFIS) (2001 – 2006)

The objective of CFIS is to disseminate information on the flood extent, duration and depth of water and water levels to the community before the flood occurs. The CFIS Project developed GIS-based flood forecasting information software named WATSURF, which implements a correlation model of a 248 km^2 study area. WATSURF is a simple gauge-to gauge correlation-based tool that uses forecasted water levels from the FFWC as input

Consolidation and Strengthening of Flood Forecasting and Warning Services (CSFFWS) project (2006)

The three immediate objectives or components of the project were:

- Component A: Development of flood forecast and inundation models.
- Component B: Dissemination of flood forecast information and warning messages; and
- Component C: Making FFWC sustainable by the end of the project.

Early Warning System Study (2006)

In 2006 an Early Warning System Study was concluded under a TA grant of the Asian Development Bank (ADB).[3] This 2006 review study included a comprehensive inventory of all earlier studies on FEWS in Bangladesh. Therefore the outcome of that study formed the starting point for the present project. The main objective of the FEWS Study in 2006 (ADB TA-4562) was to provide analytical input and prepare project portfolios and pre-feasibility studies to enhance existing early warning systems including the flood forecasting system operated by the Flood Forecasting and Warning Centre (FFWC) under the Bangladesh Water Development Board (BWDB). Twenty-two (22) possible FEWS interventions were identified (Annex B). However, prefeasibility study has been carried out only for nine interventions.

[3] *Bangladesh: Early Warning Systems Study, final report, December 2006, under TA grant of the ADB TA 4562-BAN*

2 Approach and Methodology

2.1 Overall approach

During the inception phase the main approach and methodology originally developed by ICHARM was worked out in a step-by-step manner. The first phase comprised a review of Flood Early Warning Systems (FEWS) in Bangladesh and the identification of key issues. This resulted in a long list of issues that formed the base for the first stakeholder consultation in December 2010. The outcome of the stakeholder consultation in December has led to the configuration of a list of interventions. Subsequently the interventions were ranked in the second stakeholder consultation session in March 2011. The outcome of the 2nd workshop (ranking of interventions) forms the base for a feasibility analysis and recommendations to the ADB. Figure 2.1 and Figure 2.2 illustrate this approach.

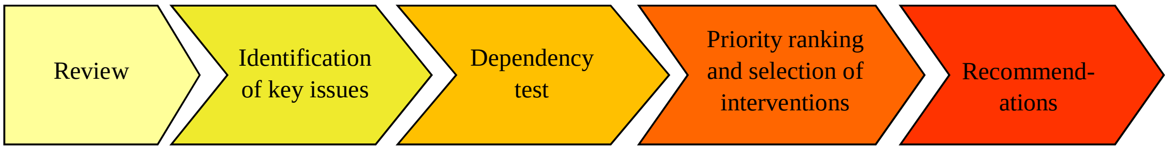

Figure 2.1 Overall project approach for development of national road map for FEWS.

Phase 1: Review

The first step concerned data collection on technical and institutional issues. During this phase the technical and institutional review was done. The technical review concentrated on existing projects and FEWS technology. For the institutional review a so called Tasks, Responsibilities, Activities and Mandate (TRAM) analysis was conducted for the main stakeholders BWDB, FFWC, Bangladesh Meteorological Department (BMD), Disaster Management Bureau (DMB), Bangladesh University of Engineering & Technology-Institute of Water & Flood Management (BUET-IWFM), Center for Natural Resources Studies (CNRS), Institute of Water Modelling (IWM) and Centre for Environmental and Geographic Information Services (CEGIS). The review was conducted based on criteria retrieved from the UNISDR checklist (see Annex C). The work for this phase was executed in November- December 2010. Results are presented in section 3.1 – 3.3. A short field visit formed an integral part of the review phase.

Phase 2: Identification of key issues

Next step comprised a cross reference with the existing 22 recommendations of the 2006 FEWS study. Together with the identified key issues of the review study a ‘long list’ of possible interventions was drafted. This ‘long list’ formed the key element for the first stakeholder consultation in December 2010. The details on identification of key issues are described in sections 4.1 and 4.2.

Phase 3: Dependency test

Subsequently all issues were classified in six steps of the FEWS development cascade cycle (risk knowledge, monitoring and data acquisition, forecasting and warning, dissemination and communication, information type and reliability and response capacity). A clustering of issues into interventions under the 6 cascade classes was done. All interventions address the most important issues as identified by the first stakeholders consultation workshop, while covering other less important issues at the same time. The

conversion process also illuminated any duplication in the issues identified by the first stakeholders consultation workshop. Besides these 6 classes there are also cross cutting issues like governance, multi-hazard approach, socio-cultural aspects and community participation. The outcome of this phase was a streamlined 'long list' of interventions.

Phase 4: Priority ranking and selection of interventions

In this phase a pair wise comparison for all interventions was performed in two consecutive steps. First the key institutes (stakeholders) were interviewed on their preferences for different interventions. This is called the Multi Criteria Analysis (MCA)[4] part. Next the same institutional stakeholders were asked to indicate their preference on Strengths Weakness Opportunities Threats (SWOT)[5] factors for each and every separate intervention. While MCA is a pair wise comparison between interventions and it may have institutional interest on priority ranking, the SWOT considers an individual intervention and analyses its importance based on the strength, weakness, opportunity and threats and therefore free from individual interest on project selection. Their answers were based on a SWOT matrix for each intervention for each stage of the FEWS cycle that was developed by the project team. The same exercise was performed in group sessions during the second stakeholder consultation in March 2011 to bring the national consensus on intervention selection. The outcome of the consultation workshop is presented and discussed in sections 6.1 and 6.2

Phase 5: Recommendations

An overall feasibility (technical, socio-cultural, institutional and financial) analysis was performed for all top prioritized interventions in each cascade. This will form the base for the conclusive recommendation to the Government of Bangladesh regarding investment in FEWS in Bangladesh. The main findings will be discussed in section 7. Throughout all steps of the approach close cooperation with the main stakeholders was maintained. This guaranteed their 'ownership' of the Government of Bangladesh (BWDB and FFWC) as well as transparency and understanding for the performed activities.

Finally the project approach and methodology is drafted in the form of a National Road Map (NRM) for flood early warning systems development in Bangladesh. The draft NRM for FEWS in Bangladesh was discussed at workshop in January 2012. The NRM was finalized by improving based on comments received from stakeholders in workshop (see also Annex I). This Road Map may be used for decision making in investments in water-related disaster risk management.

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[4] *Multi criteria analysis (MCA) is a tool that supports comparison of different interventions on the basis of a set of criteria. They are very effectively in supporting the assessment of and decision making on complex sustainability issues. The procedures and results obtained from MCA can be improved with the interaction of stakeholders (Source: Herwijnen, M.N.; http://www.ivm.vu.nl/en/Images/MCA0_tcm53-161526.pdf).*

[5] *A SWOT analysis is a strategic planning method used to evaluate the Strengths, Weaknesses, Opportunities, and Threats involved in a project or intervention, or business venture. It involves specifying the objectives of the entity and identifying the internal and external factors that are favourable and unfavourable to achieve those objectives (Source: http://www.fostercity.org/city_hall/docs/upload/Final%20Snapshot%20030812%20-%2004%20-%20Strengths-Weaknesses-Opportunities-Threats.pdf).*

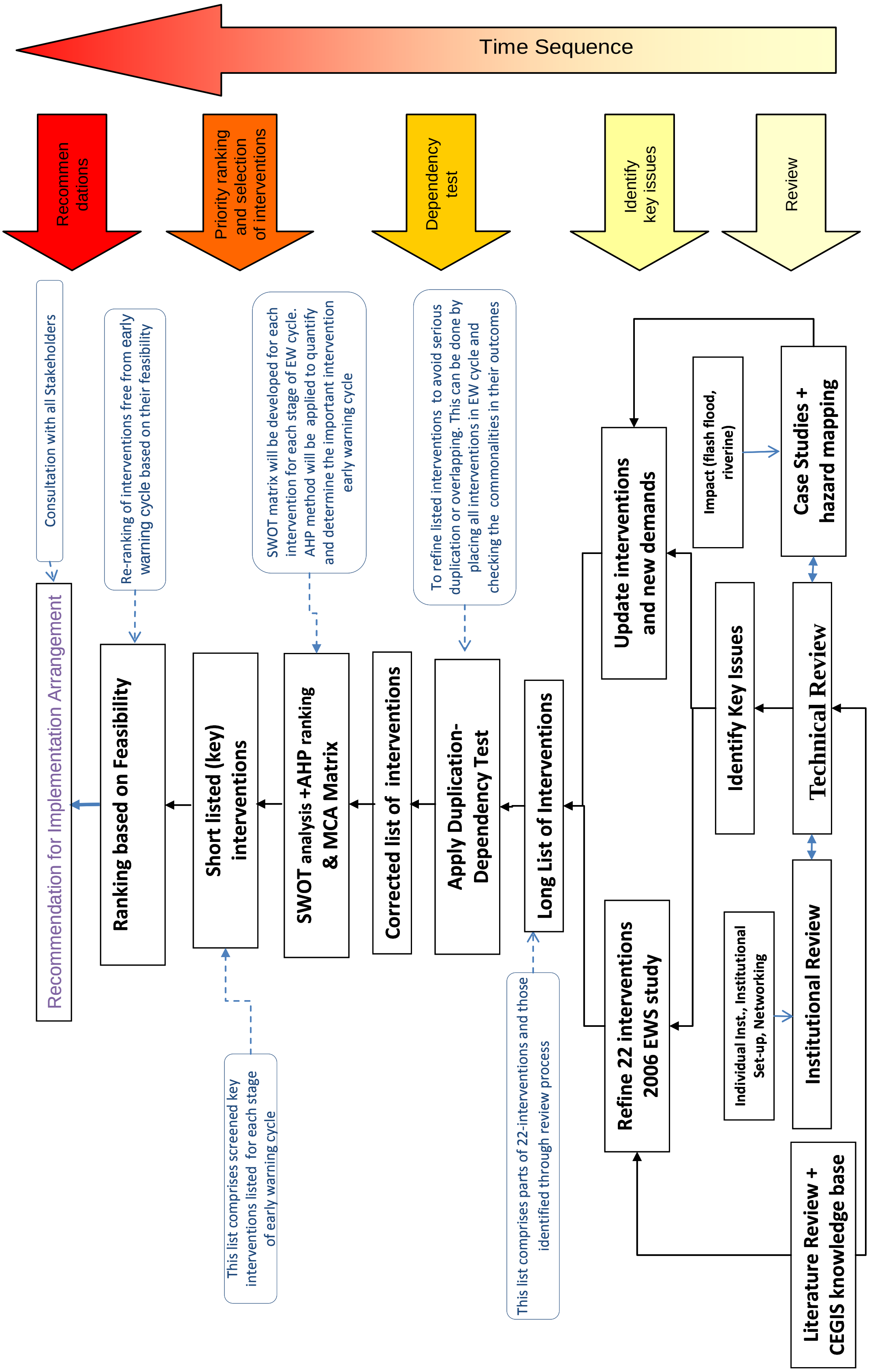


Figure 2.2 Detailed Project Phases.

2.2 Methodology

2.2.1 Review

The review process involves three independent parallel thematic activities; a. technical assessment, b. institutional assessment and impact assessment of FEWS and c. need assessment at grass-root communities. This review process is guided by the International Centre for Water Hazard and Risk Management (ICHARM) developed framework and globally accepted UN-ISDR proposed checklist on FEWS. The review summarizes the key findings that can be translated into key issues based on expert knowledge.

2.2.2 Identification of key issues

Issues on the development of FEWS in Bangladesh are identified based on technical and institutional review. The outcome resulted in a long list of approximately 72 different issues. All issues were classified into three groups:

- Technical (for instance increase the number of water level recorders);
- Institutional (for instance the mandate of the FFWC);
- Mixed (for instance organization of operation & maintenance of the monitoring network).

Checklist for split in issues

1. **Technical:**
   - Data collection and processing
   - Modeling approach (accuracy, geographic coverage)
   - Computers (hardware and software), field equipment, vehicles, offices
   - Communication facilities with target groups
   - Technical operation and maintenance

2. **Institutional:**
   - Tasks, roles, mandates
   - Capacity (knowledge, personnel)
   - Target group information needs and awareness
   - Data reliability, timing and dissemination
   - Information flow and accessibility
   - Available funding (purchase and maintenance), social Cost-Benefit Analysis (CBA) of the EWS

3. **Mixed:**
   - Management of operation and maintenance
   - International cooperation
   - Community preparedness
   - Dissemination and translation to local level

(Checklist is a comprehensive list of important or relevant actions, or steps to be taken in a specific order)

A simple questionnaire was prepared to identify importance of listed key issues. In this questionnaire all issues were clustered and per issue response was asked whether the issue was: Very important, Important or less Important. A copy of the questionnaire is presented in Annex D.

At the first stakeholder consultation in December 2010, participants were requested to respond individually on the questionnaire. Then group discussions were held in three groups: technical, institutional and mixed. The outcome of both responses was normalized and combined in a long

list with issues and their relative importance. The results are presented and discussed in sections 4.1 and 4.2. Hereafter the used methodology is illustrated by a practical example.

Creating a normalized index

Response:

Individual results			**Group results**			**End class**
Very Important	**Important**	**Less Important**	**Very Important**	**Important**	**Less Important**	
Qu1	*Qu2*	*Qu3*	*Qug1*	*Qug2*	*Qug3*	*Quality/type*
Quan1	*Quan2*	*Quan3*	*Quag1*	*Quag2*	*Quag3*	*Quantity*

Where:
Qu and *Qug* mean the qualitative class boundaries for individual and group response
Quan means the quantitative score by individual response (depends on number of interviewed persons)
Quag means the quantitative score by group response (always 1 because only 1 group result)

Formulas:
Q(invidual) = ((Qu1xQua1) + (Qu2xQua2) + (Qu3xQua3))/ (Quan1+ Quan2+ Quan3)

Q(group) = ((QugxQuag1) + (Qug2xQuag2) + (Qug3xQuag3))/ (Qug1+ Quag2+ Quag3)

Qaverage= (Q(individual) + Q(group))/2 (result 1)

Result = X

Q end = (X – 0.333) × 1/0.666

Steps on deriving a normalized index for consultation workshop results

Step 1. Attach quality value to importance for individual and group results

Qu1/Qug1 (Very Important) = 1.0
Qu2/Qug2 (Important) = 0.66
Qu3/Qug3 (Less important) = 0.33

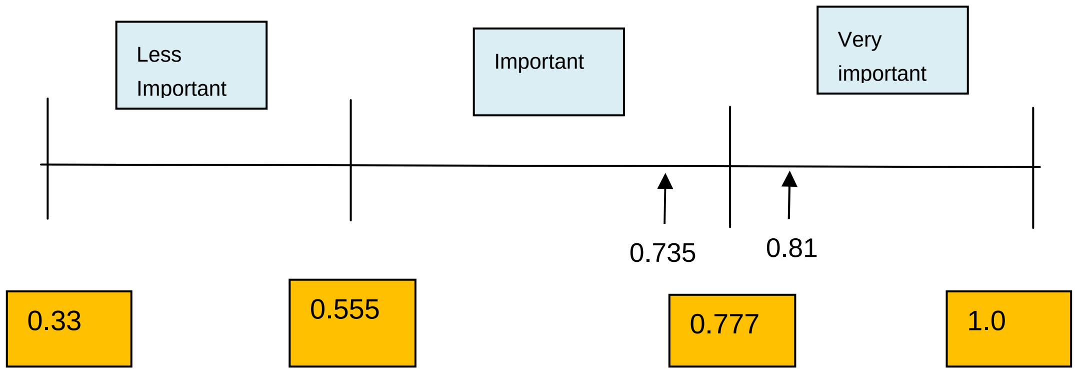
Step 2. Fill scores of individual (technical and institutional) and group results. Hereafter an example is worked out.

Individual results			**Group results**			**End class**
Very Important	**Important**	**Less Important**	**Very Important**	**Important**	**Less Important**	
1.0	0.66	0.33	1.0	0.66	0.33	*Qual*
9	2	3	0	1	0	*Quan*
1×9	0.66×2	0.33×3	1×0	0.66×1	0.33×0	
9	1.32	0.99	0	0.666	0	result forms
(9+1.32+0.99)/14			(0+0.666+0)/1			
0.81 normalized quality outcome			0.66 (normalized quality outcome group)			
(0.81+0.66)/2 = 0.735						result 1
(0.735 – 0.333)/0.666 = 0.604 (see step3)						result 2

Possible range of outcomes:

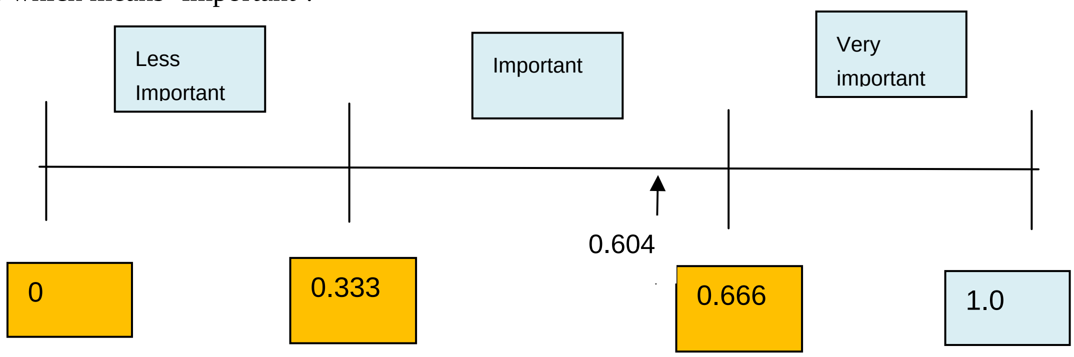
Between lower value (less important) and highest value (very important):

The average of the individual and group outcome is plotted in a scale of minimum 0.333 and maximum 1.0.



Due to the normalization of the raw data the results of the group response is weighted more heavy than the individual response (range for result 1).

Step 3. Next the outcome for result 1 is indexed on a scale from 0 – 1.0 using 0.33 and 0.66 as class dividers making it more intuitively understandable for non-specialists. The final result is 0.604 which means 'important'.



This methodology resulted in a long list of issues with relative importance clustered in three main classes.

2.2.3 Dependancy test

During phase 3 (dependency test), the long list of issues was clustered in the steps of the modified disaster risk FEWS cascade by UNISDR[6]. For the purpose of this project 6 classes were used as well as one class for cross cutting issues such as international cooperation, capacity building and strengthening of organizational structures. The steps or phases in the cascade are connected with each other. The full cycle of FEWS can only be completed if all steps are taken. If the requirements in one cascade step are not fulfilled, the previous level has to be repeated.

[6] *UNISDR: Developing Early Warning Systems: A Checklist, http://www.unisdr.org/2006/ppew/info-resources/ewc3/checklist/English.pdf*

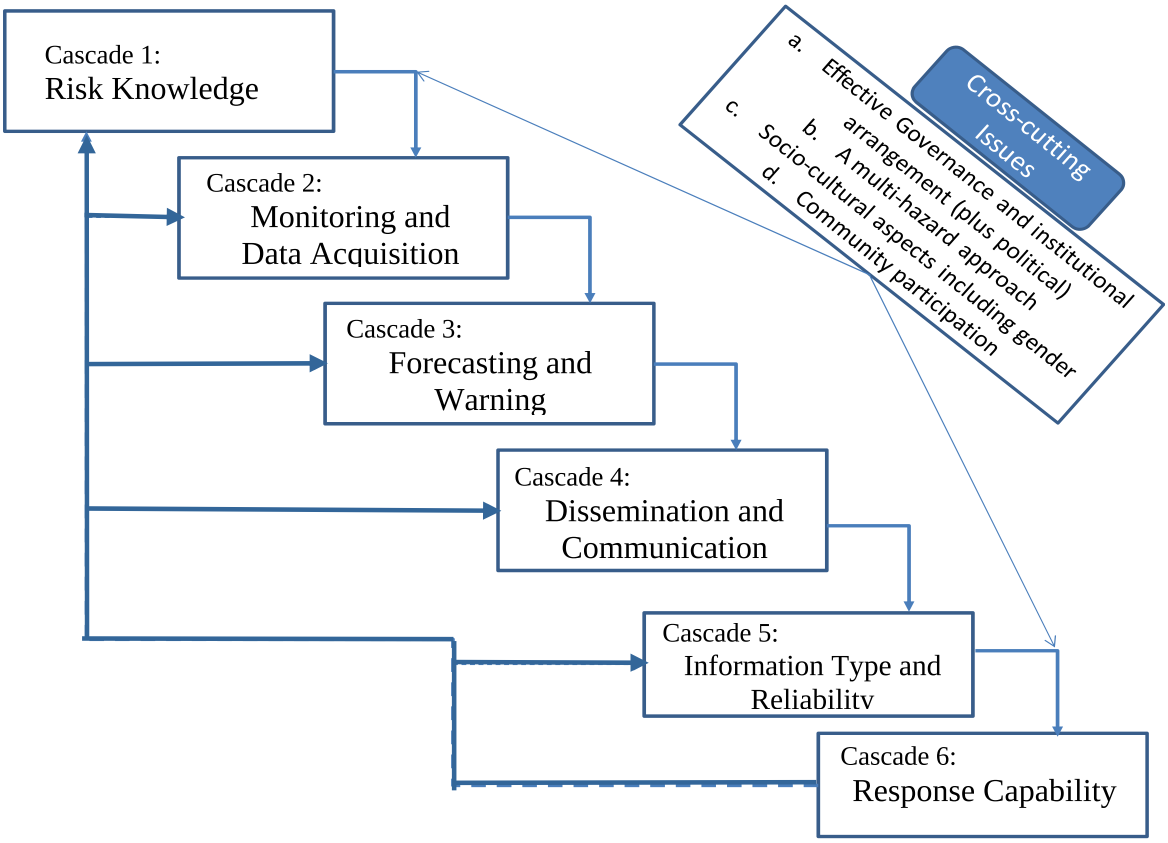


Figure 2.3 Cascades and cross cutting issues for FEWS (modified from UNISDR[7]).

The clustering has been performed, based on the outcome of the first stakeholder consultation on relative importance. An attempt was made to include all very important and important issues. Several issues were clustered in main interventions and sub-interventions. This classification was intensively discussed with BWDB/FFWC. For each intervention quantitative criteria were defined. In Annex E the list of interventions is presented. In section 5.1 and 5.2 the selection and clustering of issues into interventions is discussed.

2.2.4 Priority ranking and consistency checking

A second priority ranking was carried out on the list of clustered interventions during the second stakeholder consultation in March 2011. The participants from related organizations were divided into three groups over the cascade classes. They performed a MCA and a SWOT-AHP analysis in order to come to a priority ranking of interventions. The analysis was based on a newly developed set of questionnaires (presented in Annex G):

Both questionnaires were used in an Analytical Hierarchy Process (AHP) analysis or pair wise comparison. In the MCA approach all sub-interventions are compared with each other. In a 'pair wise comparison' the preference and intensity of that preference is compared. A software application (software name: 'make it rational') with which a statistical analysis is done on the response. The software indicates the internal consistency of the answers and any contradiction. Due to this check conflicting answers by the respondents could directly be discussed in the group sessions.

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[7] *UNISDR: Developing Early Warning Systems: A Checklist, http://www.unisdr.org/2006/ppew/info-resources/ewc3/checklist/English.pdf*

Hereafter an example is given of the discussion on ‘inconsistency answers’ as given by the stakeholders during the group sessions. The example is based on cascade 1 ‘risk knowledge development’. In the cascade 1, there are three different interventions:

Intervention-1: National and local level risk assessment
Intervention-2: Integrated planning for FEWS
Intervention-3: Formal and Informal education

To compare all interventions need to match:

Intervention-1 in relation to Intervention-2 ➔ indicate preference and intensity on scale from 1 - 9
Intervention-1 in relation to Intervention-3 ➔ indicate preference and intensity on scale from 1 - 9
Intervention-2 in relation to Intervention-3 ➔ indicate preference and intensity on scale from 1 - 9

Where 1 means not preferred or related and 9 means strongly preferred or related. Figure 2.4 illustrates the selection screen in the software application

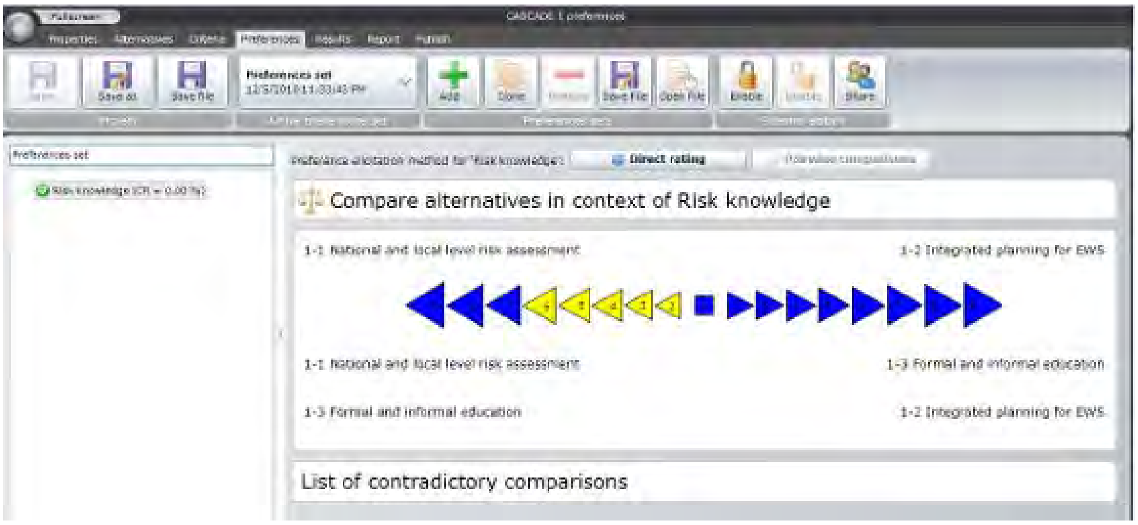

Figure 2.4 AHP entry screen for interventions per cascade step.

For the SWOT approach, an overview of possible SWOT factors for each intervention was prepared. Instead of comparing interventions the response is now focused on the comparison of SWOT-factors per intervention. With this information it is possible to compare individual interventions based on their scores for the SWOT factors.

By concentrating on one intervention at a time the chance on ‘biased’ answers due to preference of a certain stakeholder will be less. The interviewees are comparing present strength and weakness with future opportunities and threats. The full scale represents 9 intervals of 5.55% each. So for instance as indicated in Figure 2.4 the interviewee has chosen for strength – 5 which means: Strengths prevails with 77.75% against 22.25% weakness. So in all answers less than 9, a certain percentage of the opposite answer will also be included. In case the interviewee is undecided the answer should be 1 which is indicating 50 – 50% so none of the alternatives prevail.

For the final recommendation to the ADB the outcome of the SWOT factor AHP will be more valuable than the MCA. Figure 2.5 illustrates the entry screen for the SWOT-AHP for one intervention. In Annex G an overview of the SWOT factors per intervention and the questionnaires for the MCA and SWOT-AHP are presented.

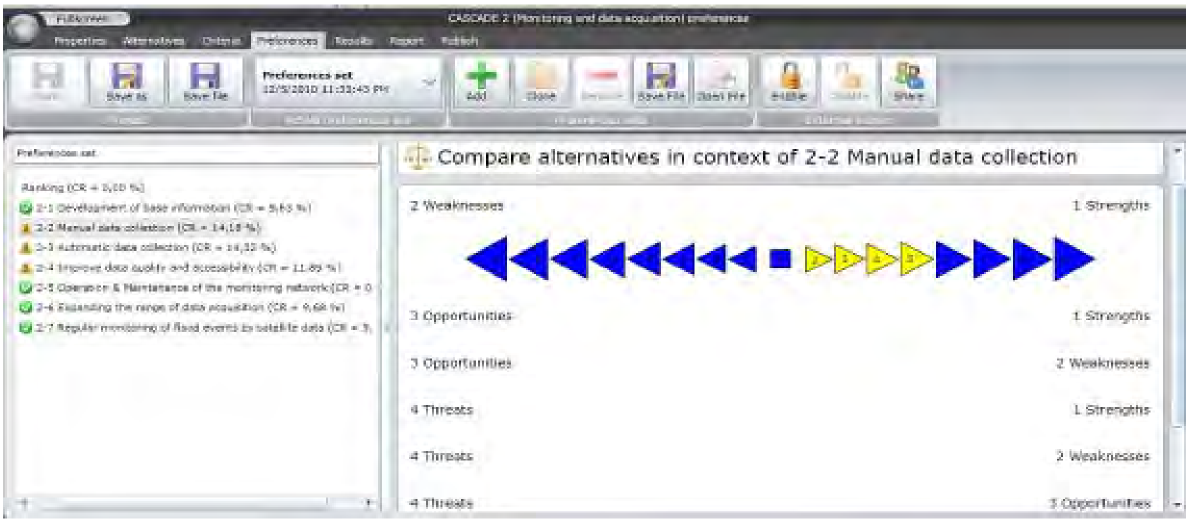

Figure 2.5 AHP entry screen on SWOT factors per intervention.

Finally a combination has been made of the MCA and SWOT-AHP results. First the MCA results are translated from percentage towards relative weight numbers. Next the SWOT results of the individual institutes and the outcome of the workshop groups are normalized and added to each other. So in the end result the SWOT-AHP will weigh two times more than the MCA results. The outcome of the interviews and working sessions is discussed in sections 6.1 and 6.2

2.3 Consultation and survey

Throughout the project, consultation with the stakeholders played a major role. Also the local knowledge and experience of the Bangladesh partner (CEGIS) in the project team proved to be very valuable. During the project the team had regular interactions with stakeholder at different levels.

Field survey
In the review phase the team performed two field visits to different locations which are frequently affected by floods (Manikganj and Comilla see also Figure 3.5). The main purpose of the field visit is to identify key issues for developing FEWS in grass root level. On both locations active discussions were held with local authorities and people in the village about their most pressing needs for FEWS. It is very clear that the ultimate goal of the project is to address the needs and demands of the local people in the flood prone areas.

Stakeholder interaction
Transparency is very important for ownership and support for the outcome of the project. Therefore the project team maintained close contact with the main stakeholders throughout the project. Besides regular meetings, the stakeholders were also contacted for interviews on the questionnaires for the long list of issues and the MCA and SWOT–AHP. Moreover all stakeholders participated in both workshops in December 2010 and March 2011. Then all the prioritized interventions through these consultation workshops are drafted in National Road Map for FEWS development in Bangladesh. The draft National Road Map for FEWS was discussed at workshop in January 2012 and it is finalized by improving the comments received in the workshop. The outcome of the feasibility study as well as the draft report was discussed with the FFWC before the recommendations were submitted to the ADB. The project team invited NGO's to the workshop sessions in December 2010 and March 2011 as representatives of the local stakeholders and end-users of the FEWS.

Survey

For the review surveys the team made use of the existing knowledge of CEGIS. They proved to be well informed about the present status of FEWS and the involved institutes in Bangladesh. In section 3.2 (institutional review) the role of the main stakeholders in the FEWS is described.

3 Review

3.1 Technical review

The technical review was based on two elements: a desk study of already carried out projects and a cross reference of existing and upcoming projects listed in Table 3.1. Besides a cross reference Table was made with the recommendations and issues of the '2006 review' study. The summary of the recommendation of the 2006 review study is presented in Annex E.

Table 3.1 Cross reference between the 2006 review and other projects

References of past and existing projects and reports for desk study	Organizations
Community Flood Information System (CFIS), 2000 - 2008	U.S. Agency for International Development
Flood Early Warning System Study (FEWS) (ADB TA-4562), 2006	BWDB, Ministry of Water Resources
Information for Flood Management in Bangladesh, 2000	U.S. Agency for International Development
National Adaptation Programme Action (NAPA)	Ministry of Environment and Forests, Government of Bangladesh, UNDP
Community based all hazards early warning dissemination systems development projects in the pilot areas in Lalmonirhat, 2008	Comprehensive Disaster Management Programme (CDMP), UNDP
Sustainable end-to-end climate/flood forecast application through pilot projects, 2006 - 2009	Asian Disaster Preparedness Center
Guidance on measuring the reduction of disaster risks and the implementation of the Hyogo Framework for Action, 2008	UN-ISDR
Consolidation and strengthening of flood forecasting and warning services project , 2006	BWDB/FFWC
Environmental monitoring information network, 2005	RADARSAT International CANADA
Climate forecast application in Bangladesh I (2000-2003) and II (2006-2009)	Asian Disaster Preparedness Center, US Agency for International Development
Investigation of hydrological aspects of flood 2004 with special emphasis on Dhaka city, 2005	Institute of Water and Flood Management, Bangladesh University of engineering and Technology
Improvement of flood forecasting and warning services, 2003	Government of Bangladesh, Japan International Cooperation Agency
National workshop on options for flood risk and damage reduction in Bangladesh (Dhaka, 2004)	Prime Minister's Office, Government of Bangladesh
Comprehensive Disaster Management Programme -Phase II	UNDP

This approach resulted in a long list of 72 issues. The full list (in form of questionnaire) is presented hereafter in Table 3.2.

Table 3.2 Full list of identified FEWS issues developed by the project in the review phase.

SN	Long list FEWS issues Bangladesh
1	National and local risk assessment based on hazard data and vulnerability information is not available. Risk assessment for key sectors is also absent
2	Initiatives on national and local risk assessment taking into account the regional/transboundary risks, with a view to regional cooperation on risk reduction is not in place
3	Multi hazard risk index mapping is also necessary
4	Baseline for the early warning system is not available
5	Proper understanding of flood plain hydrology is lacking
6	Regular or intermittent flood mapping showing the depth-duration characteristics of mega and regular flood events is not readily available
7	Flood topology and classification of different types of flood is grossly present that often lead to confusions
8	To include a search engine to store queries for further reference
9	Basin wide data/ information is a pre-requisite for reliable forecasting, which is scanty and it affects the quality of flood forecasting by FFWC
10	Manual data collection error causes erroneous forecast
11	Absence of full set of components at the rainfall gauge stations often result in data gaps
12	Hydro-metric data are not collected during night time, hence only data are available for 12 hours in a day
13	Insufficient operation and maintenance of automatic stations often creates malfunctioning of the apparatus and creates data gap
14	Many of the hydro-metric data stations are washed out by shifting of rivers course and very few of them are reinstalled
15	Inclusion of FCD structures in flood forecasting models will make the FFWC forecasting model more close to the real system
16	Most up to date and reliable topographic data and land use data is not used in the flood forecasting model which lead to erroneous forecast
17	Real time flood monitoring using satellite is useful, but not available readily.
18	Automation of hydro-meteorological data collection network is crucial
19	Evaluation of on-going community-based early warning systems including FFWS
20	There exists deficiency in the accuracy and reliability of flood forecast made by the FFWC
21	Timely and accurate flood forecasting need is crucial.
22	Short, medium and long term (seasonal) flood forecasting is required.
23	Hourly prediction will be useful
24	Increasing the lead time of flood predictions by integrating transboundary input data sources in the river models of the FFWC would give stakeholders more time to prepare for the flood event
25	Development for numerical weather model for improving the lead times is needed
26	Update and upgrade flood forecast model for more reliable results
27	Necessity for increase of number of forecast locations for the expansion of forecast
28	Monitoring tool for understanding the mechanism and tracking the flash flood extent is needed
29	Storm surge model for the coastal zone is necessary
30	Updated high resolution DEM is required for inundation model accuracy
31	Rainfall data from riparian country needed for flash flood model
32	Support to community radio for high risk areas
33	Stakeholders at the community level hardly receive any formal flood prediction information to take up necessary preparatory measures. Information collected through indigenous ways is not very reliable and no substitute for more authentic forecasts. They need long-term as well as short-term prediction information

SN	Long list FEWS issues Bangladesh
34	The district, upazila or union level institutions do not receive any location specific formal prediction information to be disseminated among the vulnerable people.
35	Participatory based early warning dissemination network will be helpful
36	Establishment of network with other international institutes will improve flood forecasting and dissemination
37	Development of community-based training and capacity building for warning dissemination is required
38	Insufficient dissemination due to communication link among upazila, union and mouza level
39	There exists lack of clarity in existing warning messages. Easily understandable communication material and documents should be prepared and disseminated.
40	Dissemination of information on flood shelter proximity to the people for emergency evacuation during disaster
41	Some social workers try to build up awareness among the community members to take up various preparatory measures like storing of food, raising of the tube wells so that these remain functional event during floods. But due to the absence of effective forecasting information it becomes difficult to make the people adopt adequate preparatory measures.
42	As NGOs do not have the prediction information to share with the local people, they are not able to implement any specific preparation program in a comprehensive manner.
43	Radio, TV and newspaper generally disseminate information, mainly on the status of floods and some general trends, rather than flood prediction.
44	Private cell phones, SMS based forecasting information dissemination technology development are required
45	Flood warnings provided by FFWC relate to water level at certain gauging stations on main rivers, which are not very useful to people lives on floodplains at a distance from the river.
46	Since lead time provided by FFWC is no more than 48 hours, many community members, particularly farmers, find such information less than what they need.
47	More location specific information is needed by the concerned institutions, and it should be presented in formats that institutions and community members find relevant.
48	River system model based forecasting done by the FFWC does not provide location specific information that community members often ask for.
49	Development of basin wide river and flood management approach will be helpful
50	Information on outbreak of various water borne diseases to the institutions responsible for providing medical services should be disseminated quickly so that the situation does not turn out to be epidemic in nature
51	Pre-harvesting flood level (max flood) information is required for agriculturists
52	Flood proofing level, flood frequency (Flood standards and statistics) related information should be monitored by BWDB
53	Cloud cover information is required for meteorological forecasts
54	Development of early warning information package, relevant to different institutions is crucial
55	Assessing base information needs for reliable forecasting is a pre-requisite
56	Any flood damage assessment guideline does not exist. For effective post-flood rehabilitation, proper damage assessments are necessary.
57	Reduction of risks from flood hazard through community participation
58	Lack of awareness/understanding of the users on the safe operation of the water and sanitation infrastructures
59	Poor level of understanding of the beneficiaries regarding sanitation and hygiene practices
60	Activities (training programs, campaigns, motivations, meetings, and courtyard sessions) initiated by projects or the Government as component of flood emergency responses should be more intensive and continuous. The activities should be repeated over the period of time on the same locations.

SN	Long list FEWS issues Bangladesh
61	Realization of the benefit of the hardware interventions (raised platform latrines, tube wells) during floods was poor, as the respondents found immature to grasp the full utility of the given facilities.
62	Operation and maintenance of the hardware intervention is poor.
63	Many flood control structures have been build, but there has been little initiative from different organizations to take preparatory measures to minimize the impact of flooding
64	It is imperative that flood affected households are supplied with food items to tide over the flood, as their stock of food is exhausted before the flood is over
65	Capacity development for the professionals engaged in dissemination of flood information is important
66	Proper planning is required for design and implementation of rehabilitation measures
67	Capacity building of FFWC's hardware and software requirement is essential
68	Strengthening of FFWC's mandate for widening its dissemination system across different institutions is required
69	Improvement of FFWC institutional status or organizational autonomy to control and utilize allocated resources will be helpful
70	Updating of hydrological monitoring network
71	strengthening disaster management linkages and coordination mechanisms between government, international and national NGOs
72	Develop ward level contingency plans

3.2 Institutional review

A number of institutes in Bangladesh are engaged in forecasting and disseminating the FEWS related information. The main organization involved in flood forecasting is FFWC. BWDB's Directorate of Hydrology and Bangladesh Meteorological Department (BMD) provide FFWC with water level and rainfall data and weather data respectively as inputs to the forecasting models.

Numerous organizations are involved in dissemination as FFWC sends flood forecast and warning information to a range of organisations involved in disasters whether for preparedness, relief rehabilitation or a combination. As per the standing order issued by the Ministry of Food and Disaster Management, the responsibility of disseminating flood warnings down to the local level lies with Disaster Management Committees at the district and upazila levels. National-level organisations involved in dissemination range from government organisations including the Prime Minister's Office, the Disaster Management Bureau (DMB) and Ministry of Food and Disaster Management (MOFDM), Ministry of Water Resources (MOWR), to non-government organisations such as CARE-Bangladesh, and Oxfam[8], BWDB's central and regional offices and the press and other information media. Flood forecasts and warnings are passed onto to district administrators by FFWC for subsequent transmission to upazila and below as needed. However the communication system below the district level is not fully operational, even though the lower levels are closer where floods have their main impact and could benefit from receiving flood warnings.

Response to flood forecasts or warnings for agencies and people at all levels requires that they are able to do something to mitigate the impact of the forecasted flood. Response involves the organizations involved in dissemination plus some additional organizations that are not involved in dissemination.

[8] *Oxfam is a global movement of people who share the belief that, in a world rich in resources, poverty isn't inevitable. It's an injustice which can, and must, be overcome (http://www.oxfam.org.uk/what-we-do/about-us).*

It is becoming more and more important for the infrastructure managers to respond in time, carry out emergency maintenance and report to the forecasting agency on the performance of the forecast. There are also organizations involved in preparedness such as the Local Government Engineering Department that are responsible for the construction of rural infrastructure including the feeder roads and flood shelters and flood dykes that are lifelines for people seeking refuge from floods. To improve the response of people on flood warnings, an assessment of infrastructure and facilities in their neighbourhood is required to ensure that people do have mitigation options when the flood comes.

In Figure 3.1 the main stakeholders (per FEWS Cascade level) and their roles or tasks are presented. Figure 3.2 shows a flow chart with actions and phases within the FEWS cycle. Per phase (or cascade) in the FEWS other stakeholders are involved.

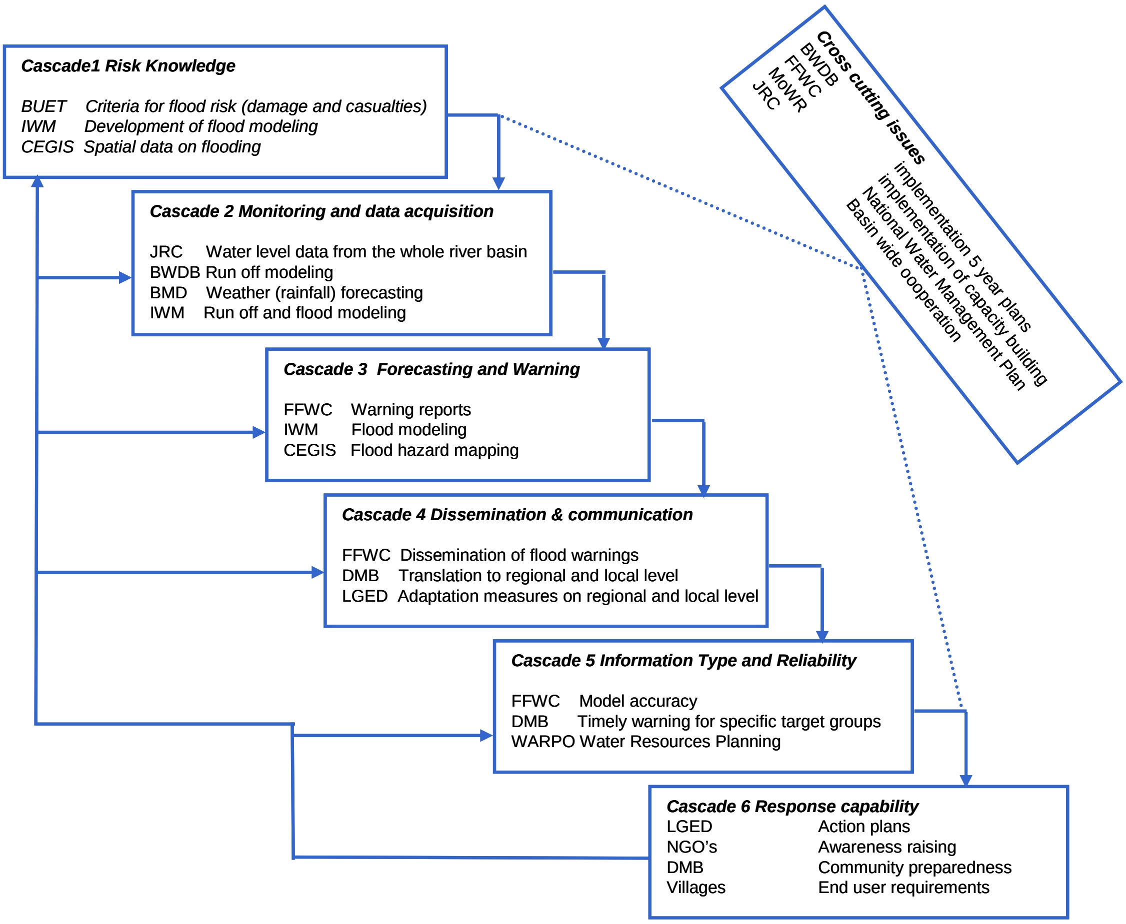

Figure 3.1 Overview of the roles and tasks of institutions involved in FEWS in Bangladesh.
(In figure, JRC: Joint Rivers Commission, LGED: Local Government Engineering Department)

Based on the concept of the cascades, several main 'building blocks' within the FEWS cycle were distinguished. Moreover, it was feasible to connect the responsible organizations to those particular steps, phases and actions. This resulted in a flowchart of subsequent actions needed to perform successful flood early warning focused on the end user needs and demands. Figure 3.3 is presenting the full flood FEWS cycle. This schedule proved to be valuable in discussion with different stakeholders. Not only because the different cascade classes are put in connection to each other but also to understand the institutional relations and constraints as described in the institutional review (Annex H). To optimize the output of the FEWS all elements need to be addressed.

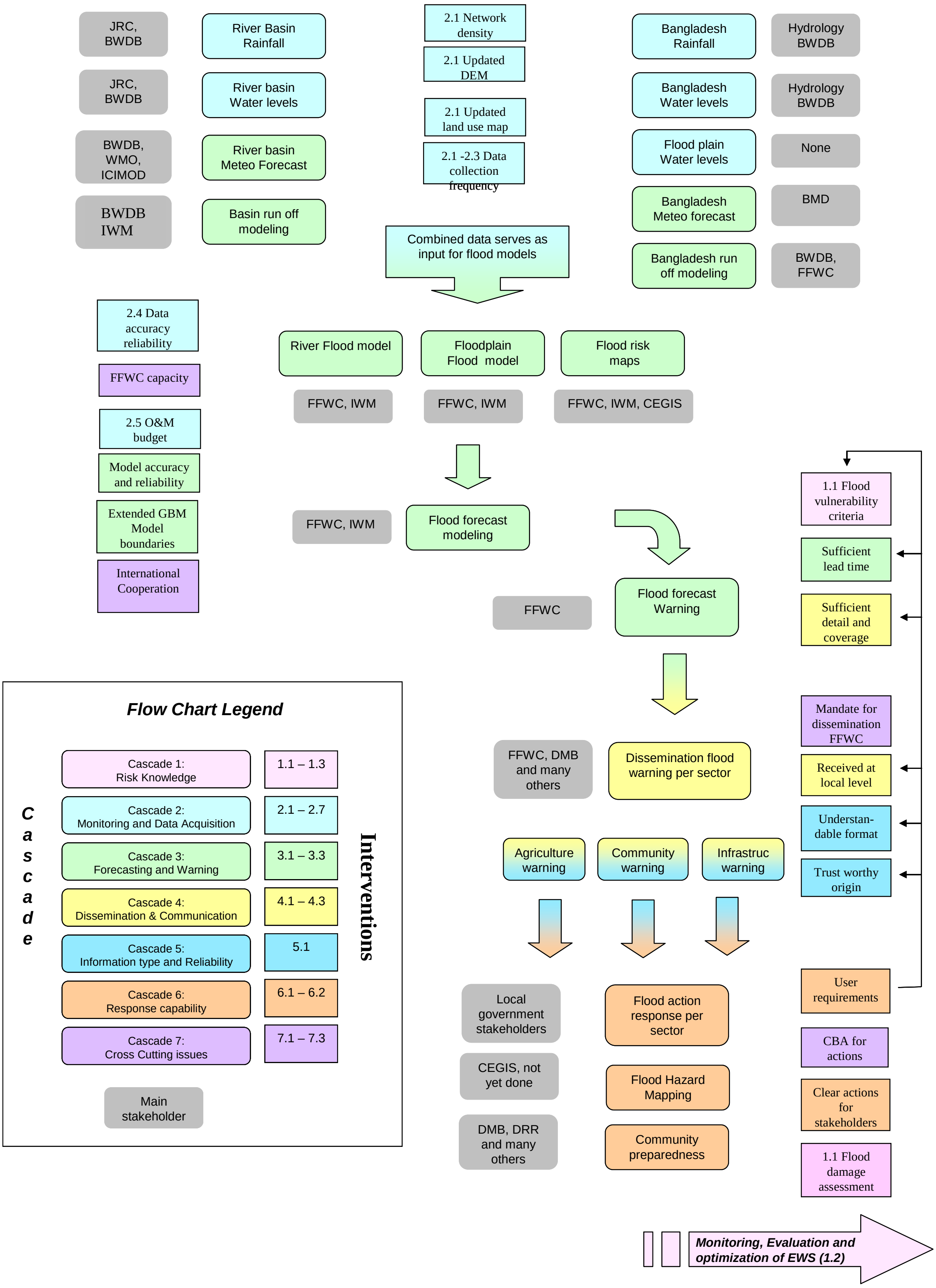

Figure 3.2 Actions and involved organizations in FEWS.

(In figure, Meteo: Metrological)

3.2.1 Standing orders on disaster

The Government of Bangladesh has the Standing Orders on Disaster (SOD) in effect since 1997. SOD outlines the disaster management arrangements in Bangladesh and describes the detailed roles and responsibilities of Committees, Ministries, Departments and other organizations involved in disaster risk reduction and emergency response. Moreover SOD establishes the necessary actions required in implementing Bangladesh's Disaster Management Model, e.g., defining the risk environment, managing the risk environment, and responding to the threat environment.

Considering the adverse impact of climate change and the recommendation of the World Conference on Disaster Reduction 2005, SOD was updated in April 2010 and is now in line with the new approach in the field of disaster management.

SOD comprises a detailed description of the tasks, roles and responsibilities of institutes and organizations at different levels in Bangladesh. As such it forms a perfect overview for the TRAM analysis in the framework of our project.

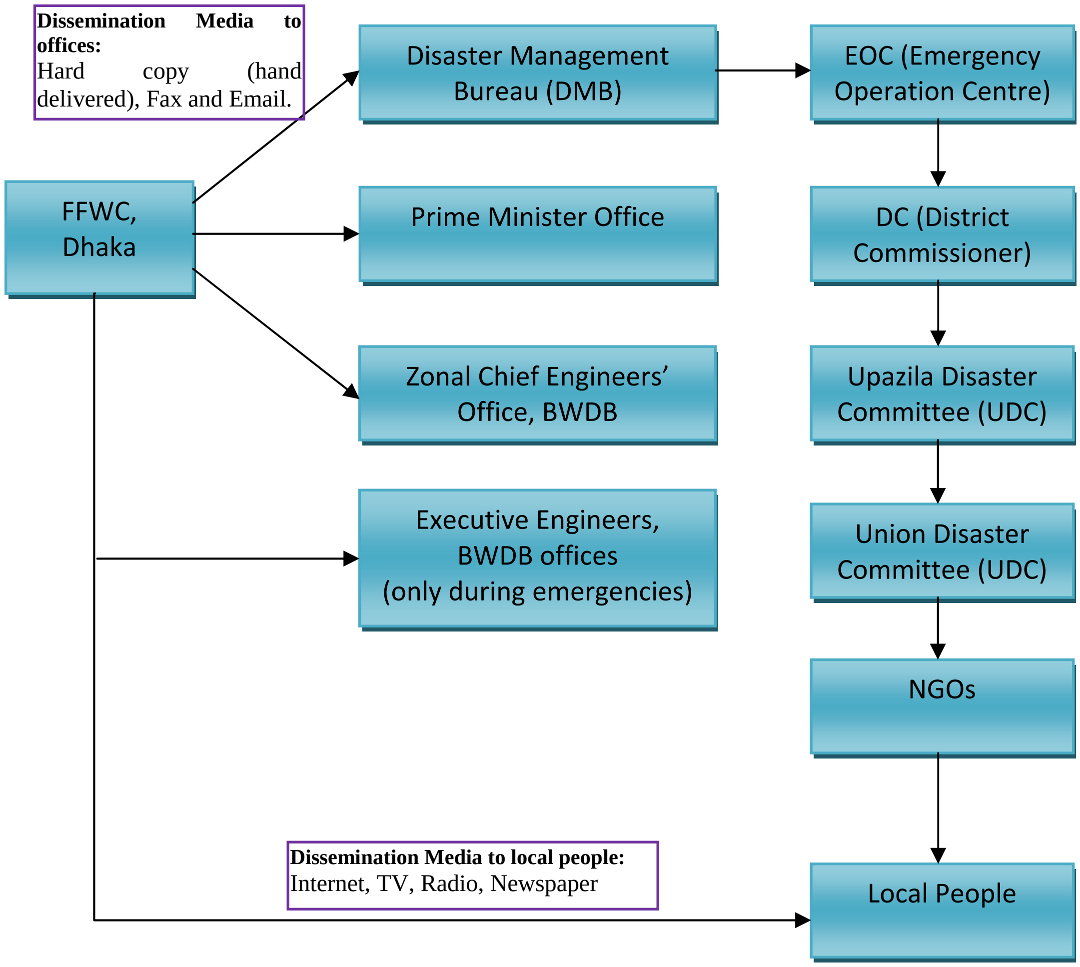

Figure 3.3 Dissemination of EW

A full overview of task, responsibilities and mandates for the organizations related to FEWS is presented in Annex H.

3.3 Field survey

A two-day field survey on 16 – 17 October 2010 formed an integral part of the inception phase of the project. The main objectives of the field survey were to investigate flood affected area to identify issues for FEWS, to investigate existing early warning system in village level and water level stations and to discuss with villagers including farmers and local authorities. The first day one of the pilot areas of the former USAID project Community Flood Information System (CFIS) in Manikganj-Tangail area was visited and this area is one of the cases where the experiment with flag hosting and Short Message Service (SMS) alert on village has been done. The pilot area is located 100 km West of Dhaka close to the flood plain of the great Jamuna River. During the second day two sites near the Gumti River were visited in the Comilla area 100 km East of Dhaka, where flash flood frequently occur and flood warning station of BWDB is also located.

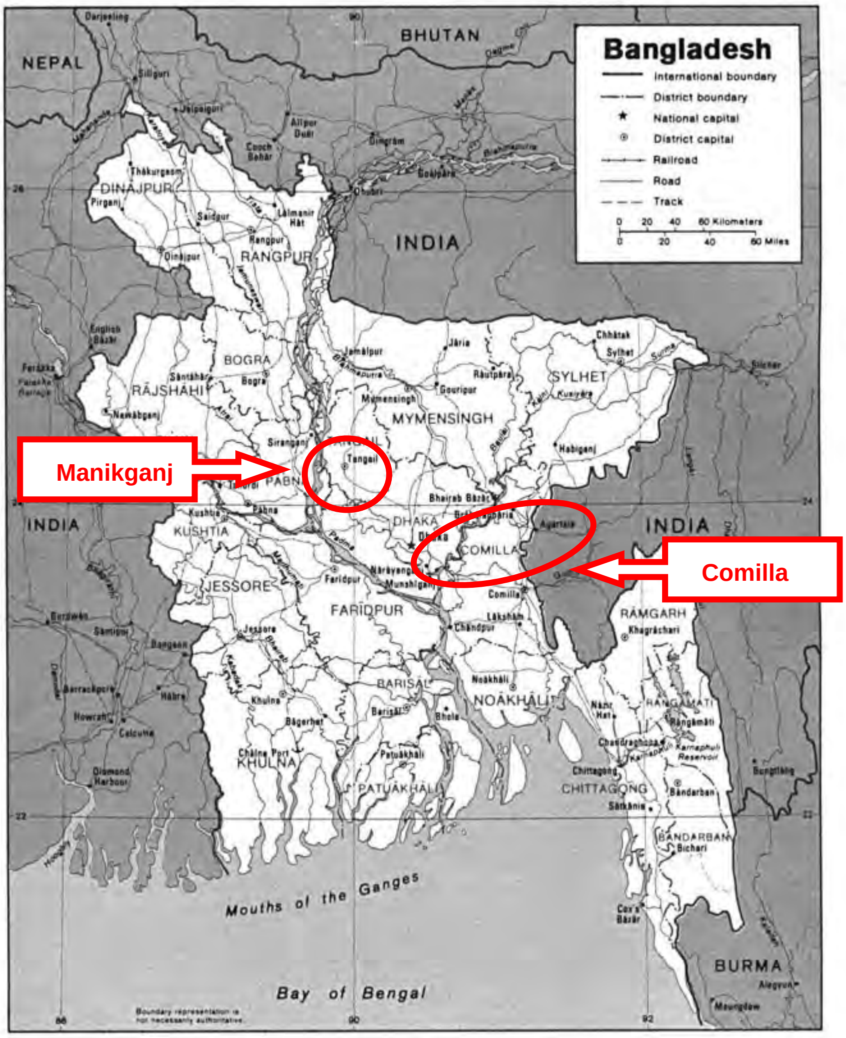

Figure 3.4 Locations of field visits in Manikganj and Comilla.

Main activities of the field visit comprised:

- The study of existing documentation (report on the USAID project on Community Flood Information System (CFIS);
- Visit to the flood (and erosion) effected areas and villages;

- Discussion with former ‘flag-hoisting-operators’ (Individuals were selected by the local community to serve as operators, to operate a flag system for informing the community of the local flood forecast (Martin et al., 2006)) (Figure 3.5);
- Discussion with villages including farmers on the need and effectiveness of flood early warning information;
- Discussion with BWDB local experts and officials of the union and upazila;
- Boat visit of the lower Gumpti River;
- Visit of the flood (and erosion) affected areas and villages;
- Visit BWDB water level recording stations and discussion on data dissemination.

In the discussions with the local authorities and the villagers, it became clear that the ‘early warning information’ does not automatically reach all end users at village level in an understandable format. As a result, people still rely mainly on indigenous knowledge on flood forecasting. The people in the village suggested to use all possible dissemination ‘channels’ including ‘rickshaw miking’ (mobile broadcast installation mounted on a man powered cycle taxi) and messages though the loud speaker system of the mosques.

The main findings of Manikganj-Tangail area visit were:

1 The main concern of villagers is damage to agriculture crops. The early warning messages need to be at least:
   - 7 days lead time to save crops from the field;
   - 3 days to save cattle and household goods by preparing floating platforms;
   - 1 day to get people and cattle to higher ground.

2 Besides the flag, extra dissemination by ‘Rickshaw Miking’ (information dissemination through mike announcements on mobile rickshaw as shown in Figure 3.5) is deemed necessary + local radio and TV, flag hoisting, union chairman, SMS alert, local songs;

3 In the village (Manikanj-Tangail area) they would like the following structural measures: raised housing, floating platforms, flood shelters;

The main findings of Comilla visit were:

1 The source of information is also important for people to gain trust;

2 Getting upstream (Tripura – India) information on water levels is very important to improve early warning in flash flood rivers;

3 The procedure for administration of the data could be enhanced.

Figure 3.5 Local information dissemination using flag signals (left) and information dissemination through mike announcements on mobile rickshaw (right).

4 Identification of Key Issues

4.1 Identification

The identified issues are used to prepare the questionnaires for the first stakeholder consultation session in December 2010. A full copy of the questionnaire including all issues is presented in Annex D.

During the workshop, participants were also requested to complete the overview of issues. Hereafter an overview of new issues is presented (Table 4.1). These new issues were integrated in the further stages of the project.

Table 4.1 New Issues.

S.N.	Issues
1	New gauge stations in the coastal area need to be established
2	Digital elevation model is very necessary for flood mapping
3	Border information
4	Identify critical issues correctly and proceed with priority
5	Linking flood forecasting different water resources in infrastructure
6	Coastal inundation forecasting taken up
7	Strengthening of the hydrology of BWDB with adequate (annual) fund is necessary
8	Trained professionals with long career path in FFWC. Transfer disrupt the knowledge in EW
9	More gauges stations particularly in the coastal area and more fund (FFWC) for the hydrology on an annual basis are required

4.2 Relative importance ranking

After analyzing the individual and group responses of the ‘issue’ questionnaires the results for the technical, institutional and mixed issues are plotted in a scale from 0 to 1. The class boundaries are:

Very important: score > 0.66
Important: score 0.33 – 0.66
Less important: score < 0.33

The outcome is presented hereafter. Table 4.2, Table 4.3 and Table 4.4 show the outcome of the relative importance ranking of technical, institutional and mixed issues, respectively.

Table 4.2 Listing relative importance technical issues.

ID	Technical Issues	Score of issue
	Very Important Issues (score > 0.66)	
T25	Updating of hydrological monitoring network	0.95
T11	Short, medium and long term (seasonal) flood forecasting is required.	0.93
T17	Private cell phone, SMS based forecasting information dissemination technology development is required	0.88
T10	Automation of hydro-meteorological data collection network is crucial	0.87
T20	Development of basin wide river and flood management approach will be helpful	0.848
T8	Inclusion of FCD structures in flood forecasting models will make the FFWC forecasting model more close to the real system	0.847
T13	Development for numerical weather model for improving the lead times is needed	0.831
T19	Lead time provided by FFWC is no more than 48 hours, so that many of the community members, particularly the farmers find such information less than what they need.	0.83
T22	Flood proofing level, flood frequency (Flood standards and statistics) related information should be monitored by the BWDB	0.80
T5	Manual data collection error causes erroneous forecast	0.76
T7	Many of the hydro-metric data stations wash out by the shifting of rivers and very few of them are reinstalled	0.71
	Important Issues (score 0.33 – 0.66)	
T24	Assessing base information needs for reliable forecasting is a pre-requisite	0.66
T12	Hourly prediction will be useful	0.64
T1	Multi hazard risk index mapping is also necessary	0.627
T16	Monitoring tool for understanding the mechanism and tracking the flash flood extent is needed	0.626
T14	Update and upgrade flood forecast model for more reliable results	0.63
T15	Necessity for increase of number of forecast locations for the expansion of forecast	0.593
T3	Proper understanding of flood plain hydrology is lacking	0.592
T4	Regular or intermittent flood mapping showing the depth-duration characteristics of mega and regular flood events is not readily available	0.561
T21	Pre-harvesting flood level (max flood) information is required for agriculturists	0.559
T18	The flood warning provided by FFWC relates to water level at certain gauging stations on the main rivers, which do not prove very useful to people who live on floodplains at a distance from the river.	0.559
T6	Absence of full set of components at the rainfall gauge stations often result in data gaps	0.543
T9	Real time flood monitoring using satellite is useful, but not available readily.	0.542
T2	Baseline for the early warning system is not available	0.33
	Less Important Issues (score <0.33)	
T23	Cloud cover information is required for meteorological forecasts	0.19

Table 4.3 Listing relative importance institutional issues.

ID	Institutional Issues	Score of issue
	Very Important Issues (score > 0.66)	
I1	Initiatives on national and local risk assessment taking into account the regional/transboundary risks, with a view to regional cooperation on risk reduction is not in place	0.93
I15	Proper planning is required for design and implementation of rehabilitation measures	0.91
I18	Updating of hydrological monitoring network	0.9
I10	Reduction of flood hazard risk through community participation	0.85
I14	Capacity development for the professionals engaged in dissemination of flood information is important	0.84
I7	There exists lack of clarity in existing warning messages. Easily understandable communication material and documents should be prepared and disseminated	0.78
I13	Project or government initiated software activities (training, campaign, motivation, meetings, and courtyard sessions) as a component of flood emergency responses should be more intensive and continuous. The software activities should be repeated over the period of time on the same locations	0.76
	Important Issues (score 0.33 – 0.66)	
I16	Strengthening of FFWC's mandate for widening its dissemination system across different institutions is required	0.64
I5	Development of community-based training and capacity building for warning dissemination is required	0.62
I4	Participatory based early warning dissemination network will be helpful	0.60
I3	The district, upazila or union level institutions do not receive any location specific formal prediction information to be disseminated among the vulnerable people	0.58
I19	Strengthening disaster management linkages and coordination mechanisms between government, international and national NGOs	0.58
I9	The information on outbreak of various water borne diseases to the institutions responsible for providing medical services should be disseminated quickly so that the situation does not turn out to be epidemic in nature	0.57
I2	Stakeholders at the community level hardly receive any formal flood prediction information to take up necessary preparatory measures. Information collected through indigenous ways is not very reliable and no substitute for more authentic forecasts. They need long-term as well as short-term prediction information	0.56
I12	Poor level of understanding of the beneficiaries regarding sanitation and hygiene practices	0.49
I11	Lack of awareness/understanding of the users on the safe operation of the WATSAN infrastructures	0.47
	Less Important Issues (score <0.33)	
I17	Improvement of FFWC institutional status or organizational autonomy to control and utilize allocated resources will be helpful	0.28
I6	Insufficient dissemination due to communication link among upazila, union and mouza level	0.26
I8	Some social workers try to build up awareness among the community members to take up various preparatory measures like storing of food, raising of the tube wells so that these remain functional even during floods. But due to the absence of effective prediction information it becomes difficult to make the people adopt adequate preparatory measures	0.24

Table 4.4 Listing relative importance mixed issues.

ID	Mixed Issues	Score of issue
	Very Important Issues	
TI8	Timely and accurate flood forecasting need is crucial.	0.95
TI26	Updating of hydrological monitoring network	0.94
TI9	Increasing the lead time of flood predictions by integrating transboundary input data sources in the river models of the FFWC would give stakeholders more time to prepare for the flood event	0.9
TI6	Most up to date and reliable topographic data and land use data is not used in the flood forecasting model which lead to erroneous forecast	0.89
TI25	Capacity building of FFWC's hardware and software requirement is essential	0.89
TI24	Proper planning is required for design and implement of rehabilitation measures	0.87
TI1	National and local risk assessment based on hazard data and vulnerability information is not available. Risk assessment for key sectors is also absent	0.82
I13	Project or government initiated software activities (training, campaign, motivation, meetings, and courtyard sessions) as a component of flood emergency responses should be more intensive and continuous. The software activities should be repeated over the period of time on the same locations	0.75
TI3	Basin wide data/ information is a pre-requisite for reliable forecasting, which is scanty and it affects the quality of flood forecasting by FFWC	0.73
TI7	There exists deficiency in the accuracy and reliability of flood forecast made by the FFWC	0.73
TI5	Insufficient O & M of automatic stations often create malfunctioning of the apparatus and creates data gap	0.72
TI16	More location specific information is needed by the concerned institutions, and it should be presented in formats that institutions and local people find relevant.	0.70
TI10	Evaluation of on-going community early warning pilots including FFWS	0.68
TI27	Develop ward level contingency plans	0.68
TI21	Operation and maintenance of the hardware intervention was found poor.	0.67
	Important Issues	
TI12	Establishment of network with other international institutes will improve flood forecasting and dissemination	0.66
TI11	Support to community radio for high risk areas	0.58
TI4	Hydro-metric data are not collected during night time, hence only data are available for 12 hours in a day	0.53
TI17	River system model based forecasting done by the FFWC does not provide the kind of location specific information that community members often ask for.	0.51
TI19	No flood damage assessment guideline is present. For post-flood rehabilitation to take place effectively, it becomes necessary to undertake proper damage assessment	0.50
TI18	Development of early warning information package, relevant to different institutions is crucial	0.49
TI13	Flood shelter proximity information dissemination to the people for emergency movement during disaster	0.49
TI22	Many flood control structures have been erected, but there has been little initiative from different organizations to take preparatory measures to minimize the impact of flooding	0.49
TI20	Realization of the benefit of the hardware interventions (raised platform latrines,	0.47

ID	Mixed Issues	Score of issue
	tube wells) during floods was poor, as the respondents found immature to grasp the full utility of the given facilities.	
TI15	Radio, TV and newspaper generally disseminate some flood information, which mainly dwell with the status of floods and some general trends, rather than prediction about floods.	0.39
	Less Important Issues	
TI23	It is imperative that flood affected households are supplied with food items to tide over the flood, as their stock of food is exhausted before the flood is over	0.30
TI14	As NGOs do not have the prediction information to share with the local peoples and hence they are not able to implement any specific preparation program in a comprehensive manner.	0.27
TI2	Food topology and classification of different types of flood is grossly present that often lead to confusions	0.26

Discussion

The results of the survey need careful interpretation. The main objective of this activity was not yet to perform a priority ranking. The main focus was to complete the overview of all issues. However, by asking the stakeholders to provide a relative importance ranking the team could obtain more feeling for the clustering in possible interventions. Also the existence of missing issues and overlapping issues becomes clearer. It is striking to see that only very few issues are ranked as ‘less important’.

5 Dependency Test

5.1 Dependency test

The first step from issues towards interventions is an analysis of overlapping issues. In several cases it appeared that issues that were ranked as very important, also (implicitly) cover issues that were classified as less important. Furthermore it is likely that one intervention covers several issues. Examples of overlapping technical issues are:

TI9	Increasing the lead time of flood predictions by integrating transboundary input data sources in the river models of the FFWC would give stakeholders more time to prepare for the flood event

and

TI3	Basin wide data/ information is a pre-requisite for reliable forecasting, which is scanty and it affects the quality of flood forecasting by FFWC

Examples for overlapping institutional issues are:

I7	There exists lack of clarity in existing warning messages. Easily understandable communication material and documents should be prepared and disseminated by the responsible agency for the area of their responsibility

And

I3	The district, upazila or union level institutions do not receive any location specific formal prediction information to be disseminated among the vulnerable people

5.2Clustering and cascading

A clustering is made for all issues following the structure of the 6 cascade classes plus cross cutting issues. In Annex F the list of clustered issues under the cascade headings is presented. This listing has been thoroughly discussed with the main stakeholders at FFWC. The Table hereafter illustrates the clustering of issues. In the final definition of interventions the relative importance and cross reference with the '2006 review study' was also taken into account. The summary of recommendations of the '2006 review study' is presented in Annex B.

The structure of cascades with cross cutting issues is used for the MCA and SWOT-AHP and the discussion with the stakeholders during the second consultation workshop in March 2011. A full listing of the classified and clustered interventions is included in Annex F. The Table hereafter is highlighting one example (Table 5.1).

Table 5.1 Example of clustered issues.

Coding	Normalized total result	Recommendation ADB 2006	Issues: Maintenance and density of monitoring network
T25	0.9	A1, B1	Updating of hydrological monitoring network
T15	0.6	A1, B1	Necessity for increase of number of forecast locations for the expansion of forecast
T6	0.5	A1, B1	Absence of full set of components at the rainfall gauge stations often result in data gaps

The shortlist of interventions is used as base for the second stakeholder consultation workshop and the MCA and SWOT-AHP. The shortlist of interventions is included in Annex E.

6 Ranking of Interventions

6.1 Institutional response

In preparation of the second stakeholder consultation workshop on 16 March 2011, individual institutional interviews were held to:

- Flood Forecasting Warning Centre (FFWC);
- Bangladesh Meteorological Department (BMD);
- Disaster Management Bureau (DMB);
- Institute of Water Modelling (IWM);
- Bangladesh University of Engineering & Technology – Institute of Water And Flood Modelling (BUET – IWFM);
- Centre for Environmental and Geographic Information Services (CEGIS);
- Centre for Natural Resources Studies (CNRS) (NGO).

For all cascades including cross cutting issues and all interventions, each stakeholders was requested to respond on the MCA and the SWOT–AHP. Through the response on these interviews the team created the opportunity to compare these results with the group response from the working sessions on 16 March 2011.

The results were processed with web-based software (Make it rational). Hereafter the results were presented in tabular (Table 6.1 and Table 6.2) format, and split in the MCA approach and SWOT–AHP.

Table 6.1 Score on MCA approach per Organization.

		MCA score per Organisation						
Cascade	**Intervention**	**CNRS**	**BUET-IWFM**	**DMB**	**FFWC**	**CEGIS**	**BMD**	**IWM**
1. Risk knowledge	1-1 National and local level risk assessment	27.97	73.52	24.49	72.57	75	72.23	29.26
	1-2 Integrated planning for FEWS	62.67	5.81	9.02	21.22	12.5	7.27	64.06
	1-3 Formal and informal education	9.36	20.67	66.48	6.21	12.5	20.5	6.68
2. Monitoring and data acquisition	2-1 Development of base information	5.03	11.12	13.57	14.75	3.55	22.13	6.42
	2-2 Manual data collection	2.27	2.79	7.09	5.92	11.84	5.09	11.75
	2-3 Automatic data collection	9.62	9.69	11.26	9.91	2.53	10.01	48.68
	2-4 Improve data quality	20.71	21.76	15.62	23.11	19.51	20.49	2.33
	2-5 Operation & Maintenance of the monitoring network	18.36	42.51	7.21	39.4	39.49	3.34	10.75
	2-6 Expanding the range of data acquisition	20.71	8.04	21.72	2.63	10.51	18.06	17.2
	2-7 Regular monitoring of flood events by satellite data	23.3	4.08	23.53	4.27	12.57	20.88	2.87
3. Forecasting and Warning	3-1 Model accuracy and upgrade software	8.77	17.13	16.77	19.47	7.8	33.33	5.62
	3-2 Flood forecast Model development	13.92	7.82	48.36	8.81	28.72	33.33	24.3

		MCA score per Organisation						
Cascade	**Intervention**	**CNRS**	**BUET-IWFM**	**DMB**	**FFWC**	**CEGIS**	**BMD**	**IWM**
	3-3 Expansion of forecasting capacity and number of institutes	77.31	75.04	34.87	71.72	63.48	33.33	70.09
4. Dissemination and communication	4-1 Extending the range of dissemination	6.51	12.96	9.24	8.19	18.75	33.33	18.65
	4-2 More precise and user friendly warning	57.35	13.77	42.32	68.17	6.25	33.33	12.65
	4-3 Capacity building for dissemination	36.14	73.27	48.44	23.63	75	33.33	68.7
5. Information type and reliability	5-1 More precise and location specific information	66.67	83.33	83.33	83.33	75	50	25
	5-2 Update warning information timely manner	33.33	16.67	16.67	16.67	25	50	75
6. Response capability	6-1 Capacity development of community	33.33	87.5	83.33	85.71	85.71	50	50
	6-2 Community preparedness	66.67	12.5	16.67	14.29	14.29	50	50
7. Cross cutting issues	7-1 FFWC capacity building	8.88	20.5	16.92	65.19	66.48	33.33	62.67
	7-2 Strengthening of organizational status	35.22	72.23	44.34	11.3	24.49	33.33	27.97
	7-3 International cooperation	55.9	7.27	38.74	23.51	9.02	33.33	9.36

Table 6.2 SWOT–AHP score per organization.

Intervention	**Alternative**	**CNRS**	**BUET-IWFM**	**DMB**	**FFWC**	**CEGIS**	**BMD**	**IWM**
Cascade 1 Risk Knowledge								
National and local level risk assessment	1 Strengths	12.11	50.44	10.33	27.16	20.49	15.3	36.29
	2 Weaknesses	27.14	30.67	47.15	7.83	30.61	8.47	32.61
	3 Opportunities	14.45	14.31	15.25	56.21	44	47.46	14.8
	4 Threats	46.3	4.58	27.28	8.81	4.9	28.78	16.3
Score (National and local level risk assessment)		0.361656	1.836879	0.343679	5.010216	1.816108	1.684832	1.044572
Integrated planning for FEWS	1 Strengths	5.1	8.28	11.73	57.43	15.29	18.15	30.76
	2 Weaknesses	65.72	64.25	50.24	23.54	40.68	56.56	10.19
	3 Opportunities	9.85	21.73	22.65	10.85	37.4	17.36	47.89
	4 Threats	19.33	5.75	15.38	8.19	6.63	7.93	11.16
Score (Integrated planning for FEWS)		0.175779	0.428714	0.523926	2.151907	1.113718	0.550628	3.683841
Formal and informal education	1 Strengths	50.48	40.9	43.11	54.72	36.99	13.82	37.5
	2 Weaknesses	11.21	9.99	20.66	7.9	16.56	24.72	9.09
	3 Opportunities	24.83	42.02	22.41	23.7	41.67	55.28	16.62
	4 Threats	13.49	7.1	13.82	13.68	4.77	6.18	36.78
Score (Formal and informal education)		3.048988	4.85196	1.900232	3.63392	3.687764	2.236246	1.179856
Cascade 2 Monitoring and data acquisition								
Development of base information	1 Strengths	33	26.64	11.86	56.05	10.2	36.01	12.46
	2 Weaknesses	14.04	12.37	52.16	6.64	47.99	13.36	7.6
	3 Opportunities	19.96	5.26	23.2	24.38	19.9	7.4	24.01
	4 Threats	33	55.73	12.78	12.92	21.92	43.23	55.92

Intervention	Alternative	CNRS	BUET-IWFM	DMB	FFWC	CEGIS	BMD	IWM
Score (Development of base information)		1.12585	0.468429	0.539883	4.111963	0.430554	0.767097	0.57415
Manual data collection	1 Strengths	14.29	4.17	10.7	57.43	5.63	11.56	26.02
	2 Weaknesses	42.39	58.35	41.55	23.54	65.36	42.14	16.36
	3 Opportunities	35.98	11.66	29.26	10.85	23.39	9.19	52.82
	4 Threats	7.34	25.82	18.5	8.19	5.63	37.11	4.79
Score (Manual data collection)		1.010859	0.188072	0.665445	2.151907	0.40879	0.26183	3.72766
Automatic data collection	1 Strengths	6.08	5.44	11.94	28.04	4.88	7.76	25.85
	2 Weaknesses	33.5	49.49	45.98	10.16	51.73	20.51	54.45
	3 Opportunities	9.45	10.02	20.09	54.21	29.98	21.32	6.89
	4 Threats	50.97	35.04	21.99	7.59	13.41	50.41	12.82
Score (Automatic data collection)		0.183852	0.182894	0.471237	4.633803	0.535155	0.410039	0.486695
Improve data quality	1 Strengths	7.25	12.69	9.02	27.36	7.68	13.21	27.2
	2 Weaknesses	15.53	47.75	38.9	9.16	63.69	7.69	9.56
	3 Opportunities	45.73	35.82	25.72	53.29	20.05	57.16	53.78
	4 Threats	31.48	3.74	26.36	10.19	8.58	21.93	9.46
Score (Improve data quality)		1.126994	0.942125	0.532332	4.167959	0.3837	2.37576	4.257624
Operation & Maintenance of the monitoring network	1 Strengths	4.49	62.46	15.84	56.67	16.1	15.11	58.59
	2 Weaknesses	11.7	8.81	39.07	13.58	6.72	18.01	26.05
	3 Opportunities	18.89	22.44	14.61	14.29	24.45	59.33	7.34
	4 Threats	64.92	6.29	30.48	15.46	52.72	7.54	8.01
Score (Operation & Maintenance of the monitoring network)		0.305142	5.622517	0.437815	2.443526	0.682201	2.913503	1.935702
Expanding the range of data acquisition	1 Strengths	5.27	21.56	16.3	59.47	7.06	63.77	47.54
	2 Weaknesses	17.2	54.62	32.61	8.75	16.39	21.34	9.73
	3 Opportunities	20.26	18.73	14.8	22.78	28.51	7.19	19.98
	4 Threats	57.27	5.09	36.29	9	48.05	7.69	22.74
Score (Expanding the range of data acquisition)		0.342823	0.674761	0.451379	4.633803	0.551986	2.444368	2.079458
Regular monitoring of flood events by satellite data	1 Strengths	30.25	19.33	19.48	49.46	9.5	11.81	6.02
	2 Weaknesses	13.32	61.47	43.36	22.42	57.46	3.85	15.03
	3 Opportunities	15.36	7.12	17.68	19.35	11.21	53.68	30.79
	4 Threats	41.08	12.08	19.48	8.76	21.84	30.66	48.16
Score (Regular monitoring of flood events by satellite data)		0.838419	0.359619	0.591343	2.206863	0.26116	1.897711	0.582529
Cascade 3 Forecasting and warning								
Model accuracy and upgrade software	1 Strengths	6.47	5.43	12.22	31.62	5.47	5.72	70
	2 Weaknesses	53.37	57.32	19.04	8.35	55.55	31.9	10
	3 Opportunities	27.11	18.15	45.44	48	28.08	33.32	10
	4 Threats	13.05	19.1	23.3	12.03	10.9	29.06	10
Score (Model accuracy and upgrade software)		0.505571	0.308558	1.361833	3.906771	0.504891	0.64042	4
Flood forecast Model development	1 Strengths	5.64	27.59	15.16	25.9	23.3	12.06	31.18
	2 Weaknesses	41.1	4.85	26.25	9.48	13.7	30.42	11.99
	3 Opportunities	39.42	58	45.47	53.58	56.54	11.1	50.3
	4 Threats	13.84	9.56	13.13	11..04	6.46	46.42	6.53
Score (Flood forecast Model development)		0.820167	5.939625	1.539614	3.873294	3.960317	0.301406	4.399568

Intervention	Alternative	CNRS	BUET-IWFM	DMB	FFWC	CEGIS	BMD	IWM
Expansion of forecasting capacity and number of institutes	1 Strengths	5.61	22.91	11.22	52.49	16.84	9.49	14.23
	2 Weaknesses	30.53	63.88	21.01	15.11	18.69	39.01	27.02
	3 Opportunities	29.04	6.24	29.44	16.2	57	13.44	48.98
	4 Threats	34.82	6.97	38.33	16.2	7.46	38.06	9.77
Score (Expansion of forecasting capacity and number of institutes)		0.530222	0.411433	0.685204	2.193868	2.823709	0.297522	1.71813
Cascade 4 Dissemination and communication								
Extending the range of dissemination	1 Strengths	17.15	20.02	6.66	54.99	14.11	17.11	61.24
	2 Weaknesses	64.3	8.98	24.13	8.75	41.73	8.1	25.49
	3 Opportunities	10.49	5.14	52.32	25.27	38.44	49.94	7.62
	4 Threats	8.06	65.86	16.9	10.98	5.72	24.85	5.65
Score (Extending the range of dissemination)		0.381979	0.336184	1.437485	4.067917	1.107482	2.034901	2.211304
More precise and user friendly warning	1 Strengths	8.71	19.82	12.36	57.14	28.21	9.59	66.91
	2 Weaknesses	61.56	8.38	42.32	14.29	9.15	50.72	9.16
	3 Opportunities	12.32	67.75	34.46	14.29	57.41	26.69	8.1
	4 Threats	17.41	4.05	10.86	14.29	5.23	13	15.83
Score (More precise and user friendly warning)		0.266304	7.045052	0.880406	2.4993	5.954103	0.569366	3.001601
Capacity building for dissemination	1 Strengths	18.12	52.54	9.48	52.49	23.31	11.55	20.31
	2 Weaknesses	45.22	13.21	25.9	15.11	8.32	24.41	6.28
	3 Opportunities	6.89	5.82	53.58	16.2	63.73	57.04	63.48
	4 Threats	29.77	28.43	11.04	16.2	4.63	7.01	9.93
Score (Capacity building for dissemination)		0.333511	1.401537	1.707093	2.193868	6.721236	2.183004	5.169031
Cascade 5 Information type and reliability								
More precise and location specific information	1 Strengths	5.09	4.83	9.39	52.29	12.5	10.72	61.59
	2 Weaknesses	44.53	59.72	22.09	9.88	32.29	36.06	8.19
	3 Opportunities	19.04	10.61	43.27	26.26	50.17	39.46	22.7
	4 Threats	31.34	24.84	25.25	11.58	5.05	13.76	7.53
Score (More precise and location specific information)		0.318044	0.182592	1.112379	3.660298	1.678361	1.007226	5.361959
Update warning information timely manner	1 Strengths	39.52	25.49	15.89	54.15	7.98	20.17	57.77
	2 Weaknesses	27.81	12.16	13.14	11.53	50.44	10.2	23.09
	3 Opportunities	16.34	4.66	44.71	22.62	32.02	53.59	11.35
	4 Threats	16.34	57.69	26.27	11.71	9.56	16.04	7.79
Score (Update warning information timely manner)		1.265232	0.431639	1.537681	3.303356	0.666667	2.810976	2.238342
Cascade 6 Response capability								
Capacity development of community	1 Strengths	14.49	23.54	25.5	58.28	25.6	9.87	61.59
	2 Weaknesses	43.69	10.95	12.22	17.13	5.13	24.09	7.12
	3 Opportunities	33.91	60.75	49.04	8.91	15.56	53.68	22.59
	4 Threats	7.91	4.76	13.25	15.68	53.71	12.36	8.7
Score (Capacity development of community)		0.937984	5.365372	2.92658	2.047851	0.699524	1.743484	5.321113
Community preparedness	1 Strengths	5.92	24.54	11.47	49.04	9.22	19.53	20.15
	2 Weaknesses	55.71	11.55	25.93	12.22	58.96	51.11	24.83
	3 Opportunities	11.15	58.35	49.24	25.5	22.61	8.77	12.48
	4 Threats	27.22	5.55	13.36	13.25	9.22	20.59	42.54

Intervention	**Alternative**	**CNRS**	**BUET-IWFM**	**DMB**	**FFWC**	**CEGIS**	**BMD**	**IWM**
Score (Community preparedness)		0.205836	4.847368	1.545177	2.92658	0.466852	0.3947	0.48434
Cascade 7 Cross cutting issues								
FFWC capacity building	1 Strengths	12.41	46.42	10.17	27.15	4.98	31.82	49.98
	2 Weaknesses	31.1	32.42	36.5	8.89	27.77	12.3	26.62
	3 Opportunities	43.35	4.51	19.18	53.2	15.88	45.32	15.22
	4 Threats	13.14	16.64	34.16	10.76	51.37	10.56	8.18
Score (FFWC capacity building)		1.260398	1.038117	0.415369	4.089059	0.263584	3.374453	1.873563
Strengthening of organizational status	1 Strengths	9.47	32.83	20.09	55.91	14.4	28.07	50.57
	2 Weaknesses	46.88	41.1	11.94	10.16	23.91	10.21	10.67
	3 Opportunities	16.81	15.26	45.98	23.76	51.62	10.21	32.78
	4 Threats	26.83	10.81	21.99	10.16	10.08	51.51	5.98
Score (Strengthening of organizational status)		0.356532	0.926411	1.947244	3.920768	1.942336	0.62022	5.006006
International cooperation	1 Strengths	15.34	15.18	7.25	54.14	8.23	9.66	28.33
	2 Weaknesses	49.46	19.52	17.24	10.69	50.87	38.08	7.91
	3 Opportunities	13.37	4.96	49.75	22.5	30.7	18.74	57.14
	4 Threats	21.83	60.34	25.75	12.68	10.2	33.53	6.62
Score (International cooperation)		0.402721	0.252191	1.32589	3.279418	0.637465	0.396593	5.882312

In Table 6.2, score of each intervention is calculated by using rating on its Strengths, Weaknesses, Opportunities and Threats as follows.

Score (Intervention)
= (Rating on strengths + Rating on opportunities) / ((Rating on weaknesses + Rating on threats)

Both scores of Table 6.1 and Table 6.2 are combined in a normalized total score for MCA and SWOT and presented in Table 6.3.

Discussion of the results
From the outcome of the MCA it becomes clear that all organizations have their own focus points. However when a SWOT–AHP is done a more consistent image emerges. During the survey it also became clear that the SWOT–AHP is asking more dedicated knowledge from interviewed experts, whereas in the MCA a more intuitive answer may be given. Therefore the project team feels that the SWOT–AHP results should receive more weight in the final classification of the end results and recommendations to the ADB.

Although it is tempting to use the total overall score for ranking, the structure of FEWS cascades needs to be respected. So the overall ranking is presented as relative ranking of each intervention per cascade.

Table 6.3 Overall score for MCA and SWOT-AHP per individual organization.

Cascade	Interventions	CNRS	BUET-IWFM	DMB	FFWC	CEGIS	BMD	IWM	All	Total Rank
1 Risk knowledge	1.1 National and local level risk assessment	38.05	99.33	36.91	118.98	102.44	109.91	46.94	552.56	1
	1.2 Integrated planning for FEWS	67.57	11.83	27.95	41.15	29.33	19.58	126.41	323.83	3
	1.3 Formal and informal education	94.37	88.84	135.13	39.87	68.23	70.51	26.65	523.60	2
2 Monitoring and data acquisition	2.1 Development of base information	27.85	16.67	28.20	31.64	16.78	29.06	10.63	160.83	6
	2.2 Manual data collection	22.76	5.02	25.13	14.76	24.40	7.46	39.07	138.59	7
	2.3 Automatic data collection	13.35	11.86	24.03	28.94	18.98	13.71	52.25	163.12	5
	2.4 Improve data quality and accessibility (completeness and reliability	43.55	32.92	30.05	40.23	31.30	41.95	33.54	253.54	2
	2.5 Operation & Maintenance of the monitoring network	24.54	109.14	19.08	49.44	60.46	29.66	24.94	317.25	1
	2.6 Expanding the range of data acquisition	27.66	16.04	33.95	21.66	27.48	40.14	32.44	199.37	3
	2.7 Regular monitoring of flood events by satellite data	40.29	8.34	39.56	13.33	20.60	38.02	7.14	167.28	4
3 Forecasting and Warning	3.1 Model accuracy and upgrade software	36.01	21.76	54.74	58.64	14.73	85.00	45.15	316.04	3
	3.2 Flood forecast Model development	58.11	97.01	91.29	47.64	83.05	57.65	67.78	502.54	2
	3.3 Expansion of forecasting capacity to increase lead time and number of forecast institutions	105.88	81.22	53.97	93.72	102.22	57.34	87.07	581.41	1
4 Dissemination and communication	4.1 Extending the range of dissemination	45.42	16.79	44.95	54.62	26.79	75.84	39.95	304.35	3
	4.2 More precise and user friendly warning	84.47	93.98	64.19	96.70	49.45	45.22	41.56	475.58	2
	4.3 Capacity building for dissemination	70.11	89.23	90.85	48.67	123.77	78.93	118.49	620.05	1
5 Information type and reliability	5.1More precise and location specific information	86.76	113.06	125.31	135.89	146.57	76.38	95.55	779.51	1
	5.2 Update warning information timely manner different stages	113.24	86.94	74.69	64.11	53.43	123.62	104.45	620.49	2
6 Response capability	6.1 Capacity development of community	115.33	140.04	148.78	126.88	145.68	131.54	141.66	949.91	1
	6.2 Community preparedness	84.67	59.96	51.22	73.12	54.32	68.46	58.34	450.09	2
7 Cross cutting issues	7.1 FFWC capacity building	71.29	67.33	28.18	101.41	75.75	110.17	77.35	531.49	1

Cascade	Interventions	CNRS	BUET-IWFM	DMB	FFWC	CEGIS	BMD	IWM	All	Total Rank
	7.2 Strengthening of organizational status	52.87	114.02	97.13	46.03	92.80	47.45	67.20	517.51	2
	7.3 International cooperation	75.84	18.65	74.69	52.56	31.44	42.36	55.45	350.99	3

6.2 Stakeholder workshop response

During the second stakeholder consultation in March 2011 the participants representing the different organizations were divided in three groups over the cascades. Every group performed an MCA and SWOT-AHP for 2 cascade classes plus all cross cutting issues.

Again the results were processed with web-based software (Make it rational). The outcome was processed in Excel in order to be able to combine the results of the individual organizations with the workshop group results. The priority ranking of the interventions was carried out in two stages based on the list of clustered interventions.

For the SWOT approach, the project team prepared an overview of possible S-W-O-T factors for each intervention. Instead of comparing the individual interventions the response is now focused on the comparison of SWOT-factors per intervention. With this information it is possible to compare individual interventions based on their scores for the SWOT factors. By concentrating on one intervention at a time the chance on 'biased' answers due to preference of a certain stakeholder will be less. The interviewees are comparing present strength and weakness with future opportunities and threats.

6.3 Prioritization of interventions

Compared to the individual results as presented in Table 6.3, it is noted that no major changes occur between the individual and workshop group results. It is also remarkable that all stakeholders are united in their overall focus on capacity development, increase of model accuracy and attention for operation & maintenance.

The outcome of the workshop groups is considered less biased (e.g. interests of a specific institute) than the outcome of the individual institutions. The outcome was processed in order to be able to combine the results of the individual organizations with the workshop group results. The final priority ranking of the possible interventions is presented hereafter in Table 6.4.

Table 6.4 Combined ranking of interventions using MCA and SWOT-AHP based on workshop group results.

Cascade Classes	Interventions	Ranking
1. Risk knowledge development	1-3 Formal and informal education	1
	1-1 National and local level risk assessment	2
	1-2 Integrated planning for FEWS	3
2. Monitoring and data acquisition	2-5 Operation & Maintenance of the monitoring network	1
	2-6 Expanding the range of data acquisition	2
	2-7 Regular monitoring of flood events by sat data	3
	2-4 Improve data quality	4
	2-3 Automatic data collection	5
	2-1 Development of base information	6
	2-2 Manual data collection	7
3. Forecasting and warning	3-1 Model accuracy and upgrade software	1
	3-2 Flood forecast model development	2
	3-3 Expansion of forecast and number of institutes	3
4. Dissemination and communication	4-2 More precise and user friendly warning	1
	4-3 Capacity building for dissemination	2
	4-1 Extending the range of dissemination	3
5. Information type and reliability	5-1 More precise and location specific information	1
	5-2 Update warning information timely manner	2
6. Response capability	6-1 Capacity development of community	1
	6-2 Community preparedness	2
7. Cross cutting issues	7-1 FFWC capacity building	1
	7-3 International cooperation	2
	7-2 Strengthening of organizational status	3

These results were presented to the BWDB as a preliminary National Road Map for FEWS in March 2011.

Figure 6.1 Preliminary National Road Map.

7 Pre-feasiblity of Interventions

7.1 Results

The ranking of the interventions as presented in Table 6.4 needs further elaboration in terms of feasibility. Therefore a (qualitative) pre-feasibility analysis of the priority interventions was performed in consultation with the main stakeholders. This pre-feasibility analysis forms the final step towards a National Road Map for FEWS. The results of Table 6.4 were classified in terms of:

- Technical aspects such as: the availability of data, equipment, software;
- Socio-cultural aspects comprising: the acceptance of warning information, response capacity, level of awareness;
- Institutional aspects: the mandate, user demands, legal feasibility, existing laws and regulations, enforcement, organization capacity;
- Financial aspects consider the availability of budget for: purchase, operation & maintenance, capacity development.

All aspects were scored. The following are the criteria for scoring range for prioritizing the intervention at pre-feasibility level. These qualitative scoring ranges are high, medium and low indicated by the range of scoring symbol. These criteria are based on expert judgement in combination with input from the main stakeholder FFWC.

Score range low, medium, high feasibility

Technical	- Low if the technology is not ready, not available, large capacity building and training needed - Medium - High if technology is already available in the organization and if well trained staff is available
Socio-cultural	- Low if there is no acceptance for the intervention or the local end-users do not see the benefit or the solution is to high end or technical/expensive for end-users - Medium - High if the intervention is proposed by the end-users itself, if the intervention is really taken into account their needs, if the intervention will be ‘owned’ by the end-users
Institutional	- Low if there is no acceptance and no ownership, or cooperation and involvement of institutes. Low if there are no laws and regulations or no enforcement in place - Medium - High if there is clear ownership and laws, regulations and law enforcement is in place
Financial	- Low if the funding is not available, the intervention is expensive and not cost effective, the intervention needs large O&M cost in the future - Medium - High if (own) funding is available, if the intervention is cost-effective and if a clear O&M planning is available

In case one of the criteria of the selected interventions is scored ‘medium low’ it means that there exist considerable bottlenecks for the implementation of related actions. In Table 7.1 an overview is presented of all interventions (as classified in Table 6.4) and the scoring of the pre-feasibility criteria.

Table 7.1 Pre-Feasibility analysis of main priority interventions (derived from expert judgment BWDB, FFWC and CEGIS experts)

Cascade	First Priority intervention	Tech-nical	Socio-cultural	Institu-tional	Finan-cial	Second Priority intervention	Tech-nical	Socio-cultural	Institu-tional	Finan-cial
1. Risk knowledge development	Formal and informal education	++	++	+++	+	National and local level risk assessment	+++	++	++	+++
2. Monitoring and data acquisition	Operation & maintenance of the monitoring network	++	++	+	+	Expanding the range of data acquisition	++	++	+++	++
3. Forecasting and warning	Model accuracy and upgrade software	+++	++	+++	++	Flood forecast model development	+	+	+	+
4. Dissemination and communication	More precise and user friendly warning	+++	+++	++	++	Capacity building for dissemination	+++	+++	++	++
5. Information type and reliability	More precise and location specific information	+++	++	++	++	Update warning information timely manner	+++	++	++	++
6. Response capability	Capacity development of community	+++	++	+	++	Community preparedness	++	+++	+	++
7. Cross cutting issues	FFWC capacity building	+++	+++	+++	++	International Cooperation	+++	+	+	+++

Range of Symbol	Descriptions (based on expert judgment)
+++	Very High - High feasibility which means that the priority interventions is very likely to be implemented
++	Medium
+	Medium - Low which means that the priority interventions will not be implemented easily

7.2 Discussion on pre-feasibility analysis

The results of the pre-feasibility analysis as presented in Table 7.1 will lead towards the National Road Map for FEWS development. By combining the input for all factors (Technical, Socio-cultural, Institutional and Financial) a cross-sector assessment was performed resulting in an overall value for the pre-feasibility of each intervention. The criteria for the assessment are:

Range of feasibility	**Descriptions (based on expert judgment)**
Very high	All factors score high, which means that the priority interventions is very likely to be implemented
High	All factors score high but one score medium. Implementation will be likely without big constraints
Medium High	Two factors score medium which means that the priority interventions could be implemented with some effort
Medium	All factors scored 'medium'
Medium - Low	At least one of the factors has scored 'low' which means that implementation will face difficulties.

Since all interventions are already classified 'with priority' the stakeholders expect that all interventions will be implemented.

8 National Road Map for FEWS Development

The final results are presented in Table 8.1 and Table 8.2 and the results are also drafted in the form of National Road Map for FEWS development in Bangladesh (Annex I). Subsequently, a timeline and sequence for the selected interventions is presented in Figure 8.1. A draft National Road Map was presented and discussed at workshop in January 2012 in Dhaka and it is finalized by improving the comments received in the workshop. The detail of workshop is described in Annex J. For the most feasible interventions (very high and high) a ‘design and monitoring framework’ was prepared in accordance to the ADB guideline as part of the NRM document. It is presented in Annex I.

Table 8.1 National Road Map for FEWS Development in Bangladesh

Cascade	**Priority intervention**	**Short Description of the intervention (more details are presented in Annex F)**	**Pre-feasibility**	**Short background on the score based on expert judgment**
1. Risk knowledge development	1. Formal and informal education	• Training for practitioners and community people; • Educational program (school curriculum) development; • Awareness campaign including drills and exercise.	Medium	Institutionally feasible but funding is deemed difficult
	2. National and local level risk assessment	• Develop flood vulnerability criteria for different land use functions (agriculture, infrastructure, fisheries, urban) and different types of flooding; • Prepare flood hazard maps at different levels (national and upazila) and type of flood.	High	Technical knowledge and funding available. Involvement of grass root level and governmental institutes needs attention
2. Monitoring and data acquisition	1. Operation & maintenance of the monitoring network	• Prepare technical Operation & Maintenance (O&M) planning for long term (1 year and 5 year plan and short term per flood season and weekly – daily); • Prepare a realistic O&M budget based on technical planning; • Set up and implement a service unit to manage O&M of all measuring stations including workshop for storage and repair of spare parts.	Medium-low	Technically feasible and wanted by stakeholders but funding as well as institutional organization is deemed a huge constraint
	2. Expanding the range of data acquisition	• Extend model boundaries to Ganges Brahmaputra Meghna basin; • Include observations based on remote sensing and satellite technique data outside Bangladesh; • Validate runoff data with measurements at the border of Bangladesh; • Improve coordination and collaboration with bordering countries (investment for data measurement may be required); • Increase temporal resolution to address the different sectors; • Forecast for short term for humans, cattle crop and harvest, respectively (1 – 3 – 7 days).	High	Technically feasible and wanted by all stakeholders. Budget will be no constraint and good cooperation and ownership of implementing agencies is expected
3. Forecasting	1. Model	• Upgrade the validation procedure for the model output with	Medium-	Technically feasible and wanted by

Cascade	Priority intervention	Short Description of the intervention (more details are presented in Annex F)	Pre-feasibility	Short background on the score based on expert judgment
and warning	accuracy and upgrade software	observed data (cross-section, rating curve); • Use most recent software version as well as a simple model; • Set up guideline for model accuracy parameters and reliability, spatial and temporal resolution of the model output.	high	all stakeholders. Budget will be no constraint and good cooperation and ownership of implementing agencies is expected
	2. Flood forecast model development	• Include satellite rainfall data with high spatial and temporal resolution; • Expand model boundaries up to GBM basin • Include high resolution DEM; • Include hydraulic structures (dams, levees, ponds, etc.) in the model as well as any physical change in the river system (erosion, deposition, etc).	Medium-high	Technically and financially possible but more specific expertise needed. International cooperation will be difficult to achieve for data quality control and validation
4. Dissemination and communication	1. More precise and user friendly warning	• Set up procedure for SMS alert using mobile phone; • Link Flood Hazard Map (historical and simulated) with FEWS; • Distribute FHMs at community levels; • Prepare communication plan for broadcast of flood warnings through community radio and others translated and understandable information per end-user group.	High	Technical feasible and much wanted by all stakeholders. Budget will be no constraint and good cooperation and ownership of implementing agencies is expected
	2. Capacity building for dissemination	• Capacity building to community people in emergency response (emergency planning); • Promote community based FEWS, similar to Comprehensive Disaster - Management Program (CDMP) and CEGIS previous project. • Set up separate unit at FFWC to translate central forecast and flood warnings for different end-user (agriculture, fish, infrastructure) specific information at different scale levels (regional & local).	High	Technical feasible and much wanted by all stakeholders. Budget will be no constraint and good cooperation and ownership of implementing agencies is expected
5. Information type and reliability	1. More precise and location specific	• Prepare warnings dedicated for stakeholder groups at appropriate scale levels.	Medium-high	Technical feasible and wanted by all stakeholders. Institutionally feasible and budget is no constraint.

Cascade	Priority intervention	Short Description of the intervention (more details are presented in Annex F)	Pre-feasibility	Short background on the score based on expert judgment
	information			
	2. Update warning information in timely manner	• Make "Standing Order for Disaster" effective; • Show different degrees of danger through different stages of warning.	Medium-high	Technically feasible and wanted by all stakeholders. Institutionally feasible and budget is no constraint.
6. Response capability	1. Capacity development of community	• Institutionalize community-based DRM group within district disaster managed communities; • Include dissemination to medical services (NGOs) in FEWS; • Create volunteer rescue group; • Support community with basic equipments for early warning dissemination within community; • Establish proper communication channel within community; • Set up and conduct community awareness campaigns and training sessions based on participatory approach for FEWS (include the user requirements and information demands).	Medium	Technically very feasible and wanted by stakeholders but institutional organization is deemed a huge constraint
	2. Community preparedness	• FFWC should have physical presence (offices) at district authority; • Perform cost benefit analysis for measures by stakeholders including flood damage assessment based on flood hazard maps and inform the responsible authority; • Prepare user requirements and demands before disaster.	Medium	Technically feasible and very much wanted by stakeholders but institutional organization is deemed a huge constraint
7. Cross cutting issues	1. FFWC capacity building	• FFWC Capacity building (equipment, hardware, software, training, personnel) to ensure the performance of all tasks related to (decentralized) FEWS.	Very High	Technically and institutionally very feasible and much wanted by stakeholders. Funding is no constraint
	2. International cooperation	• Prepare agreement for exchange of extreme event related data on: o Infrastructure operation; o Basin digital elevation model;	Medium	Although technically feasible it is deemed difficult from political and institutional perspectives. Budget is no problem due to international

Cascade	Priority intervention	Short Description of the intervention (more details are presented in Annex F)	Pre-feasibility	Short background on the score based on expert judgment
		o Basin water level; o Basin weather forecasts; o Basin rainfall; o Basin run off model.		support.

Table 8.2 Overview NRM interventions after pre-feasibility

Cascade	All priority interventions	Pre-feasibility result
7. Cross cutting issues	FFWC capacity building	Very High
1. Risk knowledge development	National and local level risk assessment	High
2. Monitoring and data acquisition	Expanding the range of data acquisition	High
3. Forecasting and warning	Model accuracy and upgrade software	High
4. Dissemination and communication	More precise and user friendly warning	High
4. Dissemination and communication	Capacity building for dissemination	High
5. Information type and reliability	More precise and location specific information	Medium-high
5. Information type and reliability	Update warning information timely manner	Medium-high
3. Forecasting and warning	Flood forecast model development	Medium-high
1. Risk knowledge development	Formal and informal education	Medium
6. Response capability	Capacity development of community	Medium
6. Response capability	Community preparedness	Medium
7. Cross cutting issues	International cooperation	Medium
2. Monitoring and data acquisition	Operation & maintenance of the monitoring network	Medium-low

Since all steps of the disaster cascade need to be addressed in the timeline of interventions, several interdependencies or sequences exist. The timeline (presented in Figure 8.1) is considering an intervention period of at least 7 years. All activities start with the capacity building of the FFWC itself.

Next the national and local level risk assessment will help prepare flood hazard maps and vulnerability zones. This information is needed to improve the forecast model and to address the needs of specific end users in the region in a more location specific manner. Next, capacity building for dissemination forms another large block of activities. The internal FFWC capacity for communication & dissemination needs to be increased first and then only formal and informal education and community involvement can be pursued.

Operation & Maintenance cannot be addressed as a separate intervention. It is integrated in the internal management of the BWDB and the FFWC. Therefore, it is highlighted in the timeline as continuous activity. The intervention cost, implementing agency and duration is also indicated in the timeline. The approximate cost is indicated in million Bangladesh Taka. The total portfolio is expected to be feasible for 725 Million Taka. An indication of investment cost is also given in the Design and Monitoring Framework in the NRM document in Annex I.

Interventions	Time line/Sequence in 3 monthly (quarterly) sections: Year 2013 (Q1 Q2 Q3 Q4)	Year 2014 (Q1 Q2 Q3 Q4)	Year 2015 (Q1 Q2 Q3 Q4)	Year 2016 (Q1 Q2 Q3 Q4)	Year 2017 (Q1 Q2 Q3 Q4)	Year 2018 (Q1 Q2 Q3 Q4)	Year 2019 (Q1 Q2 Q3 Q4)	Duration in years	Approx. cost in Mil BDT	Implementing agency
FFWC capacity building				★				3	70	BWDB
National and local level risk assessment								1.5	60	WARPO
Expanding the range of data acquisition								3	90	BWDB-BMD
Model accuracy and upgrade software								1.5	90	BWDB
Flood forecast and model development								2.5	55	BWDB
More precise and location specific information								2	130	BWDB
Update warning information in timely manner								2	20	BWDB
More precise and user friendly warning								3	55	BWDB-DMB
Capacity building for dissemination								3	40	DMB
Formal and informal education								3	45	Department of education
Capacity development of community								3	35	DMB
Community preparedness								3	35	DMB
Operation & maintenance of the monitoring network								Yearly	20	BWDB
International cooperation			★					2	30	JRC

Time limited activity

Continuous activity

Sequence

★ To be repeated every 3 years

1 Min BDT = 1200 US$ (1 June 2012)

Total Cost excluding yearly O&M cost **755**

Figure 8.1 Timeline of possible interventions in FEWS development

9 Findings and Recommendations

A well functioning FEWS in Bangladesh is of great importance in order to minimize flood damage and casualties. The importance of FEWS is highlighted not only in the context of the changing socio-economic conditions of Bangladesh but also in the context of climate change, which has already had a serious impact in Bangladesh. The majority of flood vulnerable population in rural and urban areas has little access to reliable flood information. The reliability of such information concerns not only the timing and accuracy of flood forecast information but also the process of early warning information development and dissemination as well as the clarity in disseminated information

9.1 Main findings

This Bangladesh component of the TA has been implemented in close cooperation with main stakeholders in flood early warning in Bangladesh. The main general conclusions are as follows:

- The MCA and SWOT–AHP approach is very useful in complex ranking of interventions and investment decisions;
- Intensive contact with the main stakeholders and beneficiaries (BWDB – FFWC) is indispensable for ownership of the project and support for the outcome of the project;
- This project was only possible due to the very well established network in the local flood early warning community of Bangladesh of our counterpart CEGIS;
- Due to the lack of action from ADB related to the 2006 review study there exists a sceptical attitude at Bangladesh Government regarding the possible implementation of new recommendations;
- Nevertheless, the FFWC showed keen interest in the project;
- The concept for a National Road Map for flood early warning system development in Bangladesh is broadly welcomed by all stakeholders throughout the field of flood early warning.
- In Bangladesh three workshops were organized (in December 2010, March 2011 and January 2012), which helped to build a capacity of participants of related organizations of Bangladesh in identification and prioritization of interventions for FEWS and in development of effective FEWS.

Technical conclusions

- Nearly all recommendations of the 2006 review study are still valid;
- A clear understanding amongst the main stakeholders is present regarding the urgency of capacity building, dissemination and communication and community response capability;
- Due to sub optimal communication and dissemination of the flood warnings at regional and local level the flood warning will be less effective and;
- Use of modern telecom techniques in relation to simple techniques for local dissemination (flag system, rickshaw miking, and mosques) has proved very effective (CFIS project).

9.2 Recommendations and way forward

Based on the findings of the TA study the following conclusions and recommendations can be drawn:

General recommendations

- From the two workshops it became clear that it will not be useful to concentrate on one or two interventions only in order to enhance the performance of the FEWS. Based on the

flowchart of Figure 3.3 it is suggested to perform a 'critical path analysis' in order to determine which action or intervention will have the biggest positive effect on the performance;

- Address the strong demand of the end users needs for improved effectiveness and increasing the lead time of the FEWS;
- Besides these case specific findings and recommendations the used methodology (MCA, SWOT–AHP and stakeholder consultation) proved very effective in selection of interventions and priority ranking. Therefore the project likes to propose steps to formalize the use of the SWOT – AHP approach in decision making process for large investments.

Recommendations related to the National Road Map

- A National Road Map for FEWS development in Bangladesh is prepared with clear priority ranking on interventions and actions to be taken (see 'time line' in Figure 8.1 and listing in Table 8.2);
- Overall capacity building of the FFWC (staff, equipment, training) needs to get first priority;
- Capacity building for communication and dissemination is highly wanted by the stakeholders. Cooperation with CDMP-2 is desired;
- A clear understanding amongst the main stakeholders is established regarding the urgency of capacity building, dissemination and communication and community response capability;
- Use of modern telecom techniques in combination with simple techniques for local dissemination (flag system, rickshaw 'miking', mosques) has proved to be a very effective Community Flood Information System (CFIS project);
- Most stakeholders agree upon the urgent need for better dissemination of flood warnings. This includes translation to local level and for specific user groups;
- Subsequent to better dissemination it will be beneficial to create flood hazard maps and damage assessments. Based on such an assessment the dissemination of flood warnings could be more specific for a certain geographic region or end user group. More detailed flood hazard and damage maps per sector would need to be prepared;
- In the review study of 2006 a general cost–benefit analysis per intervention was done. It is recommended to update these cost-benefit analyses for the interventions with the highest priority;
- New, more extensive pilots should be included with a combination of different techniques for communication and dissemination. During one of the field visits (Filed visit Manikganj) the combination of different forecasting and dissemination and communication techniques proved to be very promising and was favoured by local stakeholders. The project (Community Flood Information System CFIS, USAID 2008) combined early flood warning per SMS and local warning with 'flag hoisting'. It is strongly recommended to continue this experiment on a large scale in different areas.

Acknowledgement

This final report of Bangladesh Component is prepared under in-country project support program of Asian Development Bank, Technical Assistance for Supporting Investments in Water-Related Disaster Management (TA7276). The Deltares, Netherland also contributed to prepare this report. We, International Centre for Water Hazard and Risk Management (ICHARM), Public Works Research Institute (PWRI), Japan, would like to express our acknowledgement to Deltares, Netherland for their contribution. We highly appreciate for their support during project implementation and their contribution to prepare this report.

We would also like to express our gratitude to Mr. Katsuhito Miyake, Senior Disaster Risk Management Specialist, the World Bank and Mr. Kimio Takeya, Visiting Senior Advisor, Japan International Cooperation Agency for their kind support to prepare initial implementation plan of Bangladesh Component and for their suggestions when they have been assigned to ICHARM and ADB respectively.

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Annex A

Project Activities and Itinerary

Itinerary of TA7276 Bangladesh Component

The main works performed by ICHARM and International Consultant were as follows:

September – October 2010

- Inception phase. Contact with main stakeholders, preparation of the inception report, start up of the technical and institutional review and preparation of the 1st stakeholder consultation in December 2010.

November – December 2010

- Technical and institutional review, identification of EWS issues, preparation of 1st stakeholder consultation workshop (questionnaires)

December 2010

- 1st stakeholder consultation workshop in Dhaka. Individual and group response on inventory of issues, preparation of long list of issues, commitment and ownership of the main stakeholders, development of the concept for a National Roadmap for floods early warning system development in Bangladesh

January 2011 – February 2011

- Processing of workshop results, dependency test, preparation of clustered list of issues and transition into interventions

February 2011

- Intermediate mission to ensure commitment and involvement of the main stakeholders and beneficiaries. Preparation of the short list of interventions clustered along the cascade steps. Preparation of the SWOT factors and questionnaires. Set up of the software application (Makeitrational)

March 2011

- Preparations of the 2nd stakeholder consultation workshop, Preparation of interviews (7 key stakeholders), carry out the interviews and processing of the results, conduct the 2nd stakeholder workshop and process the results, prepare the interim report.

April 2011 – December 2011

- Preparation National Road Map and regional exchange workshop in Nepal
- Continued contact with the project through parallel activities in Bangladesh
- Extension of the project until 29th February 2012
- Participation at ADB Water Learning week in Manila (November 2011)

January 2012

- Knowledge transfer workshop in Nepal and presentation of the (Draft) National Road Map at BWDB and FFWC in Dhaka.
- Preparation of the final report and recommendations to ADB.

Annex B

Summary Recommendations 2006 EWS Study

Chapter 8

Summary and Recommendations

8.1 Summary

Floods continue to be a major hazard in Bangladesh. Floods in 1987, 1988, 1998 and 2004 caused widespread damage in rural and urban areas and set back the country's efforts to alleviate poverty. The impacts of floods are expected to worsen as the vulnerability of Bangladesh to natural disasters is increasing due to several factors including poverty, worsening environmental soundness, population growth, urban growth, weak governance and institutional factors, and climate change and variability.

The Early Warning System (EWS) for floods in Bangladesh developed from the flood forecasting work of BWDB's Flood Forecasting and Warning Centre (FFWC). FFWC was established in 1972, and, since then, FFWC developed a comprehensive system of collecting and processing hydrologic and other data as input to forecasting models; preparing flood forecasts and warnings on a daily basis during the flood season and disseminating the forecasts and warnings to a range of government and non-government organizations, media groups and other interested parties. FFWC's system for preparing 3-day flood forecasts and warnings is well established for stations on major and secondary rivers and produces reasonable forecasts, especially for the central region of the country. Their system has evolved to incorporate new technologies that increase the accuracy and reliability of flood forecasts.

Dissemination of flood warnings is much less developed, and works only at national level. There are considerable weaknesses in making warning messages effective in enabling people and institutions to take protective action to reduce the negative impact of floods. Dissemination from the forecast organization to warning organizations for meaningful action represents the weakest link in the flood early warning system.

The response element of the Flood EWS is neglected and is scarcely mentioned in the literature. The exception is the coastal zone where response to cyclone-induced storm surges received considerable attention after the devastating cyclone in 1991. However, there is room for making it more meaningful.

Specific gaps in the Flood EWS were identified as:

- ◊ Insufficient lead time;
- ◊ Inadequate maintenance and upgrading of FFWC System;
- ◊ Deficiencies in the accuracy and reliability of forecasts;
- ◊ Limited coverage;
- ◊ Lack of customized data;
- ◊ Flood warnings not understandable;
- ◊ Inadequate coordination and feedback; and
- ◊ Lack of ownership

As communities are becoming more vulnerable to floods, there is a need to update and improve the Flood EWS so that all elements of the Flood EWS perform effectively in providing useful flood

warnings to all potential users. Enhancing flood early warning systems to protect infrastructures and enhance livelihoods and other mitigation interventions are cost-effective ways of flood risk reduction.

The existing Early Warning System for Floods has many key components in place, but adjustments and strengthening are required for the system to achieve its potential and make a significant contribution to flood preparedness and flood damage mitigation. The programme to enhance the Flood Early Warning System was developed to address the gaps and shortcomings of the existing EWS.

The development objective of the Flood EWS Enhancement Programme is to reduce the risk to agriculture, infrastructure and rural and urban populations, particularly poor and disadvantaged households, of loss or damage from floods by improving flood preparedness. The strategy of the Programme is to strengthening the effectiveness and sustainability of the early warning system for floods. The expected outputs from the Programme are:

- ◊ System established to provide more reliable and accurate hydrologic data for flood prone areas
- ◊ System established to prepare more useful flood forecasts for flood prone areas
- ◊ Response-orientated and timely flood messages disseminated
- ◊ Sustainable and well-coordinated early warning system for floods

The types of activities that would contribute to these outputs are:

- ◊ Increase accuracy and timeliness of input data for forecasting
- ◊ Improve flood forecasts to meet demands of end-users
- ◊ Improve the extent of coverage and the penetration of the early warning system
- ◊ Expand coordination between key institutions involved in early warning system

Twenty-two (22) Interventions were identified to fit with the four types of activities, as shown in Table 8.1.

Table 8.1: Details of Possible EWS Interventions

Activity	Intervention	Tentative Cost (US$ million)	Duration	Type of intervention
A. Increase accuracy and timeliness of input data for forecasting	A.1 Upgrading collection and transmission systems for rainfall and water level data	11.50	2 years	Equipment, construction
	A.2 Enhancing the existing manual data collection system of BWDB	3.30	3 years	Equipment Training
	A.3 Updating DEM to increase spatial extent of forecasting in flood prone area of Bangladesh*	6.00	2 years	Consultancy Investment, Equipment
	A.4 Improvement of data exchange mechanism with riparian countries	0.30	5 years	Workshops, visits
	A5. Installing additional Doppler Radar at Moulvi Bazar **	Not applicable	2 years	Equipment, construction

Activity	Intervention	Tentative Cost (US$ million)	Duration	Type of intervention
B. Improve flood forecasts to meet demands of end-users	B1. Expanding the flood forecasting system to cover all flood prone areas	2.00	3 years	Consultancy, field operations
	B.2 Preparing detailed flood forecasts at regional and local levels	3.50	3 years	Consultancy, field operations
	B.3: Extending lead times by preparing medium term and long term forecasts	6.80	5 years	Consultancy, field operations
	B.4: Preparing detailed forecasts to assess performance of key infrastructure and agricultural land during floods	2.00	3 years	Consultancy, field operations
	B.5: Preparing flood forecasts for metropolitan cities (Dhaka) and urban areas	1.00	2 years	Consultancy, field operations
	B.6: Implementing forecasting tools for storm surge areas	5.00	5 years	Consultancy, field operations
	B.7 Developing and implementing forecasting tools for flash floo1s	1.00	2 years	Consultancy, field operations
C. Improve the extent of coverage and the penetration of the early warning system	C.1 Establishing network of key stakeholders to develop system for disseminating flood warnings	5.91	5 years	Consultancy, training, equipment
	C.2 Developing packages of flood forecasting information in response to needs of different end users	3.00	1 year	Consultancy, training, equipment
	C.3 Extending existing systems for disseminating flood warnings from national to local levels	1.50	5 years	Consultancy, training, equipment
	C.4 Developing people-centered flood warning and dissemination	2.00	5 years	Equipment, consultancy
D. Expand coordination between key institutions in early warning system	D.1: Institutional study for the BWDB hydrological services	0.70	1 years	Consultancy
	D.2: Strengthening of BWDB in forecast Dissemination	0.50	2 years	Consultancy, training, equipment
	D.3: Strengthening the key institutions involved in the early warning system	3.02	3 years	Consultancy, field activities, training
	D.4: Enhancing national, regional and international awareness of flood forecasting	0.25	5 years	Workshops Training

Activity	Intervention	Tentative Cost (US$ million)	Duration	Type of intervention
	D.5: Develop process to make flood forecasts and warnings useful to infrastructure managers	0.75	3 years	Training, investment (equipment)
	D.6: Establishing mechanism for monitoring, evaluation and feedback of early warning system	1.13	3 years	Consultancy, training, equipment
	Total Cost (excluding A2 and A5-see Notes)	55.16	-	-

Notes: * JICA has committed funds for this project with Survey of Bangladesh (SoB). BWDB/FFWC should request SoB to prioritize preparation of DEM for flood-prone areas

***JICA has committed funds for this project but implementation has not yet started*

Each element of the Early Warning Systems needs to perform effectively for flood warnings to provide benefits, and no single intervention will improve the overall functioning of the EWS by itself. Conversely, it is not possible to identify direct benefits from any single intervention, as each intervention is reliant on the performance of other EWS activities to produce benefits. The interventions are inter-dependent on each other to enhance the performance of the Flood EWS and produce benefits.

To identify their appropriateness, the interventions were grouped into packages, based on three key target areas for the EWS: communities, agriculture and infrastructure. Nine interventions shown in Table 8.2 were common to all of the three packages, and were used for the Pre-feasibility Study.

Table 8.2 Interventions proposed for Pre-Feasibility Study

Pre-Feasibility Package			
A1 Upgrading collection and transmission of rainfall and water level data	**B1 Expanding flood forecasting to cover all flood prone areas**	C1 Establishing network of key stakeholders for disseminating flood forecasts	**D1 Institutional study for the BWDB's Hydrologic Services**
A2 Enhancing BWDB's manual data collection system	**B3 Extending lead times of forecasts**		D3 Strengthening key EWS institutions
	B7 Developing and implementing forecasting tools for flash floods		D6 Establishing monitoring, evaluation and feedback

In the Pre-Feasibility Study, the costs of the 9 interventions have been identified in some detail, along with the partial benefits resulting from an effective Flood EWS to the 3 target areas (communities, agriculture and infrastructure). With the combined benefits from the three target areas, the economic IRR for the base case is 58%, the B/C Ratio 9.3 and the NPV is Tk 18,964, indicating that the investment in the Programme to Enhance the Flood EWS is sound.

8.2 Recommendations

The main recommendations of the Study Team are the following:

- ◊ In recognizing the urgency of accessing accurate and reliable real time data with considerable lead-time, at least following ***three*** proposed interventions can be started without delay, as they are not dependent upon any prior feasibility study:

    a. Intervention A1: Its viability and urgency have been already justified by a full fledged study of JICA. Its cost has been booked from the 1st year of the investment cost (Table-7.2) to get a ready start.

    b. Intervention B3: It is also an urgent component addressing economic reasons of flood forecasting. It will widen the margin of savings of damages by enhancing the levels of flood preparedness among the potential victims. Its funding is also under approval process (Appendix-4).

    c. Intervention D1: This study component can also start without delay, because it is itself an institutional study. The earlier the results of this study will be available, the quicker BWDB will beget institutional strength to accommodate modern methods of EW.

- ◊ Interventions A2 and B1 have been given the highest priority by BWDB and they have indicated that these should immediately be taken up to ensure the sustainability of the existing flood forecasting initiative of BWDB considering the withdrawal of donor support to the FFWC from December 2006.

- ◊ Interventions A3 and A5 (Table 6.1), although not recommended in the present package of 9 components, are expected to start immediately to address the urgent needs of catering early warning services more efficiently in flood prone areas. Funds for these activities have been committed by JICA.

- ◊ A programme to develop the response element of the Flood EWS should be developed for riverine flood plains including areas inside and outside FCD projects.

- ◊ The guidelines for planning and design of infrastructure in the flood plain prepared under the Flood Hydrology Study (see Section 2.4.5) should be used routinely by infrastructure organizations.

- ◊ Areas for further research studies include

- \- Systematic assessment of flood damages to communities and infrastructure both inside and outside FCD projects

- \- Development of improved lead time

- ◊ Review and update hydraulic design guidelines for infrastructures to withstand floods considering the project in plans and the future (FCD Dykes, RHD & LGRD Roads etc).

- ◊ Develop guidelines using flood warnings to plan, design and implement emergency maintenance /protective measures of dykes/roads/hydraulic structures during floods

Annex C

UNISDR Checklist

telecommunications authorities; quality management experts; regional technical centres; UN agencies such as UN/ISDR, WMO, FAO, UNESCO, UNEP, UNOSAT, OCHA, ITU.

Checklist

1. Institutional Mechanisms Established

- ☐ Standardized process, and roles and responsibilities of all organizations generating and issuing warnings established and mandated by law.
- ☐ Agreements and interagency protocols established to ensure consistency of warning language and communication channels where different hazards are handled by different agencies.
- ☐ An all-hazard plan to obtain mutual efficiencies and effectiveness among different warning systems established.
- ☐ Warning system partners, including local authorities, aware of which organizations are responsible for warnings.
- ☐ Protocols in place to define communication responsibilities and channels for technical warning services.
- ☐ Communication arrangements with international and regional organizations agreed and operational.
- ☐ Regional agreements, coordination mechanisms and specialized centres in place for regional concerns such as tropical cyclones, floods in shared basins, data exchange, and technical capacity building.
- ☐ Warning system subjected to system-wide tests and exercises at least once each year.
- ☐ A national all-hazards committee on technical warning systems in place and linked to national disaster management and reduction authorities, including the national platform for disaster risk reduction.
- ☐ System established to verify that warnings have reached the intended recipients.
- ☐ Warning centres staffed at all times (24 hours per day, seven days per week).

2. Monitoring Systems Developed

- ☐ Measurement parameters and specifications documented for each relevant hazard.
- ☐ Plans and documents for monitoring networks available and agreed with experts and relevant authorities.
- ☐ Technical equipment, suited to local conditions and circumstances, in place and personnel trained in its use and maintenance.
- ☐ Applicable data and analysis from regional networks, adjacent territories and international sources accessible.
- ☐ Data received, processed and available in meaningful formats in real time, or near-real time.
- ☐ Strategy in place for obtaining, reviewing and disseminating data on vulnerabilities associated with relevant hazards.
- ☐ Data routinely archived and accessible for verification and research purposes.

3. Forecasting and Warning Systems Established

- ☐ Data analysis, prediction and warning generation based on accepted scientific and technical methodologies.
- ☐ Data and warning products issued within international standards and protocols.
- ☐ Warning analysts trained to appropriate international standards.
- ☐ Warning centres equipped with appropriate equipment needed to handle data and run prediction models.
- ☐ Fail-safe systems in place, such as power back-up, equipment redundancy and on-call personnel systems.
- ☐ Warnings generated and disseminated in an efficient and timely manner and in a format suited to user needs.
- ☐ Plan implemented to routinely monitor and evaluate operational processes, including data quality and warning performance.

Key Element 1: **RISK KNOWLEDGE**

Aim: *Establish a systematic, standardized process to collect, assess and share data, maps and trends on hazards and vulnerabilities.*

Key Actors

International, national and local disaster management agencies; meteorological and hydrological organizations; geophysical experts; social scientists; engineers; land use and urban planners; researchers and academics; organizations and community representatives involved in disaster management; international and UN agencies such as WMO, UN/ISDR, UNEP, UNU-EHS, UNOSAT, UNDP, FAO, UNESCO.

Checklist

1. Organizational Arrangements Established

- ☐ Key national government agencies involved in hazard and vulnerability assessments identified and roles clarified (e.g. agencies responsible for economic data, demographic data, land use planning, social data etc).
- ☐ Responsibility for coordinating hazard identification, vulnerability and risk assessment assigned to one national organization.
- ☐ Legislation or government policy mandating the preparation of hazard and vulnerability maps for all communities in place.
- ☐ National standards for the systematic collection, sharing and assessment of hazard and vulnerability data developed, and standardized with neighbouring or regional countries, where appropriate.
- ☐ Process for scientific and technical experts to assess and review the accuracy of risk data and information developed.
- ☐ Strategy to actively engage communities in local hazard and vulnerability analyses developed.
- ☐ Process to review and update risk data each year, and include information on any new or emerging vulnerabilities and hazards established.

2. Natural Hazards Identified

- ☐ Characteristics of key natural hazards (e.g. intensity, frequency and probability) analysed and historical data evaluated.
- ☐ Hazard maps developed to identify the geographical areas and communities that could be affected by natural hazards.
- ☐ An integrated hazard map developed (where possible) to assess the interaction of multiple natural hazards.

3. Community Vulnerability Analysed

- ☐ Community vulnerability assessments conducted for all relevant natural hazards.
- ☐ Historical data sources and potential future hazard events considered in vulnerability assessments.
- ☐ Factors such as gender, disability, access to infrastructure, economic diversity and environmental sensitivities considered.
- ☐ Vulnerabilities documented and mapped (e.g. people or communities along coastlines identified and mapped).

4. Risks Assessed

- ☐ Interaction of hazards and vulnerabilities assessed to determine the risks faced by each region or community.
- ☐ Community and industry consultation conducted to ensure risk information is comprehensive and includes historical and indigenous knowledge, and local information and national level data.
- ☐ Activities that increase risks identified and evaluated.
- ☐ Results of risks assessment integrated into local risk management plans and warning messages.

5. Information Stored and Accessible

- ☐ Central 'library' or GIS database established to store all disaster and natural hazard risk information.
- ☐ Hazard and vulnerability data available to government, the public and the international community (where appropriate).
- ☐ Maintenance plan developed to keep data current and updated.

Key Element 2: MONITORING AND WARNING SERVICE

Aim: *Establish an effective hazard monitoring and warning service with a sound scientific and technological basis.*

Key Actors

National meteorological and hydrological services; specialised observatory and warning centres (e.g. for water, volcano); universities and research institutes; private sector equipment suppliers; telecommunications authorities; quality management experts; regional technical centres; UN agencies such as UN/ISDR, WMO, FAO, UNESCO, UNEP, UNOSAT, OCHA, ITU.

Checklist

1. Institutional Mechanisms Established

- □ Standardized process, and roles and responsibilities of all organizations generating and issuing warnings established and mandated by law.
- □ Agreements and interagency protocols established to ensure consistency of warning language and communication channels where different hazards are handled by different agencies.
- □ An all-hazard plan to obtain mutual efficiencies and effectiveness among different warning systems established.
- □ Warning system partners, including local authorities, aware of which organizations are responsible for warnings.
- □ Protocols in place to define communication responsibilities and channels for technical warning services.
- □ Communication arrangements with international and regional organizations agreed and operational.
- □ Regional agreements, coordination mechanisms and specialized centres in place for regional concerns such as tropical cyclones, floods in shared basins, data exchange, and technical capacity building.
- □ Warning system subjected to system-wide tests and exercises at least once each year.
- □ A national all-hazards committee on technical warning systems in place and linked to national disaster management and reduction authorities, including the national platform for disaster risk reduction.
- □ System established to verify that warnings have reached the intended recipients.
- □ Warning centres staffed at all times (24 hours per day, seven days per week).

2. Monitoring Systems Developed

- □ Measurement parameters and specifications documented for each relevant hazard.
- □ Plans and documents for monitoring networks available and agreed with experts and relevant authorities.
- □ Technical equipment, suited to local conditions and circumstances, in place and personnel trained in its use and maintenance.
- □ Applicable data and analysis from regional networks, adjacent territories and international sources accessible.
- □ Data received, processed and available in meaningful formats in real time, or near-real time.
- □ Strategy in place for obtaining, reviewing and disseminating data on vulnerabilities associated with relevant hazards.
- □ Data routinely archived and accessible for verification and research purposes.

3. Forecasting and Warning Systems Established

- □ Data analysis, prediction and warning generation based on accepted scientific and technical methodologies.
- □ Data and warning products issued within international standards and protocols.
- □ Warning analysts trained to appropriate international standards.
- □ Warning centres equipped with appropriate equipment needed to handle data and run prediction models.
- □ Fail-safe systems in place, such as power back-up, equipment redundancy and on-call personnel systems.
- □ Warnings generated and disseminated in an efficient and timely manner and in a format suited to user needs.
- □ Plan implemented to routinely monitor and evaluate operational processes, including data quality and warning performance.

Key Element 3: DISSEMINATION AND COMMUNICATION

Aim: *Develop communication and dissemination systems to ensure people and communities are warned in advance of impending natural hazard events and facilitate national and regional coordination and information exchange.*

Key Actors

International, national and local disaster management agencies; national meteorological and hydrological services; military and civil authorities; media organizations (print, television, radio and on-line); businesses in vulnerable sectors (e.g. tourism, aged care facilities, marine vessels); community-based and grassroots organizations; international and UN agencies such as UN/ISDR, IFRC, UNDP, UNESCO, UNEP, WMO, OCHA.

Checklist

1. Organizational and Decision-making Processes Institutionalised

- □ Warning dissemination chain enforced through government policy or legislation (e.g. message passed from government to emergency managers and communities etc).
- □ Recognized authorities empowered to disseminate warning messages (e.g. meteorological authorities to provide weather messages, health authorities to provide health warnings).
- □ Functions, roles and responsibilities of each actor in the warning dissemination process specified in legislation or government policy (e.g. national meteorological and hydrological services, media, NGOs).
- □ Roles and responsibilities of regional or cross border early warning centres defined, including the dissemination of warnings to neighbouring countries.
- □ Volunteer network trained and empowered to receive and widely disseminate hazard warnings to remote households and communities.

2. Effective Communication Systems and Equipment Installed

- □ Communication and dissemination systems tailored to the needs of individual communities (e.g. radio or television for those with access; and sirens, warning flags or messenger runners for remote communities).
- □ Warning communication technology reaches the entire population, including seasonal populations and remote locations.
- □ International organizations or experts consulted to assist with identification and procurement of appropriate equipment.
- □ Multiple communication mediums used for warning dissemination (e.g. mass media and informal communication).
- □ Agreements developed to utilise private sector resources where appropriate (e.g. amateur radios, safety shelters).
- □ Consistent warning dissemination and communication systems used for all hazards.
- □ Communication system is two-way and interactive to allow for verification that warnings have been received.
- □ Equipment maintenance and upgrade programme implemented and redundancies enforced so back-up systems are in place in the event of a failure.

3. Warning Messages Recognised and Understood

- □ Warning alerts and messages tailored to the specific needs of those at risk (e.g. for diverse cultural, social, gender, linguistic and educational backgrounds).
- □ Warning alerts and messages are geographically-specific to ensure warnings are targeted to those at risk only.
- □ Messages incorporate the understanding of the values, concerns and interests of those who will need to take action (e.g. instructions for safeguarding livestock and pets).
- □ Warning alerts clearly recognisable and consistent over time and include follow-up actions when required.
- □ Warnings specific about the nature of the threat and its impacts.
- □ Mechanisms in place to inform the community when the threat has ended.
- □ Study into how people access and interpret early warning messages undertaken and lessons learnt incorporated into message formats and dissemination processes.

Key Element 4: RESPONSE CAPABILITY

Aim: *Strengthen the ability of communities to respond to natural disasters through enhanced education of natural hazard risks, community participation and disaster preparedness.*

Key Actors

Community-based and grassroots organizations; schools; universities; informal education sector; media (print, radio, television, on-line); technical agencies with specialised knowledge of hazards; international; national and local disaster management agencies; regional disaster management agencies; international and UN agencies such as OCHA, UNDP, UNEP, FAO, UNESCO, UN/ISDR, IFRC, WMO.

Checklist

1. Warnings Respected

- ☐ Warnings generated and distributed to those at risk by credible sources (e.g. government, spiritual leaders, respected community organizations).
- ☐ Public perception of natural hazard risks and the warning service analysed to predict community responses.
- ☐ Strategies to build credibility and trust in warnings developed (e.g. understanding difference between forecasts and warnings).
- ☐ False alarms minimised and improvements communicated to maintain trust in the warning system.

2. Disaster Preparedness and Response Plans Established

- ☐ Disaster preparedness and response plans empowered by law.
- ☐ Disaster preparedness and response plans targeted to the individual needs of vulnerable communities.
- ☐ Hazard and vulnerability maps utilized to develop emergency preparedness and response plans.
- ☐ Up-to-date emergency preparedness and response plans developed, disseminated to the community, and practiced.
- ☐ Previous disaster events and responses analysed, and lessons learnt incorporated into disaster management plans.
- ☐ Strategies implemented to maintain preparedness for recurrent hazard events.
- ☐ Regular tests and drills undertaken to test the effectiveness of the early warning dissemination processes and responses.

3. Community Response Capacity Assessed and Strengthened

- ☐ Community ability to respond effectively to early warnings assessed.
- ☐ Response to previous disasters analysed and lessons learnt incorporated into future capacity building strategies.
- ☐ Community-focused organizations engaged to assist with capacity building.
- ☐ Community and volunteer education and training programmes developed and implemented.

4. Public Awareness and Education Enhanced

- ☐ Simple information on hazards, vulnerabilities, risks, and how to reduce disaster impacts disseminated to vulnerable communities and decision-makers.
- ☐ Community educated on how warnings will be disseminated and which sources are reliable and how to respond to different types of hazards after an early warning message is received.
- ☐ Community trained to recognise simple hydro-meteorological and geophysical hazard signals to allow immediate response.
- ☐ On-going public awareness and education built in to school curricula from primary schools to university.
- ☐ Mass media and folk or alternative media utilized to improve public awareness.
- ☐ Public awareness and education campaigns tailored to the specific need of each audience (e.g. children, emergency managers, media).
- ☐ Public awareness strategies and programmes evaluated at least once per year and updated where required.

Cross-Cutting Issue: **GOVERNANCE AND INSTITUTIONAL ARRANGEMENTS**

Aim: *Develop institutional, legislative and policy frameworks that support the implementation and maintenance of effective early warning systems.*

Key Actors

Political leaders; policy makers (e.g. environment, development and planning departments); international, national and local disaster management agencies; meteorological and hydrological organizations; researchers and academics; non-government organizations; international and UN agencies such as UNDP, UNEP, FAO, UNESCO, UN/ISDR, WMO, World Bank and regional development banks, IFRC.

Checklist

1. Early Warning Secured as a Long Term National and Local Priority

- □ Economic benefits of early warning highlighted to senior government and political leaders using practical methods such as a cost-benefit analysis of previous disasters.
- □ Examples and case studies of successful early warning systems disseminated to senior government and political leaders.
- □ Early warning role models or "champions" engaged to advocate early warning and promote its benefits.
- □ The priority natural hazard risk requiring an early warning system identified, and operational arrangements within a multi-hazard framework established.
- □ Early warning integrated into national economic planning.

2. Legal and Policy Frameworks to Support Early Warning Established

- □ National legislation or policies developed to provide an institutional and legal basis for implementing early warning systems.
- □ Clear roles and responsibilities defined for all organizations (government and non-government) involved in early warning.
- □ Overall responsibility and authority for coordination of early warning assigned to one national agency.
- □ One political leader or senior government official empowered by law as the national decision maker.
- □ Policies developed to decentralise disaster management and encourage community participation.
- □ Local decision making and implementation of early warning systems placed within broader administrative and resource capabilities at the national or regional level.
- □ Regional and cross-border agreements established to ensure early warning systems are integrated where possible.
- □ Relationships and partnerships between all organizations involved in early warning institutionalised and coordination mechanisms mandated.
- □ Early warning integrated into disaster reduction and development policies.
- □ Monitoring and enforcement regime in place to support policies and legislation.

3. Institutional Capacities Assessed and Enhanced

- □ Capacities of all organizations and institutions involved assessed and capacity building plans and training programmes developed and resourced.
- □ Non-governmental sector engaged and encouraged to contribute to capacity building.

4. Financial Resources Secured

- □ Government funding mechanism for early warning and disaster preparedness developed and institutionalised.
- □ Access to funding at the international or regional level explored.
- □ Public/private partnerships utilised to assist with early warning system development.

Annex D

Long List Issues Questionnaire

Early Warning System Development ISSUES

Technical Issues

Sl	Information type and reliability	Very Important	Important	Less Important	Don't know
1	Multi hazard risk index mapping is also necessary	X			
2	Baseline for the early warning system is not available	X			
3	Proper understanding of flood plain hydrology is lacking		X		
4	Regular or intermittent flood mapping showing the depth-duration characteristics of mega and regular flood events is not readily available		X		
5	Manual data collection error causes erroneous forecast	X			
6	Absence of full set of components at the rainfall gauge stations often result in data gaps	X			
7	Many of the hydro-metric data stations wash out by the shifting of rivers and very few of them are reinstalled	X			
8	Inclusion of FCD structures in flood forecasting models will make the FFWC forecasting model more close to the real system		X		
9	Real time flood monitoring using satellite is useful, but not available readily.	X			
10	Automation of hydro-meteorological data collection network is crucial	X			
11	Short, medium and long term (seasonal) flood forecasting is required.	X			
12	Hourly prediction will be useful	X			
13	Development for numerical weather model for improving the lead times is needed	X			
14	Update and upgrade flood forecast model for more reliable results	X			
15	Necessity for increase of number of forecast locations for the expansion of forecast	X			
16	Monitoring tool for understanding the mechanism and tracking the flash flood extent is needed	X			
17	Private cell phone, SMS based forecasting information dissemination technology development is required	X			
18	The flood warning provided by FFWC relates to water level at certain gauging stations on the main rivers, which do not prove very useful to people who live on floodplains at a distance from the river.		X		

Sl	Information type and reliability	Very Important	Important	Less Important	Don't know
19	Lead time provided by FFWC is no more than 48 hours, so that many of the community members, particularly the farmers find such information less than what they need.	X			
20	Development of basin wide river and flood management approach will be helpful	X			
21	Pre-harvesting flood level (max flood) information is required for agriculturists	X			
22	Flood proofing level, flood frequency (Flood standards and statistics) related information should be monitored by the BWDB		X		
23	Cloud cover information is required for meteorological forecasts	X			
24	Assessing base information needs for reliable forecasting is a pre-requisite	REPEAT			
25	Updating of hydrological monitoring network	X			

Additional remarks	Very Important	Important	Less Important	Don't know
No additional remarks				

*Please put the tick mark [√] in the box of your choice.

Early Warning System Development ISSUES

Institutional Issues

Sl	Information type and reliability	Very Important	Important	Less Important	Don't know
1	Initiatives on national and local risk assessment taking into account the regional/transboundary risks, with a view to regional cooperation on risk reduction is not in place	X			
2	Stakeholders at the community level hardly receive any formal flood prediction information to take up necessary preparatory measures. Information collected through indigenous ways is not very reliable and no substitute for more authentic forecasts. They need long-term as well as short-term prediction information.	X			
3	The district, upazilla or union level institutions do not receive any location specific formal prediction information to be disseminated among the vulnerable people.		X		
4	Participatory based early warning dissemination network will be helpful	X			
5	Development of community-based training and capacity building for warning dissemination is required	X			
6	Insufficient dissemination due to communication link among upazila, union and mouza level		X		
7	There exists lack of clarity in existing warning messages. Easily understandable communication material and documents should be prepared and disseminated.	X			
8	Some social workers try to build up awareness among the community members to take up various preparatory measures like storing of food, raising of the tubewells so that these remains functional event during floods. But due to the absence of effective prediction information it becomes difficult to make the people adopt adequate preparatory measures.		X		
9	The information on outbreak of various water borne diseases to the institutions responsible for providing medical services should be disseminated quickly so that the situation does not turn out to be epidemic in nature	X			
10	Reduction of flood hazard risk through community participation	X			
11	Lack of awareness/understanding of the users on the safe operation of the WATSAN infrastructures		X		

Sl	Information type and reliability	Very Important	Important	Less Important	Don't know
12	Poor level of understanding of the beneficiaries regarding sanitation and hygiene practices			X	
13	Project or government initiated software activities (training, campaign, motivation, meetings, and courtyard sessions) as a component of flood emergency responses should be more intensive and continuous. The software activities should be repeated over the period of time on the same locations.		X		
14	Capacity development for the professionals engaged in dissemination of flood information is important		X		
15	Proper planning is required for design and implement of rehabilitation measures		X		
16	Strengthening of FFWC's mandate for widening its dissemination system across different institutions is required		X		
17	Improvement of FFWC institutional status or organizational autonomy to control and utilize allocated resources will be helpful		X		
18	Updating of hydrological monitoring network	REPEAT			
19	strengthening disaster management linkages and coordination mechanisms between government, international and national NGOs		X		

Additional remarks	Very Important	Important	Less Important	Don't know

*Please put the tick mark [√] in the box of your choice.

Early Warning System Development ISSUES

Technical and Institutional Issues

Sl	Information type and reliability	Very Important	Important	Less Important	Don't know
1	National and local risk assessment based on hazard data and vulnerability information is not available. Risk assessment for key sectors is also absent	X			
2	Food topology and classification of different types of flood is grossly present that often lead to confusions		X		
3	Basin wide data/ information is a pre-requisite for reliable forecasting, which is scanty and it affects the quality of flood forecasting by FFWC	X			
4	Hydro-metric data are not collected during night time, hence only data are available for 12 hours in a day	X			
5	Insufficient O & M of automatic stations often create malfunctioning of the apparatus and creates data gap	X			
6	Most up to date and reliable topographic data and land use data is not used in the flood forecasting model which lead to erroneous forecast	X			
7	There exists deficiency in the accuracy and reliability of flood forecast made by the FFWC	X			
8	Timely and accurate flood forecasting need is crucial.	X			
9	Increasing the lead time of flood predictions by integrating transboundary input data sources in the river models of the FFWC would give stakeholders more time to prepare for the flood event	X			
10	Evaluation of on-going community early warning pilots including FFWS	X			
11	Support to community radio for high risk areas	X			
12	Establishment of network with other international institutes will improve flood forecasting and dissemination	X			
13	Flood shelter proximity information dissemination to the people for emergency movement during disaster			X	
14	As NGOs do not have the prediction information to share with the local peoples and hence they are not able to implement any specific preparation program in a comprehensive manner.		X		
15	Radio, TV and news paper generally disseminate some flood information, which mainly dwell with the status of floods and some general trends, rather than prediction about floods.	X			
16	More location specific information is needed by the concerned institutions, and it should be presented in formats that institutions and local people find relevant.	X			

Sl	Information type and reliability	Very Important	Important	Less Important	Don't know
17	River system model based forecasting done by the FFWC does not provide the kind of location specific information that community members often ask for.	X			
18	Development of early warning information package, relevant to different institutions is crucial	X			
19	No flood damage assessment guideline is present. For post-flood rehabilitation to take place effectively, it becomes necessary to undertake proper damage assessment	X			
20	Realization of the benefit of the hardware interventions (raised platform latrines, tube wells) during floods was poor, as the respondents found immature to grasp the full utility of the given facilities.		X		
21	Operation and maintenance of the hardware intervention was found poor.		X		
22	Many flood control structures have been erected, but there has been little initiative from different organizations to take preparatory measures to minimize the impact of flooding	X			
23	It is imperative that flood affected households are supplied with food items to tide over the flood, as their stock of food is exhausted before the flood is over		X		
24	Proper planning is required for design and implement of rehabilitation measures	X			
25	Capacity building of FFWC's hardware and software requirement is essential		X		
26	Updating of hydrological monitoring network	X			
27	Develop ward level contingency plans	X			

Additional remarks	Very Important	Important	Less Important	Don't know

*Please put the tick mark [√] in the box of your choice.

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Annex E

List of Issues Clustered along the FEWS cascade

ISSUES revised 9 February 2011

Risk Knowledge

Coding	Normalized total result	Recommendation ADB 2006	Issues: **Additional study**
T1	0,6	?	Multi hazard risk index mapping is also necessary
T3	0,6	A3, B2?	Proper understanding of flood plain hydrology is lacking
T16	0,6	?	Monitoring tool for understanding the mechanism and tracking the flash flood extent is needed
T4	0,6	?	Regular or intermittent flood mapping showing the depth-duration characteristics of mega and regular flood events is not readily available

Monitoring and data acquisition

Coding	Normalized total result	Recommendation ADB 2006	Issues: **Maintenance and density of monitoring network**
T25	0,9	A1, B1	Updating of hydrological monitoring network
T15	0,6	A1, B1	Necessity for increase of number of forecast locations for the expansion of forecast
T6	0,5	A1, B1	Absence of full set of components at the rainfall gauge stations often result in data gaps
T+I26	0,9	A1, B1	Updating of hydrological monitoring network

Coding	Normalized total result	Classification	Issues: **Automated hydro-meteorological data collection**

T10	0,9	A1	Automation of hydro-meteorological data collection network is crucial
T5	0,8	A2	Manual data collection error causes erroneous forecast
T9	0,5	B??	Real time flood monitoring using satellite is useful, but not available readily

Coding	Normalized total result	Recommendation ADB 2006	Issues: **Data collection**
T2	0,3	?	Baseline for the early warning system is not available
T24	0,7	?	Assessing base information needs for reliable forecasting is a pre-requisite
T23	0,2	?	Cloud cover information is required for meteorological forecasts

Coding	Normalized total result	Recommendation ADB 2006	Issues **Technical Data availability ➔ this section is also general pre-requisite**
T+I6	0,9	A3	Most up to date and reliable topographic data and land use data is not used in the flood forecasting model which lead to erroneous forecast
T+I2	0,3	A3	Flood topology and classification of different types of flood is grossly present that often lead to confusions
T+I4	0,5	A2	Hydro-metric data are not collected during night time, hence only data are available for 12 hours in a day
T+I3	0,7	A4	Basin wide data/ information is a pre-requisite for reliable forecasting, which is scanty and it affects the quality of flood forecasting by FFWC
T+I1	0,8	D4, B2	National and local risk assessment based on hazard data and vulnerability information is not available. Risk assessment for key sectors is also absent

Forecasting and warning

Coding	Normalized total result	Recommendation ADB 2006	Issues **Increase of lead time**

T11	0,9	B3	Short, medium and long term (seasonal) flood forecasting is required
T13	0,8	A1	Development for numerical weather model for improving the lead times is needed
T19	0,8	B3	Lead time provided by FFWC is no more than 48 hours, so that many of the community members, particularly the farmers find such information less than what they need

Coding	Normalized total result	Recommendation ADB 2006	Issues **Increasing lead time**
T+I18	1,0	B3	Timely and accurate flood forecasting need is crucial
T+I19d	0,9	B3, A4, D4	Increasing the lead time of flood predictions by integrating trans boundary input data sources in the river models of the FFWC would give stakeholders more time to prepare for the flood event

Dissemination and communication

Coding	Normalized total result	Recommendation ADB 2006	Issues **Multi-level information dissemination**
I3	0,6	C3, C2, C1	The district, upazilla or union level institutions do not receive any location specific formal prediction information to be disseminated among the vulnerable people
I2	0,6	C1,C2, C3, C4	Stakeholders at the community level hardly receive any formal flood prediction information to take up necessary preparatory measures. Information collected through indigenous ways is not very reliable and no substitute for more authentic forecasts. They need long-term as well as short-term prediction information
I6	0,3	C3, C2, C1	Insufficient dissemination due to communication link among upazila, union and mouza level

Coding	Normalized total result	Recommendation ADB 2006	Issues **Use of modern/additional communication techniques**
T17d	0,9	??	Private cell phone, SMS based forecasting information dissemination technology development is required

Coding	Normalized total result	Recommendation ADB 2006	Issues **Access to understandable data**
T+I14	0,3	C2, C1	As NGOs do not have the prediction information to share with the local peoples and hence they are not able to implement any specific preparation program in a comprehensive manner
T+I16	0,7	C3	More location specific information is needed by the concerned institutions, and it should be presented in formats that institutions and local people find relevant
T+I17	0,5	C2, C3, C4	River system model based forecasting done by the FFWC does not provide the kind of location specific information that community members often ask for
T+I18	0,5	C2, C3, C4	Development of early warning information package, relevant to different institutions is crucial

Information type and reliability

Coding	Normalized total result	Recommendation ADB 2006	Issues **Quality standards statistics and monitoring**
T8	0,8	??	Inclusion of FCD structures in flood forecasting models will make the FFWC forecasting model more close to the real system
T22	0,8	D1, D2	Flood proofing level, flood frequency (Flood standards and statistics) related information should be monitored by the BWDB
T14	0,6	??	Update and upgrade flood forecast model for more reliable results
T17	0,7	A2	There exists deficiency in the accuracy and reliability of flood forecast made by the FFWC
T+I19	0,5	??	No flood damage assessment guideline is present. For post-flood rehabilitation to take place effectively, it becomes necessary to undertake proper damage assessment

Coding	Normalized total result	Recommendation ADB 2006	Issues **Information at community level**
T+I15	0,4	C3	Radio, TV and news paper generally disseminate some flood information, which mainly dwell with the status of floods and some general trends, rather than prediction about floods

T+I11	0,6	C3, C4	Support to community radio for high risk areas

Response capability

Coding	Normalized total result	Recommendation ADB 2006	Issues **Household prepardness**
T+I 23	0,3	D4?	It is imperative that flood affected households are supplied with food items to tide over the flood, as their stock of food is exhausted before the flood is over

Coding	Normalized total result	Recommendation ADB 2006	Issues **Community based training and awareness raising**
I7	0,8	C2, C3, C4	There exists lack of clarity in existing warning messages. Easily understandable communication material and documents should be prepared and disseminated
I5	0,6	C4	Development of community-based training and capacity building for warning dissemination is required
I4	0,6	C4	Participatory based early warning dissemination network will be helpful
I10	0,9	C4	Reduction of flood hazard risk through community participation
I8	0,2	??	Some social workers try to build up awareness among the community members to take up various preparatory measures like storing of food, raising of the tubewells so that these remains functional event during floods. But due to the absence of effective prediction information it becomes difficult to make the people adopt adequate preparatory measures

Coding	Normalized total result	Recommendation ADB 2006	Issues **Water and Sanitation**
I12	0,5	??	Poor level of understanding of the beneficiaries regarding sanitation and hygiene practices
I9	0,6	??	The information on outbreak of various water borne diseases to the institutions responsible for providing medical services should be disseminated quickly so that the situation does not turn out to be epidemic in nature
I11	0,5	??	Lack of awareness/understanding of the users on the safe operation of the WATSAN infrastructures

Coding	Normalized total result	Recommendation ADB 2006	Issues **Awareness for use of flood shelters**
T+I13	0,5	??	Flood shelter proximity information dissemination to the people for emergency movement during disaster
T+I22	0,5	D6	Many flood control structures have been erected, but there has been little initiative from different organizations to take preparatory measures to minimize the impact of flooding
T+I20	0,5	D6	Realization of the benefit of the hardware interventions (raised platform latrines, tube wells) during floods was poor, as the respondents found immature to grasp the full utility of the given facilities

Cross Cutting Issues

Coding	Normalized total result	Recommendation ADB 2006	Issues **International cooperation**
I1	0,9	D4	Initiatives on national and local risk assessment taking into account the regional/transboundary risks, with a view to regional cooperation on risk reduction is not in place

Coding	Normalized total result	Recommendation ADB 2006	Issues **Capacity building and management**
I13	0,8	D3	Project or government initiated software activities (training, campaign, motivation, meetings, and courtyard sessions) as a component of flood emergency responses should be more intensive and continuous. The software activities should be repeated over the period of time on the same locations
I14	0,8	D3	Capacity development for the professionals engaged in dissemination of flood information is important
I15	0,9	D4	Proper planning is required for design and implement of rehabilitation measures

Coding	Normalized	Recommendation	Issues **Task, Responsibilities and mandates**

	total result	ADB 2006	
I16	0,6	D1, D2	Strengthening of FFWC's mandate for widening its dissemination system across different institutions is required
I17	0,3	D3	Improvement of FFWC institutional status or organizational autonomy to control and utilize allocated resources will be helpful
I19	0,6	D3	Strengthening disaster management linkages and coordination mechanisms between government, international and national NGOs

Coding	Normalized total result	Recommendation ADB 2006	Issues **Capacity building (equipment, knowledge, staff)**
T+I25	0,9	D3, D2	Capacity building of FFWC's hardware and software requirement is essential
T+I24	0,9	D3	Proper planning is required for design and implement of rehabilitation measures (this is after flooding measure)
T+I27	0,7	??	Develop ward level contingency plans
I13	0,7	D1, D2, D3	Project or government initiated software activities (training, campaign, motivation, meetings, and courtyard sessions) as a component of flood emergency responses should be more intensive and continuous.

Coding	Normalized total result	Recommendation ADB 2006	Issues **Basin wide (international) cooperation**
T20	0,8	D4 ?	Development of basin wide river and flood management approach will be helpful
T+I12	0,7	D4 ?	Establishment of network with other international institutes will improve flood forecasting and dissemination

Coding	Normalized total result	Recommendation ADB 2006	Issues **Operation & Maintenance**
T15	0,8	D2 ?	Insufficient O & M of automatic stations often create malfunctioning of the apparatus and creates data gap
T+I21	0,7	D2?	Operation and maintenance of the hardware intervention was found poor
T+I10	0,7	D6	Evaluation of on-going community early warning pilots including FFWS
T7	0,7	B7, B1, D2?	Many of the hydro-metric data stations wash out by the shifting of rivers and very few of them are reinstalled

Separate group of issues ➔ conditions and requirements for EWS

Coding	Normalized total result	Recommendation ADB 2006	Issues
T21	0,6	B3?	Pre-harvesting flood level (max flood) information is required for agriculturists
T18	0,6	B4	The flood warning provided by FFWC relates to water level at certain gauging stations on the main rivers, which do not prove very useful to people who live on floodplains at a distance from the river
T12	0,6	A1	Hourly prediction will be useful

➔ how to handle mixed issues?

➔ how to deal with characteristics of different flood types? This will very much influence questions regarding the physical monitoring network (spatial and temporal density of measurements) and the information demand from stakeholders

Annex F

Description of Interventions along FEWS Cascade

Annex F. Description of interventions along EWS cascade

Short List of Interventions for the improvements on Flood EWS in Bangladesh

		Intervention
Risk Knowledge	*1.1*	**National and local level risk assessment**
		- Develop flood vulnerability criteria for different land use functions (agriculture, infrastructure, fisheries, communities) and different types of flooding
		- Prepare flood hazard maps at different scale levels (national and upazila) per land use sector and type of flood
	1.2	**Integrated planning for EWS**
		- Inventory of whole EWS process (technical and institutional)
		- Perform critical path analysis
		- Perform optimization analysis for the whole EWS cycle including: Serviceable, Effectiveness (cost-benefits), Equity (stakeholders) of the EWS
		- Prepare an evaluation and monitoring system to measure the outcome of the EWS
	1.3	**Formal and informal education**
		- Trainings for practitioners and community people
		- Educational program (school curriculum) development
		- Awareness campaign including drills and exercise
Monitoring and data acquisition	*2.1*	**Development of base information**
		- Prepare a DEM with sufficient detail (vertical and horizontal) to perform flood modeling at local (Upazilla) level (currently this work is undertaken by the Survey of Bangladesh)
		- Prepare land use and sector maps (agriculture, infrastructure, fisheries, communities) with sufficient detail
		- Prepare historical flood map for different types of flood at Upzallia scale level (see also national and local risk assessment)
	2.2	**Manual data collection (*)**
		- Prepare an implementation plan to increase the network spatial density (manual stations) so that local flood forecast (Upzalila level) are feasible
		- Prepare guidelines for optimal usage (frequency of field reading, quality of data collection)
		- Prepare operation & maintenance planning and budget
		- Increase the frequency of observation
	2.3	**Automatic data collection (**)**
		- Prepare an implementation plan to increase the network spatial density (manual stations) so that local flood forecast (Upzalila level) are feasible
		- Prepare guidelines for optimal usage (frequency of field reading, quality of data collection)
		- Prepare operation & maintenance planning and budget (see also operation & maintenance)
	2.4	**Improve data quality and accessibility (completeness and reliability)**

		- Prepare guideline for data processing and storage for manual and automated recording stations
		- Set standards for data accuracy and reliability
		- Prepare standard for temporal resolution related to user requirement (lead time)
		- Prepare standard for spatial resolution related to user requirement (local level information per sector)
		- Develop incentive system for manual gauge readers in sub-optimal locations, weather conditions and night hours
	2.5	**Operation & Maintenance of the monitoring network**
		- Prepare technical O&M planning long term (1 year and 5 year plan and short term per flood season and weekly – daily)
		- Prepare a realistic O&M budget based on technical planning
		- Set up and implement a service unit to manage O&M of all measuring stations including workshop for storage and repair of spare parts
	2.6	**Expanding the range of data acquisition**
		- Extend of model boundaries to GBM basin
		- Include observations based on remote sensing and satellite technique data outside Bangladesh
		- Validation of runoff data with measurements at the border of Bangladesh
		- Improving coordination and collaboration with bordering countries (investment for data measurement may be required)
	2.7	**Regular monitoring of flood events by satellite data**
		- Prepare monitoring and validation procedure for the basin wide flood model
		- Monitor the characteristics of flooding over the years
		- Include weather data on basin wide level like cloud cover information, wind speed, rainfall etc
Forecasting and Warning	***3.1***	**Model accuracy and upgrade software**
		- Setup guidelines for model accuracy parameters and reliability, Spatial and temporal resolution of the model output
		- Use most recent software version as well as simple model
		- Upgrade the validation procedure for the model output with observed data (x-section, rating curve)
	3.2	**Flood forecast Model development**
		- Include satellite rainfall data with high spatial and temporal resolution
		- Expand model boundaries up to GBM basin
		- Include high resolution DEM
		- Include hydraulic structures(dam, levee, pond, etc) in the model as well as any physical changes in river system (erosion, deposition, etc)
	3.3	**Expansion of forecasting capacity to increase lead time and number of forecast institutions (regional BWDB offices)**
		- Downscale global climate model for seasonal forecast
		- Expand the number of forecast locations and number of forecast institutions (regional BWDB office)
		- Increase the spatial resolution to address local user at upazilla level
		- Increase the temporal resolution to address the different sectors

		- Forecast for short term for human, cattle crop and harvest, respectively (1 – 3 – 7 days).
		- Expand the number of gauge stations in neighboring counties and alternatively use satellite based rainfall estimation
Dissemination and communication	***4.1***	**Extending the range of dissemination**
		- Prepare communication and dissemination plan which addresses different scale levels district, upazilla and union level
		- Prepare agreements on interaction for communication using the existing network of public and private organizations
		- Downscale and detail forecast for upazilla and unions by local authority
	4.2	**More precise and user friendly warning**
		- Set up procedure for SMS alert using mobile phone (patch communication)
		- Prepare communication plan for broadcast of flood warnings through community radio and others translated and understandable information per end-user group
		- Link FHM (historical and simulated) with FFEW system
		- Distribute FHMs at community levels
		- Research to became out for the improvement
	4.3	**Capacity building for dissemination**
		- Capacity building BWDB and FFWC in preparation of extended EWS dissemination
		- Set up separate unit at FFWC to translate central forecast and flood warnings for different end-user (agriculture, fish, infrastructure) specific information at different scale levels (regional & local)
		- Promote community based EWS, similar to CDMP-CEGIS previous project
		- Capacity building to community people in emergency response (emergency planning)
Information type and reliability	***5.1***	**More precise and location specific information**
		- Prepare warnings dedicated for stakeholder groups at appropriate scale levels
	5.2	**Update warning information timely manner different stages**
		- Show different degree of danger through different stages of warning
		- Make "Standing Order for Disaster" effective
Response capability	***6.1***	**Capacity development of community**
		- Set up and conduct community awareness campaigns and training sessions based on participatory approach for flood EW (include the user requirements and information demands)
		- Include dissemination to medical services (NGO's) in EWS
		- Create volunteer rescue group
		- Support community with basic equipments for EW dissemination with in community
		- Establish proper communication channel with in community
		- Institutionalize community based DRM group with in district disaster managed communities
	6.2	**Community preparedness**
		- Prepare user requirements and demands before disaster
		- Perform Cost Benefit Analysis for measures by stakeholders including flood damage assessment based on flood hazard maps and warn it to the responsible authority
		- DDMC should have physical presence (fixed office) at district authority
cutting	***7.1***	**FFWC capacity building**
		- FFWC Capacity building (equipment, hardware, software, training, personnel) to ensure the performance of all tasks related to (decentralized) flood EWS
	7.2	**Strengthening of organizational status**

		- National campaign on Disaster R. R is required to active responsible agency and to promote cooperation among them
		- Work among BWDB, BMD, DMB and others should be clearly shared
		- Prepare explicit mandate and responsibilities of BWDB and FFWC, monitoring and evaluation of EWS performance
	7.3	**International cooperation**
		- Prepare agreement for exchange of extreme event related data on:
		Ø Basin Digital Elevation Model
		Ø Basin water level
		Ø Basin Weather forecasts
		Ø Basin rainfall
		Ø Basin run off model
		Ø Infrastructure operation

Description of the interventions per cascade

The clustering of issues into interventions has been performed, based on the outcome of the first stakeholder consultation on relative importance. The outcome of this classification was intensively discussed with the main stakeholder FFWC. Hereafter the interventions are presented for each cascade cluster. For each intervention the main objectives or impacts, opportunities and threats are shortly described. This approach is following the Design and Monitoring Framework guidelines of the ADB

Cascade 1: Risk Knowledge

Knowledge on the extent and occurrence of the flood risks forms the base of the disaster management. Under this cascade three interventions clustered. Besides (physical) hazard maps (risk zoning), knowledge also needs to include the institutional process. Here the investment in FEWS may be optimized by zooming in on certain steps (for instance communication and dissemination). Finally knowledge development is about training. This will comprise national and international training as well as use of indigenous knowledge at village level..

1.1 National and local level risk assessment

Main Objective: More effective investment in Disaster Risk Reduction and FEWS

Main Outcome: Clear overview of vulnerable areas and land use functions at policy level for land use planning

Main Activities and Outputs:

- Develop flood vulnerability criteria for different land use functions (agriculture, infrastructure, fisheries, communities) and different types of flooding
- Prepare flood hazard maps at different scale levels (national and upazila) per land use sector and type of flood.

Main Threats: Miscommunication with local people about hazards, omission of indigenous knowledge on flooding.

1.2 Integrated planning for FEWS
Main Objective: Effective FEWS

Main Outcome: Optimal working FEWS with self-learning system for continued improvement

Main Activities and Outputs:
- Inventory of whole FEWS process (technical and institutional).
- Perform critical path analysis.
- Perform optimization analysis for the whole FEWS cycle including: Serviceable, Effectiveness (cost-benefits), equity (stakeholders) of the FEWS.
- Prepare an evaluation and monitoring system to measure the outcome of the FEWS.

Main Threats: Interaction of different mandates of involved institutions, duplication and complexities of duties and responsibility, quality control and exchange of the monitoring information, management of the FEWS on the base of performance indicators without connection to the field situation

1.3 Formal and informal education
Main Objective: Improve awareness and preparedness against flooding

Main Outcome: Reduced number of casualties due to flooding

Main Activities and Outputs
- Trainings for practitioners and community people.
- Educational program (school curriculum) development.
- Awareness campaign including drills and exercise.

Main Threats: 'Competition' between indigenous knowledge on flooding and the official FEWS, not all stakeholders and people in the target group are reaching the same level of education, willingness to participate is not always there,

Cascade 2: Monitoring and Data Acquisition

Data and data acquisition forms the basic 'fuel' for the forecasting and warning phase. Under this cascade most technical issues regarding field data sampling and data processing are combined. Also the options for expanding the monitoring network in number of observation points as well as geographic coverage are addressed here. Moreover data quality and access to data will prove an important asset for a well working FEWS.

2.1 Development of base information
Main Objective: More effective investment in Disaster Risk Reduction and FEWS

Main Outcome: Clear overview of vulnerable areas and land use functions at policy level for land use planning and flood risk modeling.

Main Activities and Outputs:
- Prepare a Digital Elevation Model (DEM) with sufficient detail (vertical and horizontal scale) to perform flood modeling at local (upazila) level (currently this work is undertaken by the Survey of Bangladesh)
- Prepare historical flood map for different types of flood at upazila scale level (see also

national and local risk assessment)
- Prepare land use and sector maps (agriculture, infrastructure, fisheries, communities) with sufficient detail

Main Threats: Continuous budget needed to purchase and process new data, the interpretation and processing of the data into flood risk information is not enough related to the information needs of the end users, the information is classified as secret and not available for the wider public or abused for improper activities (for instance land speculation)

2.2 Manual data collection
Main Objective: improve the accuracy and reliability of the hydrologic data at BWDB

Main Outcome: enhancing the operation and maintenance of the existing data collection system of BWDB.

Main Activities and Outputs:
- Increase the frequency of observation
- Prepare Road Map for optimal usage (frequency of field reading, quality of data collection)
- Prepare operation & maintenance planning and budget
- Prepare an implementation plan to increase the network spatial density (manual stations) so that local flood forecasting (upazila level) is feasible

Main Threats: Staff capacity of the BWDB and FFWC is limited, data quality assurance of field data is difficult, difficult access of water level recorders/gauges during extreme weather or at night might lead to incomplete data ranges

2.3 Automatic data collection
Main Objective: improve the accuracy and reliability of the hydrologic data at BWDB

Main Outcome: Increase accuracy and timeliness of input data for forecasting to increase the lead time for flood warnings

Main Activities and Outputs:
- Prepare operation & maintenance planning and budget (see also operation & maintenance)
- Prepare Road Map for optimal usage (frequency of field reading, quality of data collection)
- Prepare an implementation plan to increase the network spatial density (manual stations) so that local flood forecast (upazila level) are feasible
- Procurement of equipment and staff traning

Main Threats: O&M of the installed devices needs to be ensured in the future, adequate and well trained staff is needed for proper operation and interpretation of the data, the implementation and installation will depend on the private supplier of the devices. The data output needs to be compatible with the present and future modeling software for FEWS.

2.4 Improve data quality and accessibility (completeness and reliability)
Main Objective: Increase reliability of the flood forecasts and warnings

Main Outcome: Increase action preparedness (acceptance) of the end users in case of flood warning

Main Activities and Outputs:

- Prepare Road Map for data processing and storage for manual and automated recording stations
- Set standards for data accuracy and reliability
- Prepare standard for temporal resolution related to user requirement (lead time)
- Develop incentive system for manual gauge readers in sub-optimal locations, weather conditions and night hours
- Prepare standard for spatial resolution related to user requirement (local level information per sector)

Main Threats: Too much attention spent on set up of legal and internal procedures, no balance between investment and final results (reduction of casualties and damage), the warning process in case of emergency might become to complex (or slow down) which will decrease net lead time

2.5 Operation & Maintenance of the monitoring network

Main Objective: Reduction of casualties and damage due to flooding

Main Outcome: Operational FEWS

Main Activities and Outputs:

- Prepare technical Operation & Maintenance (O&M) planning long term (1 year and 5 year plan and short term per flood season and weekly – daily)
- Prepare a realistic O&M budget based on technical planning
- Set up and implement a service unit to manage O&M of all measuring stations (manual and automated) including workshop for storage and repair of spare parts

Main Threats The mandates of the organizations within BWDB are not well coordinated, overall budget for O&M within BWDB-FFWC is not made available, the staff capacity is not sufficient, main emphasize is on new equipment and not on maintenance of existing system

2.6 Expanding the range of data acquisition

Main Objective: Reduction of number of casualties and damage

Main Outcome: Increased lead time for flood warning

Main Activities and Outputs:

- Extend of model boundaries to Ganges Brahmaputra Megna (GBM) basin
- Include observations based on remote sensing and satellite technique data outside Bangladesh
- Validation of runoff data with measurements at the border of Bangladesh
- Improving coordination and collaboration with bordering countries (investment for data measurement may be required)

Main Threats: Lack of cooperation from bordering countries due to concerning in data measurement, over-estimation and under-estimation of floods due to wrong model, lack of data standards for smooth information management

2.7 Regular monitoring of flood events by satellite data

Main Objective: Improve the overall effectiveness of the FEWS

Main Outcome: More accurate FEWS at regional and local level

Main Activities and Outputs:
- Prepare monitoring and validation procedure for the basin wide flood model
- Include weather data on basin wide level like cloud cover information, wind speed, rainfall etc
- Monitor the characteristics of flooding over the years

Main Threats: Monitoring with satellite data is relatively expensive (data and data processing), due to cloudy situation some events might be missed, forecast and warning becomes dependent on specialized input from third parties

Cascade 3: Forecasting and Warning

The interventions under this cascade form the traditional heart of an early warning system. The capacity to transfer data and information on runoff into water levels and warnings is a crucial step. The outcome needs to be of sufficient spatial detail (horizontal and vertical) and also of sufficient temporal resolution (lead time) so that end users of the warning can take their pre-cautions.

3.1 Model accuracy and upgrade software

Main Objective: Improve the overall effectiveness and reliability of the FEWS

Main Outcome: More accurate FEWS at regional and local level

Main Activities and Outputs:
- Upgrade the validation procedure for the model output with observed data (cross-section, rating curve)
- Use most recent software version as well as simple model
- Setup Road Map for model accuracy parameters and reliability, spatial and temporal resolution of the model output

Main Threats: besides the model accuracy also the input data needs to be of good quality, staff capacity at FFWC is limited,

3.2 Flood forecasting model development

Main Objective: Meet end user demands for flood risk preparedness
Main Outcome: Increased lead time for FEWS

Main Activities and Outputs:
- Include satellite rainfall data with high spatial and temporal resolution
- Expand model boundaries up to GBM basin
- Include high resolution DEM
- Include hydraulic structures (dam, levee, pond, etc) in the model as well as any physical changes in river system (erosion, deposition, etc)

Main Threats: Models become complex and handling will be difficult, Missing data from trans boundary regions may halt the model operations, no real connection between the regional satellite data and the local circumstances on the ground (for instance how to deal with flash floods and very short warning time)

3.3 Expansion of forecasting capacity to increase lead time and number of forecasting institutions (regional BWDB offices)

Main Objective Reduced number of casualties and damage due to flooding

Main Outcome: Increased lead time for FEWS

Main Activities and Output:

- Expand the number of gauge stations in neighboring countries and alternatively use satellite based rainfall estimation
- Downscale global climate model for seasonal forecast
- Expand the number of forecast locations and number of forecast institutions (regional BWDB office)
- Increase the spatial resolution to address local user at upazila level
- Increase the temporal resolution to address the different sectors
- Forecast for short term for human, cattle crop and harvest, respectively (1 – 3 – 7 days)

Main Threats: Not all areas in BGD are covered for forecast, even the 1-7 days short-term forecast is just for emergency purpose, Satellite based rainfall data need calibration and correction, end users become more dependent on warnings (loss of indigenous knowledge on flooding)

Cascade 4: Dissemination and Communication

A FEWS is not effective if the produced warnings do not reach the end-users in time or in a format they do not understand. In the Bangladesh situation this step proves to be of crucial importance for the operation of the total FEWS. The warning needs to be translated into an understandable message for the end-user. This includes the necessity for the FFWC to be sufficiently decentralized to prepare meaningful warnings adapted to the different local situations. Recently pilot projects have been executed by United States Aid (USAID) and Center for Environmental and Geographic Information Services (CEGIS) to develop community based information systems using SMS alert and simple 'flag hosting' systems in the flood affected areas.

4.1 Extending the range of dissemination

Main Objective: Understandable FEWS for all stakeholders and end-users

Main Outcome: End-user specific FEWS

Main Activities and Output:

- Downscale and detail forecast for upazila and unions by local authority
- Prepare agreements on interaction for communication using the existing network of public and private organizations
- Prepare communication and dissemination plan which addresses different scale levels district, upazila and union level

Main Threats: No systematic hierarchical info dissemination system exist, Lack of coordination among departments, Only Top-down approach exist, No two-way communication

4.2 More precise and user friendly warning

Main Objective: Understandable, response oriented FEWS for all stakeholders and end-users

Main Outcome Localized FEWS

Main Activities and Outputs:
- Set up procedure for SMS alert using mobile phone (patch communication)
- Research to became out for the improvement
- Link Flood Hazard Map (FHM) (historical and simulated) with FEWS
- Distribute FHMs at community levels
- Prepare communication plan for broadcast of flood warnings through community radio and others translated and understandable information per end-user group

Main Threats: To much data input needed, warnings not accurate and/or reliable, too much information is causing confusion at village level, lack of awareness and capacity of end-users to deal with the detailed FEWS

4.3 Capacity building for dissemination
Main Objective: Increased awareness and preparedness for flooding

Main Outcome: Trained stakeholders and target group

Main Activities and Outputs
- Capacity building to community people in emergency response (emergency planning)
- Promote community based FEWS, similar to Comprehensive Disaster Management Program (CDMP) and CEGIS previous project
- Set up separate unit at FFWC to translate central forecast and flood warnings for different end-user (agriculture, fish, infrastructure) specific information at different scale levels (regional & local)

Main Threats: The mandates for dissemination are covered by different organizations af different ministries, no direct linkage between BWDB and local community exist, there are very many flood-prone communities in the country, The mandate of FFWC is not crystal clear

Cascade 5: Information Type and Reliability

A variety of end-users needs to be served with flood warnings based on the same data sources. All end users need to be confident in the accuracy of the warning. Based on its wider mandate in prevention and relief of disasters the Disaster Management Bureau (DMB) may play an active role in dissemination of early warning information as trustworthy organization at local level.

5.1 More precise and location specific information
Main Objective: Increase accuracy and reliability of local FEWS

Main Outcome: Local FEWS

Main Activities and Outputs:
- Prepare warnings dedicated for stakeholder groups at appropriate scale levels

Main Threats: Much data needed, not all end-users need the same level of information, warnings are not reliable or not disseminated through trustworthy communication channel

5.2 Update warning information timely manner different stages
Main Objective: Improve cooperation between institutes in the FEWS cycle

Main Outcome effective FEWS (decreased number of casualties and damage)

Main Activities and Outputs:
- Make "Standing Order for Disaster" effective
- Show different degree of danger through different stages of warning

Main Threats: SOD may not be effective as there is no provision for control, SOD has not been legalized and no one is following SOD rules, FFWC can only produce forecast info but converting it to warning is not FFWC mandate

Cascade 6: Response Capability

Response capacity and the level of preparedness in the villages is the final step in the FEWS. However the level of response capacity is not just a technical matter. Awareness raising and evacuation drills will improve the preparedness considerably. Moreover it need to be clear for the end-users at grass root level which alternative adaptation measures they have to protect themselves against the effects of flooding. Due to the variety of natural hazards in Bangladesh there are many organizations in Bangladesh which are working in different part of Disaster Risk Management (DRM) cycle. Attention for cooperation will increase the effectiveness of the FEWS.

6.1 Capacity development of community

Main Objective: Optimal community preparedness for flooding

Main Outcome Community Disaster Management plan for flooding

Main Activities and Outputs:
- Institutionalize community based DRM group with in district disaster managed communities
- Include dissemination to medical services (NGOs) in FEWS
- Create volunteer rescue group
- Support community with basic equipments for early warning dissemination with in community
- Establish proper communication channel with in community
- Set up and conduct community awareness campaigns and training sessions based on participatory approach for FEWS (include the user requirements and information demands)

Main Threats: Capacity building is continuous effort which needs to be actively transformed to the next generation, FFWC has no mandate to execute such community development work. Cooperation with DMB needs attention

6.2 Community preparedness

Main Objective: Minimal number of casualties and damage through community preparedness for flooding

Main Outcome Well prepared communities in flood prone areas

Main Activities and Outputs:
- FFWC should have physical presence (fixed office) at district authority
- Perform cost benefit analysis for measures by stakeholders including flood damage assessment based on flood hazard maps and warn it to the responsible authority
- Prepare user requirements and demands before disaster

Main Threats: There are many organization in BGD which are working in different part of DRM cycle but separately (Government as well as NGO's), Lack of mandate at FFWC and cooperation with DMB

Cascade 7: Cross Cutting Issues

Several of the interventions as mentioned by the stakeholders could not be clustered under the cascades. They are however equally important for the further upgrade of the FEWS in Bangladesh. One of the most obvious interventions will be the overall upgrade of the capacity at the FFWC. Next the institutional status of the FFWC in relation to the DMB needs to be clear. Does the work and responsibility of FFWC stop after issuing the warning? Or do they also have a task in dissemination? And finally the international cooperation in exchange of data on precipitation, run off and water levels will greatly enhance the possibilities for increase the lead time of the warnings.

7.1 FFWC capacity building

Main Objective: Sustainable and well coordinated FEWS

Main Outcome: Well established FFWC responsible for effective FEWS

Main Activities and Outputs:

- FFWC Capacity building (equipment, hardware, software, training, personnel) to ensure the performance of all tasks related to (decentralized) FEWS

Main Threats: the institutional setting at BWDB is not suitable for an effectively operational FFWC, Huge investment needed but less efficient work due to lack of human resources/capacity, incentives to keep well trained FFWC staff onboard

7.2 Strengthening of organizational status

Main Objective: Well established FFWC responsible for effective FEWS

Main Outcome: Clear mandate, roles and responsibility for the FFWC

Main Activities and Outputs:

- Prepare explicit mandate and responsibilities of BWDB and FFWC, monitoring and evaluation of FEWS performance
- Work among BWDB, Bangladesh Meteorology Department (BMD), DMB and others should be clearly shared
- National campaign on Disaster Risk Reduction is required to active responsible agency and to promote cooperation among them

Main Threats: Internal and external 'overlapping' organizations might block the more clear mandate of the FFWC for there own benefit and existence, Duties and responsibilities over lapping among agencies, conflict of interest between involved organisations

7.3 International cooperation

Main Objective: Optimize and more effective FEWS basin wide

Main Outcome: FEWS with increased lead time and high accuracy

Main Activities and Outputs:
- Prepare agreement for exchange of extreme event related data on:
  - Ø Infrastructure operation
  - Ø Basin digital elevation model
  - Ø Basin water level
  - Ø Basin weather forecasts
  - Ø Basin rainfall
  - Ø Basin run off model

Main Threats: Data not timely and not reliable data, dependency on international cooperation, lack of (international) data standards, missing data might hold the forecast model

Annex G

SWOT Factors and MCA and SWOT – AHP Questionnaires

Questionnaire for Early Warning System

(Multi Criteria Analysis)

- CASCADE 1: Risk Knowledge
- CASCADE 2: Monitoring and Data Acquisition
- CASCADE 3: Forecasting and Warning
- CASCADE 4: Dissemination and Communication
- CASCADE 5: Information Type and Reliability
- CASCADE 6: Response capability
- CASCADE 7: Cross cutting issues

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Pair-wise Comparison (Multi-Criteria Analysis)

Cascade 1: Risk knowledge

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

1-1 National and local level risk assessment | 1-2 Integrated planning for EWS

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

1-1 National and local level risk assessment | 1-3 Formal and informal education

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

1-3 Formal and informal education | 1-2 Integrated planning for EWS

Pair-wise Comparison (Multi-Criteria Analysis)

Cascade 2: Monitoring and data acquisition

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

2-1	Development of base information		2-2	Manual data collection

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

2-1	Development of base information		2-3	Automatic data collection

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

2-1	Development of base information		2-5	Operation & Maintenance of the monitoring network

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

2-1	Development of base information		2-6	Expanding the range of data acquisition

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

2-1	Development of base information		2-7	Regular monitoring of flood events by satellite data

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

2-2	Manual data collection (*)		2-5	Operation & Maintenance of the monitoring network

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

2-2	Manual data collection (*)		2-6	Expanding the range of data acquisition

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

2-2	Manual data collection (*)		2-7	Regular monitoring of flood events by satellite data

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

2-3	Automatic data collection		2-2	Manual data collection (*)

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

2-3	Automatic data collection		2-5	Operation & Maintenance of the monitoring network

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

2-3	Automatic data collection		2-6	Expanding the range of data acquisition

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

2-3	Automatic data collection		2-7	Regular monitoring of flood events by satellite data

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

2-4	Improve data quality and accessibility (completeness and reliability)	2-1	Development of base information

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

2-4	Improve data quality and accessibility (completeness and reliability)	2-2	Manual data collection (*)

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

2-4	Improve data quality and accessibility (completeness and reliability)	2-3	Automatic data collection (**)

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9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

2-4	Improve data quality and accessibility (completeness and reliability)	2-5	Operation & Maintenance of the monitoring network

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

2-4	Improve data quality and accessibility (completeness and reliability)	2-6	Expanding the range of data acquisition

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

2-4	Improve data quality and accessibility (completeness and reliability)	2-7	Regular monitoring of flood events by satellite data

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

2-5	Operation & Maintenance of the monitoring network	2-6	Expanding the range of data acquisition

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

2-5	Operation & Maintenance of the monitoring network	2-7	Regular monitoring of flood events by satellite data

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

2-6	Expanding the range of data acquisition	2-7	Regular monitoring of flood events by satellite data

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Pair-wise Comparison (Multi-Criteria Analysis)

Cascade 3: Forecasting and Warning

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

3-2	Flood forecast Model development	3-1	Model accuracy and upgrade software

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

3-3	Expansion of forecasting capacity to increase lead time and number of forecast institutions	3-1	Model accuracy and upgrade software

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

3-3	Expansion of forecasting capacity to increase lead time and number of forecast institutions	3-2	Flood forecast Model development

Pair-wise Comparison (Multi-Criteria Analysis)

Cascade 4: Dissemination and communication

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

4-1	Extending the range of dissemination

4-2	More precise and user friendly warning

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

4-1	Extending the range of dissemination

4-3	Capacity building for dissemination

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

4-2	More precise and user friendly warning

4-3	Capacity building for dissemination

Pair-wise Comparison (Multi-Criteria Analysis)

Cascade 5: Information type and reliability

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

5-1	More precise and location specific information

5-2	Update warning information timely manner different stages

Pair-wise Comparison (Multi-Criteria Analysis)

Cascade 6: Response capability

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

6-1	Capacity development of community

6-2	Community preparedness

Pair-wise Comparison (Multi-Criteria Analysis)

Cascade 7: Cross cutting issues

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

7-1	FFWC capacity building		7-2	Strengthening of organizational status

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

7-1	FFWC capacity building		7-3	International cooperation

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

7-2	Strengthening of organizational status		7-3	International cooperation

		Intervention	Strength	Weakness	Opportunity	Threat
Risk Knowledge	*1*	**National and local level risk assessment**	- National GIS experts are available - Basic data are available - Less cost - synoptic view	- Time consuming - Low resolution and less accuracy result - Lack of risk experts	- Easily updatable - Satellite technology can be used to replace - Can support good developed planning	- mis interpretation by local people - damage to the local knowledge - Scale of external force may be change
		- Develop flood vulnerability criteria for different land use functions (agriculture, infrastructure, fisheries, communities) and different types of flooding				
		- Prepare flood hazard maps at different scale levels (national and upazila) per land use sector and type of flood				
	2	**Integrated planning for EWS**	- Already existing several institutions on flood - focus on overall EWS performance	- Not well-coordinated institutions - Trans boundary issues are critical	- Enhance cooperation - optimize (concentrate) investments	- Duplication and complexities of duties and responsibility - management on indices
		- Inventory of whole EWS process (technical and institutional)				
		- Perform critical path analysis				
		- Perform optimization analysis for the whole EWS cycle including: Serviceable, Effectiveness (cost-benefits), Equity (stakeholders) of the EWS				
		- Prepare an evaluation and monitoring system to measure the outcome of the EWS				
	3	**Formal and informal education**	- NGOs are available - Many donor agencies may be interested to fund - Local knowledge can be used	- Cannot cover whole area at once - Many experts will be involved	- Same approach can be continued - The system will help to spread the knowledge in next generation	- Local people may think their knowledge is much - Trained practices may leave true position - Less cooperation from community people
		- Trainings for practitioners and community people				
		- Educational program (school curriculum) development				
		- Awareness campaign including drills and exercise				
Monitoring and data acquisition	*4*	**Development of base information**	- High-tech data monitoring are practiced in BGD - Local knowledge is available - high resolution data available for multiple use	- Cannot purchase high resolution data - expensive	- Systematic long-term data accumulation so easy to refer in the future	- Cannot continue to update available data due to lack of regular budget
		- Prepare a DEM with sufficient detail (vertical and horizontal) to perform flood modeling at local (Upazilla) level (currently this work is undertaken by the Survey of Bangladesh)				
		- Prepare land use and sector maps (agriculture, infrastructure, fisheries, communities) with sufficient detail				
		- Prepare historical flood map for different types of flood at Upzallia scale level (see also national and local risk assessment)				
	5	**Manual data collection (*)**	- Good data transmission technique such as mobile - continuous data readings - density and frequency of data	- Cannot pay additional salary of gauge readers - Cannot install so many stations and may over run the exiting capacity of BWDB	- Increase of flood forecast lead time - Behavior of flood inundation can be analyzed using frequent and dense gauge network - Good for water resource management	- Difficult to check the accuracy - data reading errors
		- Prepare an implementation plan to increase the network spatial density (manual stations) so that local flood forecast (Upzalila level) are feasible				
		- Prepare guidelines for optimal usage (frequency of field reading, quality of data collection)				
		- Prepare operation & maintenance planning and budget				
		- Increase the frequency of observation				
	6	**Automatic data collection (**)**	- Experienced in using automatic system - continuous data readings - density and frequency of data	- Heavy investment required - sensible equipment	- Very frequent data availability which keep close monitoring of any flood events - Human error will be minimized	- Cannot repair and maintenance - Bank erosion and deposition may damage the system
		- Prepare an implementation plan to increase the network spatial density (manual stations) so that local flood forecast (Upzalila level) are feasible				
		- Prepare guidelines for optimal usage (frequency of field reading, quality of data collection)				
		- Prepare operation & maintenance planning and budget (see also operation & maintenance)				
	7	**Improve data quality and accessibility (completeness and reliability)**	- Many local BWDB office can be used - using existing system - relatively small investment and high output	- Need extra time for engineers to do the jobs - Legal process and documentation require long time	- Accurate good forecast can be made - Advance runoff modeling can be performed	- Lengthy process and not good for emergency situation - no enforcement of data standards
		- Prepare guideline for data processing and storage for manual and automated recording stations				
		- Set standards for data accuracy and reliability				
		- Prepare standard for temporal resolution related to user requirement (lead time)				
		- Prepare standard for spatial resolution related to user requirement (local level information per sector)				
		- Develop incentive system for manual gauge readers in sub-optimal locations, weather conditions and night hours				
	8	**Operation & Maintenance of the monitoring network**	- FFWC is already functioning only need to expand its scope Effectiveness investment	- Either number of FFWC engineers will be increased or the work load of existing engineers will be increased	- Decrease the number of missing data for flood forecast	- Cannot work during flood time??? What do you mean - misuse of budget
		- Prepare technical O&M planning long term (1 year and 5 year plan and short term per flood season and weekly – daily)				
		- Prepare a realistic O&M budget based on technical planning				

		- Set up and implement a service unit to manage O&M of all measuring stations including workshop for storage and repair of spare parts				
	9	**Expanding the range of data acquisition** - Extend of model boundaries to GBM basin - Include observations based on remote sensing and satellite technique data outside Bangladesh - Validation of runoff data with measurements at the border of Bangladesh - Improving coordination and collaboration with bordering countries (investment for data measurement may be required)	- existing data collection network can be expand - Cooperation with JAXA are already on going	- Lack of capacity to handle satellite saved rainfall data including poor internet quality - Not timely data will be available	- Many sources of satellite based rainfall data will be available at free of cost	- Lack of cooperation from bordering countries due to concerning in data measurement - Over estimation and under estimation of floods
	10	**Regular monitoring of flood events by satellite data** - Prepare monitoring and validation procedure for the basin wide flood model - Monitor the characteristics of flooding over the years - Include weather data on basin wide level like cloud cover information, wind speed, rainfall etc	- Some sources provides free images - CEGIS like institute can be promoted to interesting images	- High resolution image data are expensive - monitoring interval is bit longer	- Inundation depth, are, duration and timing can be analyzed for future reference	- Due to image taken in different timing. Some peak events may be missed. So, people can misinterpret the events.
Forecasting and Warning	11	**Model accuracy and upgrade software** - Setup guidelines for model accuracy parameters and reliability, Spatial and temporal resolution of the model output - Use most recent software version as well as simple model - Upgrade the validation procedure for the model output with observed data (x-section, rating curve, etc)	- Already known issue - FFWC engineers know how to operate the numerical models Step by step approach	- Available basic data such as rating curve, x-section, etc are in poor quality or need to be cross-checked	- Many new numerical models are available - High degree of prediction in good quality can be possible	- Uncertainty in output results depending on the type of model used - Good model but poor input data may lead to poor performance
	12	**Flood forecast Model development** - Include satellite rainfall data with high spatial and temporal resolution - Expand model boundaries up to GBM basin - Include high resolution DEM - Include hydraulic structures(dam, levee, pond, etc) in the model as well as any physical changes in river system (erosion, deposition, etc)	- Good satellite images of BGD and GBM basin is available to analyze the flood characteristics - Some donors (DANIDA) has already been working in BGD - JAXA is aiming at supporting BGD to promote satellite based rainfall application system	- Little flexibility in selecting new models - Lack of trained people to run any new models	- Increase lead time for forecast - Better forecast for inundation extent - Time for simulation and therefor result dissemination will be shorten	- Models become complex and handling will be difficult - Missing data from transboundary region may halt the model operations
	13	**Expansion of forecasting capacity to increase lead time and number of forecast institutions (regional BWDB offices)** - Downscale global climate model for seasonal forecast - Expand the number of forecast locations and number of forecast institutions (regional BWDB office) - Increase the spatial resolution to address local user at upazilla level - Increase the temporal resolution to address the different sectors - Forecast for short term for human, cattle crop and harvest, respectively (1 – 3 – 7 days). - Expand the number of gauge stations in neighboring counties and alternatively use satellite based rainfall estimation	- Existing situation, BWDB is practicing 72 hours forecast - Central BGD and southern BGD can still be provided with forecast with few days lead time with stage correlation technology - Freely available satellite rainfall data in global scale - enhance forecasting	- Not all areas in BGD is covered for forecast - 1-7 days short-term forecast is just for emergency purpose - Satellite based rainfall data need some correction	- Increasing number forecast locations means many self-dependent forecast communities - enhance forecasting	- Local forecast may not be accurate as no specialist will be available at the regional level - Satellite data as well as gauge data received from bordering countries may be less accurate
Dissemination and communication	14	**Extending the range of dissemination** - Prepare communication and dissemination plan which addresses different scale levels district, upazilla and union level - Prepare agreements on interaction for communication using the existing network of public and private organizations - Downscale and detail forecast for upazilla and unions by local authority	- Many BWDB regional offices can play active role in EW info dissemination - NGOs and INGOs can be used to disseminate info quickly and widely	- No systematic hierarchical info dissemination system exist - Lack of coordination among departments - Only Top-down approach exist. No two-way communication	- Top-down and bottom-up communication will be possible - Better access to EW information for community people	- Even people who do not evacuate may evacuate and cause prepare on the system - Over run of capacity of local authority to manage
	15	**More precise and user friendly warning** - Set up procedure for SMS alert using mobile phone (patch communication) - Prepare communication plan for broadcast of flood warnings through community radio and others translated and understandable information per end-user group - Link FHM (historical and simulated) with FFEW system - Distribute FHMs at community levels	- Community people are very eager to get EW information and possible hazard situation - CDMP and other institutions are already committed to do	- BWDB has lack on the understanding care social problems and internet - No FHM is available - No alternative communication channel exist other than mobile phone	- On time evacuation - On time disaster preparation	- Too many communication channel means confusing to local people

		- Research to became out for the improvement				
	16	**Capacity building for dissemination** - Capacity building BWDB and FFWC in preparation of extended EWS dissemination - Set up separate unit at FFWC to translate central forecast and flood warnings for different end-user (agriculture, fish, infrastructure) specific information at different scale levels (regional and local Upazilla) - Promote community based EWS, similar to CDMP-CEGIS previous project - Capacity building to community people in emergency response (emergency planning)	- Many NGOs and INGOs are supporting capacity building - Taking loan for development activities is possible - Community based activities are already experienced by CDMP-CEGIS Regional BWDB offices	- No direct linkage between regional BWDB and local community exist - So many flood-prone communities	- Independent warning and dissemination system will be established - Bring closeness between government and local community that help better interaction	- FFWC may think of loss of duties and responsibility?? What do you mean - Different others means taking longer than usual time for info dissemination
Information type and reliability	17	**More precise and location specific information** - Prepare warnings dedicated for stakeholder groups at appropriate scale levels	- FFWC is already practicing 48 hours flood forecast. These forecasts cab easily be translated for different stakeholders	- FFWC doesn't have enough capacity to translate engineering result to warning information per sector	- Provided EW information will fit to the local demand - Easy to optimize the preparedness level	- Different groups and people may need different types of information that cannot be covered at sufficient level of detail
		Update warning information timely manner different stages - Show different degree of danger through different stages of warning - Make "Standing Order for Disaster" effective	- SOD is already exist - Disaster management bureau can play a active role in dissemination of EW information	- SOD has not been legalized ?? or enforced and no one is following SOD rules - FFWC can only produce forecast info but converting it to warning is not FFWC mandate	- Easy and Smooth emergent operation (evacuation planning, agriculture management etc)	- SOD may not be effective as there is no provision for control and enforcement
Response capability	18	**Capacity development of community** - Set up and conduct community awareness campaigns and training sessions based on participatory approach for flood EW (include the user requirements and information demands) - Include dissemination to medical services (NGO's) in EWS - Create volunteer rescue group - Support community with basic equipments for EW dissemination with in community - Establish proper communication channel with in community - Institutionalize community based DRM group with in district disaster managed communities	- CBDRM is already practiced and know-how can be used - Many NGOs and INGOs presence at local levels and community development packages are on going	- FFWC has no mandate to execute such community development work. These new agency or unit should be appointed	- Capacity development will support to the over all DRM cycle	- Built capacity may not be transformed to true next generation - Without NGOs, government will be over loaded
	19	**Community preparedness** - Prepare user requirements and demands before disaster - Perform Cost Benefit Analysis for measures by stakeholders including flood damage assessment based on flood hazard maps and warn it to the responsible authority - DDMC should have physical presence (fixed office) at district authority	- There are many organization in BGD which are working in different part of DRM cycle but separately	- Lack of coordination among agencies - Not enough capacity for preparedness of budget	- Minimize duplication and overlapping in rescue operation	- Increase dependency of communication - There are many organization in BGD which are working in different part of DRM cycle but separately
Cross cutting issues	20	**FFWC capacity building** - FFWC Capacity building (equipment, hardware, software, training, personnel) to ensure the performance of all tasks related to (decentralized) flood EWS	- FFWC already exists and basic infrastructure available	- Not so much budget of BWDB to support capacity building of FFWC	ADB/WB like donor agency may fund for future improvement or soft loan can be available	- Huge investment but less efficient work due to lack of human resources/capacity
	21	**Strengthening of organizational status** - National campaign on Disaster R. R is required to active responsible agency and to promote cooperation among them - Work among BWDB, BMD, DMB and others should be clearly shared - Prepare explicit mandate and responsibilities of BWDB and FFWC, monitoring and evaluation of EWS performance	- Standing order on disaster (SOD) is already available	- Duties and responsibilities over lapping among agencies	- Task burden will be reduced if shared among agencies - Effective uses of resources	- Conflict of interest among involving parties
	22	**International cooperation** - Prepare agreement for exchange of extreme event related data on: Ø Basin Digital Elevation Model Ø Basin water level Ø Basin Weather forecasts Ø Basin rainfall Ø Basin run off model Ø Infrastructure operation	- Currently BWDB is receiving some data from bordering countries - Available international flood forecast can be used	- Not timely and not reliable data Low spatial and temporal resolution	- Natural collaboration with win-win situation can be promoted such as Bangladesh will help install gauge station in upstream countries but get data from them regularly	- Chances of data missing or security related problem may disturb the system

(GROUP 2)

Questionnaire for Early Warning System

(AHP-SWOT Analysis)

- CASCADE 1: Risk Knowledge
- CASCADE 2: Monitoring and Data Acquisition
- CASCADE 3: Forecasting and Warning
- CASCADE 4: Dissemination and Communication
- CASCADE 5: Information Type and Reliability
- CASCADE 6: Response capability
- CASCADE 7: Cross cutting issues

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Pair-wise Comparison (AHP-SWOT)

Cascade 1: Risk knowledge

Intervention 1-1: National and local level risk assessment

- Develop flood vulnerability criteria for different land use functions (agriculture, infrastructure, fisheries, communities) and different types of flooding
- Prepare flood hazard maps at different scale levels (national and upazila) per land use sector and type of flood

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Weakness
- Time consuming
- Low resolution and less accuracy result
- Lack of risk experts

Strength
- National GIS experts are available
- Basic data are available
- Less cost
- Synoptic view

CASCADE 1: Risk Knowledge

CASCADE 1
(Risk knowledge)

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

Opportunity
- Easily updatable
- Satellite technology can be used to replace
- Can support good development planning

Strength
- National GIS experts are available
- Basic data are available
- Less cost
- Synoptic view

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

Opportunity
- Easily updatable
- Satellite technology can be used to replace
- Can support good development planning

Weakness
- Time consuming
- Low resolution and less accuracy result
- Lack of risk experts

2

CASCADE 1: Risk Knowledge

CASCADE 1
(Risk knowledge)

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

Threat
- Mis interpretation by local people
- Damage to the local knowledge
- Scale of external force may change

Strength
- National GIS experts are available
- Basic data are available
- Less cost
- Synoptic view

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

Threat
- Mis interpretation by local people
- Damage to the local knowledge
- Scale of external force may change

Weakness
- Time consuming
- Low resolution and less accuracy result
- Lack of risk experts

CASCADE 1: Risk Knowledge

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Threat
- Miss interpretation by local people
- Damage to the local knowledge
- Scale of external force may be change

Opportunity
- Easily updatable
- Satellite technology can be used to replace
- Can support good development planning

CASCADE 1: Risk Knowledge

Intervention 1-2: Integrated planning for EWS

- Inventory of whole EWS process (technical and institutional)
- Perform critical path analysis
- Perform optimization analysis for the whole EWS cycle including: Serviceable, Effectiveness (cost-benefits), Equity (stakeholders) of the EWS
- Prepare an evaluation and monitoring system to measure the outcome of the EWS

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Weakness
- Not well-coordinated institutions
- Transboundary issues are critical

Strength
- Already existing several institutions on flood
- Focus on overall EWS performance

CASCADE 1: Risk Knowledge

CASCADE 1
(Risk knowledge)

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Opportunity
- Enhance cooperation
- Optimize (concentrate) investments

Strength
- Already existing several institutions on flood
- Focus on overall EWS performance

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Opportunity
- Enhance cooperation
- Optimize (concentrate) investments

Weakness
- Not well-coordinated institutions
- Transboundary issues are critical

CASCADE 1: Risk Knowledge

CASCADE 1
(Risk knowledge)

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Threat
- Duplication and complexities of duties and responsibility
- Management on indices

Strength
- Already existing several institutions on flood
- Focus on overall EWS performance

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Threat
- Duplication and complexities of duties and responsibility
- Management on indices

Weakness
- Not well-coordinated institutions
- Transboundary issues are critical

CASCADE 1: Risk Knowledge

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Threat
- Duplication and complexities of duties and responsibility
- Management on indices

Opportunity
- Enhance cooperation
- Optimize (concentrate) investments

CASCADE 1: Risk Knowledge

Intervention 1-3: Formal and informal education

- Trainings for practitioners and community people
- Trainings for practitioners and community people
- Educational program (school curriculum) development
- Awareness campaign including drills and exercise

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Weakness
- Cannot cover whole area at once
- Many experts will be involved

Strength
- NGOs are available
- Many donor agencies may be interested to fund
- Local knowledge can be used

CASCADE 1: Risk Knowledge

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Opportunity
- Same approach can be continued
- The system will help to spread the knowledge to the next generation

Strength
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CASCADE 1: Risk Knowledge

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Threat
- Local people may think their knowledge is much
- Trained staff may leave their position
- Less cooperation from community people

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- NGOs are available
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- Less cooperation from community people

Opportunity
- Same approach can be continued
- The system will help to spread the knowledge to the next generation

CASCADE 1: Risk Knowledge

Pair-wise Comparison (AHP-SWOT)

Cascade 2: Monitoring and data acquisition

Intervention 2-1: Development of base information

- Prepare a DEM with sufficient detail (vertical and horizontal) to perform flood modeling at local (Upazilla) level (Currently this work is undertaken by the Survey of Bangladesh)
- Prepare land use and sector maps (agriculture, infrastructure, fisheries, communities) with sufficient detail
- Prepare historical flood map for different types of flood at Upazila scale level

(see also national and local risk assessment)

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Weakness
- Cannot purchase high resolution data
- Expensive

Strength
- High-tech data monitoring is practiced in BD
- Local knowledge is available
- High resolution data available for multiple use

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Opportunity
- Systematic long-term data accumulation, so easy to refer in the future

Strength
- High-tech data monitoring is practiced in BD
- Local knowledge is available
- High resolution data available for multiple use

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CASCADE 2: Monitoring and Data

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Threat
- Cannot continue to update available data due to lack of regular budget

Strength
- High-tech data monitoring is practiced in BD
- Local knowledge is available
- High resolution data available for multiple use

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

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- Cannot purchase high resolution data
- Expensive

CASCADE 2: Monitoring and Data

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Threat
- Cannot continue to update available data due to lack of regular budget

Opportunity
- Systematic long-term data accumulation, so easy to refer in the future

Intervention 2-2: Manual data collection

- Prepare an implementation plan to increase the network spatial density (manual stations) so that local flood forecast (Upazilla level) are feasible
- Prepare guidelines for optimal usage (frequency of field reading, quality of data collection)
- Prepare operation & maintenance planning and budget
- Increase the frequency of observation

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Weakness
- Cannot pay additional salary of gauge readers
- Cannot install so many stations and may over run the existing capacity of BWDB

Strength
- Good data transmission technique such as mobile
- Continuous data readings
- Density and frequency of data

CASCADE 1
(Risk knowledge)

9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9

Opportunity
- Increase of flood forecast lead time
- Behavior of flood inundation can be analyzed using frequent and dense gauge network
- Good for water resource management

Strength
- Good data transmission technique such as mobile
- Continuous data readings
- Density and frequency of data

9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9

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CASCADE 2: Monitoring and Data

CASCADE 1
(Risk knowledge)

9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9

Threat
- Difficult to check the accuracy
- Data reading errors

Strength
- Good data transmission technique such as mobile
- Continuous data readings
- Density and frequency of data

9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9

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- Data reading errors

Weakness
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CASCADE 2: Monitoring and Data

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- Data reading errors

Opportunity
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- Behavior of flood inundation can be analyzed using frequent and dense gauge network
- Good for water resource management

Intervention 2-3: Automatic data collection

- Prepare an implementation plan to increase the network spatial density (manual stations) so that local flood forecast (Upazilla level) are feasible
- Prepare guidelines for optimal usage (frequency of field reading, quality of data collection)
- Prepare operation & maintenance planning and budget (see also operation & maintenance)

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Weakness
- Heavy investment required
- Sensitive equipment

Strength
- Experienced in using automatic system
- Continuous data readings
- Density and frequency of data

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Opportunity
- Very frequent data availability which keep close monitoring of any flood events
- Human error will be minimized

Strength
- Experienced in using automatic system
- Continuous data readings
- Density and frequency of data

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

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CASCADE 2: Monitoring and Data

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Threat
- Cannot repair and maintenance
- Bank erosion and deposition may damage the system

Strength
- Experienced in using automatic system
- Continuous data readings
- Density and frequency of data

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Threat
- Cannot repair and maintenance
- Bank erosion and deposition may damage the system

Weakness
- Heavy investment required
- Sensitive equipment

CASCADE 2: Monitoring and Data

CASCADE 1
(Risk knowledge)

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Threat
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- Bank erosion and deposition may damage the system

Opportunity
- Very frequent data availability which keep close monitoring of any flood events
- Human error will be minimized

CASCADE 2: Monitoring and Data

CASCADE 1
(Risk knowledge)

Intervention 2-4: Improve data quality and accessibility (Completeness and reliability)

- Prepare guidelines for data processing and storage for manual and automated recording stations
- Set standards for data accuracy and reliability
- Prepare standard for temporal resolution related to user requirement (lead time)
- Prepare standard for spatial resolution related to user requirement (local level information per sector)
- Develop incentive system for manual gauge readers in sub-optimal locations, weather conditions and night hours

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Weakness
- Need extra time for engineers to do the jobs
- Legal process and documentation require long time

Strength
- Many local BWDB offices can be used
- Using existing system
- Relatively small investment and high output

CASCADE 2: Monitoring and Data

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Opportunity
- Accurate good forecast can be made
- Advance runoff modeling can be performed

Strength
- Many local BWDB offices can be used
- Using existing system
- Relatively small investment and high output

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CASCADE 2: Monitoring and Data

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Threat
- Lengthy process and not good for emergency situation
- No enforcement of data standards

Strength
- Many local BWDB office can be used
- Using existing system
- Relatively small investment and high output

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

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- Lengthy process and not good for emergency situation
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CASCADE 2: Monitoring and Data

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

Threat
- Lengthy process and not good for emergency situation
- No enforcement of data standards

Opportunity
- Accurate good forecast can be made
- Advance runoff modeling can be performed

CASCADE 2: Monitoring and Data

Intervention 2-5: Operation & Maintenance of the monitoring network

- Prepare technical O&M planning long term (1 year and 5 year plan) and short term (per flood season and weekly – daily)
- Prepare a realistic O&M budget based on technical planning
- Set up and implement a service unit to manage O&M of all measuring stations including workshop for storage and repair of spare parts

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

Weakness
- Either number of FFWC engineers will be increased or the work load of existing engineers will be increased

Strength
- FFWC is already functioning only need to expand its scope
- Effective investment

9 8 7 6 5 4 3 2 **1** 2 3 4 5 6 7 8 9

Opportunity
- Decrease the number of missing data for flood forecast

Strength
- FFWC is already functioning only need to expand its scope
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CASCADE 2: Monitoring and Data

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- Decrease the number of missing data for flood forecast

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- Either number of FFWC engineers will be increased or the work load of existing engineers will be increased

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Threat
- Cannot work during flood time

Opportunity
- Decrease the number of missing data for flood forecast

CASCADE 2: Monitoring and Data

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Threat
- Cannot work during flood time

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- FFWC is already functioning only need to expand its scope
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Threat
- Cannot work during flood time

Weakness
- Either number of FFWC engineers will be increased or the work load of existing engineers will be increased

CASCADE 2: Monitoring and Data

Intervention 2-6: Expanding the range of data acquisition

- Extend model boundaries to GBM basin
- Include observations based on remote sensing and satellite technique data outside Bangladesh
- Validation of runoff data with measurements at the border of Bangladesh
- Improving coordination and collaboration with bordering countries (investment for data measurement may be required)

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Weakness
- Lack of capacity to handle satellite based rainfall data including poor internet quality
- Data will not be available timely

Strength
- Existing data collection network can be expanded
- Cooperation with JAXA are already ongoing

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Opportunity
- Many sources of satellite based rainfall data will be available free charge

Strength
- Existing data collection network can be expanded
- Cooperation with JAXA are already ongoing

CASCADE 2: Monitoring and Data

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

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- Many sources of satellite based rainfall data will be available free of charge

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Opportunity
- Many sources of satellite based rainfall data will be available free of charge

Threat
- Lack of cooperation from bordering countries due to constraints in data measurement
- Overestimation and underestimation of floods

CASCADE 2: Monitoring and Data

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Threat
- Lack of cooperation from bordering countries due to constraints in data measurement
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- Lack of cooperation from bordering countries due to constraints in data measurement
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Weakness
- Lack of capacity to handle satellite based rainfall data including poor internet quality
-Data will not be available timely

CASCADE 2: Monitoring and Data

Intervention 2-7: Regular monitoring of flood events by satellite data

- Prepare monitoring and validation procedure for the basin wide flood model
- Monitor the characteristics of flooding over the years
- Include weather data on basin wide level like cloud cover information, wind speed, rainfall etc

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Weakness
- High resolution image data are expensive
- Monitoring interval is bit longer

Strength
- Some sources provide free images
- CEGIS like institutes can be mobilized to produce analysis

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Opportunity
- Inundation depth, area, duration and timing can be analyzed for future reference

Strength
- Some sources provides free images
- CEGIS like institutes can be mobilized to produce analysis

CASCADE 2: Monitoring and Data

CASCADE 1
(Risk knowledge)

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

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Opportunity
- Inundation depth, area, duration and timing can be analyzed for future reference

Threat
- Due to images taken at different times some peak events may be missed. So, people can misinterpret the events.

CASCADE 2: Monitoring and Data

CASCADE 1
(Risk knowledge)

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

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- Due to images taken at different times some peak events may be missed. So, people can misinterpret the events.

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CASCADE 2: Monitoring and Data

Pair-wise Comparison (AHP-SWOT)

Cascade 3: Forecasting and warning

Intervention 3-1: Model accuracy and upgrade software

- Setup guidelines for model accuracy parameters and reliability, Spatial and temporal resolution of the model output
- Use most recent software version as well as simple model
- Upgrade the validation procedure for the model output with observed data (x-section, rating curve, etc)

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Weakness
- Available basic data such as rating curve, x-section, etc are of poor quality or need to be cross-checked

Strength
- Already known issue
- FFWC engineers know how to operate the numerical models

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

Opportunity
- Many new numerical models are available
- High degree of prediction in good quality can be possible

Strength
- Already known issue
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- Many new numerical models are available
- High degree of prediction in good quality can be possible

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- Available basic data such as rating curve, x-section, etc are of poor quality or need to be cross-checked

CASCADE 3: Forecasting and

Annex H

Institutional Review

Review of existing institutional EWS arrangements

List of Abbreviations

AAB	Action Aid Bangladesh
AFD	Armed Forces Division
ALGAS	Asia Least-cost Greenhouse Gases Abatement Strategy
BCAS	Bangladesh Centre for Advanced Studies
BDPC	Bangladesh Disaster Preparedness Centre
BDRCS	Bangladesh Red Crescent Society
BMD	Bangladesh Meteorological Department
BNBC	Bangladesh National Building Code
BTV	Bangladesh Television
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CANSA	Climate Action Network South Asia
CDMP	Comprehensive Disaster Management Programme
CEE	Centre for Environment Education
CEGIS	Centre for Environmental and Geographical Information Services
CHMor	Coastal Hydraulics and Morphology
CPP	Cyclone Preparedness Program
CSD	Committee for Speedy Dissemination
DDMC	District Disaster Management Committee
DG	Director General
DM&RD	Disaster Management & Relief Division
DMB	Disaster Management Bureau
DMC	Disaster Management Committee
DMIC	Disaster Management Information Centre
DMRD	Disaster Management and Relief Division
DRR	Directorate of Relief and Rehabilitation
EIA	Environmental Impact Assessment
EMSM	Estuary and Marine System Management
EOC	EOC Emergency Operation Centre
FFWC	Flood Forecasting and Warning Centre
FHRM	Fluvial Hydraulics and River Morphology
FldM	Flood Management
GEO	Global Environment Outlook
GFEP	Global Forum on Environment and Poverty
GIS	Geographical Information System
GOB	Government of Bangladesh
GSB	Geological Survey of Bangladesh
GWM	Ground Water Management
ICZM	Integrated Coastal Zone Management

IMDMCC	Inter-Ministerial Disaster Management Co-ordination Committee
IrriM	Irrigation Management
IWM	Institute of Water Modelling
IWRM	Integrated Water Resources Management
LGED	Local Government Engineering Department
MoFDM	Ministry of Food and Disaster Management
MoWR	Ministry of Water Resources
NCS	National Conservation Strategy
NDMAC	National Disaster Management Advisory Committee
NDMC	National Disaster Management Council
NEMAP	National Environment Management Action Plan
NGO	Non Governmental Organization
NPDM	National Plan for Disaster Management
NSD	North South Dialogue
OfS&Pl	Offshore Structure and Pipelines
PCSM	Port and Coastal Structure Management
PPPDU	Policy, Program and Partnership Development Unit
PWD	Public Works Department
RiEngg	River Engineering
RRAP	Risk reduction action plan
SEMP	Sustainable Environment Management Programme
SIA	Social Impact Assessment
SMIT	Software Management and IT Solutions
SWC	Storm Warning Centre
UDMC	Union Disaster Management Committee
UNOs	Upazila Nirbahi Officer
UWM	Urban Water Management
UzDMC	Upazila Disaster Management Committee
WARPO	Water Resources Planning Organization
WeLkM	Wetland and lakes management
WQ&Ec	Water Quality & Ecology
WQI	Water Quality Investigation
WSSD	World Summit on Sustainable Development

Contents

Background of the Project:

The Asian Development Bank (ADB) and International Centre for Water hazard and Risk management (ICHARM) signed Partnership Agreement for this Technical Assistance (TA) and in this agreement defined the role of ADB as for the Executing Agency and ICHARM as for the Implementing Agency of this TA, hence all of the consultants work of this TA will be done under the overall supervision of ICHARM. The TA has two components (i) in-country project support and (ii) program quality support through regional cooperation. The project support will be provided to Bangladesh, India, Indonesia and to the Mekong River Commission Secretariat.

In Bangladesh TA will support the preparation of the upcoming National Disaster Risk Mitigation Project (NDRMP) to implement the recommendations of an earlier TA for Early Warning Systems Study. This TA may be enriching the scope of NDRMP to cover water related disaster management especially improved flood forecasting. The TA will give technical support to the following:

i. Technical Review of early warning systems (EWS) currently being practiced in Bangladesh and recommendation for improvement, and

ii. Capacity building of engineers and managers, who are responsible to look after disaster management projects and programs in Bangladesh.

Under this project the following tasks is expected to be carried out in Bangladesh:

Task-1: Review documentation on the status quo of institutional, technical and social aspects of EWS in Bangladesh

Task 2: Identify and visit relevant institutes including those related to 22 point agendas recommended by previous TA (TA No 4562-BAN) and review the individual EWS related activity currently undertaken by each institute.

Task 3: Check the existing EWSs and their functionality as well as the effectiveness (Strengths, Weakness, Opportunity and Risk)

Task 4: Carry out field surveys to cross check the findings from review process and identify main gaps in development and dissemination of EW information.

Task 5: Recommend improvement measures for effective EWS and its application both at local and national levels and help prioritize them.

This review of existing institutional EWS arrangements is prepared under Task 2. Desk studies were conducted of the relevant literature to identify the relevant institutes and their individual EWS related activity.

Institutional Review

A number of institutes in Bangladesh are engaged in forecasting and disseminating the EWS related information. 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.

The main organisation involved in Forecasting is BWDB's Flood Forecasting and Warning Centre (FFWC). BWDB's Directorate of Hydrology and Bangladesh Meteorological Department (BMD) provide FFWC with water level and rainfall data and weather data respectively as inputs to the forecasting models.

Numerous organisations are involved in Dissemination as FFWC send flood forecast and warning information to a range of organisations involved in disasters whether for preparedness, relief rehabilitation or a combination of these. National-level organisations involved in dissemination range from government organisations including the Prime Minister's Office, Ministry of Food and Disaster

Management (MoFDM) and the Disaster Management Bureau (DMB), Ministry of Water Resources (MoWR), to non-government organisations such as CARE-Bangladesh, and Oxfam, international donor organisations such as the World Bank and Asian Development Bank, BWDB's central and regional offices and the press and other information media. Flood forecasts and warnings are passed onto to district administrators for subsequent transmission to upazila and below as needed. However the communication system below the district level is not fully operative although the lower levels are closer where floods have their main impact and could benefit from receiving flood warnings.

Response to flood forecasts or warnings for agencies and people at all levels requires that they are able to do something to mitigate the impact of the forecasted flood. Response involves the organisations involved in dissemination plus some additional organisations that are not involved in dissemination. It is becoming more and more important for the infrastructure managers to respond in time, carry out emergency maintenance and report to the forecasting agency on the performance of the forecast. There are also organisations involved in preparedness such as the Local Government Engineering Department that are responsible for the construction of rural infrastructure including the feeder roads and flood shelters and BWDB flood dykes that are lifelines for people seeking refuge from floods. To improve the response of people to flood warnings requires an assessment of infrastructure and facilities in their neighbourhood to ensure that people do have mitigation options when the flood comes.

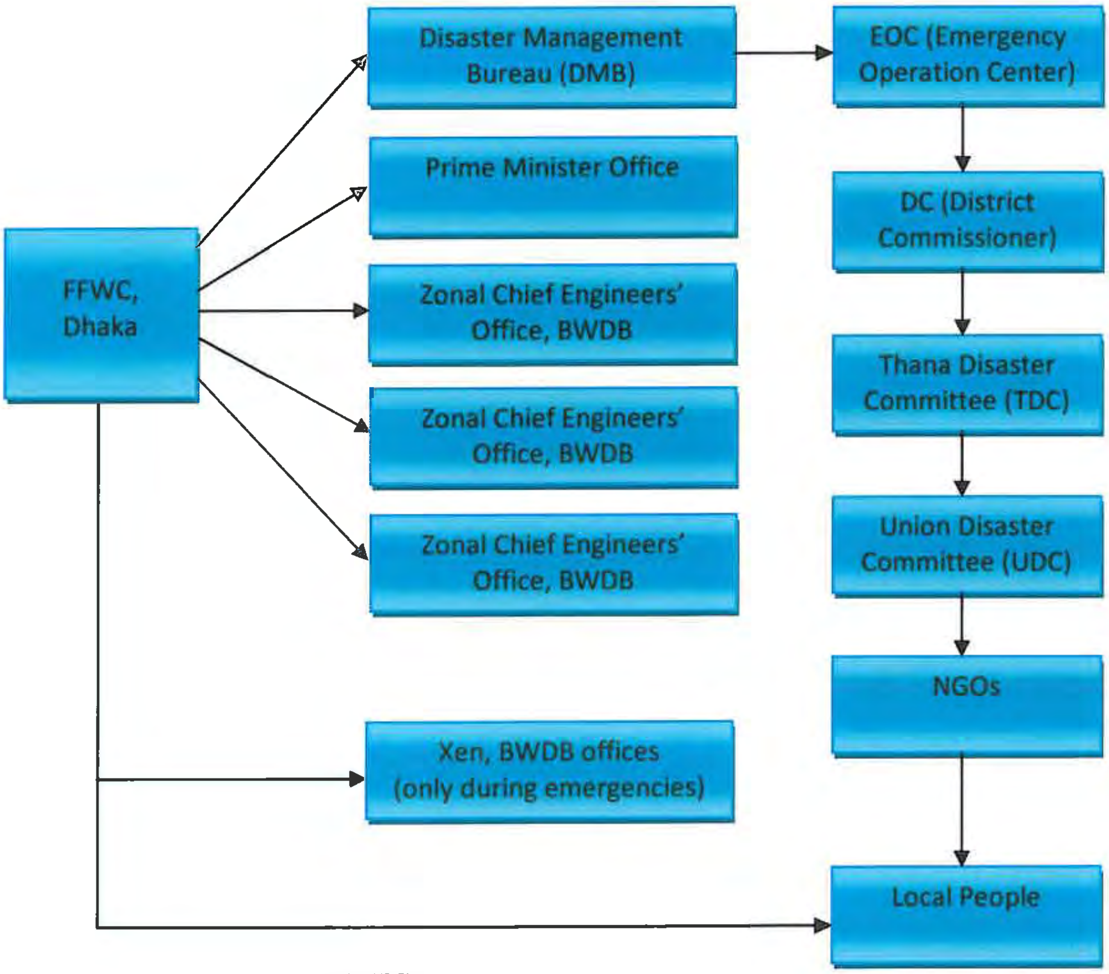


Figure: Dissemination from FFWC

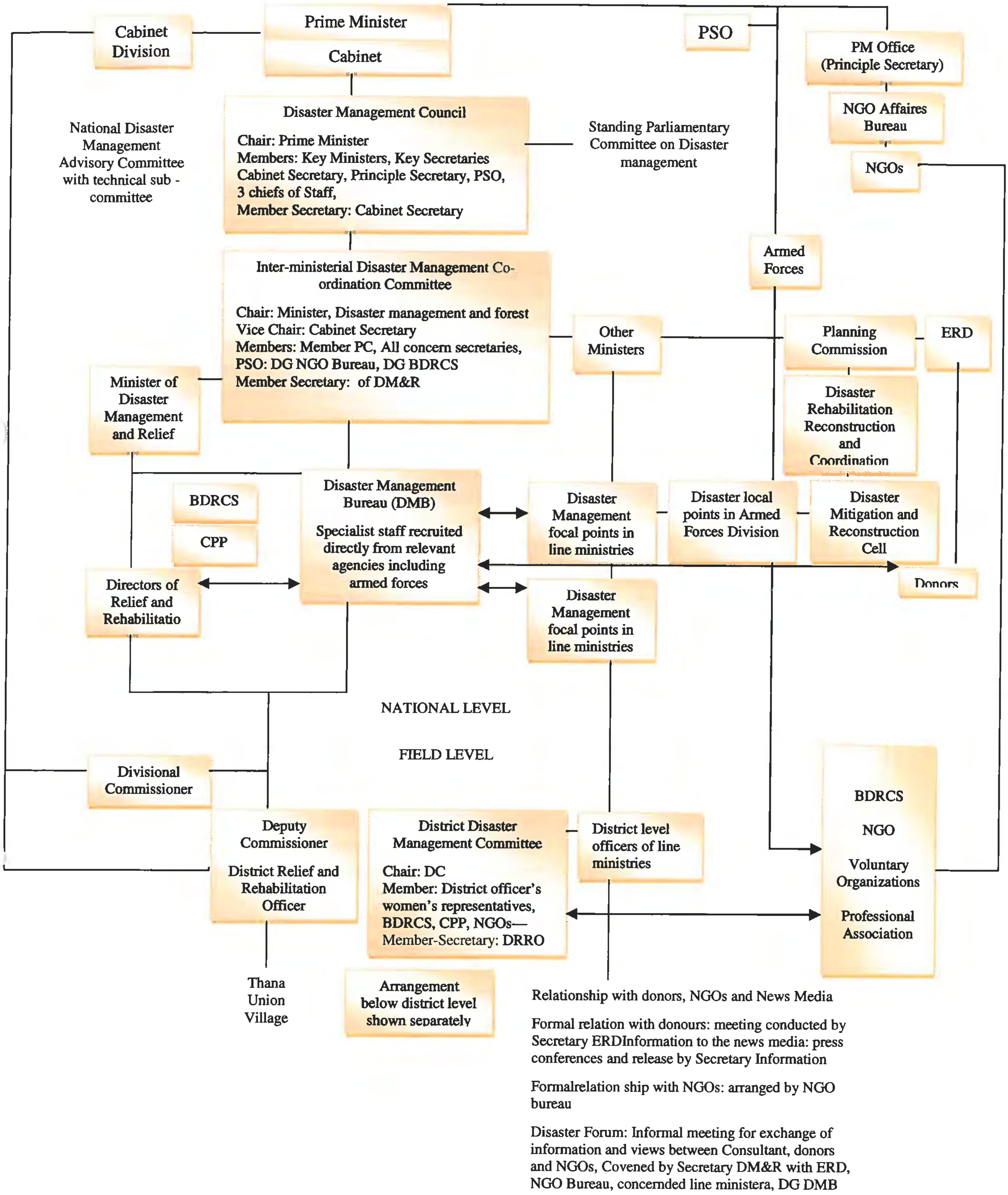


Figure: Institutional arrangement for disaster management in Bangladesh (Rahman 2006)

Bangladesh – EWS Institutions and responsibilities

Institution	EWS related responsibilities
Ministry of Water Resources	• Incorporate disaster risk reduction • Develop sectoral risk mitigation and preparedness strategy • Ensure budgetary provision for risk reduction activities and programs • Ensure implementation of the risk reduction programs and activities • Establish a sectoral risk communication system. • Monitor water levels of all major river systems. • Provide flood forecasting and warnings • Ensure effective communication, information and reporting during emergency response and recovery operations
Flood Forecasting and Warning Centre (FFWC)	• Conduct flood risk assessment and develop a long-term risk reduction action plan for floods and other water-related disaster. • Continue research in extending the lead-time for flood and flash flood forecasting and main linkages with regional flood forecasting sources. • Identify the flood-prone areas in Bangladesh. • Identify the flash flood-prone areas in Bangladesh. • Take steps to alert all stakeholders through telephone, cell phone, email, telex and wireless according to needs regarding floods and flash floods. • Inform DMB and BMD about the long, mid and short term flood foresting information for ensuring better preparedness.
Disaster Management Bureau (DMB)	• Promote awareness building activities. • A facilitator for the preparation of local disaster management action plans at union, upazila and district levels. • Maintain coordination with line departments/agencies, NGOs, social organizations etc. • A facilitator and a depository of all Disaster Management Related Information. • Maintain Inventory of Skilled Disaster Management Personnel. • Monitoring unit to monitor disaster preparedness activities through district administrations
Bangladesh Water Development Board (BWDB)	• Support the Ministry in incorporating disaster risk reduction considerations into the water sector policies, plans and programs. • Develop an action plan based on sectoral risk mitigation and preparedness strategy of the Ministry of Water Resources.

	• Implement the risk reduction programsand activities. • Improve the flood prediction system including technologies and modeling. • Strengthen the Flood Forecasting and Warning centre with improved technology and expert manpower. • Design the embankments considering the current and future risks of all hazards. • Building the risk reduction capacity of the field level officials. • Issue directives and warnings to field level officials through sub-centre. • Designate one Liaison Officer for maintaining liaison with DMB. • Make continuous arrangement for ascertaining the leakage, breach, collapse, damage etc in the embankment. Undertake repair work priority basis with the participation of local people. • Keep ready required equipment/materials for use in the affected areas. • Extend assistance to local civil administration in rescue, evacuation and relief operations and instruct lower level officers to make technical knowledge, equipment articles and transports etc available.
Directorate of Relief and Rehabilitation (DRR)	• Develop and establish guidelines and procedures to assess hazard risks and vulnerabilities at the community level. • Conduct national, District, Upazila and Union level hazard, risk and vulnerability assessments and mapping to identify the disaster Upazilas and special disaster areas under such Upazilas and the population likely to be affected by the disaster. • Design and implement the safety net programmes to contribute to the community level risk reduction efforts Introduce agency contingency planning. • Organize regular training for the selected volunteers on earthquake preparedness. • Organize training on earthquake preparedness and response for selected DRR officials. • Ensure stock, security and maintenance of adequate materials in disaster-prone areas. • Utilize the materials received under the Food for Works Programme for construction of roads to raised places and shelter places and for tree plantation.
Comprehensive Disaster Management Programme (CDMP)	• Professionalising the disaster management system • Mainstreaming of risk management programming (partnership development) • Strengthening of community institutional

	mechanisms (community empowerment) • Expanding risk reduction programming across a broader range of hazards • Earthquake and Tsunami Preparedness • Climate Change and Research • Strengthening emergency response systems (operationalising response)
Bangladesh Meteorological Department (BMD)	• Develop sectoral risk mitigation and preparedness strategy of the department. • Ensure budgetary provision for risk reduction activities and programs. • Undertake continuous improvement of cyclone forecast and warning systems. • Ensure improvement of cyclone forecast processes/procedures/methodologies, and continuous monitoring of the weather conditions, dissemination of all information in this regard on a regular basis. • Improve the equipment facilities for quickest dissemination of the information/warnings to all concerned, such as fax, E-mail arrangements must be established with all Print and electronic medias and MoFDM. • 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. Fax, email and other message transmission arrangement must be established between SWC of BMD and Radio, Television and the MoFDM.
Water Resources Planning Organization (WARPO)	• Monitoring implementation of the National Water Management Plan (NWMP) and its impact Upkeep of water resource assessments • Maintenance, updating and dissemination of the National Water Resources Database (NWRD) and MIS • Functioning as a "clearing house" • Secretariat to the National Water Resources Council (NWRC) and the Executive Committee of the National Water Resources Council (ECNWRC) • Responding to the NWRC/ECNWRC requests for information and advice • Periodic update of the National Water Management Plan (NWMP) • Assisting other agencies in planning, monitoring, studies and investigations • Adhoc advice on policy, strategy, institutional and legal issues

	• Special studies and research as required from time to time
Bangladesh University of Engineering and Technology (BUET)	• River Response, Training Works and Erosion Protection • Prevention of bank erosion using revetments, groins, bottom vanes etc. • Study on hydraulic jump in abruptly sloping channel • Hydrologic Forecasting using Artificial Neural Networking • Characterization and impact evaluation of drought • Flood discharge and flood frequency analysis • Development of unit-hydrograph in halda river basin • Coastal Engineering and Coastal Zone Management • Estimation of wave height near the coastal belt of Bangladesh • Impact of agricultural land use changes on surface and ground water • Study of floating pump irrigation in Bangladesh • Solution of dam-break problem by Collocation method in conjunction with hermite element • Assessment of crop damage due to flood using GIS technology
District Disaster Management Committee (DDMC)	• Arrange training and workshops on disaster-related issues regularly by keeping the DMB informed. • Regularly review the implementation status of the short, medium and long-term action plans through coordinating the programmes of development and service organizations at District level. • Provide necessary support to Union, Pourashava and Upazila disaster management committees to create local level fund appropriate for the implementation of the risk reduction action plans. • Inform the DMB on the progress of action plan and other activities at District level. • Disseminate forecasts and warnings regarding disasters and make the people conscious about them. • Prepare a District disaster risk reduction action plan (RRAP) including the following issues with a view to keep the District authority and local organizations well prepared so as to meet the disaster effectively and efficiently in the light of warning signals about imminent disaster and the occurrence of disaster: • Select specific safe centres/shelters for evacuation of the people from District headquarters and to build capacity and assign responsibility to different individuals and organizations for rendering various services and securities at the shelters. Build their capacity and instruct all the departments to provide necessary support to the Union, Pourashava and Upazila DMCs.

	• Ensure supply of safe drinking water, which can be filled in cans, ensure security and other essential services at the safe centres/shelters located in the District headquarters. And arrange similar services and facilities at Union, Pourashava and Upazila levels in communication with Union, Pourashava and Upazila DMCs. • Take all necessary measures to activate Union, Pourashava and Upazila DMCs; at the same time, provide necessary support to the Union, Pourashava and Upazila DMCs in rescue work and emergency relief work and preparation of contingency plans for essential services in the interior of the District along with District headquarters, Upazila headquarters and Pourashava (grade 'A') and disaster management information centre (DMIC). • Arrange occasional rehearsals or drills on the dissemination of warnings/forecasts, evacuation, rescue and primary relief operations with assistance from DMB and Upazila/Pourashava authority. • Monitor the progress of the activities and implementation status of the action plans of Upazila and Pourashava DMCs (grade'A') and submit a comprehensive progress report to DMB regularly.
Disaster Management & Relief Division (DM&RD)	• b) Review the own Action Plan of the Ministry on disaster management every 3 (three) months. • Identify the disaster Upazilas and special disaster areas under such Upazilas and the population likely to be affected by the disaster. • Update the list of foreign and private agencies willing to participate in the disaster preparedness, emergency response and rehabilitation programmes. • Preserve information regarding food, relief materials and transports usable at all levels during disaster. • Direct all concerned for ensuring availability of the SOD at village, Union, Upazila and District DMCs and to stakeholders. • Arrange meetings of the NDMC and IMDMCC to assess the disaster preparedness of different • Ministries, agencies, departments, local governments, autonomous bodies, CPP, BDRCS, NGOs, etc. • Ensure non-stop telecom link of the Ministry with District and Upazila Headquarters. • Issue necessary orders for proper coordination of steps relating to disaster and response.
Inter-Ministerial Disaster Management Co-ordination Committee (IMDMCC)	• Recommend enactment of legislation, policies, Standing Orders and national level plans (sector and hazard specific) to the Cabinet Committee / Council

	of Advisers • Review, revise and approve contingency plans of various First Responding Organizations • Approve guidelines and templates prescribed by the NPDM and SOD • Approve City Corporation Disaster Management Plans and District Disaster • Approve national and sub-national programs for disaster risk reduction • Advocate and ensure disaster risk reduction is mainstreamed in development policies, plans and programmes • Monitor DRR activities and programs, and keep the NDMC informed of their progress • Review and promote emergency preparedness and public awareness capacity development in disaster management • Promote monitoring, evaluation, education, and research on disaster risk reduction and emergency response management • Emergency Response • Evaluate emergency preparedness status and recommend corrective measures. • Approve response and recovery plans. • Promote preparedness activities, such as fire evacuation drills, search and rescue mock exercise, etc. • Ensure whole-of-government coordination in emergency response, relief and rehabilitation operations. • Approve guideline for multi-agency incident management. • Establish Urban Search and Rescue Taskforces.
Institute of Water Modelling	• Water resources assessment and management • Master planning and policy development • Water supply and demand assessment • River Basin management • Environmental impact analysis • Wetland and lakes management (WeLkM) • Analysis of the overall effect of irrigation schemes on the water balance • Water shortage and irrigation management • Ground Water Management (GWM) • Urban Water Management (UWM) • Hydrological assessments • Monitoring networks and information systems • Flood risk and damage assessment • Flood Mapping • Real-time flood forecasting and operational water management systems • Land use and climate change studies

	• Flood mitigation planning and designs and operations • Integrated Coastal Zone Management (ICZM) • Port and Coastal Structure Management (PCSM) • Estuary and Marine System Management (EMSM) • Water Quality Investigation (WQI) • Software Management and IT Solutions (SMIT) • Topographic, hydrographic, sediment transport, water quality and hydrological, meteorological field measurements, necessary laboratory analysis and data management and mapping;
Local Government Engineering Department (LGED)	• Repair and maintain small roads, bridges and culverts for communication to cyclone shelters, educational institutions, community centres and health centres for the purpose of providing easy communication for evacuation and security during disaster. • In cyclone-prone areas, advise for raising the banks of water reservoir (pond) above the levelof cyclone induced tidal bore and in other places above flood level so that the water reservoir can be used by people as supply source of drinking water and the banks can be used as shelter place for animals. Several rows of trees should be planted. • Maintain stock of Baily bridges for bridge and culverts, and for repairing the breach on roads for the purpose of quick movement of relief materials. • Keep the foundations level of cyclone shelter under the control of Upazila Parishad above flood level and undertake regular maintenance work. • Train the Engineer, including Secretary of the Union Parishad and technical and non-technical employees in disaster preparedness and management programmes and make them known to the people.
Ministry of Water Resources (MoWR)	• Regulation and development of rivers and river valleys. • General policy and technical assistance in the field of irrigation, flood control, anti-water-logging, drainage and anti-erosions. • All matters relating to irrigation, flood forecasting and warring, flood control, flood control works, causes off floods and damage caused by floods to irrigation projects, embankments, etc. • Basic, fundamental and applied research on river valley projects and flood control works. • International cooperation in the field of flood control and development of water resources. • International commissions and conferences relating to irrigation, flood control and water resourse management. • Construction and maintenance of canals under W.

	D. B. Project; construction and maintenance of water control structures for the canals executed under the Canal Digging programme. • Soil conservation drainage and water-logging. • Storage of water and construction of reservoirs, embankment and barrages. • Land reclamation, estuary control. • Anti-salinity measures and anti-desertification. • Hydrological survey and data collection. • Matters relating to Joint Rivers Commission; Joint Committee, Standing Committee, etc and Common Border Rivers. • Secretariat administration including financial matters. • Administration and control of Subordinate office organization under this Ministry. • Liaison with International Organization and matters relating to treaties and agreements with other countries and world bodies relating to subjects allotted to this Ministry. • All laws on subject to this Ministry. • Inquiries and statistics on any of the subject allotted to this Ministry. • Fees in respect of any of the subjects allotted to this Ministry except fees taken in courts.
National Disaster Management Advisory Committee (NDMAC)	• Advise NDMC, IMDMCC, MoFDM and DMB on technical matters and socioeconomic aspects of Disaster Risk Reduction and emergency response management. • Alert the Committee members about the risk of disaster and mitigation possibilities and encourage them in respect of workshop, training and research. • Create a forum for discussion by experts on the risk of disaster, opening opportunities for cooperation towards solution of problems relating to disaster management. • Recommend release of funds for special project works and also for introduction of special emergency methods or empowerment, if needed. • Recommend solution of problems identified by the DMB or any other agency/person. • Propose long term recovery plans. • Hold post-mortem or prepare final evaluation on programmes undertaken to meet the disaster and • Submit a report with recommendations to the NDMC.
National Disaster Management Council (NDMC)	• Review national disaster management system and provide strategic advice for disaster risk reduction and emergency response management. • Review policy and planning documents on disaster management and provide strategic advice.

	• Promote dialogue across sectors with a view to integrate disaster risk reduction into sectoral development plans and programmes. • Promote awareness regarding disaster risk reduction among top policy makers. • Evaluate disaster preparedness measures and provide strategic advice. • Evaluate response and recovery measures, particularly after a large-scale disaster and provide strategic direction towards improvement of the system and procedures, and • Facilitate coordination of multi-hazard and multi-sectoral measures in relation to disaster risk reduction and emergency response management.
Public Works Department (PWD)	• Organize training programmes and awareness campaigns with the civil engineers involved in the construction works and the masons to ensure proper execution of the Building Codes. • Establish a strong monitoring system to monitor the quality of construction works of the government and in the private sector. • Keep manpower and materials ready for protection and repair of government property. • Protect all government stock and ensure their security by shifting them to safer place, if necessary. • If necessary, send materials and workers from other places to areas likely to be affected, for meeting emergency situation and keep Headquarters and concerned local DMC informed about it.
Union Disaster Management Committee (UDMC)	• Ensure that local people are kept informed and capable of taking practical measures for the reduction of risk at household and community level and also disseminate the success stories of reducing disaster risks at household and community level widely among the local people. • Arrange training and workshops on regular basis on disaster issues and keep the UzDMC informed. • Hold a hazard, vulnerability and risk analysis at Union level and prepare risk reduction action plan (RRAP) and contingency plan for earthquake and other hazards. • Identify the most vulnerable or people at high risk by sex, age, physical ability, social status, occupation and economic status. • Prepare a short, medium and long-term vulnerability reduction and capacity building action plan for the identified high-risk people with active participation of the people at risk. • Facilitate coordination among the development agencies and service providers through quarterly coordination meeting and take decision about

	implementation of the action plan for risk reduction as well as review the progress of the risk reduction action plan. • Raise fund at local level to implement the risk reduction action plan.
Upazila Disaster Management Committee (UzDMC)	• Assist Union and Pourashava DMC • to form and activate a comprehensive DMC at Union and Pourashava level, so that the DMCs can provide proper guidance, get the right and correct information and can exploit benefits from imparted training. • to increase their efficiency in developing local warning system, risk reduction programming, rescue and recovery strategy and awareness raising strategy. • to hold a hazard, vulnerability and risk analysis at Union and Pourashava level; compile hazard, vulnerability and risk assessment of Unions and Pourashavas and prepare a hazard, vulnerability and risk assessment report for the Upazila. • to identify the most vulnerable area or people at high risk by sex, age, physical-ability, social status, occupation and economic status, compile the list of people at high risk at different Union and Pourashavas and based on the lists prepare a report and location map of people at risk in the Upazila and to send the report to the DDMC. • to prepare a short, medium and long-term vulnerability reduction and capacity building action plan for the identified high risk people with active participation of the people at risk; compile the action plans and prepare a Upazila level action plan and send a copy to DDMC. • Ensure that disaster risk reduction approaches are well considered during planning and implementation of development programmes of Union, Pourashava and Upazila. • Arrange training and workshops on regular basis on disaster issues and assist Union and Pourashava DMCs to arrange training and workshop and keep the DDMC informed of progress and constraints.
Centre for Environmental and Geographical Information Services (CEGIS)	• Environmental Impact Assessment (EIA) • Social Impact Assessment (SIA) • Feasibility Studies • Environmental and social monitoring • Integrated planning and management of water resources • Socio-economic and institutional analysis • Remote sensing and image processing • Natural resources assessment and land use monitoring

	• Disaster monitoring and damage assessment • Land information management • Climate change and adaptation
Bangladesh Centre for Advanced Studies (BCAS)	• Works with communities through eco-specific participatory management processes. • Established eco-specific research centres in different parts of country such as the Wetlands Research and Training Centre (WRTC) in Chanda Beel in the Modhumati Floodplain. • Carried out several national level studies on climate change issues: • Vulnerability Assessment for Bangladesh to Climate Change and Sea Level Rise • Bangladesh Climate Change Study under USCCS • Asia Least-cost Greenhouse Gases Abatement Strategy (ALGAS) • Works closely and carried out numerous studies and advisory inputs for the government of Bangladesh • Involved in a number of collaborative research and initiatives with leading Bangladeshi NGOs including BRAC, Grameen Bank, Grameen Shakti, Proshika etc. • Involved in a number of collaborative research, policy analysis and advocacy including North South Dialogue (NSD) on Climate Change, Global Compact Initiative under aegis of UN as RING member. • Participated in all the preparatory meetings of UNCED in Rio and WSSD in Johannesburg as a NGO representative, where it also played a key role in giving advice to the government delegations. • Provides secretarial support to Global Forum on Environment and Poverty (GFEP) originated during the Earth Summit in Rio. • Involved in the process of formulation and reporting on all Global Environment Outlook (GEO) Reports of UNEP.
Bangladesh Disaster Preparedness Centre (BDPC)	• Capacity Development • Advocacy and Lobbying • Strategy Formulation and Planning • Awareness, Knowledge, and Communication
Action Aid Bangladesh (AAB)	• Livelihood Security and Risk Reduction • Women's Rights and Gender Equality • Rights and Social Justice • Social Development and Economic Justice

Annex: Detail Information on Institutions and their responsibilities in EWS

1. Flood Forecasting and Warning Centre (FFWC)

Risk Reduction

(a) Conduct flood risk assessment and develop a long-term risk reduction action plan for floods and other water-related disaster.
(b) Continue research in extending the lead-time for flood and flash flood forecasting and main linkages with regiona l flood forecasting sources.
(c) Identify the flood-prone areas in Bangladesh.
(d) Identify the flash flood-prone areas in Bangladesh.

Alert and Warning Stage

(a) Take steps to alert all stakeholders through telephone, cell phone, email, telex and wireless according to needs regarding floods and flash floods.
(b) Inform DMB and BMD about the long, mid and short term flood foresting information for ensuring better preparedness.

Field Level Offices of Chief Engineer/Superintendent Engineer/Executive Engineer/Assistant Engineer (Flood-Related) of BWDB

In addition to their normal functions, these offices will perform the following duties in the light of delegation of powers in their respective spheres:

Risk Reduction

(a) Conduct local level assessment and prepare the local level risk reduction plan in the water sector.
(b) Construct the embankments as per the design approved by the BWDB suitable to the local context.
(c) Conduct the situation analysis and maintain a database on the existing infrastructure such as embankments, polders and sluice gates. Carry out regular maintenance work to strengthen the system.
(d) Construct protecting embankments in time and maintaining satisfactory standard after receiving approval of the authority.
(e) Strengthen the data collection system for flood forecast.

EMERGENCY RESPONSE

Normal Times

Ensure the following:

(a) Manage the Flood Information Centre from April up to November every year.
    i. Arrange to collect information on rainfall and water level at different points of rivers originated in India
    ii. Submit flood forecast, through respective Head of Office, to Flood Control Room of BWDB and the Control Room of the Ministry of Water Resources
(b) Inform and alert BWDB, Ministry of Water Resources, and EOC of the MoFDM, concerned DCs and UNOs about the increase of flood level and flash floods.
(c) Inform all concerned about the weekly flood position.
(d) Attend meeting of the local DMC.
(e) Ensure support and assistance to local administration regarding rescue, shifting and relief operations with required mechanical implements, transports and materials and tactical support.
(f) Designate one Liaison Officer for keeping the link with local Disaster Control Room.

(g) Alert all concerned speedily by telephone, fax, wireless etc. as flash floods allow very little time.
(h) Complete repair of leakage, holes etc in the embankments of respective areas before April every year and keep the materials/implements for emergency work ready at convenient place and complete the on-going projects like construction of embankments and gates. The board will identify earmark funds and responsibilities for these works.

Alert and Warning Stage

(a) Arrange for guards for sluice and lock gates to avoid loss.
(b) Send reports to higher officials about conditions of sluice gates, embankments and installations and progress of their repair.
(c) Take precautionary steps for the protection of life, assets, equipment and transports.

Disaster Stage

(a) Operate Flood Information Centre day and night (24 hrs) on a full time basis and send Liaison Officer to the local disaster Control Room.
(b) Inform Flood Control Cell of BWDB and local Disaster Control Room about any untoward incident.
(c) Support and assist the local civil administration in rescue, evacuation and relief operations in respective areas.
(d) Repair the damaged installations and supply sources by managing technical manpower and materials.
(e) Assess loss and damage as soon as the flood waters recede, prepare plans, designs for emergency repair, reconstruction, reinstallation under the short and long term perspective plan. The BWDB will assign responsibility and arrange funds.
(f) Supervise works by paying repeated visits to affected areas and take preventive measures on emergency basis.
(g) In case of difficult problem/situation beyond the control of concerned office, ask for help of the IMDMCC through local Civil Administration or the MoFDM.
(h) Take any suitable action in the exigency of circumstances for saving life and assets and also for evacuation.

Rehabilitation Stage

(a) Assess loss and damage and prepare plans and designs for repair, reinstallation or reconstruction according to necessity on priority basis.
(b) With the help of local agency/non-governmental organization, restore physical infrastructure, sluice gate, water drains and re-establish within minimum possible time.
(c) Co-operate and assist civil administration, and other agencies, including NGOs in the rehabilitation activities.
(d) Prepare project designs of new type with a view to preventing floods in specific areas. The field offices of Water Development Board will send daily flood situation report to the following offices:
    (i) Control Room of the Ministry of Food and Disaster Management
    (ii) Chairman, Water Development Board
    (iii) Concerned Divisional Commissioner
    (iv) All Deputy Commissioners of the affected areas
    (v) All Upazila Nirbahi Officers of the affected areas

2. Disaster Management Bureau (DMB)

Risk Reduction

a) Advise the government on all matters relating to disaster management.
b) Propose legislation on disaster preparedness and mitigation and other instructions.
c) Maintain liaison with different government agencies, aid-giving agencies, NGOs and Voluntary Organizations and ensure their maximum cooperation and coordination in all matters of disaster management.
d) Prepare guidelines/instructions for reducing cyclone, flood, earthquake and other disaster risks and vulnerabilities.

e) Prepare guideline for mitigation of disaster and mainstreaming disaster risk reduction with the assistance of Planning Commission and other relevant agencies for devising steps to reduce disaster risk.
f) Provide training to government officials, elected representatives and others on cyclone, flood, earthquake and other disaster management in support with the ministries, local government departments and NGOs.
g) In support of the Geological Survey of Bangladesh, make available the earthquake risk maps of vulnerable areas.
h) Prepare earthquake risk maps of the most vulnerable cities.
i) Prepare a list of the search and rescue equipments and transports/vessel required for earthquake, cyclone, flood, tsunami and other disaster response management and keep the government informed.
j) Procure search and rescue equipments for earthquake, cyclone, flood, tsunami and other disaster response and distribute to the proper responding authority.
k) After completion of the 1st phase of the project for "procurement of equipment for search and rescue operation for earthquake and other disasters", will take steps for further extension of the project as required by the government.
l) Ensure DRR activities in the coastal districts of the country and facilitated livelihood activities of the affected people through Emergency 2007 Cyclone Recovery and Restoration project and by taking other appropriate projects and activities.
m) Organize an annual drill on earthquake preparedness and simulation exercise on cyclones, floods and hazards with the relevant first responding organizations/DMCs and review the preparedness status/position.
n) Conduct research on earthquake disaster management, drought mitigation, livelihood support and disaster recovery funding etc.
o) Conduct research on climate change effect and coping mechanism of any new hazards.
p) Assist, coordinate and monitor the activities of the relevant agencies to ensure proper implementation of the Building Codes.
q) Analyze the risk maps to be produced by the Geological Survey of Bangladesh and prepare guidelines with suggestions and recommendations for house-building projects.
r) Produce earthquake vulnerability and risk reduction plan and guideline for hazard specific contingency planning and ensure its proper execution.
s) Conduct all related activities for tsunami risk reduction.
t) Support the Ministry in the:
i. Establishment of the national policy, planning and legislative frameworks for comprehensive disaster management in Bangladesh
ii. Preparation and implementation of framework for Action Plan on disaster management at District, Upazila and Union levels
iii. Development of specific guidelines and templates facilitating mainstreaming disaster management principles and practices in the national development planning processes at all levels
iv. Coordinating the inter-sectoral risk reduction efforts of the government

EMERGENCY RESPONSE

Normal Times

a) Undertake various activities for creating awareness among the people, government employees and people of other professions for reducing risks during disaster.
b) Provide secretarial support to the NDMAC on disasters.
c) Arrange publication and distribution of the SOD, National Disaster Management Plan and other related guidelines.
d) Impart training to the government employees, elected representatives and others on disaster management in cooperation with different Ministries, local authorities, training institutions, Academies and NGOs.
e) Establish an EOC and DMIC with improved communication facilities at national level and to disseminate inputs/information to government and private agencies.
f) Distribute books, maps and other information to those associated with disaster management.

g) Monitor obstacles to the Action Plan or project implementation on probable disaster risks to lives and properties, preparedness, disaster response and mitigation, and inform the DM&RD.
h) Collect and preserve lists with location, condition and ownership of cyclone shelters, embankments, platforms at higher than flood level (flood-proofing).
i) Coordinate the activities of NGOs regarding disaster management.
j) Ensure awareness-raising campaigning on weather signals.
k) Arrange public awareness programmes at regular intervals in radio and television on various disaster-related issues.
l) Organize meetings/seminars/workshops at national, District, Upazila and Union levels to increase awareness about disasters through concerned DMCs and other organizations.
m) Ensure liaison with the Ministry of Education and Ministry of Primary and Mass Education for inclusion of disaster topics in the curricula of schools, colleges and Universities.
n) Facilitate publicity of cyclone signals at the community level through posters, cultural functions, documentary films etc.

Alert and Warning stage

a) Ensure receipt of warning signals of imminent disasters by all concerned officials, agencies and mass communication media.
b) Assist the DM&RD for undertaking emergency programmes in risk areas by different agencies and the people in the structured areas.
c) Ensure publicity and of awareness-raising campaigning on newly-introduced early warning system all around the country.
d) Ensure publicity of Gano Durjog Barta after issuing Signal No. 4.
e) Introduce local warning (siren) system on tsunami and storm surge.
f) Activate EOC and keep touch with other agencies for making their Action Plan effective and also to activate the Control Room.
g) Publish daily bulletins during disaster period for foreign embassies and UN Missions.
h) Instruct local authorities for assessment of loss and damage and requirement of relief.

Disaster Stage

a) Keep EOC open on non-stop basis (24 hours).
b) Assist the DM&RD for formation of groups for primary assessment of loss and damage and needs.
c) Establish and institutionalize damage, loss and need assessment cell at DMB.
d) Assist the IMDMCC for ensuring coordination among government, NGOs and different agencies for relief and rehabilitation activities.
e) Monitor progress of rescue, relief and rehabilitation operations, identify the problems and needs and to draw the attention of the proper authority.
f) Assist the DM&RD in supplying required information to the Economic Relations Division, Ministry of Information, foreign agencies, NGOs etc.
g) Supply information to foreign missions and UN agencies including all international organizations and the World Bank regularly through daily news bulletins.
h) Keep the Ministry informed about the progress of use of materials in relief and response operations.

Ensure deployment of procured and distributed equipment for search and rescue operation.

Rehabilitation Stage

a) Supply information/input to concerned authority for the preparation of rehabilitation plan.
b) Ensure adoption of steps for minimizing future disaster risks in the rehabilitation plans.
c) Undertake post-mortem of steps taken in the overall management in the emergency response of disaster, prepare reports on the basis of experience/knowledge acquired in this respect, and publish the same and bring required changes accordingly in the training programmes and future policy.

3. Prime Minister's Office

a) Issue directives to all concerned to ensure that disaster risk reduction is a national and local priority.
b) Approval/endorsement of the SOD as a legislative framework and its legal basis of all its activities and actions for all Ministries and relevant government departments and bodies as outlined respective duties and responsibilities in the SOD.
c) Supporting the creation and strengthening of national integrated disaster risk reduction mechanisms.
d) Integrating risk reduction, as appropriate, into development policies, programming and planning at all levels of government, including in poverty reduction strategies and sectors and multi-sector policies and plans.
e) Adopting or modify where necessary, legislation to support disaster risk reduction, including regulations and mechanisms that encourage compliance and that promote incentives for undertaking risk reduction and mitigation activities.
f) Allocating resources for the development and the implementation of disaster risk management policies, programmes, laws and regulations on disaster risk reduction in all relevant sectors and authorities at all levels of administrative and budgets on the basis of clearly prioritized actions.
g) Demonstrating the strong political determination required to promote and integrate disaster risk reduction into development programming.
h) Supporting the recommendations of the NDMC, IMDMCC, EPAC and NDMAC for implementation by the concerned ministries, departments, bodies.
i) Issue directives to concerned Ministries to arrange disaster management education, research, training and awareness for their staff on disaster management so that the staff acquired adequate and appropriate skills and abilities to participate in the disaster risk management activities.
j) Coordinate all the activities of the NDMC.
k) Ensure that the concerned Ministries review their contingency plan in each year to ensure adequacy and consistency with the lessons learnt from previous response, relief and recovery operations.
l) Take initiatives to issue directives to the concerned Ministries for activating all necessary resources in support of response, relief and recovery operations.
m) Ensure representation of the PM Office in all meetings of the IMDMCC, EPAC and NDMAC held during response, relief and recovery operations and establish a close monitoring system of the ongoing decisions and actions.
n) Disaster Monitoring and Coordination Cell will facilitate easy access of collection and dissemination of information to ensure better coordination.
o) Establish effective communication with the DMIC.
p) Ensure support to response, relief and recovery operations as requested.
q) Monitor proper and effective warnings disseminated by the responsible department.
r) Ensure necessary support to the Intra Ministry Coordination efforts of IMDMCC during response, relief and recovery operations.
s) Ensure resources reallocation of concerned Ministry including staff from non-affected areas to affected areas for need-based support to relief, recovery and rehabilitation operations/initiatives as and where necessary.

4. Bangladesh Water Development Board (BWDB)

Risk Reduction

(a) Support the Ministry in incorporating disaster risk reduction considerations into the water sector policies, plans and programmes.
(b) Develop an action plan based on sectoral risk mitigation and preparedness strategy of the Ministry of Water Resources.
(c) Implement the risk reduction programmes and activities.
(d) Improve the flood prediction system including technologies and modeling.

(e) Strengthen the Flood Forecasting and Warning centre with improved technology and expert manpower.
(f) Design the embankments considering the current and future risks of all hazards.
(g) Building the risk reduction capacity of the field level officials.

EMERGENCY RESPONSE

Normal Times

(a) The FFWC of BWDB will act as Focal Point and the Deputy Director in Charge of the Centre will act as Liaison Officer.
(b) Undertake operation of sluice gates and other water discharging devices in completed embankment areas.
(c) Monitor continuously the condition of the embankment and repair the breaches and weak points in adequate manner.
(d) Operate the FFWC from April up to November.
(e) Open warning sub-centres at field level offices of Superintendent Engineer/Executive Engineer.
(f) Collect special weather bulletins regularly from the Meteorological Office.

Cautionary/Warning Stage

(a) Issue directives and warnings to field level officials through sub-centre.
(b) Designate one Liaison Officer for maintaining liaison with DMB.
(c) Make continuous arrangement for ascertaining the leakage, breach, collapse, damage etc in the embankment. Undertake repair work on top priority basis with the participation of local people.
(d) Keep ready required equipment/materials for use in the affected areas.
(e) Extend assistance to local civil administration in rescue, evacuation and relief operations and instruct lower level officers to make technical knowledge, equipment articles and transports etc available.

Disaster Stage

(a) Operate the Control Room day and night (24 hours), warn all concerned about the imminent disaster and alert all to take security steps for the safety of lives, assets, machineries, transports, materials etc.
(b) Identify the technical manpower and materials required for the emergency repairs of loss/damage to installations and supply lines.
(c) Request the MoFDM regarding all appropriate assistance requirements for emergency rehabilitation.
(d) Undertake actions in the exigency of circumstances to safeguard human lives, property and evacuation.

Rehabilitation Stage

(a) Determine the extent of loss/damage in details and, if possible, prepare rehabilitation plans with estimates of expenditures by providing funds from own department or with additional funds from other sources.
(b) Implement suitable projects for the stability of newly formed offshore islands.
(c) Assist civil administration and other agencies in all possible ways in the rehabilitation activities.

Field Offices of Chief Engineer/Superintending Engineer/Executive Engineer/Assistant Engineer (Cyclone-Related) of the BWDB

The field level officials and staff of BWDB shall perform the following duties in their respective areas.

Risk Reduction

(a) Conduct local level assessment and prepare the local level risk reduction plan in the water sector.
(b) Construct the embankments as per the design approved by the BWDB suitable to the local context.

(c) Conduct the situation analysis and maintain a database on the existing infrastructure such as embankments, polders and sluice gates. Carry out regular maintenance work to strengthen the system.

(d) Construct protecting embankments in time and maintaining satisfactory standard after receiving approval of the authority.

EMERGENCY RESPONSE

Normal Times

(a) The Chief Engineer or Superintending Engineer will identify the Disaster Focal Points in their respective offices and inform the FFWC.

(b) Arrange to collect special weather bulletins/news and inform all concerned at field level and direct for security steps in embankments and other installations.

(c) Attend the meeting of the local DMC.

(d) The Chief Engineer at field level will appoint Liaison Officer for communicating with the local DMC.

(e) Coordinate and cooperate with civil administration for rescue, evacuation and relief operations and make available implements, materials, transports and technical assistance to them.

(f) Repair leakage, breaches, holes, and weak points in the embankment in their own area and also repair the broken sluice gates. Also keep ready the materials at suitable place for repair purpose.

(g) Appoint guards for protecting the polders against entry of saline water during tidal bore whipped up by cyclonic storm and also to protect damage to sluice gates.

(h) Submit reports at regular intervals to higher authority stating the condition of sluice gate, embankment and other works and progress of repair and reconstruction.

Alert and Warning Stage

(a) Take precautionary steps for protection of the lives of the employees of BWDB and secure BWDB assets, machinery, transports etc.

(b) Maintain link with the local DMC and coordinate activities with other agencies.

(c) Give priority to emergency construction of physical infrastructure and repair and maintenance.

Disaster Stage

(a) Ensure non-stop operation of information centre day and night (24 hrs.) and send liaison officer to the local DMC.

(b) Inform the information centre of BWDB and Control Room of the local administration about any disaster.

(c) Assist and support the local administration for rescue, evacuation and relief activities.

(d) Repair any damage, unserviceable installations and supply source by organizing technical persons and materials.

(e) Assess damage/loss and initiate action plan for repair, reconstruction and reinstallation as soon as possible after the recession of water in accordance with the short term and perspective plan of the government.

(f) Take preventive action on emergency basis through tours in the affected area.

(g) Request the local civil administration or DMC in case of any difficulty or any exceptional circumstances, the solution of which is beyond the control of own office.

(h) On exigencies, take any suitable action for the protection of lives and property and evacuation in coordination with the civil administration and DMC.

Rehabilitation Stage

(a) After assessing the loss/damage, prepare plan and designs, as quickly possible for repair, reinstallation and reconstruction of physical infrastructure, embankments, and sluice gates at required places.

(b) Assist and cooperate with the civil administration in relief activities as far as possible.

(c) Identify places for the construction of embankments as protective measure against future disasters like tidal bore or floods, prepare plans and request for approval and sanction of funds from the concerned authorities.

<u>Bangladesh Water Development Board (Flood-Related Activities)</u>

In addition to normal functions and Contingency Plan on floods, the BWDB will also perform the following duties.

Risk Reduction

(a) Conduct sectoral risk assessment and develop a long term risk reduction action plan for the sector.
(b) Consider all hazard risk and use the historical disaster data and information while designing the embankments, protection walls, sluice gates and other infrastructure.
(c) Keep budget provision for building of protection walls, repairing of embankments, sluice gates and lock gates in disaster areas.

EMERGENCY RESPONSE

Normal Times

(a) Ensure efficient management of FFC and improve procedure for flood forecasts and after necessary revisions inform the appropriate authority.
(b) Operate "Flood Information Centre" from April to November every year.
(c) Establish flood information Sub-Centre at field level from April every year.
(d) Collect, during monsoon period, weather forecasts, water level of all principal rivers originating from different places in Bangladesh and India. The BWDB will request the Ministry of Water Resources regarding the receipt of information from India.
(e) Inform all concerned regularly about daily weather news and issue regular press bulletins.
(f) Alert MoFDM and concerned DCs.
(g) Inform all concerned about weekly flood situation reports.
(h) Instruct all subordinate offices in April every year about the following:
(i) Coordination with local administration
(ii) Supply of required implements, materials, transports, articles and technical know how
(j) Inform DMB and MoFDM about operation of Information Cell of the Board.
(k) Ensure Coordination with IMDMCC, MOFDM and DMB.
(l) Designate one Liaison Officer in Board Office to maintain link with the EOC of the MoFDM. Deputy Director of FFWC will be in charge of this responsibility.

Alert and Warning Stage

(a) Since flash floods visit within shortest possible time, so take steps to alert all through telephone, telex and wireless according to needs.
(b) Appoint guards to locate leakage, breach, and holes in embankments and also alert warning centres. Take steps for repairing work on emergency basis by month of April through employment of local people. For this purpose, materials and implements are to be stored at suitable place.
(c) Keep the officials alert for the security of life, supplies, goods in stock and implements.

Disaster Stage

(a) Operate information cell and Flood Control Centre day and night and send a Liaison Officer to the EOC of the Ministry of Food and Disaster Management.
(b) Inform IMDMCC and the EOC of the MoFDM about brewing up of any special situation.
(c) Ensure gathering of all technical people and raw materials for the repair of damage to installations and supply source.
(d) Give all support and assistance to local civil administration for rescue, evacuation and relief operations through field level administrative machinery.
(e) Issue the following orders as per delegation of powers, to field level officials of Chief Engineer/Superintending Engineer/Executive Engineer/Assistant Engineer of BWDB:

(i) To perform duties as member of DMC of their own area
(ii) To gather all technical people and materials for repair work of damage caused to installations and supply sources
(iii) To make plan and programme for repairing, reconstruction and reinstallation according to short and long term planning of the government within shortest possible time after assessment of loss/damage and recession of water

(f) Appoint supervisors for frequent visit to affected areas.
(g) In case of any difficulty in flood disasters or if any matter not possible to solve or if help of the IMDMCC/NDMC is needed, request for intervention by the MOFDM.
(h) Take any suitable step in the exigency of circumstances for protection of life and properties.
(i) Send daily flood reports to following offices:
    (1) President's Office
    (2) Prime Minister's Office
    (3) Ministry of Food and Disaster Management
    (4) Ministry of Home Affairs
    (5) Ministry of Information
    (6) Secretary, Ministry of Agriculture
    (7) Secretary, Ministry of Water Resources
    (8) Secretary, Ministry of Fisheries and Live Stock
    (9) Secretary, Ministry of Power, Energy and Mineral Resources
    (10) Secretary, Ministry of Education
    (11) Secretary, Roads and Highways Division
    (12) Secretary, Railways Division
    (13) Secretary, Ministry of Water Transport
    (14) Secretary, Ministry of Health and Family Welfare
    (15) Secretary, Ministry of Industries
    (16) Secretary, Ministry Local Government, Rural Development and Cooperatives.
    (17) Secretary, Ministry of Social Welfare
    (18) Secretary, Ministry of Defence
    (19) DG, Disaster Management Bureau
    (20) DG, Relief and Rehabilitation Directorate
    (21) Director-General, Radio/Television
    (22) Concerned Chief Engineers
    (23) Concerned Deputy Commissioners
    (24) Concerned Upazila DMC leaders

Rehabilitation Stage

(a) Quickly assess the loss and damage and prepare required plans for repair and reconstruction work on priority basis.
(b) Ensure the restoration of infrastructure, logistics and installations in shortest possible time for domestic, industrial and export use projects. Projects connected with agriculture, fisheries and industrial rehabilitation will be given top priority.
(c) Render assistance and cooperation in the rehabilitation programme of civil administration and other agencies.
(d) Prepare new plans and designs for the control, reduction of loss/damage and prevention of recurrence of floods.
(e) Evaluate the strengths and weaknesses of the current operations with a view to providing guidelines for future planning.

5. Directorate of Relief and Rehabilitation (DRR)

Risk Reduction

a) Develop and establish guidelines and procedures to assess hazard risks and vulnerabilities at the community level.
b) Conduct national, District, Upazila and Union level hazard, risk and vulnerability assessments and mapping to identify the disaster Upazilas and special disaster areas under such Upazilas and the population likely to be affected by the disaster.

c) Design and implement the safety net programmes to contribute to the community level risk reduction efforts Introduce agency contingency planning.
d) Organize regular training for the selected volunteers on earthquake preparedness.
e) Organize training on earthquake preparedness and response for selected DRR officials.

EMERGENCY RESPONSE

Normal Times

a) Ensure stock, security and maintenance of adequate materials in disaster-prone areas.
b) Utilize the materials received under the Food for Works Programme for construction of roads to raised places and shelter places and for tree plantation.

Alert and Warning Stage

a) Open Control Room in the Department and maintain link with the EOC of the Ministry.
b) Direct all officials to remain alert.
c) Inform the Ministry about relief preparedness in affected areas.
d) Send Daily Situation Report to the Ministry.
e) Keep information about the available quantity of relief materials and food grains in the LSD and CSD of the affected areas.

Disaster Stage

a) Ensure quick dispatch of relief materials to affected areas.
b) Instruct field officers for helping the local administration in evacuation and rescue operations.
c) Place the water transports at the disposal of appropriate authority for transportation of relief materials and evacuation and rescue operations of affected people.
d) Inform the Ministry about the requirement of relief materials.
e) Inform the Ministry instantaneously about special relief.
f) Ensure proper account keeping of the use of allotted relief materials.

Rehabilitation Stage

g) Recommend allocation of relief materials after assessing the requirement by touring the affected areas with intimation to the Ministry.
h) Ensure quick supply of house building grants, gratuitous relief and other materials in accordance with the delegation of powers.
i) Recommend to the Ministry for allocation of (needed) house building grant, test relief, gratuitous relief and other materials beyond delegation of power.
j) Issue required government order.
k) Continue the most essential rehabilitation work.
l) Submit the consolidated expenditure accounts to the government.

6. Comprehensive Disaster Management Programme (CDMP)

1 Professionalising the disaster management system
1a Policy, Program and Partnership Development Unit (PPPDU)
1b Professional Development
2. Mainstreaming of risk management programming (partnership development)
2a Advocacy and Awareness
2b Capacity Building
3. Strengthening of community institutional mechanisms (community empowerment)
3a Program Gap Analysis
3b Risk Reduction Planning
3c Local Disaster Risk Reduction Fund
3d Support for Livelihood Security – Hazard Awareness
4. Expanding risk reduction programming across a broader range of hazards
4a Earthquake and Tsunami Preparedness
4b Climate Change and Research
5. Strengthening emergency response systems (operationalising response)
5a Disaster Management Information Centre

5b Support for a Disaster Management Information Network

7. Bangladesh Meteorological Department (BMD)

Risk Reduction

a) Develop sectoral risk mitigation and preparedness strategy of the department.
b) Ensure budgetary provision for risk reduction activities and programs.
c) Undertake continuous improvement of cyclone forecast and warning systems.
d) Ensure improvement of cyclone forecast processes/procedures/methodologies, and continuous monitoring of the weather conditions, dissemination of all information in this regard on a regular basis.
e) Improve the equipment facilities for quickest dissemination of the information/warnings to all concerned, such as fax, E-mail arrangements must be established with all Print and electronic medias and MoFDM.

EMERGENCY RESPONSE

Normal Times

a) Develop sectoral emergency response system.
b) Develop a contingency plan.
c) Keep ever careful watch over weather conditions, and ensure improvement of cyclone forecast procedures and supply of information on regular basis.
d) Ensure full time effectiveness of the quickest channel of communication for disseminating weather warnings to all concerned. Fax, email and other message transmission arrangement must be established between SWC of BMD and Radio, Television and the MoFDM.

Alert Stage

a) 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.
b) Supply information through Fax/telephone/tele-printer to CPP about the formation of depression in Bay of Bengal so as to allow CPP to take appropriate actions including dissemination of information to all concerned.
c) Prepare and submit Special Weather Bulletin and broadcast/publicize the same through national news media such as the all stations of Radio and Television and in national newspapers for the benefit of the general people. In case of Local Cautionary Signal no. 3, arrange for adequate and full time coordination between SWC of the BMD, Bangladesh Betar, and Bangladesh Television for publicity beyond normal broadcasting hours.
d) Send Special Weather Bulletins to EOC at the MoFDM, the DRR, the CPP and BRCS for undertaking adequate arrangements.

Warning Stage

Publicize warning signals 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 MoFDM, Control Room of the DMB, the DRR, the CPP and the BDRCS.

The following information should be mentioned in the signals to be disseminated.

a) Position of the storm centre.
b) Velocity and direction of the storm.
c) Mention of the Upazilas of the Districts likely to be affected, if possible.

Rehabilitation Stage

a) Work in collaboration with the DMB to perform the following tasks.
i. Compare the severity of cyclone with that of warning signal

ii. Collect data from affected areas for research purpose
iii. Obtain opinion of the people about the signals issued

8. Water Resources Planning Organization (WARPO)

Routine Core Functions of WARPO:

1. Monitoring implementation of the National Water Management Plan (NWMP) and its impact
2. Upkeep of water resource assessments
3. Maintenance, updating and dissemination of the National Water Resources Database (NWRD) and MIS
4. Functioning as a "clearing house"
5. Secretariat to the National Water Resources Council (NWRC) and the Executive Committee of the National Water Resources Council (ECNWRC)
6. Responding to the NWRC/ECNWRC requests for information and advice

Periodic Functions of WARPO:

1. Periodic update of the National Water Management Plan (NWMP)
2. Assisting other agencies in planning, monitoring, studies and investigations
3. Adhoc advice on policy, strategy, institutional and legal issues
4. Special studies and research as required from time to time

9. Bangladesh University of Engineering and Technology (BUET)

A significant part of research works of the department is directed towards the study and solution of field problems. Some research works conducted by the department are listed below:

River Response, Training Works and Erosion Protection

- Local scour around bridge piers and abutments
- Prevention of bank erosion using revetments, groins, bottom vanes etc.
- Behavior of river bifurcation
- Roughness of various bed materials
- Sedimentation rate of alluvial rivers

Hydraulics and Hydraulic Structures

- Regulator with gravity flap gate
- Effect of sluice gate opening angle on the behavior of flow
- Study on hydraulic jump in abruptly sloping channel
- Behavior of flow in constricted and expanded section

Hydrology and IWRM

- *In stream flow* requirements *of rivers*
- Hydrologic Forecasting using Artificial Neural Networking
- Characterization and impact evaluation of drought
- Flood discharge and flood frequency analysis
- Development of unit-hydrograph in halda river basin

Coastal Engineering and Coastal Zone Management

- Coastal erosion protection
- Saline water intrusion
- Estimation of wave height near the coastal belt of Bangladesh
- Effectiveness of floating breakwater as protection structure

Groundwater

- Optimization of groundwater monitoring network
- Impact of agricultural land use changes on surface and ground water
- Optimal evaluation of aquifer parameters in Dhaka city by Krigging
- Groundwater level depletion and its impact on aquifer parameters

Irrigation and drainage engineering

- Relationship of observed and estimated evapo-transpiration of rice
- Study of floating pump irrigation in Bangladesh
- Stochastic analysis of deficiency of crop water requirement

Numerical Modeling

- Solution of dam-break problem by Collocation method in conjunction with hermite element
- Three-dimensional saturated-unsaturated flow simulation by Galerkin finite element method
- Numerical model for salinity intrusion in the Pussur river

GIS and Remote Sensing

- Rainfall estimation over Bangladesh using satellite data
- Computation of runoff in the Jamuneswari basin (using Arc-info)
- Assessment of crop damage due to flood using GIS technology
- Assessment of flood inundation using GIS technology

10. District Disaster Management Committee (DDMC)

Risk Reduction

a. Ensure the constitution of UzDMC and Pourashava DMCs (Grade 'A') with its activation, ensure receipt of directives and information and draw benefits from available training facilities.
b. Arrange training and workshops on disaster-related issues regularly by keeping the DMB informed.
c. Ensure that the risk factors of disaster and the possibilities of reduction of risks have been fully considered while preparing and implementing development programmes at District level. Ensure BNBC is fully met while constructing public or private structures.
d. Prepare a comprehensive report on "Hazard, vulnerability and risk assessment' at District level based on the compilation of 'Hazard, vulnerability and risk assessment report' prepared by Upazila and Pourashava (grade 'A') DMCs and submit the same to the DMB.
e. Prepare a contingency plan (emphasis on earthquake and fire) and update it regularly.
f. Prepare a comprehensive report on the lists of vulnerable community and location map' at District level based on the compilation of 'lists of vulnerable community and location map' prepared by individual Upazila and Pourashava (grade 'A') DMCs and submit the same to the DMB.
g. Prepare comprehensive short, medium and long-term risk reduction action plans at District level based on the compilation of short, medium and long-term risk reduction action plans prepared by Upazilas and Pourashava (grade 'A') DMCs and submit the same to the DMB.
h. Regularly review the implementation status of the short, medium and long-term action plans through coordinating the programmes of development and service organizations at District level.
i. Provide necessary support to Union, Pourashava and Upazila disaster management committees to create local level fund appropriate for the implementation of the risk reduction action plans.
j. Inform the DMB on the progress of action plan and other activities at District level.
k. Disseminate forecasts and warnings regarding disasters and make the people conscious about them.
l. Prepare a District disaster risk reduction action plan (RRAP) including the following issues with a view to keep the District authority and local organizations well prepared so as to meet the disaster effectively and efficiently in the light of warning signals about imminent disaster and the occurrence of disaster:
m. Ensure speedy and effective publicity of forecasts and warnings relating to disasters (tornado, cyclone, tidal surge, earthquake, landslide, river erosion, tsunami, heavy rainfall, no rainfall, drought, flood, water logging, high tide, cold wave, etc.) among all officials of the District, relevant individuals/organizations and take measures to send the messages to the concerned individuals at the
n. Union, Pourashava and Upazila levels; and assist the implementation of the action plans prepared by the Union, Pourashava and UzDMCs with the coordination efforts of District level government and non-government organizations.

o. Select specific safe centres/shelters for evacuation of the people from District headquarters and to build capacity and assign responsibility to different individuals and organizations for rendering various services and securities at the shelters. Build their capacity and instruct all the departments to provide necessary support to the Union, Pourashava and Upazila DMCs.
p. Ensure supply of safe drinking water, which can be filled in cans, ensure security and other essential services at the safe centres/shelters located in the District headquarters. And arrange similar services and facilities at Union, Pourashava and Upazila levels in communication with Union, Pourashava and Upazila DMCs.
q. Take all necessary measures to activate Union, Pourashava and Upazila DMCs; at the same time, provide necessary support to the Union, Pourashava and Upazila DMCs in rescue work and emergency relief work and preparation of contingency plans for essential services in the interior of the District along with District headquarters, Upazila headquarters and Pourashava (grade 'A') and disaster management information centre (DMIC).
r. Arrange occasional rehearsals or drills on the dissemination of warnings/forecasts, evacuation, rescue and primary relief operations with assistance from DMB and Upazila/Pourashava authority.
s. Monitor the progress of the activities and implementation status of the action plans of Upazila and Pourashava DMCs (grade'A') and submit a comprehensive progress report to DMB regularly.

EMERGENCY RESPONSE

Warning Period

- Disseminate warnings/forecasts, evacuate the vulnerable people as per evacuation plan, check the overall preparation for rescue operation and prepare the rescue team.
- Engage trained institutions, volunteers and people in the field for effective and speedy dissemination of early warnings/forecasts and to coordinate and monitor the whole warnings/forecasts dissemination system.
- Visit the pre-selected emergency shelters/safe centres and ensure that different organizations and individuals are alert and ready to provide essential services and security at the centres.
- Review and take alternative measures to ensure the supply of safe drinking water from the selected places nearby the safe centres/shelters.
- Conduct a mock or drill, on a small scale, with the trained students, youths, club members and volunteers on the community-based water-purification techniques and ensure all the relevant preparatory measures for speedy supply of water after proper purification.
- Take emergency measures to fill up the stock of lifesaving drugs after carefully scrutinizing the stock of life-saving drugs at Pourashava level.
- Prepare a checklist of emergency activities including the time schedule of the assigned personnel.

During Disaster

- Operate "Emergency Operation 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 within the District.
- Operate emergency rescue work with the facilities locally available and coordinate mobilization of rescue teams for rescue operations in severely affected Upazilas and Pourashavas.
- Coordinate all relief activities (GO-NGO) at Union, Pourashava, Upazila and District level so that relief materials are distributed impartially.
- Ensure dissemination of correct information for protecting the people from being upset by rumour related to disaster.
- Take necessary measures for ensuring the security of local and external relief workers during disaster.
- Ensure the overall security of women, children and persons with disability during disaster (residing in safe centres/shelters and other places).

- Take necessary measures to protect environmental degradation by arranging quick memorial services of dead bodies and quick disposal of dead domestic animals.
- Assist people to transfer their essential resources (livestock, poultry, essential food, kerosene, candle, matches, fuel, radio, etc.) to safe places.

3.2.5.4 Post Disaster Period

- Collect and verify statistics relating to loss according to instructions issued by Disaster Management Bureau and other national authorities from Upazila officials and members of the Upazila/Pourashava DMCs regarding loss due to disaster according to directives of DMB and other national authorities; to determine priority and requirements through emergency survey by officials or any other competent persons.
- Supply information relating to loss, needs, available resources and priority needs for relief and rehabilitation work to the EOC at the MoFDM and DMIC of DMB.
- Prepare contingency plans for rehabilitation work carefully based on priority measures for risk reduction at District level.
- Allocate and distribute the materials to Upazila/Pourashava, received from local source or Relief Directorate/any other sources on realistic basis according to necessity as per directives issued from DMB and District authority.
- Supervise the distribution of materials under relief and rehabilitation activities and maintain their account and send the same to national authority and other relief donor organizations.
- Take necessary measures so that people can return to their previous places after the disaster is over. In such cases, if there is any dispute regarding the legality of the land that should not be an obstacle to returning to the previous place after disaster.
- Arrange counseling for people suffering from psycho-trauma due to the disaster, with the collaborative support of experts and community elites.
- Instruct the health-related personnel of the District and Upazila level to provide appropriate and adequate care to disaster affected people and if needed, request the District health authority for assistance.
- Arrange workshop with the participation of concerned institutions and individuals on the lessons learned during and after the disaster.
- Perform responsibility of overall coordination among various departments at District level.
- In addition, follow the SOD and comply with instant orders from appropriate authority.

11. Disaster Management & Relief Division (DM&RD)

Risk Reduction

a) Designate a senior staff as the Focal Point of the DM&RD.
b) Create and establish national policy, planning and legislative frameworks for comprehensive disaster management in Bangladesh with the following strategic goals:
i. Professionalizing the disaster management system
ii. Mainstreaming risk reduction
iii. Strengthening institutional mechanisms
iv. Empowering at risk communities
v. Expanding risk reduction programming across hazards, risks and sectors
vi. Strengthening emergency response systems
vii. Developing and strengthening networks
c) Prepare and periodically review and update the National Plan for Disaster Management and revise the SOD after a regular interval.
d) Develop specific guidelines and templates facilitating mainstreaming disaster management principles and practices across hazards, sectors and within national development planning processes at all levels.
e) Conduct national, District, Upazila and Union level hazard, risk and vulnerability assessments; prepare risk reduction action plans (RRAP) and its implementation strategies.
f) Conduct mapping to identify the disaster-prone Upazilas and special disaster-prone areas under such Upazilas and the population likely to be affected by the disaster.
g) Will review the inter-ministerial earthquake contingency plan every six months.

h) Will keep prepared the EOC to deal with earthquake emergencies.
i) Will ensure availability of the earthquake risk maps of all vulnerable areas and its elements.
j) Coordinate with the city development authorities and the Ministry of Public Works to ensure proper execution of the Building Codes.
k) Prepare earthquake risk reduction action plan and contingency plans for emergencies.
l) Coordinate inter-sectoral risk reduction efforts of the Government.

EMERGENCY RESPONSE

Normal Times

a) Review the own Action Plan of the Ministry on disaster management every 3 (three) months.
b) Identify the disaster Upazilas and special disaster areas under such Upazilas and the population likely to be affected by the disaster.
c) Update the list of foreign and private agencies willing to participate in the disaster preparedness, emergency response and rehabilitation programmes.
d) Preserve information regarding food, relief materials and transports usable at all levels during disaster.
e) Direct all concerned for ensuring availability of the SOD at village, Union, Upazila and District DMCs and to stakeholders.
f) Arrange meetings of the NDMC and IMDMCC to assess the disaster preparedness of different Ministries, agencies, departments, local governments, autonomous bodies, CPP, BDRCS, NGOs, etc.
g) Ensure non-stop telecom link of the Ministry with District and Upazila Headquarters.
h) Issue necessary orders for proper coordination of steps relating to disaster and response.

Alert and Warning Stage

a) Issue orders for dispatch of relief materials to required places and to keep the transports ready.
b) To select a Focal Point in the Ministry and to inform all concerned about his/her designation and telephone number.
c) To direct the DMB to open EOC of its own, open Control Room at all levels related to disaster activities and also to reactivate the EOC located at MoFDM.
d) Ensure direct communication with BMD and BWDB, and issue orders for collection of inputs (warning message and signal) from the department.
e) Ensure publicity of warning signals through radio, television, fax, telephone, e-mail, mobile phones and all other means of mass communication. Also, inform Ministries, agencies, departments, CPP, BDRCS, NGOs, Deputy Commissioners and other concerned agencies and officials.
f) Keep the EOC open 24hrs a day.
g) Call a meeting of the CPP Implementation Board and inform the decisions to all concerned.
h) Inform the Chairman of the NDMC, the Prime Minister and the Chairman of the IMDMCC about the disaster situations and the steps taken to meet them.
i) Ensure convening of meetings of the concerned District, Upazila and Union DMCs.
j) Request the AFD to keep a helicopter and transport plane ready for reconnaissance of loss and damages and for relief operations.
k) Request the AFD and the BIWTC to keep water vessels ready for rescue and relief operations.
l) Issue directives to evacuate to safer places for saving life and property.
m) Request the Army through AFD to be ready for speedy mobilization to the affected areas.
n) Inform all concerned, especially the Chairs of DMCs (Divisional Commissioners, Deputy Commissioners, Upazila Nirbahi Officers, and Union Parishad Chairmen) and other concerned agencies about great danger signals and the arrangement to be made in this respect.
o) Instruct District and Upazila authorities to requisition required transports for rescue and relief work.
p) Arrange for convening of the meetings of the NDMC and the IMDMCC.
q) In consultation with the BMD, issue instructions to local administration for evaluation of the people likely to be affected to safer places.
r) Ensure issuance of Warning Signals repeatedly through the Bangladesh Betar (Radio) and the BTV.
s) Ensure non-stop communication with District Control Room, CPP and BMD.

t) Arrange in advance necessary relief materials for the disaster areas.
u) Designate one Liaison Officer to the Prime Minister's co-ordination cell at the Prime Ministers office.

Disaster Stage

a) Request the Bangladesh Navy and Bangladesh Air Force to keep vessels and air planes ready for assessment of loss and damage and rescue operations as soon as weather becomes favorable.
b) Request the civil authorities to assist the AFD in relief and rescue operations on the basis of need.
c) Coordinate rescue and relief work with NGOs.
d) Arrange meetings of the NDMC and the IMDMCC.
e) Collect information on loss and damage.
f) Fix additional requirement of funds and materials for relief and rehabilitation work.
g) Quickly collect funds and relief materials for gratuitous relief.

Rehabilitation Stage

a) Arrange for housing building grant, test relief and Food for Work programmes.
b) Continue emergency rehabilitation work in affected areas until return of normalcy.
c) Coordinate rehabilitation programmes.

12. Inter-Ministerial Disaster Management Co-ordination Committee (IMDMCC)

Risk Reduction

- Act on advice of the National Disaster Management Council
- Recommend enactment of legislation, policies, Standing Orders and national level plans (sector and hazard specific) to the Cabinet Committee / Council of Advisers
- Review, revise and approve contingency plans of various First Responding Organizations
- Approve guidelines and templates prescribed by the NPDM and SOD
- Approve City Corporation Disaster Management Plans and District Disaster

Management Plans

- Recommend an appropriate regulatory mechanism for the implementation of the Bangladesh Disaster Management Framework, including prevention, mitigation, preparedness, emergency response, recovery and rehabilitation
- Approve national and sub-national programs for disaster risk reduction
- Advocate and ensure disaster risk reduction is mainstreamed in development policies, plans and programmes
- Monitor DRR activities and programs, and keep the NDMC informed of their progress
- Review and promote emergency preparedness and public awareness capacity development in disaster management
- Promote monitoring, evaluation, education, and research on disaster risk reduction and emergency response management
- Emergency Response
- Evaluate emergency preparedness status and recommend corrective measures.
- Approve response and recovery plans.
- Promote preparedness activities, such as fire evacuation drills, search and rescue mock exercise, etc.
- Ensure whole-of-government coordination in emergency response, relief and rehabilitation operations.
- Approve guideline for multi-agency incident management.
- Establish Urban Search and Rescue Taskforces.

13. Institute of Water Modelling

a) Integrated Water Resources Management (IWRM)
- Water resources assessment and management
- Master planning and policy development
- Water supply and demand assessment
- River Basin management
- Environmental impact analysis

b) Wetland and lakes management (WeLkM)
- Optimised operation rules
- Interaction between groundwater and the surface water bodies (i.e. drawdowns caused by groundwater withdrawals),
- Land erosion due to water logging and waves mitigated,
- Effects of land use changes on runoff patterns (e.g. deforestation)
- Soil – water processes analysed.
- By mapping flood extent and performing a statistical evaluation of flood duration, flood frequency, flood depth, groundwater table, and root zone water content the environmental and ecological impacts are assessed.

c) Irrigation Management (IrriM)
- An analysis of the overall effect of irrigation schemes on the water balance
- Optimization of irrigation schemes, reduction of conveyance and seepage losses
- Canal and structure analysis
- Analysis and optimization of structure operations
- Water shortage and irrigation management
- Irrigation, drainage and water logging
- Salinity
- Pesticides and nutrients in drainwater and groundwater recharge
- Effects of irrigation management on crop yields

d) Ground Water Management (GWM)
- Groundwater exploitation/resources
- Groundwater vulnerability mapping and protection
- Ground water management
- Groundwater quality
- Salt Intrusion

e) Urban Water Management (UWM)
f) Water Quality & Ecology (WQ&Ec)
g) Fluvial Hydraulics and River Morphology (FHRM)
h) River Engineering (RiEngg)
i) Flood Management (FldM)
- Hydrological assessments
- Monitoring networks and information systems
- Flood risk and damage assessment
- Flood Mapping
- Real-time flood forecasting and operational water management systems
- Land use and climate change studies
- Flood mitigation planning and designs and operations

j) Integrated Coastal Zone Management (ICZM)
k) Coastal Hydraulics and Morphology (CHMor)
l) Port and Coastal Structure Management (PCSM)
m) Estuary and Marine System Management (EMSM)
n) Offshore Structure and Pipelines (OfS&Pl)
o) Water Quality Investigation (WQI)

p) Software Management and IT Solutions (SMIT)
q) Topographic, hydrographic, sediment transport, water quality and hydrological, meteorological field measurements, necessary laboratory analysis and data management and mapping;
r) Any other field or area which may be conveniently and beneficially done through the facilities of IWM.

14. Local Government Engineering Department (LGED)

Risk Reduction

(a) Designate one Liaison Officer in the LGED as the Disaster Management Focal Point.
(b) Consider all hazard risks in preparing the Action Plan of the LGED.
(c) Draw up plans of feeder roads, bridges and culverts and complete their construction keeping provision for easy flow of waters and easy discharge of tidewaters.
(d) Encourage and inspire people through Union Parishads for construction of two storied buildings if possible. Suggest that at least one room on the roof of cyclone/flood resisting brick built residential house for the purpose of using them as shelter place during cyclone/flood.
(e) Prepare maps identifying population centres, water holes (wells), protected ponds/water reservoir/tube-wells for drinking water and other water sources.
(f) Prepare and periodically update the agency contingency plan.
(g) Follow Building Code and take necessary measure to ensure its proper execution where necessary.
(h) To mitigate earthquake risks in the construction and urban planning arrange training programmes for government engineers, planners and the architects on infrastructure and urban planning.
(i) Work with the GSB to identify earthquake risks and ensure involvement of specialist engineers in the reconstruction works of the affected areas.

Normal Times

(a) Repair and maintain small roads, bridges and culverts for communication to cyclone shelters, educational institutions, community centres and health centres for the purpose of providing easy communication for evacuation and security during disaster.
(b) In cyclone-prone areas, advise for raising the banks of water reservoir (pond) above the levelof cyclone induced tidal bore and in other places above flood level so that the water reservoir can be used by people as supply source of drinking water and the banks can be used as shelter place for animals. Several rows of trees should be planted.
(c) Maintain stock of Baily bridges for bridge and culverts, and for repairing the breach on roads for the purpose of quick movement of relief materials.
(i) Keep the foundations level of cyclone shelter under the control of Upazila Parishad above flood level and undertake regular maintenance work.
(j) Train the Engineer, including Secretary of the Union Parishad and technical and non-technical employees in disaster preparedness and management programmes and make them known to the people.

Alert and Warning Stage

(a) Operate one Control Room in the Directorate's head office.
(b) Attend the meeting of Local DMC and assist in evacuation, rescue and relief operations.
(c) Alert all concerned about the imminent disaster and take precautionary steps for the security of materials, stock and implements.
(d) Ensure steps for removing blockades of flow of water in small roads.
(e) Help in identifying shelter places, fortified earthen mounds, private buildings, schools and Madrasahs and high safe places in disaster areas for use as shelter place of people and livestock.

Disaster Stage

(a) Ensure operation of the Control Room round the clock (24 hrs) and assist in evacuation, rescue and relief operations.
(b) Coordinate with Inter-Ministerial Disaster Management Coordination Committee.

(c) Ensure communication with cyclone/flood shelters and take up immediate repair work, if necessary.

Rehabilitation Stage

(a) Assess and quantify loss, damage and needs.
(b) Assist in rescue and rehabilitation works at all levels.
(c) Organize reconstruction of damaged houses, small roads, bridges and culverts on self help basis with materials from local source and these received from the government.
(d) Take up repair/reconstruction works of small roads, bridges and culverts damaged in disasters.
(e) Prepare short and long-term programmes for indispensable small roads, for the purpose of communication, evacuation and relief operations during disaster.

15. Ministry of Food and Disaster Management (MoFDM)

16. Ministry of Water Resources (MoWR)

Risk Reduction

(a) Incorporate disaster risk reduction considerations into the water sector policies, plans and programmes.
(b) Develop sectoral risk mitigation and preparedness strategy of the Ministry of Water Resources.
(c) Ensure budgetary provision for risk reduction activities and programs.
(d) Ensure implementation of the risk reduction programmes and activities through establishing an effective monitoring and evaluation system.
(e) Establish a sectoral risk communication system.

EMERGENCY RESPONSE

Normal Times

(a) Designate one senior staff as the Focal Point of this Ministry.
(b) Participate in the meeting of NDMC and IMDMCC and direct BWDB to implement the decisions taken in the meetings.
(c) Issue directives to all its department and divisions to ensure execution of all the relevant decisions of the meetings of NDMC, IMDMCC and NDMAC.
(d) Issue directives to all its divisions down to the District, Upazila and Union Parishad level to support civil administration, NGOs and civil society.
(e) Mainstream disaster management principles and practices within the Ministry.
(f) Ensure disaster risk reduction is mainstreamed in development policies.
(g) Ensure budgetary provision for the Ministry for its risk reduction and management activities.
(h) Undertake risk reduction activities, which includes embankment construction in high-risk areas, sluice gate operations, and embankment maintenance.
(i) Operate and manage the Flood Forecasting and Warning Centre (FFWC), and the Flood Information Centre (April-November).
(j) Monitor water levels of all major river systems.
(k) Provide weekly flood situation reports.
(l) Undertake risk reduction activities that ensure the control or reduction of loss and damage from recurring floods.
(m) Develop a sectoral contingency plan for disaster risk reduction and management activities of the Ministry.

Cautionary/Warning Stage

(a) Monitor water levels of all major river systems.
(b) Provide flood forecasting and warnings.
(c) Ensure effective communication, information and reporting during emergency response and recovery operations.

Disaster Stage

(a) Provide daily flood reports.
(b) Protect sluice gates, repair breaches, leakages and weak points in embankments.
(c) Ensure quick assessment of damage and take necessary action.
(d) Ensure effective dissemination of warning signals of the Ministry.

Rehabilitation Stage

(a) Undertake loss and damage, and needs assessments and manage the repair, reconstruction and rehabilitation of infrastructure.
(b) Ensure the restoration of infrastructure, logistics and installations for domestic, industrial and export use projects. Projects connected with agriculture, fisheries and industrial rehabilitation will be given the highest priority.

17. National Disaster Management Advisory Committee (NDMAC)

- Advise NDMC, IMDMCC, MoFDM and DMB on technical matters and socioeconomic aspects of Disaster Risk Reduction and emergency response management.
- Alert the Committee members about the risk of disaster and mitigation possibilities and encourage them in respect of workshop, training and research.
- Create a forum for discussion by experts on the risk of disaster, opening opportunities for cooperation towards solution of problems relating to disaster management.
- Recommend release of funds for special project works and also for introduction of special emergency methods or empowerment, if needed.
- Recommend solution of problems identified by the DMB or any other agency/person.
- Propose long term recovery plans.
- Hold post-mortem or prepare final evaluation on programmes undertaken to meet the disaster and
- Submit a report with recommendations to the NDMC.

18. National Disaster Management Council (NDMC)

- Review national disaster management system and provide strategic advice for disaster risk reduction and emergency response management.
- Review policy and planning documents on disaster management and provide strategic advice.
- Promote dialogue across sectors with a view to integrate disaster risk reduction into sectoral development plans and programmes.
- Promote awareness regarding disaster risk reduction among top policy makers.
- Evaluate disaster preparedness measures and provide strategic advice.
- Evaluate response and recovery measures, particularly after a large-scale disaster and provide strategic direction towards improvement of the system and procedures, and
- Facilitate coordination of multi-hazard and multi-sectoral measures in relation to disaster risk reduction and emergency response management.

19. Public Works Department (PWD)

Risk Reduction

(a) Ensure proper execution of the BNBC.
(b) Include current and future disaster risks in the policies, programmes and guidelines of all the development works of the Department.
(c) Prepare manual explaining seismic capacity evaluation and earth proofing design.
(d) Prepare and periodically update the list of the vulnerable structure and disseminate the information to concerned.
(e) Disseminate the Technical information related to earthquake and Tsunami to engineers.
(f) Support the retrofitting works.

EMERGENCY RESPONSE

Normal Times

(a) Organize training programmes and awareness campaigns with the civil engineers involved in the construction works and the masons to ensure proper execution of the Building Codes.
(b) Establish a strong monitoring system to monitor the quality of construction works of the government and in the private sector.

Alert and Warning Stage

(a) Establish the Control Room to keep in touch with field level offices and the local Disaster Management Committee.
(b) Alert all concerned after receipt of cautionary signals.
(c) Keep manpower and materials ready for protection and repair of government property.
(d) Protect all government stock and ensure their security by shifting them to safer place, if necessary.
(e) If necessary, send materials and workers from other places to areas likely to be affected, for meeting emergency situation and keep Headquarters and concerned local DMC informed about it.

Disaster Stage

(a) Coordinate with all activities by keeping in touch with local administration and assist in the evacuation, rescue and relief operations.
(b) Assess loss and damage and prepare estimates for repair and reconstruction and arrange funds for it.
(c) Assist in rescue work of people in distress.

Rehabilitation Stage

(a) Start as quickly as possible repair and reconstruction work of government property damaged in the disaster.
(b) Arrange repair and reconstruction works immediately and prepare long-term perspective of damaged government property.
(c) Coordinate with local administration and authorities in relief and rehabilitation work.
(d) Prepare detailed programmes, work plans and estimates for protection of government property in similar disaster in future and submit them to appropriate authority.
(e) If necessary, extend technical assistance and supervision to reconstruction work.

20. Union Disaster Management Committee (UDMC)

Risk Reduction

- Ensure that local people are kept informed and capable of taking practical measures for the reduction of risk at household and community level and also disseminate the success stories of reducing disaster risks at household and community level widely among the local people.
- Arrange training and workshops on regular basis on disaster issues and keep the UzDMC informed.
- Hold a hazard, vulnerability and risk analysis at Union level and prepare risk reduction action plan (RRAP) and contingency plan for earthquake and other hazards.
- Identify the most vulnerable or people at high risk by sex, age, physical ability, social status, occupation and economic status.
- Prepare a short, medium and long-term vulnerability reduction and capacity building action plan for the identified high-risk people with active participation of the people at risk.
- Facilitate coordination among the development agencies and service providers through quarterly coordination meeting and take decision about implementation of the action plan for risk reduction as well as review the progress of the risk reduction action plan.
- Raise fund at local level to implement the risk reduction action plan.
- Update the progress of implementation of action plan and other activities and report to the Upazila DMC
- Prepare a Comprehensive Disaster Management Action Plan with a view to enabling local people, Union authority and local organizations to increase the capacity of poor and vulnerable

people to enhance their income and other assets for risk reduction and also to take up security arrangement in the perspective of imminent danger-related warnings or occurrence of disaster including the issues already mentioned under this paragraph.

- Take steps for capacity building of relevant persons and institutions, Union authority, volunteers and people in a way that they can forecast and publicize warnings relating to hazards (cyclones, storms, floods, droughts, tidal surge, tsunami, over-rainfall under-rainfall, water logging, high tide, cold wave etc.) in the quickest possible manner and also inform people about their responsibilities of saving their lives and properties from disaster.
- Build the capacity of local institutions, volunteers and people in a way that they can help and motivate people to adopt disaster-resistant (cyclone/tidal surge/tsunami/earthquake/ tornado / flood /water logging/salinity/high tide/cold wave) housing features.
- Build the capacity of local institutions, volunteers and people in a way that they can help and motivate people to adapt with disaster-resistant agriculture and other livelihood options.
- Determine specific safe centres/shelters where the population of certain areas will go at the time of need and assign responsibilities to different persons for various services and securities at the shelters/centres.
- Ensure supply of safe water and if necessary other services from specific points near the shelters/centres with the help of Upazila authority.
- Train the students, youths, local club members and volunteers on community based water purification technology. So that during disaster, they can supply water-purifying technology during emergencies in their community until external support reaches the high-risk people.
- Plan for preparing some community-based high land, which can be used as a playground in normal time and can be used as a shelter place during disaster period and where livestock, poultry, emergency food, kerosene, lamp, candle, matches, fuel wood, radio and other important resources could be shifted along with the people.
- Stock emergency life-saving medicines at Union level (Union Health and Family Welfare Centre) for use during disaster.
- Prepare relevant plans for rescue, primary relief operation, and restoration of communication with Upazila Headquarters and local arrangement for rehabilitation of severely affected families.
- Arrange for rehearsals or drills on the dissemination of warning signals/forecasts, evacuation, rescue and primary relief operations (if necessary committee can seek assistance from Upazila Authority).

EMERGENCY RESPONSE

Warning Period

- Disseminate warning and security messages, evacuate the vulnerable people as per evacuation plan, monitor the last moment check of rescue team and its preparation and take effective measures to minimize gaps as a high priority.
- Engage trained institutions, volunteers and people in field for effective and rapid dissemination of early warning messages to the vulnerable community and monitor the whole security and warning message dissemination activities.
- Visit the pre-determined emergency shelter centres and be sure that for essential services and security different organizations and volunteers are alert and ready to provide services.
- Review the practicality of water supply sources nearby the shelters/centres and if necessary, fill the gaps that people can get safe water supply during disaster from these water sources.
- On a minimum scale, conduct a mock or drill to ensure that the trained students, youths, clubs and volunteers can prepare water-purification technology at their locality and can supply to the victims during emergencies and to monitor that adequate materials are ready to prepare such water-purification technology.
- Review the stock of life-saving medicines at Union level and evaluate its adequacy for supply among the victims during disaster.
- To prepare a checklist of emergency works to-do during disaster and be sure that appropriate materials and people are available for use.

During Disaster

- Organize emergency rescue work by using locally available facilities in times of need and if directed assist others in rescue work.
- Prepare water purification technology (tablet) at local level with the help of trained students, youths, clubs and volunteers; and distribute those products at emergency among the people at risk before being caught by diarrhoea or other waterborne diseases.
- Coordinate all relief activities (GO-NGO) in the Union in a manner that social justice (on the basis of who needs, what is needed and how much is needed) is ensured in relief distribution.
- Protect people from becoming upset by rumors during hazard period by providing them correct and timely information.
- During hazard, ensure security of local and external relief workers.
- Ensure the security of women, children and person with disability during hazard.
- Take necessary actions to protect environmental degradation by arranging quick funeral of corpses and burying the dead animal bodies.
- Help people to transfer their essential resources (livestock, poultry, essential food, kerosene, candle, matches, fuel, radio, etc.) to safe places.

Post-Disaster Period

- Collect statistics of loss incurred in disaster in the light of guidelines of DMB and
- Upazila DMC and send the same to Upazila DMC.
- Take steps for distribution of articles for rehabilitation received locally or from Relief and Rehabilitation Directorate and from any other source following the guidelines from DMB and Upazila DMC.
- Send accounts of materials received to UzDMC and donor agency (if the donor provided relief funds).
- Ensure that due to hazard the people who were displaced can return to their previous place. In this case, dispute (if any) regarding the land of the displaced people should not be an obstacle to returning to the place after disaster.
- Arrange counseling for people suffering from psycho-trauma due to the disaster, with the collaborative support of experts and community elites.
- Ensure that the injured people are getting fair and just treatment from health service providers, if necessary; committee can recommend for Upazila and District level assistance.
- Arrange a lesson-learning session with the participation of concern institutions and individuals on learning from during hazard and after hazard.
- In addition to the above, follow the SOD and instant orders of appropriate authority.

21. Upazila Disaster Management Committee (UzDMC)

Risk Reduction

- Assist Union and Pourashava DMC to form and activate a comprehensive DMC at
- Union and Pourashava level, so that the DMCs can provide proper guidance, get the right and correct information and can exploit benefits from imparted training.
- Assist Union and Pourashava DMCs to increase their efficiency in developing local warning system, risk reduction programming, rescue and recovery strategy and awareness raising strategy.
- Ensure that disaster risk reduction approaches are well considered during planning and implementation of development programmes of Union, Pourashava and Upazila.
- Arrange training and workshops on regular basis on disaster issues and assist Union and Pourashava DMCs to arrange training and workshop and keep the DDMC informed of progress and constraints.
- Assist Union and Pourashava disaster management committees to hold a hazard, vulnerability and risk analysis at Union and Pourashava level; compile hazard, vulnerability and risk assessment of Unions and Pourashavas and prepare a hazard, vulnerability and risk assessment report for the Upazila.

- Assist Union and Pourashava DMCs to identify the most vulnerable area or people at high risk by sex, age, physical-ability, social status, occupation and economic status, compile the list of people at high risk at different Union and Pourashavas and based on the lists prepare a report and location map of people at risk in the Upazila and to send the report to the DDMC.
- Assist Union and Pourashava DMCs to prepare a short, medium and long-term vulnerability reduction and capacity building action plan for the identified high risk people with active participation of the people at risk; compile the action plans and prepare a Upazila level action plan and send a copy to DDMC.
- Facilitate coordination among the development agencies and service providers through Quarterly coordination meeting and take decision about implementation of the short, medium and long-term action plan for risk reduction as well as review the progress of the implementation of the RRAPs.
- Assist Union and Pourashava DMCs to raise funds in a legal way at local level to implement the risk reduction action plan.
- Update the progress of implementation of Upazila level action plan and other related activities and report to the DDMC.
- Prepare a Comprehensive Disaster Management Action Plan to enable local people, Union, Pourashava and Upazila authorities and local organizations to increase the capacity of the poor and vulnerable people to enhance their income and other assets for risk reduction and also to take up security arrangement in the perspective of imminent danger-related warnings or occurrence of disaster including the issues already mentioned under this paragraph.
- Take steps for capacity building of Upazila officers, relevant persons and institutions, Union and Pourashava authorities, volunteers and other people so that they can forecast and publicize warnings relating to hazards (cyclones, storms, floods, droughts, tidal surge, tsunami, over-rainfall, under-rainfall, water logging, high tide, cold waves etc.) in the quickest possible way and also inform people about their responsibilities of saving their lives and properties from disaster.
- Building the capacity of Union and Pourashava disaster management committees, local institutions, volunteers and people in a way that they can help and motivate people to adopt disaster (cyclone/tidal surge/tsunami/earthquake/tornado/flood/water logging/salinity/high tides/ cold wave) resistant housing features.
- Building the capacity of Union and Pourashava DMCs, local institutions, volunteers and people in a way that they can help and motivate people to adapt with disaster resistant agriculture and other livelihood options.
- Determine specific safe centres/shelters where the population of certain areas will go at the time of need and assign responsibilities to different persons for various services and securities at the centres/shelters. Assist Union and Pourashava DMCs to be more efficient to do the same work at Union and Pourashava level.
- Ensure supply of safe water and if necessary other services from specific points near the shelters/centres with the help of Upazila authority. Assist Union and Pourashava DMCs to be more efficient to do the same work at Union and Pourashava level.
- Assist Union and Pourashava DMCs to train the students, youths, local clubs and volunteers on community-based water purification technology, so that during a disaster, they can supply water-purifying technology during emergencies in their community until external support reaches the high-risk people.
- Assist Union and Pourashava DMCs to plan for preparing some community based high land, which can be used as a playground in normal time and can be used as shelter during disaster period where livestock, poultry, emergency food, kerosene, lamp, candle, matches, fuel wood, radio and other important resources could be shifted along with the people.
- Assist Union and Pourashava DMCs to stock emergency life-saving medicines at Union and Pourashava level for use during disaster.
- Prepare relevant plans for rescue, primary relief operation, and restoration of communication with District Headquarters and Union Authorities and local arrangement for rehabilitation of severely affected families.
- Monitor the activities and Progress of Implementation of Action Plans of Union and Pourashava DMC and submit a progress report of Upazila Disaster Management Action Plan to the DDMC.

- Arrange for rehearsals or drills on the dissemination of warning signals/forecasts, evacuation, rescue and primary relief operations (if necessary committee can seek assistance from District Authority).

EMERGENCY RESPONSE

Warning Period

- Disseminate warning and security messages, evacuate the vulnerable people as per evacuation plan, monitor last moment checks of rescue team and its preparation and take effective measure to minimize gaps as a high priority.
- Engage trained institutions, volunteers and people in field for effective and rapid dissemination of early warning messages to the vulnerable community and monitor the whole security and warning message dissemination activities.
- Visit the pre-determined emergency shelter centres and be sure that for essential services and security different organizations and volunteers are alert and ready to provide services.
- Review the practicality of water supply sources nearby the shelter centres and if necessary, fill the gaps that people can get safe water supply during disaster from these water sources.
- Conduct a mock or drill to be ensured that the trained students, youths, with club members and volunteers can prepare water-purification technology at their locality and can supply the victims during emergencies and to monitor that adequate materials are ready to prepare such water-purification technology.
- Review the stock of life-saving medicines at Union level and evaluate its adequacy to supply victims during disaster.
- Prepare a checklist of emergency works to be done during disaster and be sure that appropriate materials and people are available for use.

During Disaster

- Operate "EOC" at Upazila level to coordinate evacuation, rescue and relief activities.
- Organize emergency rescue work by using locally available facilities in times of need and if directed, assist others in rescue works.
- Coordinate all relief activities (GO-NGO) in the Upazila in a manner that social justice (on the basis of who needs, what is needed and how much is needed) is ensured in relief distribution;
- Protect people from becoming upset due to rumors during hazard period by providing them correct and timely information.
- During hazard ensure security of local and external relief workers.
- Ensure the security of women, children and person with disability during hazard.
- Take necessary actions to protect environmental degradation by quick funeral of corpses and burying the animal dead bodies.
- Help people to transfer their essential resources (livestock, poultry, essential food, kerosene, candle, matches, fuel, radio, etc.) to safe places.
- Enforce Union and Pourashava DMCs to prepare water purification technology (tablet) at local level with the help of trained students, youths, clubs and volunteers; and distribute those products at emergency among the people at risk before being caught by diarrhea or other waterborne diseases.

Post-Disaster Period

- Collect statistics of loss incurred in disaster in the light of guidelines of Upazila Engineer, and DDMC and send the same to DDMC.
- Provide data and statement to the DDMC regarding damage, need, received resources and priority for relief and rehabilitation works.
- Plan the rehabilitation work in a way that essential measures for future risk reduction is well considered.
- Take steps for distribution of articles for rehabilitation received locally or from Relief and Rehabilitation Directorate and from any other source following the guidelines from Upazila Engineer, and UzDMC.

- Supervise and keep accounts of the relief and rehabilitation materials distributed and send it to DDMC and donor agency (if the donor provided relief fund).
- Ensure that people displaced from hazard can return to their previous places; in this case, disputes (if any) regarding the land of the displaced people should not be an obstacle to them returning after disaster.
- Arrange counseling for people suffering from psycho-trauma due to the disaster, with the collaborative support of experts and community elites.
- Ensure that the injured people are getting fair and just treatment from health service providers, if necessary; committee can recommend for Upazila and District level assistance.
- Arrange a lesson learning session with the participation of concern institutions and individuals on learning from during hazard and after hazard. Coordinate the disaster relevant activities of different departments at Upazila level.
- In addition to the above, follow the SOD and instant orders of appropriate authority.

22. Centre for Environmental and Geographical Information Services (CEGIS)

CEGIS offers its services in the following areas:

- Environmental Impact Assessment (EIA)
- Social Impact Assessment (SIA)
- Feasibility Studies
- Environmental and social monitoring
- Integrated planning and management of water resources
- Socio-economic and institutional analysis
- Remote sensing and image processing
- Natural resources assessment and land use monitoring
- Disaster monitoring and damage assessment
- Land information management
- Climate change and adaptation

CEGIS also provides training on:

- Environmental Impact Assessment (EIA)
- River morphology
- IWRM
- GIS and RS
- Development of GIS databases, GIS based software and Web GIS
- Spatial modeling
- Design and development of Spatial Decision Support Systems
- Mapping and GPS/DGPS/Total Station survey
- Assistance for setting up GIS and RS labs
- Design and development of databases, MIS and IT solutions
- Development of WEB portals
- Development of data quality standards and guidelines

23. Bangladesh Centre for Advanced Studies (BCAS)

Local and Grass-roots Level

❖ Works with communities through eco-specific participatory management processes.
❖ Established eco-specific research centres in different parts of country such as the Wetlands Research and Training Centre (WRTC) in Chanda Beel in the Modhumati Floodplain to:

- Develop natural resource management capability with active participation of local communities
- Initiated diffusion of renewable energy technology (solar photovoltaic) among the islands dwellers in the River Meghna
- Integrated local level Water Resources Management Study Centre in Tangail
- Fisheries resource enhancement through community husbandry in Maulavibazar, Gazipur, and Sherpur
- Providing Environmental Education to non-formal schools in Dhaka, Gazipur and Chanda Beel areas

National Level

❖ At the national level, BCAS has spearheaded and initiated numerous activities, along with others like:
  - National Environment Management Action Plan (NEMAP)
  - Sustainable Environment Management Programme (SEMP)
  - National Conservation Strategy (NCS)
  - New Fisheries Management Programmes
  - Different aspects of Social Forestry
  - Integrated Coastal Zone Management (ICZM) Strategy
  - New Fisheries Management Policy
  - Monitoring and Evaluation of Third Fisheries Project of the Government of Bangladesh
  - Fourth Fisheries Project
  - Bangladesh State of Environment Report 2001

❖ It has also carried out several national level studies on climate change issues:
  - Vulnerability Assessment for Bangladesh to Climate Change and Sea Level Rise
  - Bangladesh Climate Change Study under USCCS
  - Asia Least-cost Greenhouse Gases Abatement Strategy (ALGAS)

❖ It also works closely and carried out numerous studies and advisory inputs for the government of Bangladesh, particularly with:
  - Ministry of Environment and Forest
  - Department of Environment
  - Ministry of Science and Technology
  - Ministry of Agriculture
  - Bangladesh Agricultural Research Council
  - Ministry of Energy and Mineral Resources
  - Local Government and Engineering Department

❖ BCAS has also been involved in a number of collaborative research and initiatives with leading Bangladeshi NGOs including BRAC, Grameen Bank, Grameen Shakti, Proshika etc.

Regional Level

❖ At the regional level, BCAS is the secretariat for the Climate Action Network South Asia (CANSA) working on Climate Change related issues.

❖ BCAS publishes CANSA's Newsletter "Clime Asia". BCAS is also working as the secretariat of the South Asia Sustainable Livelihood Forum.

❖ BCAS is the international wing of Centre for Environment Education (CEE), it is also a member of Regional and International Networking Group (RING) in South Asia

❖ BCAS has undertaken a number of collaborative research and policy advocacy on sustainable livelihoods, trade and environment, climate change, civil society initiatives on sustainable development and community action, and environmental, socially responsible public-private partnership and intergovernmental input in World Summit on Sustainable Development (WSSD).

International Level

- At the international level, BCAS is involved in a number of collaborative research, policy analysis and advocacy including North South Dialogue (NSD) on Climate Change, Global Compact Initiative under aegis of UN as RING member.
- BCAS participated in all the preparatory meetings of UNCED in Rio and WSSD in Johannesburg as a NGO representative, where it also played a key role in giving advice to the government delegations.
- BCAS provides secretarial support to Global Forum on Environment and Poverty (GFEP) originated during the Earth Summit in Rio.
- As a centre of excellence from the south, BCAS has been involved in the process of formulation and reporting on all Global Environment Outlook (GEO) Reports of UNEP.
- Scientists of BCAS are actively involved in promoting science for sustainable development under the auspices of Pugwash and other movements.

24. Bangladesh Disaster Preparedness Centre (BDPC)

- **Capacity Development:** BDPC promotes the learning processes among individuals and organizations, and communities, professionals, scientists and practitioners to respond adequately and effectively to the challenges and risks associated with natural disaster by providing specialized knowledge and information, training, tools and materials with special reference to the real life issues and problems;

- **Advocacy and Lobbying:** BDPC takes lead in the advocacy and lobbying for all actors and institutions to address disaster risk reduction particularly in relevance to the poverty reduction goals and strategies, and to overcome these uncertainties through a concerted and well coordinated long-term enabling process;

- **Strategy Formulation and Planning:** BDPC participates and provides impulsion to Donors, government and non-government agencies in recognizing the need to integrate disaster management and risk reduction into development policies, programmes and projects;

- **Awareness, Knowledge, and Communication:** BDPC builds information bases on understanding and knowledge on natural disasters, how they impact on people, society and economy, how to manage disasters through prevention, preparedness, and mitigation of impacts, and what processes build capacities and institutions to mainstream the integration of disaster management and risk reduction.

25. Action Aid Bangladesh (AAB)

- Livelihood Security and Risk Reduction: Ensure a more secure livelihood for the poor and marginalised people. Promotion and strengthening of **livelihoods**, protection from **disasters**, access to and control over **natural resources** are the three themes in this sector.

- Women's Rights and Gender Equality: Gender sensitivity and promotion of women's right and equal access for women in all the programme and projects are primary focus of AAB. It works to advance **women's rights** for gender equality, create an enabling culture to practice gender equality among **youth** and adolescents and prevent **violence against women.**

http://www.actionaid.org/bangladesh/1133

- Rights and Social Justice: ActionAid Bangladesh works for a socially inclusive culture where diversity is celebrated, equal citizenship exercised and non-discrimination is actively practiced. Themes in this sector are **diversity** and citizenship, **disability** and enabling environment and **social inclusion** for sex workers, trafficked women and children and people living with HIV/AIDS.

- Social Development and Economic Justice: ActionAid Bangladesh tends to strengthen people's movements for social development and economic justice through ensuring quality **education**, **economic justice** and quality **health care** for all.

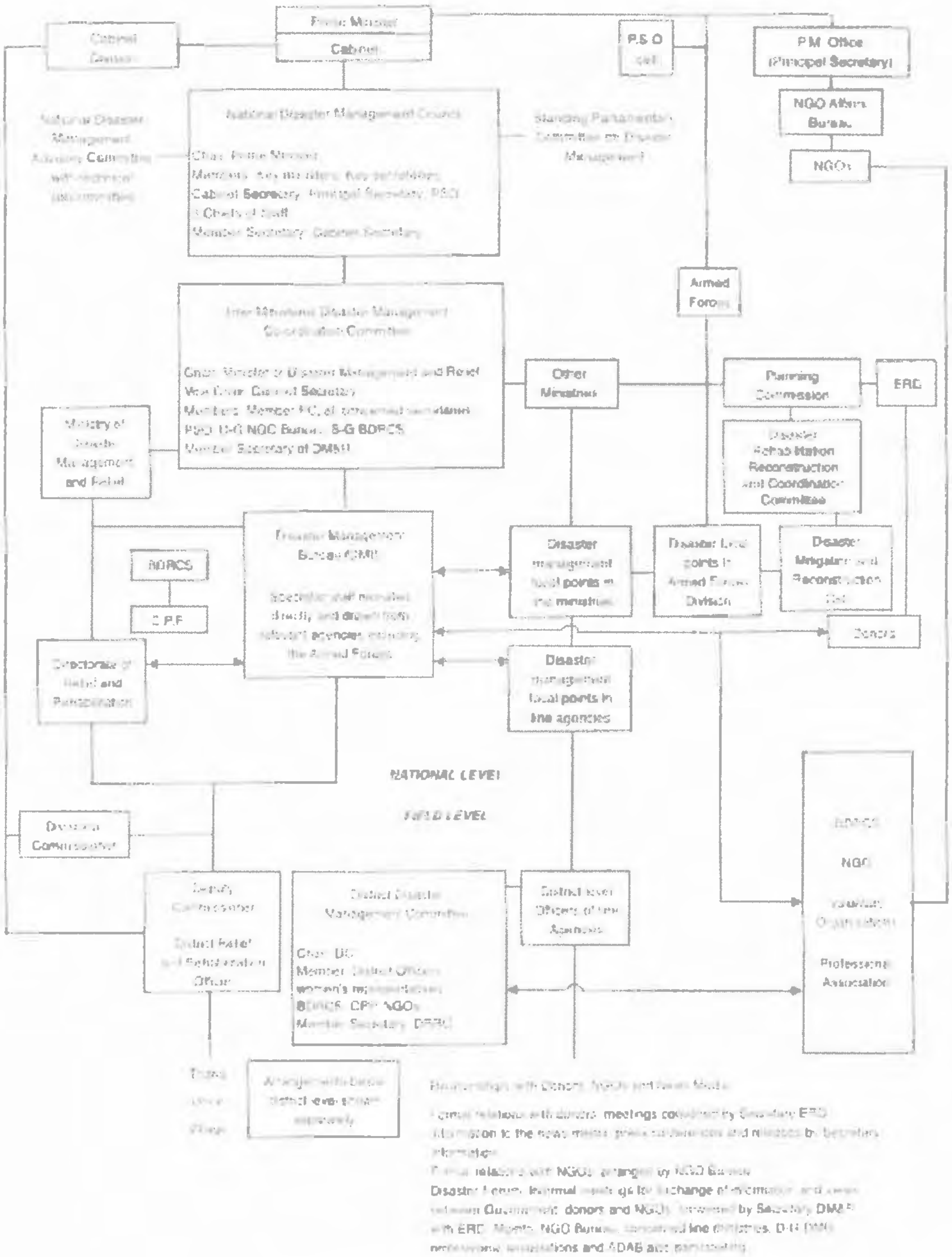
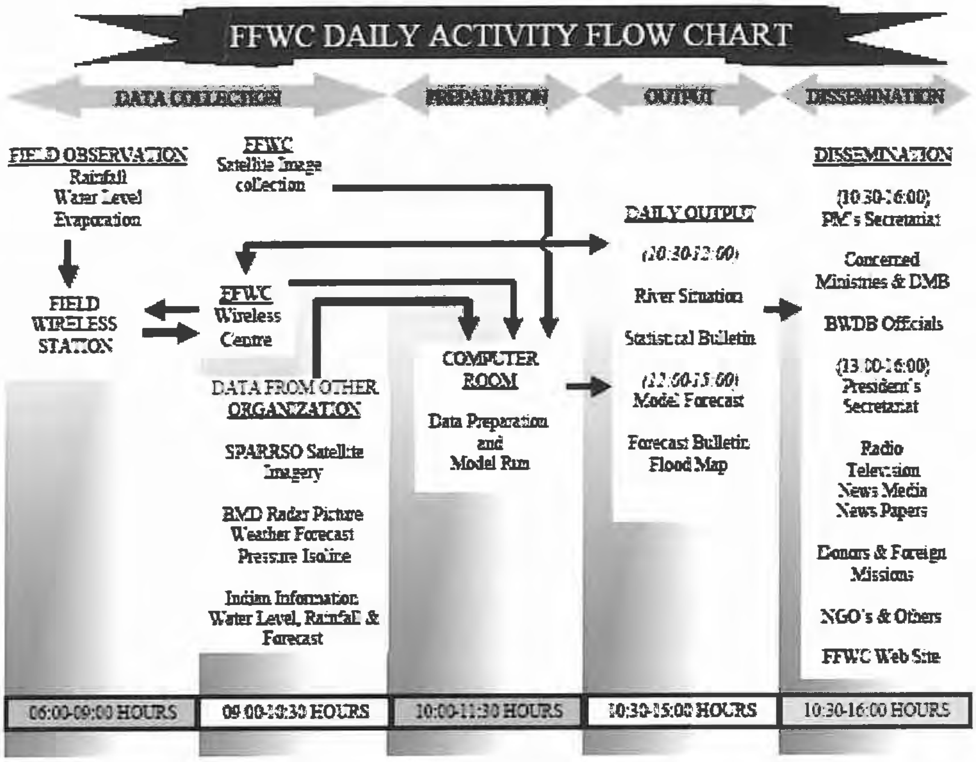


Figure 2.8: Institutional arrangement for disaster management in Bangladesh (Rahman, 2006)



(Source: FFWC BWDB)

Figure 2.5: FFWC daily activity flow chart

Annex I

National Road Map Document

National Road Mapping

Early Warning System Development in Bangladesh

National Road Mapping

Early Warning System Development in Bangladeshh

Presented for

People’s Republic of Bangladesh

Bangladesh Water Development Board (BWDB), Ministry of Water Resources

Disaster Management Bureau (DMB), Ministry of Food and Disaster Management

Bangladesh Meteorological Department (BMD), Ministry of Defense

Prepared through

ADB Technical Assistance (TA) 7276-REG

“Supporting Investments in Water-Related Disaster Management”

Prepared by

Asian Development Bank (ADB), Philippines

International Centre for Water Hazard and Risk Management (ICHARM), Public Works Research Institute (PWRI), Japan

Deltares, The Netherlands

Centre for Environmental and Geographic Information Services (CEGIS), Bangladesh

Photos:

Summary

Bangladesh is located in part of the world's most dynamic hydrological system. The river flow and the rainfall, with their distribution in different seasons and variations from year to year pose a formidable challenge and water-related disasters. The development, implementation and operation and maintenance of Flood Early Warning Systems (FEWS) can help decrease the number of casualties and socio-economical damages in flood affected areas. A good working FEWS, combined with structural measures, can further reduce vulnerability to water-related disasters.

The Flood Forecasting and Warning Centre (FFWC) under the Bangladesh Water Development Board (BWDB) has already been developing and operating a FEWS for over a decade. In order to assess the need for further improvement of the FEWS in Bangladesh, a study was conducted under ADB's regional capacity development technical assistance for Supporting Investments in Water-Related Disaster Management (TA7276).
The two main outcomes of the project are:

- A generic framework for prioritization of interventions in a participatory approach: and
- A National Road Map (NRM) with a clear portfolio of most feasible interventions including a time line and sequence for implementation

Based on case studies, field visits and intensive stakeholder consultations an inventory and priority ranking was made for the interventions needed to optimize the Flood Early Warning System (FEWS) in Bangladesh. The study assessed the needed interventions and performed a priority ranking of interventions based on a participatory stakeholder approach. By evaluating the Strength-Weakness-Opportunities-Threats (SWOT) of each short-listed intervention and weighing the importance of each intervention through an Analytical Hierarchical Process (AHP) a validated selection could be made.[1]

This approach may prove to be valuable for parallel projects in which selection and priority ranking of interventions are requested. Therefore, the methodology is presented as generic approach in form of this publication 'National Road Mapping for Early Warning System development in Bangladesh'

1 *Analytical Hierarchy Process (AHP) is a structured technique for organizing and analyzing complex decisions. Multi Criteria Analysis (MCA) techniques are used to perform qualitative pair wise comparison of alternatives. More precise and less biased results can be obtained if the pair wise comparison is performed on the Strength-Weakness-Opportunity-Threat (SWOT) factors of the alternatives. More information is available on Wikipedia http://en.wikipedia.org/wiki/Analytic_Hierarchy_Process*

Recommendations and way forward

A well functioning FEWS in Bangladesh is of great importance in order to minimize flood damage and casualties. The importance of FEWS is highlighted not only in the context of the changing socio-economic conditions of Bangladesh but also in the context of climate change, which has already had a serious impact in Bangladesh. The majority of flood vulnerable population in rural and urban areas has little access to reliable flood information. The reliability of such information concerns not only the timing and accuracy of flood forecast information but also the process of early warning information development and dissemination as well as the clarity in disseminated information. The main recommendations are outlined hereafter:

- The team prepared a Road Map with clear priority ranking on interventions and actions to be taken (see 'time line' in figure 3.4 and listing in table 3.3);
- Overall capacity building of the FFWC (staff, equipment, training) needs to get first priority;
- Capacity building for communication and dissemination is highly wanted by the stakeholders. Cooperation with CDMP-2 is desired;
- Use of modern telecom techniques in combination with simple techniques for local dissemination (flag system, rickshaw 'miking', mosques) has proved to be a very effective Community Flood Information System (CFIS project);
- Subsequent to better dissemination it will be beneficial to create flood hazard maps and damage assessments. Based on such an assessment of the dissemination of flood warnings could be more specific for a certain geographic region or end user group. More detailed flood hazard and damage maps per sector would need to be prepared;

- The model accuracy and subsequently forecast accuracy needs to be increased by improving the model validation procedure and to increase the range of data acquisition within the GBM-basin;
- More precise and user friendly warnings are needed to address the flood hazard situation at local level;
- In the review study of 2006 a general cost–benefit analysis per intervention was done. It is recommended to update these cost-benefit analyses for the interventions with the highest priority;
- New, more extensive pilots should be included with a combination of different techniques for communication and dissemination. During one of the field visits (Field visit Manikganj) the combination of different forecasting and dissemination and communication techniques proved to be very promising and was favoured by local stakeholders. The project (Community Flood Information System CFIS, USAID 2008) combined early flood warning per SMS and local warning with 'flag hoisting'. It is strongly recommended to continue this exercise on a large scale in different areas;

Besides these case specific findings and recommendations the used methodology (MCA, SWOT – AHP and stakeholder consultation) proved very effective in selection of interventions and priority ranking. Therefore the project likes to propose steps to formalize the use of the SWOT – AHP approach in decision making process for large investments.

ADB	Asian Development Bank
CBFRM	Community Based Flood Risk Management
ADB-DMC	Asian Development Bank-Developing Member Country
IR	Inception Report
ICHARM	International Centre for Water Hazard and Risk Management, Japan
IFAS	Integrated Flood Analysis System
IWRM	Integrated Water Resources Management
NDRMP	National Disaster Risk Mitigation Project, Bangladesh
PPTA	Project Preparation Technical Assistance
PWRI	Public Works Research Institute
R-CDTA	Regional Capacity Development Technical Assistance
REG	Regional Technical Assistance
TA	Technical Assistance
TAR	Technical Assistance Report
TOR	Terms of Reference
TRAM	Tasks, Responsibilities, Activities and Mandate
WFP	Water Financing Program 2006–2010

AHP	Analytical Hierarchical Process
BWDB	Bangladesh Water Development Board
BRIC	Bangladesh River Information and Conservation project
BMD	Bangladesh Meteorological Department
BUET	Bangladesh University of Engineering & Technology
CDMP-2	Comprehensive Disaster Management Program - II
CEGIS	Centre for Environmental and Geographic Information Services
CFIS	Community Flood Information System
DMB	Disaster Management Bureau
DDMC	District Disaster Management Committee
EWS	Early Warning System
FEWS	Flood Early Warning System
FFWC	Flood Forecasting and Warning Centre
GBM	Ganges-Brahmaputra-Meghna
IWFM	Institute of Water & Flood Management
IWM	Institute of Water Modelling
JRC	Joint Rivers Commission Bangladesh
JAXA	Japan Aerospace Exploration Agency
MCA	Multi Criteria Analysis
MoWR	Ministry of Water Resources
NRM	National Road Map
SOD	Standing Orders on Disasters
SWOT	Strengths Weakness Opportunities Threats
UNISDR	United Nations International Strategy for Disaster Reduction
WARPO	Water Resources Planning Organization

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Introduction

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1.1 Background

This publication presents the final results of the Bangladesh in-country component of the Asian Development Bank's regional capacity development technical assistance for Supporting Investments in Water-Related Disaster Management (ADB TA 7276-REG). The main objective of the TA is to help prepare and implement flood management investment projects through knowledge and capacity development services that will reduce vulnerability to water-related disasters. The Bangladesh in-country component of the TA had originally two activities: 1) in-country project support with focus on the review of an ADB study of 2006 on the status of the Flood Early Warning System (FEWS) in Bangladesh, and 2) program quality support through regional cooperation.

The study assessed the needed interventions and performed a priority ranking of interventions based on a participatory stakeholder approach. By evaluating the Strength-Weakness-Opportunities-Threats (SWOT) of each short-listed intervention and weighing the importance of each intervention through an Analytical Hierarchical Process (AHP) a validated selection could be made. The followed approach (SWOT-AHP) may prove to be valuable for parallel projects in which selection and 'priority ranking' of interventions are requested. Therefore, the methodology is also presented as a generic approach described in Appendix A.

1.2 Rationale

Bangladesh, being situated in the mega delta area of the Ganges-Brahmaputra-Meghna river system, is one of the most flood prone countries in the world. Flooding normally occurs during the monsoon season from June to September. Bangladesh has a total land area of 147,570 km² and is administratively divided into 7 divisions, 64 districts and 482 sub-districts. There are 230 rivers in total, including 57 international rivers of which three are major rivers (Ganges, Meghna and Jamuna). Their total catchment area is approximately 1.6 million sq-km of which only about 7.5% lies in Bangladesh and the rest, 92.5% lies outside the territory. It is assumed that an average flow of 1,009,000 Million cubic meters passes through these river systems during the monsoon season. Monsoon flood inundation of about 20% to 25% area of the country is assumed

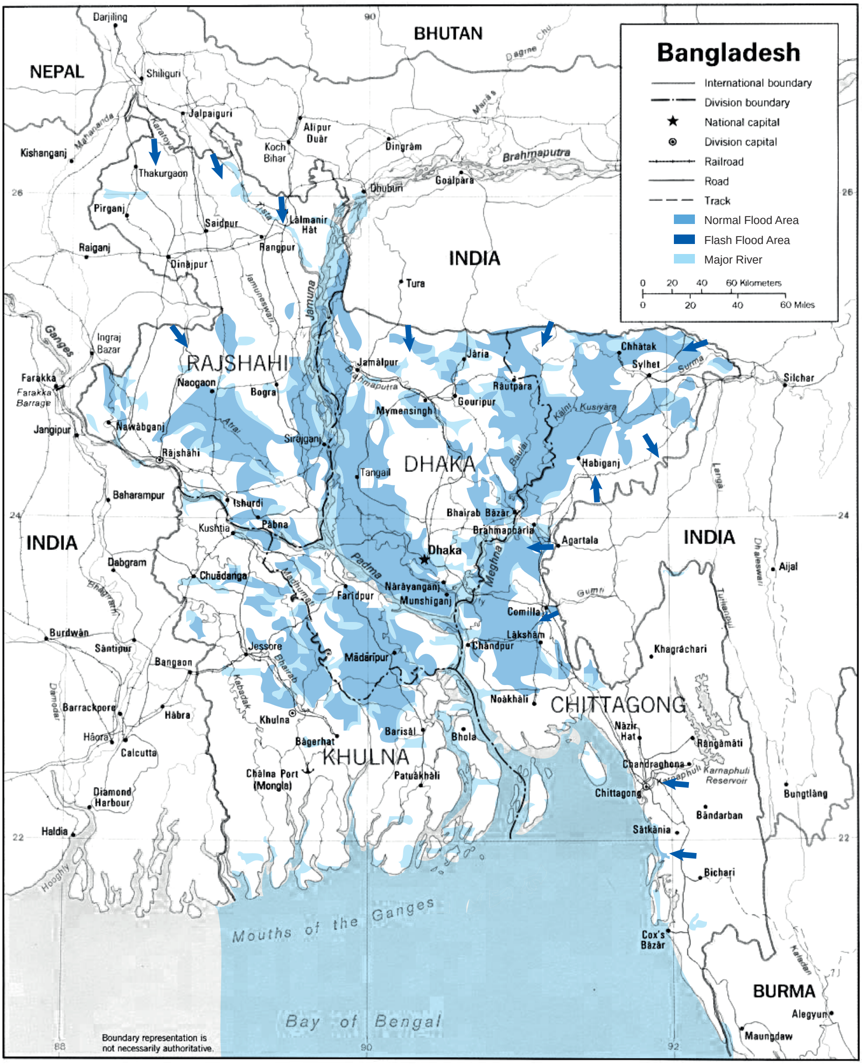


Figure 1.1 Overview of main features and location in Bangladesh (Source: CEGIS/internet)

beneficial for crops, ecology and environment, inundation of more than that cause direct and indirect damages and considerable inconveniences to the population, (Source: FFWC Annual Flood Report 2011[2]).

The urban population has increased rapidly since the 1980s mainly due to the growth of the slum population. Since many slum areas develop in flood prone areas a direct correlation exists between flood risk and (slum) population density. The slums expanded partly by migration of displaced people due to disaster events in the rural areas. The population density in Bangladesh is amongst the highest in the world and is now currently at 1100 people/km^2. This increased population density has posed further stress to create vulnerability towards flooding. Recognizing the increasing level of risk, early warning for flood has become a most important and prominent challenge for the Government of Bangladesh in order to reduce the number of flood casualties and minimize damage. It is widely acknowledged that a real or nearly real-time flood forecasting and associated warning mechanism, if implemented properly, can save human lives and mitigate economic damage to a great extent, (Source: FFWC Annual Flood Report 2009 and 2010[3]).

River flow and rainfall, with their distribution in different seasons and variations from year to year, pose the formidable problem of water-related disasters. In Bangladesh investment in flood early warning proved to be very effective. The development, implementation and operation & maintenance of FEWS can help decrease the number of casualties and socio-economic damage in flood affected areas. A good working FEWS, which is combined with structural measures, can further reduce vulnerability to water-related disasters.

2 FFWC Processing & Flood Forecasting Circle, BWDB, Annual Flood Report 2011

3 FFWC Processing & Flood Forecasting Circle, BWDB, Annual Flood Report 2009 and 2010

1.3 Previous studies on Flood Early Warning Systems

In Bangladesh, a considerable number of studies and projects related to the development of flood early warning systems have been undertaken in recent years. All these projects and studies produced valuable background information on the development and improvement of FEWS. Some key projects are:

Environmental Monitoring Information Network (EMIN) (2000-2007)

The project is an information network that facilitates planning and management of water and land resources in flood and erosion monitoring. The purpose of the project is to implement an information network to facilitate the planning and management of water and land resources as it relates to flood and erosion monitoring among national stakeholders and relevant agencies in the Brahmaputra-Jamuna rivers region.

Improvement of Flood Forecasting and Warning Services (IFFWS)

The feasibility study for the Improvement of Flood Forecasting and Warning Services was funded by the Government of Bangladesh and the Japan International Cooperation Agency (JICA). The study was aimed at:

- Formulating improvement plan of the flood forecasting and warning system in Bangladesh in order to mitigate flood damage focusing particularly on improvement of the data communication system;
- Conducting a feasibility study of the selected optimal scheme; and
- Transferring technology to Bangladesh counterpart personnel in the course of the study.

Community Flood Information System (CFIS) (2001 – 2006)

The objective of CFIS is to disseminate information on the flood extent, duration and depth of water and water levels to the community before the flood occurs. The CFIS Project developed GIS-based flood forecasting information software named WATSURF, which implements a correlation model of a 248 km^2 study area. WATSURF is a simple gauge-to gauge correlation-based tool that uses forecasted water levels from the FFWC as input

Consolidation and Strengthening of Flood Forecasting and Warning Services (CSFFWS) project (2006)

The three immediate objectives or components of the project were:

- Component A: Development of flood forecast and inundation models.
- Component B: Dissemination of flood forecast information and warning messages; and
- Component C: Making FFWC sustainable by the end of the project.

Early Warning System Study (2006)

In 2006 an Early Warning System Study was concluded under a TA grant of the Asian Development Bank (ADB).[4] This 2006 review study included a comprehensive inventory of all earlier studies on FEWS in Bangladesh. Therefore the outcome of that study formed the starting point for the present project. The main objective of the FEWS Study in 2006 (ADB TA-4562) was:

“To provide analytical input and prepare project portfolios and pre-feasibility studies to enhance existing early warning systems including the flood forecasting system operated by the Flood Forecasting and Warning Centre (FFWC) under the Bangladesh Water Development Board (BWDB). “

4 Bangladesh: Early Warning Systems Study, final report, December 2006, under TA grant of the ADB TA 4562-BAN

Flood Early Warning System 2

2.1 Components of a Flood Early Warning System

Flood damage has been a big setback for the national economy. Therefore, the development and implementation of FEWS as well as the development of infrastructural measures has become an essential element in the development process. The importance of FEWS is highlighted not only in the context of the changing socio-economic conditions in Bangladesh but also in the context of climate change, which has already had a serious impact in Bangladesh. Besides the already mentioned changes in river discharge and monsoon rainfall, sedimentation and erosion patterns are also distressed by climate change. The majority of the vulnerable population in rural areas as well as urban population receive flood warning information through mass media. Even though there is a wide coverage there are still large groups of affected people that are not receiving adequate warning in time. Especially the limited lead time of the flood warning is giving the affected population very little option to decrease the impacts. Moreover, the timing and accuracy of flood forecast information, the process of early warning information development and dissemination, and the clarity of the disseminated information all are indicators for flood information reliability.

According to the United Nations International Strategy for Disaster Reduction (UNISDR), a FEWS contains the following main elements: meteorological data gathering, flood forecasting & warning, dissemination, and response & preparedness. The general approach for a FEWS is illustrated in Figure 2.1.

Figure 2.1 Main elements and phases in a Flood Early Warning System

(Source: UNISDR

Also indicated in the ‘2006 FEWS review’ report, all elements and phases are equally important in order to achieve an effective FEWS. For instance, dissemination and communication are as important as the preparation of the flood warning itself. In case the flood warning is not reaching the affected people in time the effectiveness is limited even if the warning itself is of good quality.

Flood Early Warning System

(a) Information dissemination through mike announcements on mobile rickshaw

(b) Local information dissemination using flag signals

Some of the dissemination and communication systems in local community.

(c) Local information on danger levels of flood is needed

(d) Central processing of flood warning at the facilities of the FFWC, Dhaka

The main steps and phases as mentioned in Figure 2.1 are connected to the UNISDR approach for flood disaster management. The steps of FEWS are divided into six main subsequent steps for simplifying. Figure 2.2 presents the six main subsequent steps or cascades in FEWS as well as one class for cross-cutting issues. The steps or cascades are all connected to each other. The full cycle of FEWS can only be completed if all steps are taken. In the system, a feedback mechanism is used. If the requirements in one cascade step are not fulfilled the previous level has to be repeated.

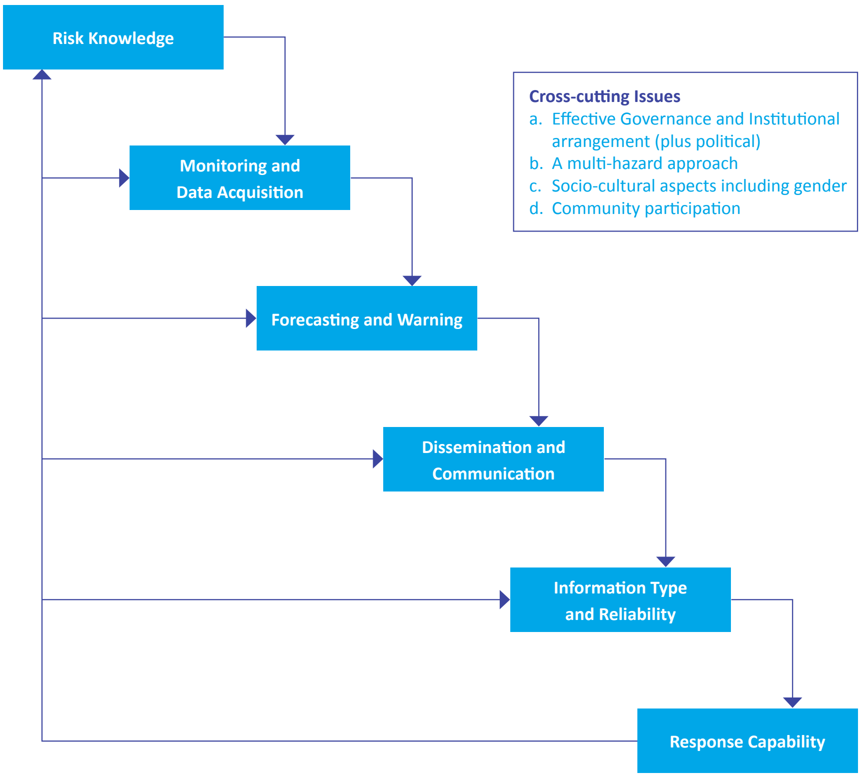


Figure 2.2 Cascades and cross cutting issues for FEWS (modified from UNISDR)

2.2 FEWS in Bangladesh

The Government of Bangladesh has recognized the need for a suitable national FEWS and therefore established in 1972 a Flood Forecast and Warning Centre at the BWDB. Since then, it has developed a comprehensive system of collecting and processing hydrologic and other data as input to forecasting models, preparing flood forecasts and warnings on a daily basis during the flood season and disseminating the same to a range of government and non-government organizations, media groups and other interested parties.

The FFWC's system for preparing 3-day flood forecasts and warnings is well established for stations on major and secondary rivers and is known to produce forecasts, especially for the central region of the country. Their system has evolved to incorporate new technologies that increase the accuracy and reliability of flood forecasts.

Dissemination of flood warnings is developed, at national, regional and local level. All DDMC's and local water management agencies, institutions & organizations are receiving direct flood warning through e-mail. Besides this an active real time warning system is operated through the FFWC website. Approximately 600 stakeholders receive a direct (daily) warning in case of possible flooding. The photo's on the left page are illustrating the different steps in the FEWS cycle.

The mandate given to FFWC/BWDB is limited to production and dissemination of the flood warning. Other government agencies such as the Bangladesh Metrological Department (BMD) and the Disaster Management Bureau (DMB) are responsible for the meteorological data to produce the flood warnings and community involvement and preparedness.

In the revised Standing Orders on Disaster (April 2010) the mandate of the BWDB and FFWC is agreed. The SOD provides a clear National framework on flood risk management. However, improvements are still possible. The present flood early warning system is very much focusing on the main river flood. Coastal flooding, flash floods and flood plain floods are not sufficiently covered by the present system.

In spite of the large efforts on flood early warning dissemination, it is still difficult to reach the people at risk (in the villages) in time. There are considerable weaknesses in making warning messages effective for enabling people and institutions to take protective action to reduce the negative impact of floods. Dissemination from the forecast organization to warning organizations for meaningful action represents the weakest link in the early warning system. However this is not just a task for the FFWC alone.

In Bangladesh, several departments and institutions are working directly or indirectly in the field of FEWS. The BWDB, the FFWC, the BMD, and the DMB are the four pillar institutions directly dealing with FEWS. In figure 2.3 an overview of the main institutes and their involvement in FEWS in Bangladesh are presented.

Other organizations, such as the Bangladesh Haor and Wetland Development Board (BHWDB), Department of Agricultural Extension (DAE) etc., are users of early flood warning information mainly to make effective use of such information at the grass root communities. The Water Resources Planning Organization (WARPO) is a policy formulation body within the government that formulates the strategy for implementing FEWS.

Besides government agencies, there are also semi-governmental agencies and Non Governmental Organizations (NGOs) that are involved in flood forecasting model development and in the different stages of the early warning cycle.

Enhancing coordination among involved agencies and improvement on the total understanding of the early warning cycle will lead to clear objectives and goals. In addition, there is a need to harmonize the responsibilities among institutions and therefore the mandate of each institution. Different stakeholders have different FEWS related issues to handle and therefore have different priorities. Since a FEWS can only be effective if all 'cascade phases' are addressed a closer look at the roles and tasks of the involved institutions and their level of cooperation is needed.

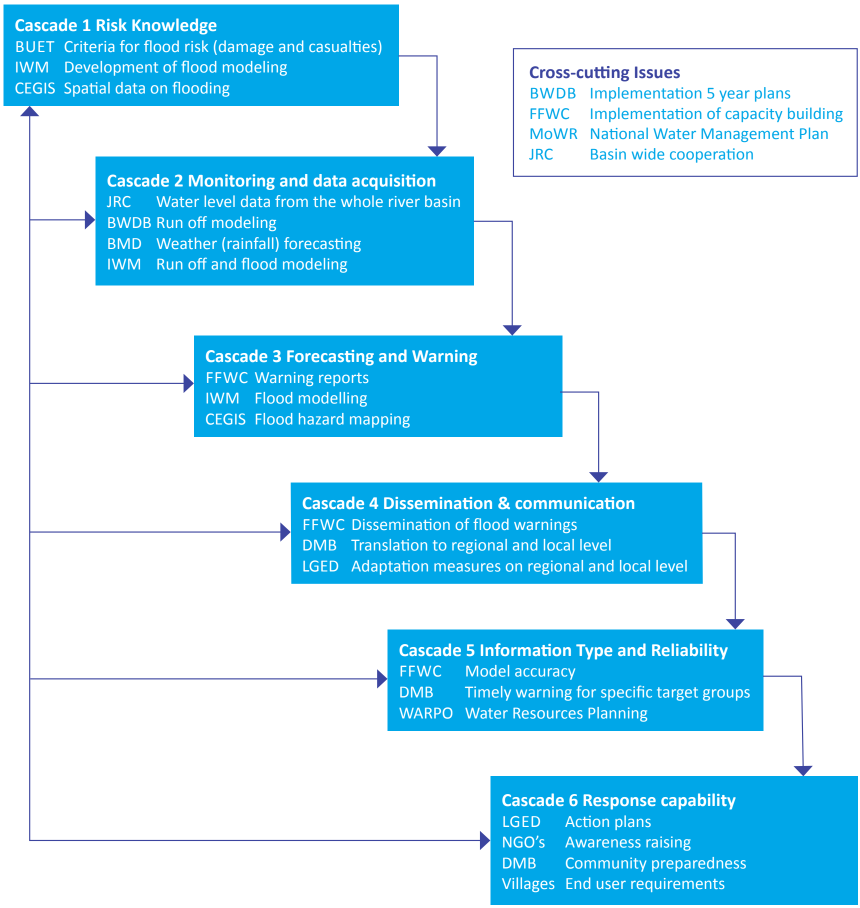


Figure 2.3 Overview of the roles and tasks of institutions involved in FEWS in Bangladesh

2.3 Need for National Road Map

The existing FEWS has many key components in place, but adjustments and strengthening are required for the system to achieve its potential and make a significant contribution to flood preparedness and flood damage mitigation. In the ADB review study of 2006 an enhancement program was developed by ADB to address the gaps and shortcomings of the existing FEWS. The strategy of the program is to strengthen the effectiveness and sustainability of FEWS. The expected outputs from the Program are:

- System established to provide more reliable and accurate hydrological data for flood prone areas
- System established to prepare more useful flood forecasts for flood prone areas
- Response-orientated and timely flood messages disseminated
- Sustainable and well-coordinated early warning system for floods

The types of activities that would contribute to these outputs are:

- Increase accuracy and timeliness of input data for forecasting
- Improve flood forecasts to meet demands of end-users
- Improve the extent of coverage and the penetration of the early warning system
- Expand coordination between key institutions involved in early warning system

In total, twenty-two (22) Interventions were identified.

Although the 2006 review study covered many aspects of FEWS developments, there were also some shortcomings. The most important ones were:

- The 2006 review was mainly based on expert judgment
- Although separate interventions were identified and described, the project did not include a Road Map with clear priority actions towards implementation

In order to address this, the present TA project comprised three key elements:

- Active involvement of all stakeholders in a participatory approach on selection and ranking of interventions
- Ranking and prioritization of interventions through a SWOT- AHP approach. The outcome of the study is governed by stakeholders common interests supported by experts judgment and not biased on individual stakeholder's interest.
- Development of a Road Map for FEWS with a portfolio of the most feasible interventions including a time line, project sequence and preliminary design and monitoring framework

Flood Early Warning System

2

The professional and enthusiastic response of the stakeholders at the beginning of this project has led to a wider understanding and interpretation of the original objectives of the project. Based on the reaction of the stakeholders and a review of the '2006 recommendations', a proposal was made to widen the scope of the Bangladesh in-country component towards a more generic approach to developing the National Road Map.

The Road Map is expected to be useful in guiding the preparation of a long-term national plan and after finalization and approval by the government, it could be used by government agencies and donor agencies for screening and ranking investment on development projects on early warning systems. In order to do so, more intensive interaction with the stakeholders in Bangladesh is needed.

Some of the key objectives of developing the National Road Map are:

- To identify key issues and interventions deemed essential for improving the existing situation.
- To achieve national (stakeholders) consensus on priority projects on FEWS development for the improvement of flood forecasting and early warning system.
- To address the key concerns of stakeholders and to check the practicality of proposed projects and at the same time, to avoid overlapping and duplication in project implementation.
- To maximize the benefits from task sharing approach or promote coordination among involved agencies and grass-root communities.
- To build a common platform for action.

Development of a National Road Map for FEWS can help avoid overlapping, duplication, and conflict of interest among the agencies concerned. The presented methodology is focused on addressing the mentioned challenges and to assist in making necessary choices in the development of an effective FEWS for Bangladesh.

Stakeholder Consultation Workshop on
Investment in Water-related Disaster Management in Bangladesh
CEGIS

Development of National Road Map for FEWS

3

3.1 Overall approach

Based on case studies, field visits and intensive stakeholder consultations an inventory and priority ranking was made for the interventions needed to optimize the Flood Early Warning System (FEWS) in Bangladesh. The main approach of the project comprises three elements (figure 3.1):

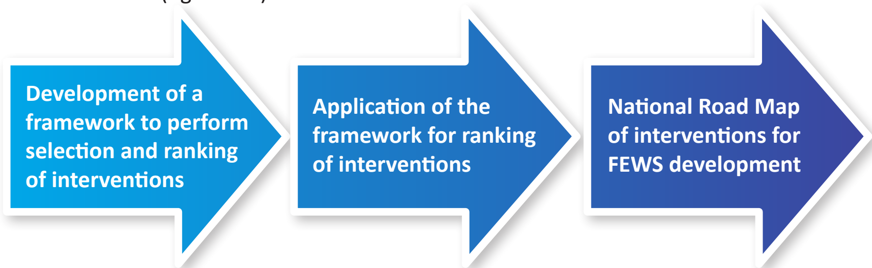


Figure 3.1 Main elements in the development of a National Road Map for FEWS in Bangladesh

Through this approach the two main outcomes of the project are:

- A generic framework for prioritization of interventions in a participatory approach: and
- An approach towards a National Road Map (NRM) with a clear portfolio of most feasible interventions including a time line and sequence for implementation

During the inception phase of the project the general approach for the development of a National Road Map was worked out in a step-by-step manner. The first step comprised a review of flood Early Warning Systems (FEWS) in Bangladesh and the identification of key issues. This resulted in a long list of issues that formed the basis of the first stakeholder consultation in December 2010. The outcome of the workshop in December led to the configuration of a list of interventions. Subsequently the interventions were ranked, in the second stakeholder consultation session in March 2011. The outcome of the 2nd workshop (ranking of interventions) formed the basis of the feasibility analysis and recommendations to the ADB in the form of a National Road Map. Figure 3.2 illustrates this approach.

Development of National Road Map for FEWS

Phase 1: Review

The first step concerned data collection on technical and institutional issues. During this phase the technical and institutional review was done. The technical review concentrated on existing projects and FEWS technology. For the institutional review a so called TRAM (Tasks, Responsibilities, Activities and Mandate) analysis was conducted for the main stakeholders. The review was conducted based on criteria retrieved from the UNISDR checklist.

Phase 2: Identification of key issues

The next step comprised a cross reference with the existing 22 recommendations of the 2006 FEWS review study. Together with the identified key issues of the review study a 'long list' of possible interventions was drafted. This 'long list' formed the key element for the first stakeholder consultation.

Phase 3: Dependency test

Subsequently all issues were classified in six classes of the FEWS development cascade cycle (risk knowledge, monitoring and data acquisition, forecasting and warning, dissemination and communication, information type and reliability and response capacity). Based on expert knowledge a clustering of issues into interventions under the 6 cascade classes was done in a qualitative way. All interventions address the most important issues as identified by the first stakeholders meeting, while covering other less important issues at the same time. The conversion process also illuminated any duplication in the issues identified by the first stakeholder workshop. Besides these 6 classes there are also cross cutting issues like governance, multi-hazard approach, socio-cultural aspects and community participation. The outcome of this phase was streamlined in the 'long list' of interventions.

Phase 4: Priority ranking and selection of interventions

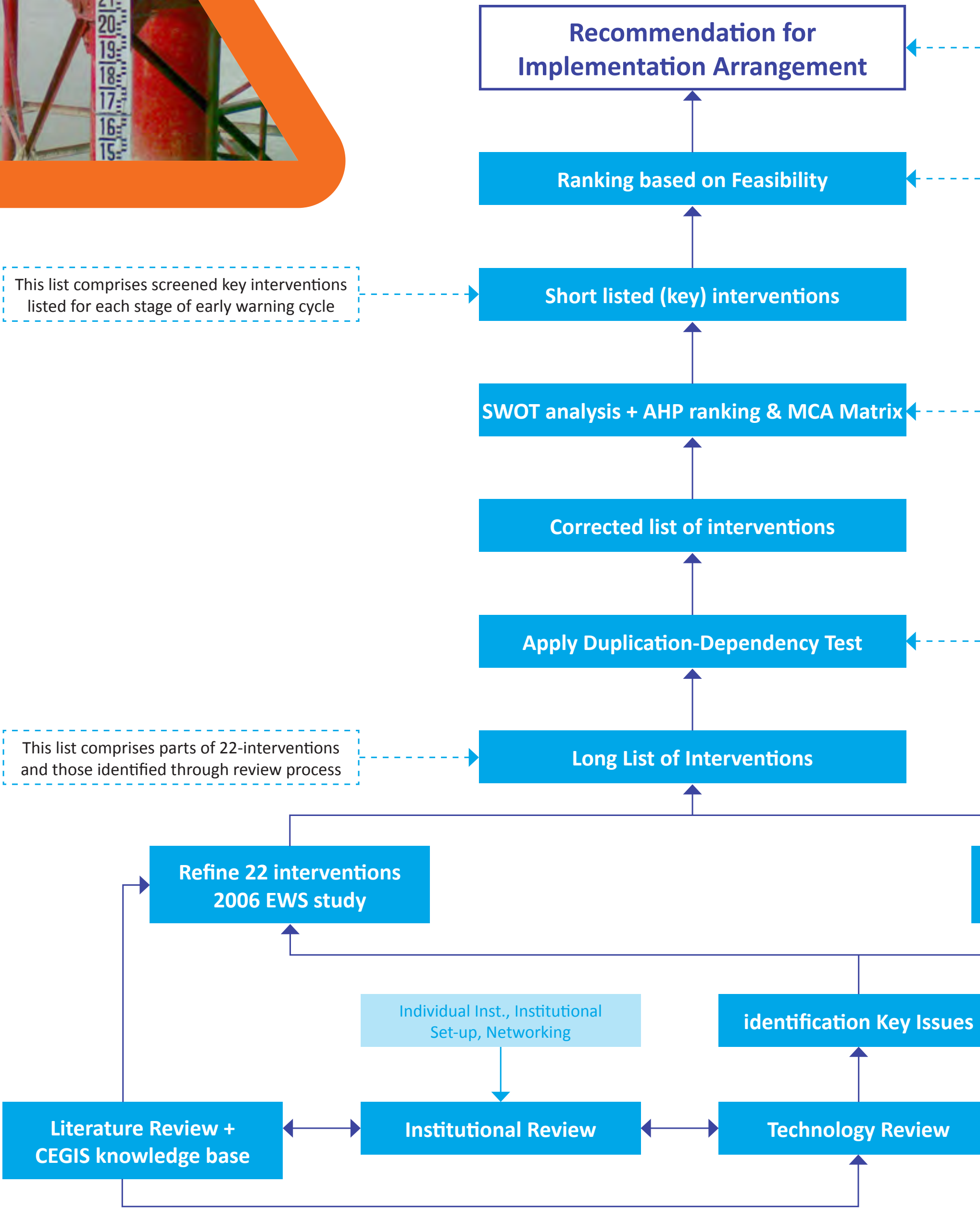
In this phase a pair wise comparison (AHP) for all interventions was performed in two consecutive steps. The AHP consisted of a MCA and a SWOT analysis. The MCA might be biased because of institutional interest in priority ranking. Therefore a SWOT analysis

was also performed for each intervention. The SWOT analysis is considered to be focused more on the strength, weakness, opportunity and threats of the intervention itself and therefore free from individual interest in project selection.

Phase 5: Recommendations

Finally, an overall feasibility (technical, socio-eco, financial) analysis was performed for all top prioritized interventions in each cascade. This formed the base of the National Road Map on FEWS development and the conclusive recommendation to the ADB regarding investment in FEWS in Bangladesh.

Framework for the Flood Early



Warning Review Study

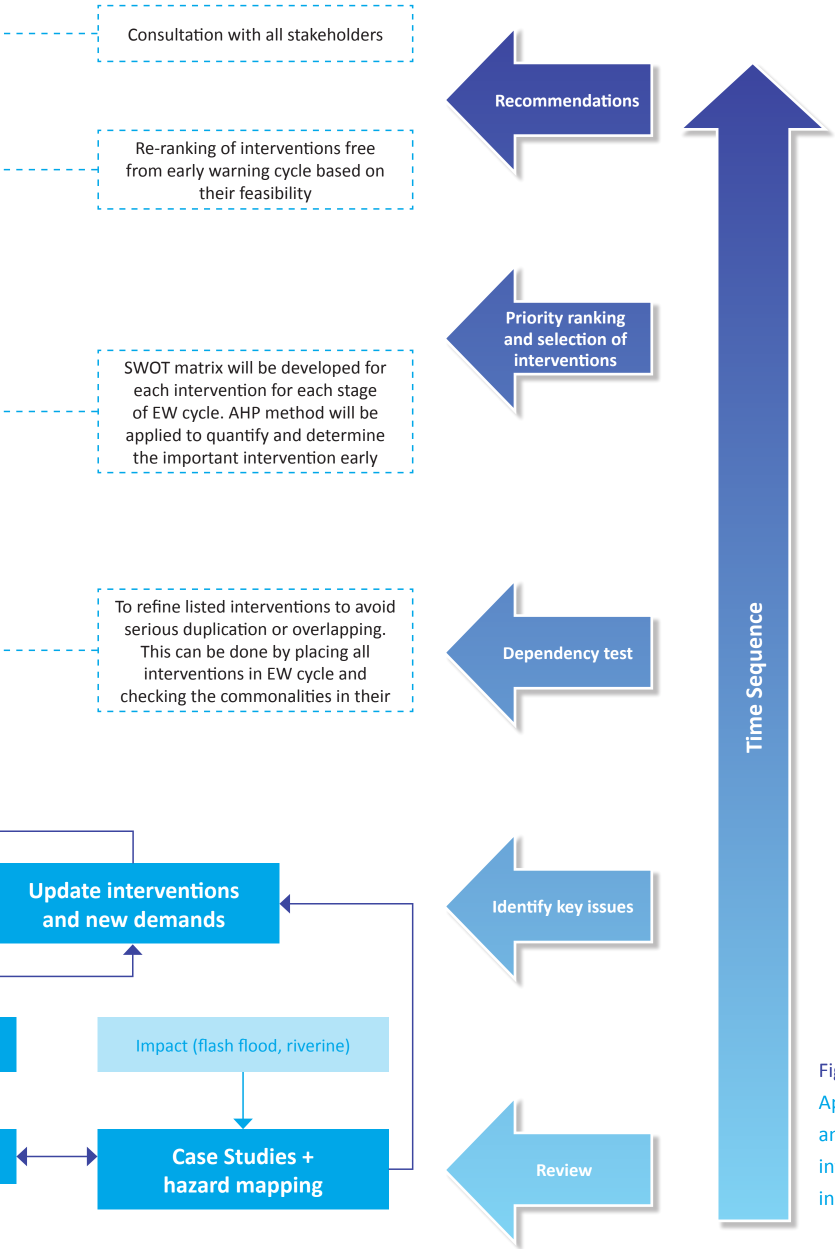


Figure 3.2
Approach for selection and prioritizing of interventions for FEWS in Bangladesh

3.2 Prioritization of Interventions

During the second stakeholder consultation round, the participants representing the different organizations were divided into three groups over the cascade classes. They performed a MCA and a SWOT-AHP analysis in order to come to a priority ranking of interventions (see Appendix A for details). The priority ranking was carried out on the list of clustered interventions. Therefore a set of questionnaires was developed:

- One for a Multi Criteria Analysis (MCA) approach to compare all different interventions
- A second for a Strength – Weakness – Opportunity – Threat (SWOT) approach to compare the interventions one by one.

Both questionnaires were used in an Analytical Hierarchy Process (AHP) analysis or pair wise comparison. In the MCA approach all sub-interventions are compared with each other. In a 'pair wise comparison' the preference and intensity of that preference is compared. The team introduced a software application ('make it rational') with which a statistical analysis is done on the response. The software indicates the internal consistency of the answers and any contradiction. Due to this check conflicting answers by the respondents could directly be discussed in the group sessions.

This analysis was performed for all cascade classes and cross cutting issues. The outcome was processed in order to be able to combine the results of the individual organizations with the workshop group results. The final priority ranking of the possible interventions is presented on the right page in Table 3.1.

The result of Table 3.1 is presented in a graphical form in figure 3.3. In March 2011 these results were presented by the team to the Bangladesh Government (BWDB and FFWC) as the preliminary National Road Map.

Cascade Classes	Interventions		Ranking
1 Risk knowledge	1-3	Formal and informal education	1
	1-1	National and local level risk assessment	2
	1-2	Integrated planning for EWS	3
2 Monitoring and data acquisition	2-5	Operation & Maint. of the monitoring network	1
	2-6	Expanding the range of data acquisition	2
	2-7	Regular monitoring of flood events by sat data	3
	2-4	Improve data quality	4
	2-3	Automatic data collection	5
	2-1	Development of base information	6
	2-2	Manual data collection	7
3 Forecasting and warning	3-1	Model accuracy and upgrade software	1
	3-2	Flood forecast model development	2
	3-3	Expansion of forecast and number of institutes	3
4 Dissemination and communication	4-2	More precise and user friendly warning	1
	4-3	Capacity building for dissemination	2
	4-1	Extending the range of dissemination	3
5 Information type and reliability	5-1	More precise and location specific information	1
	5-2	Update warning information timely manner	2
6 Response capability	6-1	Capacity development of community	1
	6-2	Community preparedness	2
7 Cross cutting issues	7-1	FFWC capacity building	1
	7-3	International cooperation	2
	7-2	Strengthening of organizational status	3

Table 3.1 Combined ranking of interventions using MCA and SWOT-AHP based on workshop group results (derived from interim report ADB TA 7276-REG)

National Roadmap for Floods Early Warning System Development in Bangladesh

Prepared through

ADB-ICHARM
Technical Assistance TA 7276-REG
'Supporting Investments in Water Related Disaster Management'

Presented to

Bangladesh Water Development Board,
Bangladesh Meteorological Department,
Disaster management Bureau,
Bangladesh

Figure 3.3 Preliminary National Road Map

Bangladesh
CASCADE 1. RISK KNOWLEDGE
Priority 1: Formal and informal education
Priority 2: National and local level risk assessment
CASCADE 2. MONITORING & DATA ACQUISITION
Priority 1: Operation & Maintenance of the monitoring network
Priority 2: Expanding the range of data acquisitions
CASCADE 3. FORECASTING & WARNING
Priority 1: Model accuracy and upgrade software
Priority 2: Expansion of forecasting capacity to increase lead time and number of forecast institutions
CASCADE 4. DISSEMINATION AND COMMUNICATION
Priority 1: More precise and user friendly warning
Priority 2: Capacity building for dissemination
E 5. INFORMATION TYPE AND RELIABILITY
More precise and location specific information
Update warning information timely manner in different stages
ABILITY
ent of community
dness
BHUTAN
Alipur Duar
Dingram
Goalpara
Dhubri
Lalmanir Hat
Jamuna
Kilometers
40
60 Miles
Silchar
INDIA
Agartala
Aijal
Khagrachari
Noakhali
CHITTAGONG
Nazir Hat
Rangamati
Chandraghona
Chittagong
Bandarban
Satkania
Bungtlang
Bichari
Bhola
Patuakhali

3.3 Pre-feasibility of interventions

The ranking of the interventions as presented in Table 3.1 needs further elaboration in terms of feasibility. Therefore a (qualitative) pre-feasibility analysis of the priority interventions was performed in consultation with the main stakeholders. This pre-feasibility analysis forms the final step towards a National Road Map for FEWS. This is based on existing capacities (i.e. Technical, Socio-cultural, Institutional). The results of Table 3.1 were classified in terms of:

- Technical aspects such as: the availability of data, equipment, software
- Socio-cultural aspects comprising: the acceptance of warning information, response capacity, level of awareness
- Institutional aspects: the mandate, user demands, legal feasibility, existing laws and regulations, enforcement, organization capacity
- Financial aspects consider the availability of budget for: purchase, operation & maintenance, capacity development

Table 3.2 Pre-feasibility analysis of main priority interventions (derived from expert judgment BWDB, FFWC and CEGIS experts)

Cascade	First Priority intervention	Technical	Socio-cultural	Institutional
1 Risk knowledge development	Formal and informal education	++	++	+++
2 Monitoring and data acquisition	Operation & maintenance of the monitoring network	++	++	+
3 Forecasting and warning	Model accuracy and upgrade software	+++	++	+++
4 Dissemination and communication	More precise and user friendly warning	+++	+++	++
5 Information type and reliability	More precise and location specific information	+++	++	++
6 Response capability	Capacity development of community	+++	++	+
7 Cross cutting issues	FFWC capacity building	+++	+++	+++

All aspects were scored. The following are the criteria for scoring range for prioritizing the intervention at pre-feasibility level. These qualitative scoring ranges are high, medium and low indicated by the following range of scoring symbol. These criteria are based on expert judgement in combination with input from the main stakeholder (e.g. FFWC).

Range of Symbol	Descriptions (based on expert judgment)
+++	Very High - High feasibility which means that the priority interventions is very likely to be implementewd
++	Medium
+	Medium - Low which means that the priority interventions will not be implemented easily

In case one of the criteria of the selected interventions is scored 'medium low' it means that there exist considerable bottlenecks for the implementation of related actions. In Table 3.2 an overview is presented of all interventions (as classified in Table 3.1) and the scoring of the pre-feasibility criteria.

Financial	Second Priority intervention	Technical	Socio-cultural	Institutional	Financial
+	National and local level risk assessment	+++	++	++	+++
+	Expanding the range of data acquisition	++	++	+++	++
++	Flood forecast model development	++	++	+	++
++	Capacity building for dissemination	+++	+++	++	++
++	Update warning information timely manner	+++	++	++	++
++	Community preparedness	++	+++	+	++
++	International cooperation	+++	+	+	+++

Score range low, medium, high feasibility

Technical

- Low if the technology is not ready, not available, large capacity building and training needed
- Medium
- High if technology is already available in the organization and if well trained staff is available

Socio-cultural

- Low if there is no acceptance for the intervention or the local end-users do not see the benefit or the solution is to high end or technical/expensive for end-users
- Medium
- High if the intervention is proposed by the end-users itself, if the intervention is really taken into account their needs, if the intervention will be 'owned' by the end-users

Institutional

- Low if there is no acceptance and no ownership, or cooperation and involvement of institutes. Also low if there are no existing laws and regulations or that the enforcement is not in place
- Medium
- High if there is clear ownership and laws, regulations and law enforcement is in place

3.4 National Road Map for FEWS Development

The results of the pre-feasibility analysis as presented in Table 3.2 will lead towards the National Road Map for FEWS development. By combining the input for all factors (technical, socio-cultural, institutional and financial) a cross-sector assessment was performed resulting in an overall value for the pre-feasibility of each intervention. The criteria for the assessment are:

Range of feasibility	Descriptions (based on expert judgment)
Very high	All factors score high, which means that the priority interventions is very likely to be implemented
High	All factors score high but one score medium. Implementation will be likely without big constraints
Medium High	Two factors score medium which means that the priority interventions could be implemented with some effort
Medium	All factors scored 'medium'
Medium - Low	At least one of the factors has scored 'low' which means that implementation will face difficulties.

Since all interventions are already classified 'with priority' the stakeholders expect that all interventions will be implemented.

The final results are presented in Table 3.3 and Table 3.4 and form the base for the National Road Map. Subsequently, a timeline and sequence for the selected interventions is presented in Figure 3.4. For the most feasible interventions (very high and high) a 'design and monitoring framework' was prepared in accordance to the ADB guideline. The results are presented in Appendix B.
Since all steps of the disaster cascade need to be addressed in the timeline of interventions, several interdependencies or sequences exist. The timeline (presented in Figure 3.4) is considering an intervention period of at least 7 years. All activities start with the capacity building of the FFWC itself.

Next the national and local level risk assessment will help prepare flood hazard maps and vulnerability zones. This information is needed to improve the forecast model and to address the needs of specific end users in the region in a more location specific manner. Next, capacity building for dissemination forms another large block of activities. The internal FFWC capacity for communication & dissemination needs to be increased first and then only formal and informal education and community involvement can be pursued.

Operation & Maintenance cannot be addressed as a separate intervention. It is integrated in the internal management of the BWDB and the FFWC. Therefore, it is highlighted in the timeline as continuous activity. The intervention cost, implementing agency and duration is also indicated in the timeline. The approximate cost is indicated in million Bangladesh Taka. The total portfolio is expected to be feasible for 725 Million Taka. An indication of investment cost is also given in the Design and Monitoring Framework in Appendix B.

Table 3.3 National Road Map for FEWS development in Bangladesh

Cascade	Priority intervention	Short Description of the intervention (more details are presented in Appendix A)
1 Risk knowledge	1 Formal and informal education	- Training for practitioners and community people - Educational program (school curriculum) development - Awareness campaign including drills and exercise
	2 National and local level risk assessment	- Develop flood vulnerability criteria for different land use functions (agriculture, infrastructure, fisheries, urban) and different types of flooding. - Prepare flood hazard maps at different levels (national and upazila) and type of flood
2 Monitoring and data acquisition	1 Operation & maintenance of the monitoring network	- Prepare technical Operation & Maintenance (O&M) planning for long term (1 year and 5 year plan and short term per flood season and weekly – daily) - Prepare a realistic O&M budget based on technical planning - Set up and implement a service unit to manage O&M of all measuring stations including workshop for storage and repair of spare parts
	2 Expanding the range of data acquisition	- Extend model boundaries to Ganges Brahmaputra Meghna basin - Include observations based on remote sensing and satellite technique data outside Bangladesh - Validate runoff data with measurements at the border of Bangladesh - Improve coordination and collaboration with bordering countries (investment for data measurement may be required) - Increase temporal resolution to address the different sectors - Forecast for short term for humans, cattle crop and harvest, respectively (1 – 3 – 7 days)
3 Forecasting and warning	1 Model accuracy and upgrade software	- Upgrade the validation procedure for the model output with observed data (cross-section, rating curve) - Use most recent software version as well as a simple model - Set up guideline for model accuracy parameters and reliability, spatial and temporal resolution of the model output
	2 Flood forecast model development	- Include satellite rainfall data with high spatial and temporal resolution - Expand model boundaries up to GBM basin - Include high resolution DEM - Include hydraulic structures (dams, levees, ponds, etc.) in the model as well as any physical change in the river system (erosion, deposition, etc)
4 Dissemination and communication	1 More precise and user friendly warning	- Set up procedure for SMS alert using mobile phone - Link Flood Hazard Map (historical and simulated) with FEWS - Distribute FHMs at community levels - Prepare communication plan for broadcast of flood warnings through community radio and others translated and understandable information per end-user group

Pre-feasibility	Short background on the score based on expert judgment
Medium	Institutionally feasible but funding is deemed difficult
High	Technical knowledge and funding available. Involvement of grass root level and governmental institutes needs attention
Medium-low	Technically feasible and wanted by stakeholders but funding as well as institutional organization is deemed a huge constraint
High	Technically feasible and wanted by all stakeholders. Budget will be no constraint and good cooperation and ownership of implementing agencies is expected
Medium-high	Technically feasible and wanted by all stakeholders. Budget will be no constraint and good cooperation and ownership of implementing agencies is expected
Medium-high	Technically and financially possible but more specific expertise needed. International cooperation will be difficult to achieve for data quality control and validation
High	Technical feasible and much wanted by all stakeholders. Budget will be no constraint and good cooperation and ownership of implementing agencies is expected

Cascade	Priority intervention	Short Description of the intervention (more details are presented in Appendix A)
	2 Capacity building for dissemination	- Capacity building to community people in emergency response (emergency planning) - Promote community based FEWS, similar to Comprehensive Disaster - Management Program (CDMP) and CEGIS previous project - Set up separate unit at FFWC to translate central forecast and flood warnings for different end-user (agriculture, fish, infrastructure) specific information at different scale levels (regional & local)
5 Information type and reliability	1 More precise and location specific information	- Prepare warnings dedicated for stakeholder groups at appropriate scale levels
	2 Update warning information in timely manner	- Make “Standing Order for Disaster” effective - Show different degrees of danger through different stages of warning
6 Response capability	1 Capacity development of community	- Institutionalize community-based DRM group within district disaster managed communities - Include dissemination to medical services (NGOs) in FEWS - Create volunteer rescue group - Support community with basic equipments for early warning dissemination within community - Establish proper comamunication channel within community - Set up and conduct community awareness campaigns and training sessions based on participatory approach for FEWS (include the user requirements and information demands)
	2 Community preparedness	- FFWC should have physical presence (offices) at district authority - Perform cost benefit analysis for measures by stakeholders including flood damage assessment based on flood hazard maps and inform the responsible authority - Prepare user requirements and demands before disaster
7 Cross cutting issues	1 FFWC capacity building	- FFWC Capacity building (equipment, hardware, software, training, personnel) to ensure the performance of all tasks related to (decentralized) FEWS
	2 International cooperation	- Prepare agreement for exchange of extreme event related data on: • Infrastructure operation • Basin digital elevation model • Basin water level • Basin weather forecasts • Basin rainfall • Basin run off model

Pre-feasibility	Short background on the score based on expert judgment
High	Technical feasible and much wanted by all stakeholders. Budget will be no constraint and good cooperation and ownership of implementing agencies is expected
Medium- high	Technical feasible and wanted by all stakeholders. Institutionally feasible and budget is no constraint.
Medium- high	Technically feasible and wanted by all stakeholders. Institutionally feasible and budget is no constraint.
Medium	Technically very feasible and wanted by stakeholders but institutional organization is deemed a huge constraint
Medium	Technically feasible and very much wanted by stakeholders but institutional organization is deemed a huge constraint
Very High	Technically and institutionally very feasible and much wanted by stakeholders. Funding is no constraint
Medium	Although technically feasible it is deemed difficult from political and institutional perspectives. Budget is no problem due to international support.

Cascade	All priority interventions	Pre-feasibility result
7 Cross cutting issues	FFWC capacity building	Very High
1 Risk knowledge	National and local level risk assessment	High
2 Monitoring and data acquisition	Expanding the range of data acquisition	High
3 Forecasting and warning	Model accuracy and upgrade software	High
4 Dissemination and communication	More precise and user friendly warning	High
4 Dissemination and communication	Capacity building for dissemination	High
5 Information type and reliability	More precise and location specific information	Medium-high
5 Information type and reliability	Update warning information timely manner	Medium-high
3 Forecasting and warning	Flood forecast model development	Medium-high
1 Risk knowledge	Formal and informal education	Medium
6 Response capability	Capacity development of community	Medium
6 Response capability	Community preparedness	Medium
7 Cross cutting issues	International cooperation	Medium
2 Monitoring and data acquisition	Operation & maintenance of the monitoring network	Medium-low

Table 3.4 Overview NRM interventions after pre-feasibility

Discussion on pre-feasibility analysis

Based on the outcome of the pre-feasibility analysis a 'top' ranking of first and second priority interventions can be made. In table 2 the most feasible interventions are shaded in light blue color.

- Intervention 'FFWC capacity building'. Especially the support for capacity strengthening (equipment, software, staff and training) is a top priority.
- Intervention 'More precise and user friendly warning'. The overall performance of the FEWS in Bangladesh can be greatly improved when more emphasis is put upon communication and dissemination of the early warning to the end-users.
- Intervention 'Model accuracy and upgrade software'. Increasing the lead time will also prove to create great benefits for the end-users in the flood prone areas.

Besides the top 3 interventions there will also be some challenges in implementation of priority interventions. These challenges will be mainly in the field of institutional development and financing. This indicates that for several interventions the institutions involved will not be in a position in terms of capacity or mandate to implement the interventions. For financing of implementation of the projects not sufficient budget might be available in the present planning or pipeline. Therefore these interventions form good potential for donor agencies to invest in the development of FEWS.

By fine tuning and quantifying the pre-feasibility criteria it will be possible to further optimize the selection of the priority interventions and to prepare a detailed 'no-regret' investment planning for the development and implementation of a FEWS in Bangladesh.

3

Development of National Road Map for FEWS

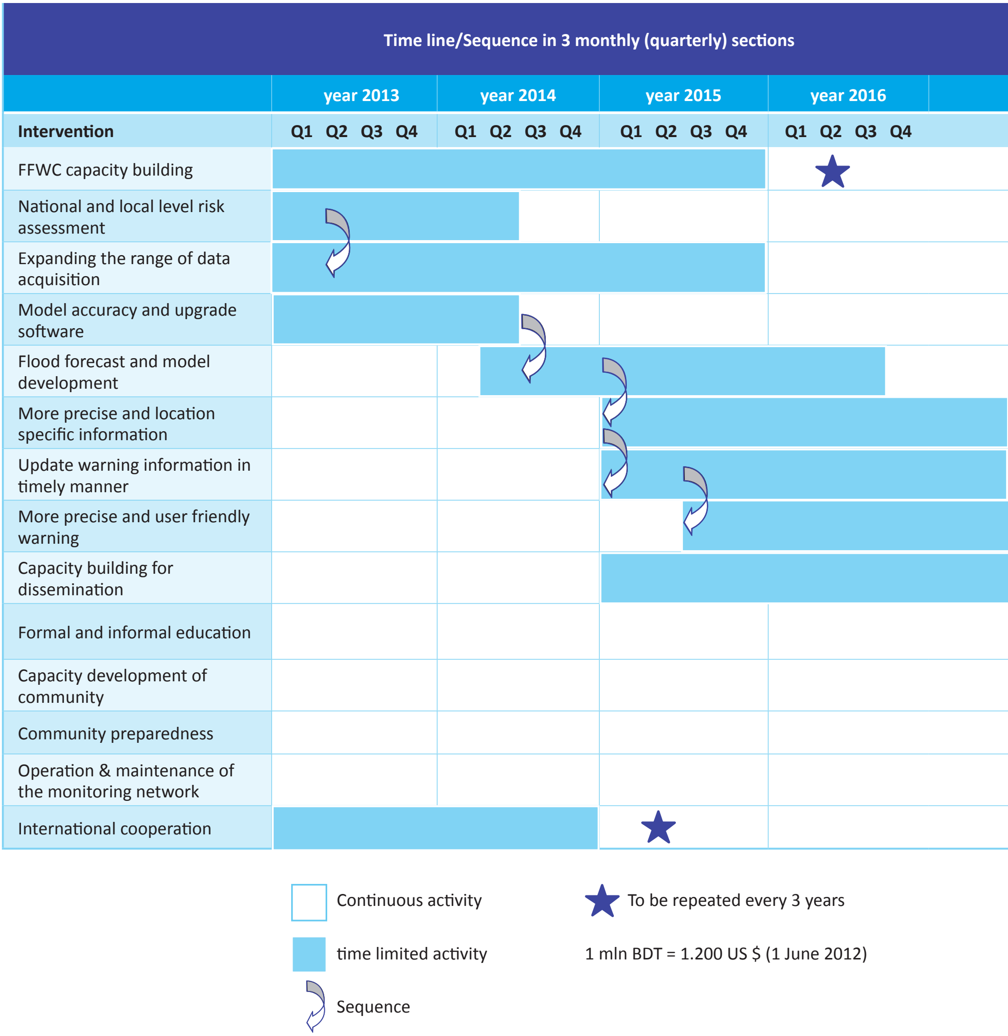


Figure 3.4 Timeline of possible interventions in FEWS development

year 2017	year 2018	year 2019	Duration in years	Approximate Cost in Million BDT	Implementing agency
Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4			
			3	70	BWDB
			1.5	60	WARPO
			3	90	BWDB-BMD
			1.5	90	BWDB
			2.5	55	BWDB
			2	130	BWDB
			2	20	BWDB
			3	55	BWDB-DMB
			3	40	DMB
			3	45	Depart of Education
			3	35	DMB
			3	35	DMB
			yearly	20	BWDB
			2	30	JRC
			Total Cost excluding yearly O&M cost	755	

Way Forward

4

4.1 Linkage to existing initiatives

In order to avoid overlap and duplication of interventions a cross reference analysis with existing and upcoming initiatives and the final interventions from the recommendations of the ADB – TA 4562 study (see section 2.3 '2006 review study'), was performed by the team.

The most important outcome is the fact that the objective 'upgrading the capacity of the FFWC as a whole' (as main intervention) is not addressed as such in any of the parallel projects and activities. This result is not coming as a surprise. Already in the '2006 review study' indicated clear recommendations for capacity building of the FFWC. These recommendations comprised technological and institutional aspects as well as human resources. One of the main issues regarding human resources is to sustain well skilled staff members at FFWC for the operation and maintenance of the FEWS.

Last year (2011) the second phase of the CDMP-2 project started. In the text box hereafter, a short description of the project is presented. One of the components is 'Strengthening Early warning Capacity of FFWC'. The main objective of that component is focussing at, increasing the lead time for flood warning to 5 days. This is just one off the issues regarding capacity building at FFWC.

Since April 2012, ADB TA 8074 project on Regional-Capacity Development Technical Assistance for Applying Remote Sensing Technology in River Basin Management has been implementing in Bangladesh. This project will help the Government of Bangladesh to achieve following three prioritized interventions: (i) flood forecast model development, (ii) more precise and user friendly warning, and (iii) capacity building for dissemination. The Comprehensive Disaster Management Programme (Phase II) or CDMP-2 project aims to further reduce Bangladesh's vulnerability to adverse natural and anthropogenic hazards and extreme events, including the devastating potential impacts of climate change. It will do so through risk management and mainstreaming. CDMP II is a natural expansion and a logical scaling up of its first phase. That pioneering phase laid the foundations for institutionalising the risk reduction approaches and frameworks developed through pilot testing. CDMP II aims to institutionalise the adoption of risk reduction approaches, not just in its host Ministry of Food and Disaster Management, but more broadly across thirteen key ministries and agencies.

CDMP II (2010-2014) is a vertical and horizontal expansion of its Phase I activities designed based on the achievements, lessons learned and the strong foundation laid during CDMP I by continuing the processes initiated, deriving actions from the lessons learned, utilizing knowledge resources generated and knowledge products published. The approach of CDMP II is to channel support through government and development partners, civil society and NGOs into a people-oriented disaster management and risk reduction partnership. That partnership will promote cooperation, provide coordination, rank priority programmes and projects, and allocate resources to disaster management activities, risk reduction activities and climate change adaptation activities in Bangladesh.

An overview of parallel running projects and future projects at FFWC is presented in Appendix C.

4.2 Findings for implementation of the Road Map

The conclusions of the project are as follows:

- The MCA and SWOT – AHP approach is very useful in complex ranking of interventions and investment decisions;
- Intensive contact with the main stakeholders and beneficiaries (BWDB – FFWC) is indispensable for ownership of the project and support for the outcome of the project;
- This project was only possible due to the very well established network in the local flood early warning community of Bangladesh of ;
- The concept for a national Road Map for flood early warning system development in Bangladesh is broadly welcomed by all stakeholders throughout the sector of flood early warning.
- Nearly all recommendations of the 2006 review study are still valid;
- A clear understanding amongst the main stakeholders is present regarding the urgency of capacity building, dissemination and communication and community response capability;
- Due to sub optimal communication and dissemination of the flood warnings at regional and local level the flood warning will be less effective and;
- Use of modern telecom techniques in relation to simple techniques for local dissemination (flag system, rickshaw miking, mosques) has proved very effective (CFIS project).

4.3 Recommendations and way forward

Based on the findings of the TA study the following recommendations can be drawn:

General recommendations

- From the two workshops it became clear that it will not be useful to concentrate on one or two interventions only in order to enhance the performance of the FEWS. Based on the flowchart of Figure 2.3 the project team suggests to perform a 'critical path analysis' in order to determine which action or intervention will have the biggest positive effect on the performance.
- Address the strong demands of the end users needs for improved effectiveness and increasing the lead time of the FEWS.
- Besides these case specific findings and recommendations the used methodology (MCA, SWOT – AHP and stakeholder consultation) proved very effective in selection of interventions and priority ranking. Therefore the project likes to propose steps to formalize the use of the SWOT – AHP approach in decision making process for large investments.

Recommendations related to the National Road Map

- The team prepared a Road Map with clear priority ranking on interventions and actions to be taken (see 'time line' in figure 3.4 and listing in table 3.3).
- Overall capacity building of the FFWC (staff, equipment, training) needs to get first priority.
- Capacity building for communication and dissemination is highly wanted by the stakeholders. Cooperation with CDMP-2 is desired.
- Use of modern telecom techniques in combination with simple techniques for local dissemination (flag system, rickshaw 'miking', mosques) has proved to be a very effective Community Flood Information System (CFIS project).
- Subsequent to better dissemination it will be beneficial to create flood hazard maps and damage assessments. Based on such an assessment the dissemination of flood warnings could be more specific for a certain geographic region or end user group. More detailed flood hazard and damage maps per sector would need to be prepared.

4 Way forward

- The model accuracy and subsequently forecast accuracy needs to be increased by improving the model validation procedure and to increase the range of data acquisition within the GBM-basin.
- More precise and user friendly warnings are needed to address the flood hazard situation at local level.
- In the review study of 2006 a general cost–benefit analysis per intervention was done. It is recommended to update these cost-benefit analyses for the interventions with the highest priority.
- New, more extensive pilots should be included with a combination of different techniques for communication and dissemination. During one of the field visits (Filed visit Manikganj) the combination of different forecasting and dissemination and communication techniques proved to be very promising and was favoured by local stakeholders. The project (Community Flood Information System CFIS, USAID 2008) combined early flood warning per SMS and local warning with ‘flag hoisting’. It is strongly recommended to continue this experiment on a large scale in different areas.

Annexes

A Development of a National Road Map for FEWS

A.1 Participatory approach

One of the main elements in the methodology towards the National Road Map for investment in FEWS is formed through interaction with stakeholders at different levels. During the review analysis two rounds of intensive consultation of stakeholders are anticipated. Based on their input the preliminary a long list of issues and interventions is drawn up. Photo A1 shows consultations with stakeholders, at organization level and with experts. Next the stakeholders will provide the final decision for priority ranking of the selected interventions.

Ownership of the interventions will guarantee a more sustainable development of FEWS. Moreover, due to the active involvement of stakeholders the process will become more demand driven.

A.2 Description of the interventions per cascade

The clustering of issues into interventions has been performed based on the outcome of the first stakeholder consultation on relative importance. The outcome of this classification was intensively discussed with the main stakeholder, the FFWC. In the following the interventions are presented for each cascade cluster. For each intervention the main objectives or impacts, opportunities and threats are shortly described. This approach follows the Design and Monitoring Framework guidelines of the ADB

Cascade 1: Risk knowledge

Knowledge on the extent and occurrence of flood risks forms the basis of disaster management. Three interventions are clustered under this cascade. Besides (physical) hazard maps (risk zoning), knowledge also needs to be included in the institutional process. Here investment in FEWS may be optimized by zooming in on certain steps (for instance communication and dissemination). Finally, knowledge development is about training for practitioners, facilitators and communities . This will comprise national and international training as well as use of indigenous knowledge at village level.

(c) Consultation at individual expert level

Some photographs of consultations with stakeholders, organization level and experts

(a) Consultation of stakeholders at village level

(b) Consultation at organizational level

Annexes

1.1 National and local level risk assessment

The main purpose of this intervention is to make effective investment in disaster risk reduction and FEWS which will provide a clear overview of vulnerable areas and land use functions at policy level for land use planning. The major activities are to develop flood vulnerability criteria for different land use functions (agriculture, infrastructure, fisheries, and communities) and different types of flooding. It also includes preparation of flood hazard maps at different scale levels (national and upazila) per land use sector and type of flood. However, the potential threat could be the miscommunication with local people about hazards, omission of indigenous knowledge on flooding.

1.2 Integrated planning for FEWS

The main purpose of this intervention is to increase the effectiveness of FEWS for development of a self learning system for continued improvement of FEWS. The major activities are to make an inventory of the whole FEWS process (technical and institutional); perform critical path analysis and optimization analysis for the whole FEWS cycle including service provision, effectiveness (cost-benefits), and equity (stakeholders) of the FEWS; and prepare an evaluation and monitoring system to measure the outcome of FEWS. The main integrated approach of this intervention are the different mandates of involved institutions, duplication and complexities of duties and responsibility, quality control and exchange of monitoring information, and management of FEWS on the basis of performance indicators without connection to the field situation.

1.3 Formal and informal education

The main purpose of the intervention is to improve the awareness and preparedness against flooding through reduction of number of casualties due to flooding. The major activities are to offer training for practitioners and community people; introduce educational program (school curriculum) development; and develop awareness campaigns including drills and exercises. There is chance of loss of indigenous knowledge and it will be difficult to reach the same level of education due to the different types of target groups and the varying degrees of their willingness to participate in the program.

Cascade 2: Monitoring and data acquisition

Data and data acquisition forms the basic 'fuel' for the forecasting and warning phase. Under this cascade most technical issues regarding field data sampling and data processing are combined. Also the options for expanding the monitoring network in number of observation points as well as geographic coverage are addressed here. Moreover, data quality and access to data will prove an important asset for a well-working FEWS.

2.1 Development of base information

The main purpose of this intervention is to help in disaster risk reduction and FEWS with a clear overview of vulnerable areas and land use functions at policy level for land use planning and flood risk modelling. The major activities include preparing a Digital Elevation Model (DEM) with sufficient detail (vertical and horizontal scales) to perform flood modelling at local (upazila) level (currently this work is undertaken by the Survey of Bangladesh); develop historical flood map for different types of flood at upazila scale (see also national and local risk assessment); and prepare land use and sector maps (agriculture, infrastructure, fisheries, communities) with sufficient detail.

2.2 Manual data collection

The purpose of this intervention is to improve the accuracy and reliability of the hydrologic data at the BWDB through enhancing the operation and maintenance of the existing data collection system of BWDB. The major activities are to increase the frequency of observation; prepare a National Road Map for optimal usage (frequency of field reading, quality of data collection); prepare operation & maintenance planning and budget; prepare an implementation plan to increase the network spatial density (manual stations) so that local flood forecasting (upazila level) is feasible.
The present capacity of the BWDB and FFWC is limited including in terms of assurance of data quality, access of water level recorders/gauges during extreme weather or at night.

2.3 Automatic data collection

The main objective of the intervention is to improve the accuracy and reliability of the

hydrologic data at the BWDB for timely input of data for forecasting to increase the lead time for flood warnings. The major activities are to prepare operation & maintenance planning and budget (see also operation & maintenance); preparation of a National Road Map for optimal usage (frequency of field reading, quality of data collection); and preparing an implementation plan to increase the network spatial density (manual stations) so that local flood forecast (upazila level) are feasible. Installed devices of the BWDB need to be ensured in the future, adequate and well trained staff is needed for proper operation and interpretation of the data and implementation. Installation of new items will depend on the private supplier of the devices. The data output needs to be compatible with the present and future modelling software for FEWS.

2.4 Improve data quality and accessibility (completeness and reliability)

The purpose of the intervention is to increase reliability of the flood forecasts and warnings through preparedness (acceptance) of the end users in case of flood warning. The major activities are prepare National Road Map for data processing and storage for manual and automated recording stations; set standards for data accuracy and reliability; prepare standard for temporal resolution related to user requirement (lead time); develop incentive system for manual gauge readers in sub-optimal locations, weather conditions and night hours; and prepare standard for spatial resolution related to user requirement (local level information per sector). The main risk is to spend much attention on set up of legal and internal procedures, no balance between investment and final results (reduction of casualties and damage), the warning process in case of emergency might become complex (or slow down) which will decrease net lead time.

2.5 Operation & Maintenance of the monitoring network

The purpose of this intervention is to reduce the casualties and damage due to flooding by improvement of operational activities of FEWS. The main activities are prepare technical Operation & Maintenance (O&M) planning long term (1 year and 5 year plan and short term per flood season and weekly – daily); prepare a realistic O&M budget based on technical planning; and set up and implement a service unit to manage O&M of all measuring stations (manual and automated) including workshop for storage and repair of spare parts.

2.6 Expanding the range of data acquisition

The purpose of this intervention is to reduce the casualties and damage by increased lead time for flood warning. The main activities are to extend of model boundaries to Ganges Brahmaputra Meghna (GBM) basins; include observations based on remote sensing and satellite technique data outside Bangladesh; validate of runoff data with measurements at the border of Bangladesh; and improve coordination and collaboration with bordering countries (investment for data measurement may be required). There is lack of cooperation from bordering countries due to concerning in data measurement, over-estimation and under-estimation of floods due to wrong model, lack of data standards for smooth information management.

2.7 Regular monitoring of flood events by satellite data

The main objective of this intervention is to improve the overall effectiveness of the FEWS through more accurate FEWS at regional and local level. The main activities are to prepare monitoring and validation procedure for the basin wide flood model; include weather data on basin wide level like cloud cover information, wind speed, rainfall etc; and monitor the characteristics of flooding over the years. Monitoring with satellite data is relatively expensive (data and data processing), due to cloudy situation some events might be missed, forecast and warning becomes dependent on specialized input from third parties.

Cascade 3: Forecasting and warning

The interventions under this cascade form the traditional heart of an early warning system. The capacity to transfer data and information on runoff into water levels and warnings is a crucial step. The outcome needs to be of sufficient spatial detail (horizontal and vertical) and also of sufficient temporal resolution (lead time) so that end users of the warning can take their pre-cautions.

3.1 Model accuracy and upgrade software

The main objective of this intervention is to improve the overall effectiveness and reliability of the FEWS through more accurate FEWS at the regional and local level. The main activities are to upgrade the validation procedure for the model output with observed data (cross-section, rating curve), using the most recent software version as well as simple model and setup of National Road Map for model accuracy parameters, reliability and spatial and temporal resolution of the model output. Besides the model accuracy also the input data needs to be of good quality. Another threat to this intervention is that staff capacity at FFWC is limited.

3.2 Flood forecasting model development

The main objective of this intervention is to meet end user demands for flood risk preparedness by increased lead time for FEWS. The main activities are to include satellite rainfall data with high spatial and temporal resolution, expand model boundaries up to GBM basin, include high resolution DEM and include hydraulic structures (dam, levee, pond, etc) in the model as well as any physical changes in river system (erosion, deposition, etc). But these models are complex and handling becomes difficult. Missing data from transboundary regions may halt the model operations and there exist no real connection between the regional satellite data and the local circumstances on the ground (for instance how to deal with flash floods and very short warning time).

3.3 Expansion of forecasting capacity to increase lead time and number of forecasting institutions (regional BWDB offices)

The main objective of this intervention is to reduce the number of casualties and damage due to flooding with increased lead time for FEWS increase the warning time to provide additional time for emergency preparation with increased lead time. The main activities are to expand the number of gauge stations in neighbouring countries and alternatively use satellite based rainfall estimation, to downscale global climate model for seasonal forecast, expand the number of forecast locations and number of forecast institutions (regional BWDB office), increase the spatial resolution to address local user at upazila level, increase the temporal resolution to address the different sectors and to forecast

future condition for short term for human, cattle crop and harvest, respectively (1–3–7 days). The threats to these interventions are such that only a few areas in BGD are covered for forecast, not all. Also, even the 1-7 days short-term forecast is just for emergency purpose. Satellite based rainfall data need calibration and correction. It is also a matter of concern that forecasting might make the end users become more dependent on warnings and eventually indigenous knowledge on flooding is lost.

Cascade 4: Dissemination and communication

A FEWS is not effective if the produced warnings do not reach the end-users in time or in a format they do not understand. In the Bangladesh situation this step proves to be of crucial importance for the operation of the total FEWS. The warning needs to be translated into an understandable message for the end-user. This includes the necessity for the FFWC to be sufficiently decentralized to prepare meaningful warnings adapted to the different local situations. Recently pilot projects have been executed by United States Aid (USAID) and Centre for Environmental and Geographic Information Services (CEGIS) to develop community based information systems using SMS alert and simple 'flag hosting' systems in the flood affected areas.

4.1 Extending the range of dissemination

The main objective of this intervention is to promote understandable FEWS for all stakeholders and end-users by developing end-user specific FEWS. The main activities are to downscale and forecast for upazila and unions by local authority, prepare agreements on interaction for communication using the existing network of public and private organizations and prepare communication and dissemination plan which addresses different scale levels e.g. district, upazila and union level. But there is no systematic hierarchical info dissemination system and also, lack of coordination among departments as only top-down approach exist, No two-way communication.

4.2 More precise and user friendly warning

The main objective of this intervention is to provide understandable and response oriented FEWS for all stakeholders and end-users. The main activities are to set up procedure for SMS alert using mobile phone (patch communication), research for the improvement of FEWS, linking Flood Hazard Map (FHM) (historical and simulated) with FEWS, distribution of FHMs at community levels, to prepare communication plan for broadcast of flood warnings through community radio and others translated and understandable information per end-user group. The main threats to this intervention are that too much data input is needed which also causes confusion at village level, lack of awareness and capacity of end-users to deal with the detailed FEWS and warnings that are given are not accurate and/or reliable.

4.3 Capacity building for dissemination

The main objective of this intervention is to increase awareness and preparedness for flooding by trained stakeholders and target group. The main activities are capacity building to community people in emergency response (emergency planning), promote community based FEWS similar to Comprehensive Disaster Management Program (CDMP) and CEGIS previous projects and setting up separate unit at FFWC to translate central forecast and flood warnings for different end-user (agriculture, fish, infrastructure) by specifying information at different regional and local levels. Threats to properly pertain this intervention include the great number of flood prone area within the country. Furthermore, the mandate of FFWC is not crystal clear. Different mandates for dissemination of different organizations of different ministries and lack of linkage between BWDB and local community also pose some problems.

Cascade 5: Information type and reliability

A variety of end-users needs to be served with flood warnings based on the same data sources. All end users need to be confident in the accuracy of the warning. Based on its wider mandate in prevention and relief of disasters the Disaster Management Bureau (DMB) may play an active role in dissemination of early warning information as trustworthy organization at local level.

5.1 More precise and location specific information

The main objective of this intervention is to increase accuracy and reliability of local FEWS. The main activity is to prepare warnings dedicated for stakeholder groups at appropriate scale levels. But much data is needed for this to take place and not all end-users need the same level of information. Another problem is warnings are not reliable or not disseminated through trustworthy communication channel.

5.2 Update warning information timely manner different stages

The main objective is to improve cooperation between institutes in the FEWS cycle by decreasing number of casualties and damage. The main activities include effective implementation of "Standing Order for Disasters" (SOD) and different stages of warning at different degrees of danger. But SOD may not be effective as there is no provision for control. Also, it is important to convert the forecasts produced by FFWC to warning which beyond the scope of FFWC mandate.

Cascade 6: Response capability

Response capacity and the level of preparedness in the villages is the final step in the FEWS. However the level of response capacity is not just a technical matter. Awareness raising and evacuation drills will improve the preparedness considerably. Moreover it need to be clear for the end-users at grass root level which alternative adaptation measures they have to protect themselves against the effects of flooding. Due to the variety of natural hazards in Bangladesh there are many organizations in Bangladesh

which are working in different part of Disaster Risk Management (DRM) cycle. Attention for cooperation will increase the effectiveness of the FEWS.

6.1 Capacity development of community

The main objective of this intervention is optimal community preparedness for flooding through a flood disaster management plan. The main activities include institutionalization of community based DRM group within district disaster managed communities; include dissemination to medical services (NGOs) in FEWS, create volunteer rescue group, support community with basic equipments for early warning dissemination with in community, establish proper communication channel with in community and setting up and conducting community awareness campaigns and training sessions based on participatory approach for FEWS (include the user requirements and information demands). But capacity building is a continuous effort which needs to be actively transformed to the next generation. Also, FFWC has no mandate to execute such community development work and cooperation with DMB needs attention.

6.2 Community preparedness

The main objective is to minimal number of casualties and damage through community preparedness for flooding. The main activities include performing of cost benefit analysis for measures by stakeholders including flood damage assessment based on flood hazard maps and reporting to the responsible authority.

Activity also includes preparation of user requirements and demands before disaster. There are many organizations in BGD which are working in different part of DRM cycle but separately (Government as well as NGO's) which is not very productive. Lack of mandate at FFWC and cooperation with DMB also may pose threat to proper implementation of this intervention. FFWC should have physical presence (fixed office) at district authority.

Cascade 7: Cross cutting issues

Several of the interventions as mentioned by the stakeholders could not be clustered under the cascades. They are however equally important for the further upgrade of the FEWS in Bangladesh. One of the most obvious interventions will be the overall upgrade of the capacity at the FFWC. Next the institutional status of the FFWC in relation to the DMB needs to be clear. Does the work and responsibility of FFWC stop after issuing the warning? Or do they also have a task in dissemination? And finally the international cooperation in exchange of data on precipitation, run off and water levels will greatly enhance the possibilities for increase the lead time of the warnings.

7.1 FFWC capacity building

The main objective of this intervention is sustainable and well coordinated FEWS. The main activity is Capacity building (equipment, hardware, software, training, personnel) of FFWC to ensure the performance of all tasks related to (decentralization) FEWS. But the institutional setting at BWDB is not suitable for an effectively operational FFWC and huge investment is needed for this though there is lack of human resources/capacity. Incentives might be provided to keep well trained FFWC staff onboard.

7.2 Strengthening of organizational status

The main objective is organization of well established FFWC responsible for effective FEWS with clear mandate, roles and responsibility for the FFWC. The main activities include preparation of explicit mandate and responsibilities of BWDB and FFWC, monitoring and evaluation of FEWS performance and coordination of work among BWDB, Bangladesh Meteorology Department (BMD), DMB and others. National campaign on Disaster Risk Reduction is required to activate responsible agency and to promote cooperation among them. The main threats are internal and external 'overlapping' organizations which may block the more clear mandate of the FFWC for their own benefit and existence and conflict of interest between involved organizations.

7.3 International cooperation

The main objective of this intervention is to optimize FEWS more effectively and basin wide with increased lead time and high accuracy. The main activity include- preparation of agreement for exchange of extreme event related data on infrastructure operation, basin digital elevation model, basin water level, basin weather forecasts, basin rainfall and basin run off model. Unreliable and untimely data, dependency on international cooperation, lack of (international) data standards and missing data might hold back the forecast model.

B ADB Design and Monitoring Framework for the most feasible interventions

Design and Monitoring Framework (DMF) for the most feasible interventions of the National Road Map for Floods Early Warning System Development in Bangladesh. The following (most feasible) interventions are worked out in the format of the ADB DMF.

Cascade	Interventions
7. Cross cutting issues	FFWC capacity building
1. Risk knowledge	National and local level risk assessment
2. Monitoring and data acquisition	Expanding the range of data acquisition
3. Forecasting and warning	Model accuracy and upgrade software
4. Dissemination and communication	More precise and user friendly warning
4. Dissemination and communication	Capacity building for dissemination

Cascade 7. Cross cutting issues	FFWC capacity building

Design Summary	Performance targets/ indicators	Data sources/Reporting Mechanism	Assumptions and risks
Impact: Sustainable and well coordinated FEWS	Decrease number of flood casualties and damage	Annual investigation by the Bangladesh National Bureau of Statistics	**Assumption:** The BBS will include number of flood casualties and flood damage in their surveys
Outcome: Well established FFWC responsible for effective FEWS	Timely and correct flood warnings Warnings dedicated to regional and local end users	Number of warnings issued at the FFWC website Number of satisfied end users at regional and local level	**Risk:** The BWDB institutional setting is supporting FFWC effectively **Assumption:** FFWC will get sufficient support from BWDB to perform the tasks
Outputs: FFWC Capacity building (equipment, hardware, software, training, personnel) to ensure the performance of all tasks related to (decentralized) FEWS	Number of well trained permanent staff Number of equipment (PC hardware, model software, communication, vehicles)	Annual FFWC report and BWDB 5 year plan Annual FFWC report and BWDB 5 year plan	**Risk:** no funding will be made available **Risk:** well trained staff cannot be offered incentive to stay with FFWC

Activities and milestone:

- Purchase of computer hardware and software
- Purchase of vehicles
- Purchase and installation of Water level devices
- Training for FFWC staff
- Recruitment of FFWC staff

Inputs:
70 Mln BDT

Cascade 1. Risk knowledge	National and local level risk assessment

Design Summary	Performance targets/ indicators	Data sources/Reporting Mechanism	Assumptions and risks
Impact: More effective investment in Disaster Risk Reduction and FEWS	Decrease in number of flood victims and flood damage	Annual survey of the Bangladesh Bureau of Statistics	**Assumption:** The number of flood victims and damage is included in the BBS surveys **Assumption:** Flood hazard maps are included in the SOD
Outcome: Clear overview of vulnerable areas and land use functions at policy level for land use planning	Availability of recent Flood hazard maps at sufficient detailed scale level	BWDB and FFWC annual reports. Websites of the ministry of Water resources and Disaster Management Bureau	**Risk:** Spatial planning is complex and involves many stakeholders and ministries
Outputs: 1 Vulnerability criterion for landuse functions 2 Flood Hazard Map	Standard for selection of criterion for vulnerability Defining hazard, Tools and techniques used for mapping	Spatial and non-spatial data layers from national database in Bangladesh. Customized international standard, tools and techniques	**Assumption:** Different scale of data are harmonized and available **Risk:** Hazard map will be based secondary data
Activities and milestone: • Collection and collation base information for risk assessment • Identify the land use functions for different type of flood • Development of vulnerability criterion for different land use functions • Preparation of hazard map for district and upazila level			**Inputs:** 70 Mln BDT

Cascade 2. Monitoring and data acquisition	Expanding the range of data acquisition

Design Summary	Performance targets/ indicators	Data sources/Reporting Mechanism	Assumptions and risks
Impact: Reduction of number of casualties and damage	Number of flood casualties and damage	Annual survey of the Bangladesh Bureau of Statistics	**Assumption:** The number of flood victims and damage is included in the BBS surveys
Outcome: Expand the flood warning to all flood prone areas	Number days/hours of early warning for the end users	FFWC annual flood report	**Assumption:** international cooperation is constructive **Risk:** over-estimation and under-estimation of floods due to wrong model
Outputs: Increased lead time for flood warning	Number of flood prone areas covered with effective FEWS	Overview Map prepared by IWM and/ or CEGIS	**Risk:** data quality is not sufficient
Activities and milestone: • Extend of model boundaries to Ganges Brahmaputra Meghna (GBM) basin • Include observations based on remote sensing and satellite technique data outside Bangladesh • Validation of runoff data with measurements at the border of Bangladesh • Improving coordination and collaboration with bordering countries (investment for data measurement may be required)			**Inputs:** 60 Mln BDT

Cascade 3. Forecasting and warning	Model accuracy and upgrade software

Design Summary	Performance targets/ indicators	Data sources/Reporting Mechanism	Assumptions and risks
Impact: Improve the overall effectiveness and reliability of the FEWS	Reduced number of flood casualties and flood damage	Annual survey of the Bangladesh Bureau of Statistics	**Assumption:** The BBS will include number of flood casualties and flood damage in their surveys
Outcome: More accurate FEWS at regional and local level	Number of Timely warned end users Number of correct flood warnings at regional and local level Number of satisfied end users	FFWC annual flood report NGO's cross reference Annual Agriculture census	**Assumption:** FFWC will receive sufficient support to purchase the software and train the staff **Risk:** The trained staff will leave FFWC
Outputs: Standardized and Operational Flood Early warning System with high accuracy	Number of correct Flood warnings at regional and local level Warning lead time at end user level	FFWC annual flood report NGO's cross reference	**Assumption:** FFWC and NGO's will work together to create a realistic overview of the effect of the FEWS at field level

Activities and milestone:
- Upgrade the validation procedure for the model output with observed data (cross-section, rating curve)
- Purchase of new modelling software
- Training of FFWC on new software
- Use most recent software version as well as simple model
- Setup National Road Map for model accuracy parameters and reliability, spatial and temporal resolution of the model output

Inputs:
90 Mln BDT

Cascade 4. Dissemination and communication	More precise and user friendly warning

Design Summary	Performance targets/ indicators	Data sources/Reporting Mechanism	Assumptions and risks
Impact: Understandable, response oriented FEWS for all stakeholders and end-users	Number of satisfied end users of the FEWS at different levels	Annual report FFWC Inventory of user demands by NGO's at local level	**Assumption:** FFWC has sufficient capacity to prepare warnings dedicated to local demands
Outcome: Localized FEWS	Scale level of the monitoring system and warnings issues	Inventory by BWDB and FFWC Annual flood report FFWC	**Risk:** detailed local data is not available
Outputs: Community based early warning system	Percentage of communities in flood prone areas with well established FEWS	Census data BBS Annual flood report FFWC Inventory NGO's at local level	**Risk:** the lead time will decrease due to lack of data and more complex processing

Activities and milestone:

- Set up procedure for SMS alert using mobile phone (patch communication)
- Research to became out for the improvement
- Link Flood Hazard Map (FHM) (historical and simulated) with FEWS
- Distribute FHMs at community levels
- Prepare communication plan for broadcast of flood warnings through community radio and others translated and understandable information per end-user group

Inputs:
130 Mln BDT

Cascade 4. Dissemination and communication	Capacity building for dissemination

Design Summary	Performance targets/ indicators	Data sources/Reporting Mechanism	Assumptions and risks
Impact: Increased awareness and preparedness for flooding	Number of flood casualties and damage	BBS census	**Risk:** Due to overlapping mandates between DMB and BWDB no effective campaign is implemented
Outcome: Well prepared target group	Number of Trained stakeholders and target group	Inventory by BWDB and FFWC	**Assumption:** The demands of the target group are well defined and known at FFWC
Outputs: User oriented EWS operational in flood affected communitiesap	Number of operational systems at community level Number of satisfied end users	Census BBS Annual FFWC report Inventory NGO's at village level	**Risk:** there are too many flood prone communities (priority ranking needed)

Activities and milestone:

- Capacity building to community people in emergency response (emergency planning)
- Promote community based FEWS, similar to Comprehensive Disaster Management Program (CDMP) and CEGIS previous project
- Set up separate unit at FFWC to translate central forecast and flood warnings for different end-user (agriculture, fish, infrastructure) specific information at different scale levels (regional & local)

Inputs:
40 Mln BDT

C Cross reference with existing projects

Ongoing projects for development of Early Warning System in Bangladesh under FFWC:

1 **Title:** Strengthening Early warning Capacity of FFWC (through CDMP-phase 2)
Duration: 4 Years (2011-2014)
Donor: UNDP through Ministry of Food and Disaster Management
Cost: USD 500,000
Main Objective:
- Extending lead time of deterministic flood forecast upto 5 days from present 3 days
- Structure Based Forecast for few Bangladesh Water Development Board's Projects (MDIP, PIDIRP) and Dhaka Mawa Highway
- Development & Improvement of LAN, existing website. Continuous display

2 **Title:** (Study Project) Bangladesh River information & System Conservation (BRIC)
Duration: 9 months
Donor: World Bank
Cost:
Main Objective:
- Prepare & Recommendation for development of Hydrological Network System in Bangladesh
- Modernization of data collection, data transmission and processing

3 **Title:** Regional-Capacity Development Technical Assistance for Applying Remote Sensing Technology in River Basin Management (TA8074-REG)
Duration: 2 Years (April 2012-March 2014)
Target Areas: Bangladesh, especially Jamalpur District
Target Agencies: Bangladesh Water Development Board, Disaster Management Bureau
Donor: Asian Development Bank
Cost: USD $2milion (including Philippines and Viet Nam components)
Main Objective:
- Development of flood forecasting and flood warning dissemination by applying remote sensing technology and information-communication technology. Specific activities in Bangladesh are: (i) application of remote sensing for flood prediction in collaboration with CDMP II, (ii) development of remote sensing application

methodology and capacity for local flood prediction and warning, (iii) development of web-based GIS, and (iv) location based flood warning dissemination system using SMS.

Proposed projects to be implemented for development of Early warning System in Bangladesh under FFWC

1 **Title:** Introduction of Flood Forecasting & Warning Service due to Tidal Fluctuations in the Coastal Zone of Bangladesh

Duration: 3 years

Donor:

Cost:

Main Objective:

- Develop flood forecasting and early warning models for Tidal fluctuations (including wave)
- Flood inundation forecast for the coastal community and agency related to flood management
- Identify flood vulnerabilities due to high tide and storm surge
- Develop community level flood preparedness of the coastal zone of Bangladesh
- Improved disaster preparedness, reduce flood vulnerability & Hood damages to lives and properties of the coastal zone of Bangladesh
- Strengthening of institutional capacity for tidal Hood forecasting

2 **Title:** Extension of Flood Forecasting and Warning Services in 7 Districts of South West Hydrological Region of Bangladesh

Duration: 3 years

Donor:

Cost: 6 Crore BDT

Main Objective:

- Extension of FFWS point in 7 Districts (Rajbari, Faridpur, Kushtia, Narail, Shariatpur, Madaripur, Gopalganj) of south west hydrological region of Bangladesh

3 **Title:** Development of Flash Flood System for the North East Region of Bangladesh
Duration: 3 years
Donor:
Cost:
Main Objective:
- Introduction of Flash Flood System for the North East Region of Bangladesh

4 **Title**: Extension & Propagation of 10 day (medium range) probabilistic forecasting
Duration: 3 years
Donor:
Cost:
Main Objective:
- Extension of 10 day probabilistic forecast from 18 stations upto 40 stations to cover more areas
- Improvement and development of probabilistic forecast for existing 18 stations

5 **Title:** Introduction of Dry season Long Range flow availability in the major river system of Bangladesh
Duration: 4 years
Donor:
Cost
Main Objective:
Long Range water availability forecast in the major river system of Bangladesh in dry season

Annex J

Information and Photographs of Workshops

- **1st Stakeholder Consultation Workshop in December 2010**
- **2nd Stakeholder Consultation Workshop in March 2011**
- **A Meeting on National Road Map Presentation in January 2012**

1st Stakeholder Consultation Workshop in December 2010:

ICHARM held the First Multi-stakeholder Consultation Workshop jointly with the Bangladesh Water Development Board (BWDB) on 12 December 2010 in Dhaka. The main objective of the workshop was to review long listed issues on early warning system development in Bangladesh. The workshop was attended by about 30 participants from different institutions related to flood early warning in Bangladesh. It started with the opening remark by chief hydrologist Mr. A. H. M. Kausher of BWDB, followed by the key notes from invited guests including Mr. Kimio Takeya, a senior consultant from ADB. The workshop successfully screened and categorized the listed issues as very important, important or less-important. These issues were used for a dependency test and converted into interventions to develop a national road map for an early warning system development in Bangladesh.

The program agenda of workshop is shown below.

Programme		
09:30 - 10:00 am	:	Registration
10:00 - 10:05 am	:	Tilwat from The Holy Qur'an
10:05 - 10:15 am	:	Welcome address by **Mr. A.H.M. Kausher** Chief Engineer Hydrology, BWDB-FFWC
10:15 - 10:25 am		Background of the project by **Mr K.Takeya,** Senior Water Related Disaster Management Specialist, ADB
10:25 - 10:35 am		Involvement of ICHARM and explanation of the day order by **Dr. R. Osti**
10:35 – 10:50 am		Progress of the project and presentation of results of the review and the long list of issues. **Mr. D. van den Bergh,** Deputy Chief Flood Risk Management Specialist (Deltares)
10:50 – 11:00 am		Outline of applied methods on MCA, AHP-SWOT by **Dr. Miyamoto**
11:00 – 11:05 am		Instruction for brainstorm session in sub groups on completeness of the long list for issues by **Mr. D. van den Bergh**
11:05 - 11:15 am		Individual evaluation of long list of issues
11:15-11:30 am		Tea Break
11:30-01:00		Group discussion and preparation for plenary presentation
01:00 – 01:45 pm		Lunch break
01:45 – 02:45 pm		Plenary presentation on the outcome of the workshop sessions by the group representatives and discussion chaired by **Mr. S. Bhuiyan** Superintending Engineer, Processing and Flood Forecasting Circle
02:45 - 03:00 pm		Closing address by **Mr. S. Bhuiyan** Superintending Engineer, Processing and Flood Forecasting Circle

The participants were invited from following organizations.

1. Bangladesh Water Development Board (BWDB)
2. Flood Forecasting and Warning Centre (FFWC), BWDB
3. Water Resources Planning Organization (WARPO)
4. Bangladesh Metrological Department (BMD)
5. Comprehensive Disaster management Programme (CDMP)
6. Disaster Management Bureau (DMB)
7. Institute of Water modeling (IWM)
8. International Center for Water Hazard and Risk Management (ICHARM)
9. Center for Environmental and Geographic Information Services (CEGIS)
10. Asian Development Bank (ADB)
11. Deltares, Netherlands

Photographs of workshop:

Photograph of workshop and group photo

Participants of workshop and group discussion

2nd Stakeholder Consultation Workshop in March 2011:

2nd Stakeholder Consultation Workshop was held on 16th March 2011 in Dhaka, which was jointly organized by FFWC/BWDB, ICHARM, CEGIS and Deltares. The main objective of the workshop was to present and discuss on results of MCA and SWOT-AHP analysis and prioritization of interventions for early warning system development in Bangladesh. The workshop was attended by about 28 participants from different institutions related to flood early warning in Bangladesh. It started with the opening remark by chief planning Mr. Wadud Bhuyian of BWDB, followed by the key note on overall project objectives. It was discussed on the analyses results of MCA and SWOT-AHP of possible interventions of FEWS development. A second priority ranking was carried out on the list of clustered interventions during this stakeholder consultation workshop. The participants from related organizations were divided into three groups over the cascade classes. They performed a MCA and a SWOT-AHP analysis in order to come to a priority ranking of interventions. The analysis was based on a newly developed set of questionnaires

The program agenda of workshop is shown below.

Programme

09:30 - 10:00 am	:	Registration
10:00 - 10:05 am	:	Tilwat from The Holy Qur'an
10:05 - 10:15 am	:	Welcome address by **Mr. Wadud Bhuyian** Chief Planning BWDB
10:15 - 10:25 am		Key note on Overall Project Objectives
10:25 – 10:30 am		Project progress and future developments (Mr. R. Osti, ICHARM)
10:30 – 11:00 am		Progress of the project and presentation of results of the SWOT and AHP analysis and the short list of interventions. **Mr. D. van den Bergh,** Deputy Chief Flood Risk Management Specialist (Deltares).
00:00 - 00:30 pm		Discussion in sub groups and plenary session, presentation of the sub-groups and reflection on the results by **Mr. S. Bhuiyan** Superintending Engineer, Processing and Flood Forecasting Circle
00:30 – 01:15 pm		Lunch break
02:30 - 03:00 pm		Plenary presentation on the outcome of the workshop sessions by the group representatives and discussion chaired by **Mr. M.F. Khan** National Flood Risk Management Specialist (CEGIS)
03:00 - 03:15 pm	:	Closing address by **Mr. S. Bhuiyan** Superintending Engineer, Processing and Flood Forecasting Circle
07:00 - 09:00 pm	:	Informal Workshop dinner (in Gulshan)

List of Participants

S.N.	Name	Designation	Organization
1.	Md A Wadud Bhuyian	Chief Planning	BWDB
2.	Md Sarafat Hossain Khan	Executive Engineer, Planning	BWDB
3.	Robin Biswash	Sub-divisional Engineer	BWDB
4.	A H M Kausher	Chief Engineer, Hydrology	BWDB
5.	Belayet Hossain	Superintending Engineer, Hydrology	BWDB
6.	Shohel Masud	Executive Engineer	BWDB
7.	Amirul Hossain	Executive Engineer	FFWC
8.	Md.Salim Bhuiyan	Superintending Engineer	FFWC
9.		Sub-divisional Engineer	FFWC
10.		Assistant Engineer	FFWC
11.	Khandoker Abu Taher	Director General	WARPO
12.	Md Siddiqur Rahman	PSO	WARPO
13.	Shah Alam	Deputy Director	BMD
14.			DMB
15.		Consultant	CDMP
16.	S M Shah-Newaz	Director, Flood Management	IWM
17.	Abu Saleh Khan	Deputy Executive Director(P&D)	IWM
18.	Dick van den Bergh	Senior Policy Advisor	Deltares
19.	Rabindra Osti	Senior Researcher	ICHARM
20.	Giasuddin Ahmed Choudhury	Executive Director	CEGIS
21.	Malik Fida A Khan	Director, Climate Change Study Division	CEGIS
22.	Ahmadul Hassan	Director, R & D and Training Division	CEGIS
23.	Awlad Hossain	Director, GIS Division	CEGIS
24.	Sultan Ahmed	Director, Business Development, Administration and HRD	CEGIS
25.	Nandan Mukherjee	Senior Professional	CEGIS
26.	Raqibul Hassan	Junior Professional	CEGIS
27.	Zahir Uddin Ahmed	Head, Water Resources Management, Bangladesh Resident Mission	ADB

List of participated organizations:

1. Bangladesh Water Development Board (BWDB)
2. Flood Forecasting and Warning Centre (FFWC), BWDB
3. Water Resources Planning Organization (WARPO)
4. Bangladesh Metrological Department (BMD)
5. Comprehensive Disaster management Programme (CDMP)
6. Disaster Management Bureau (DMB)
7. Institute of Water modeling (IWM)

8. International Center for Water Hazard and Risk Management (ICHARM)
9. Center for Environmental and Geographic Information Services (CEGIS)
10. Asian Development Bank (ADB)
11. Deltares, Netherlands

Photographs of workshop:


Participants of workshop and presentation


Group discussion

A Meeting on National Road Map Presentation in January 2012:

A meeting on the national road map concerning interventions for improvement of the flood early warning system (FEWS) in Bangladesh was held on 23 January 2012 at the Bangladesh Water Development Board (BWDB), Dhaka, Bangladesh. The meeting was jointly organized by BWDB, ICHARM and ADB. Deltares, Netherlands and CEGIS, Bangladesh also supported to organize this meeting. About 46 participants from related organizations joined this meeting. The purpose of the meeting was to present the draft National Road Map (NRM) to improve the current flood early warning system in Bangladesh for stakeholders and donor agencies and to discuss the plan for official legalization. Such NRMs are expected to be useful to guide the preparation of long-term national plans and can be used by government and donor agencies for investments in FEWS development projects. By considering comments and suggestions received in the meeting, ICHARM revised the NRM and prepare final version of NRM. The Flood Forecasting and Warning Centre (FFWC) of BWDB is the main beneficiary of this NRM.

The program agenda of workshop is shown below.

Programme Schedule		
09:00 - 09:30 am	:	Registration
09:30 - 09:40 am	:	Speech by **Mr. Giasuddin Ahmed Choudhury**, Executive Director, CEGIS
09:40 - 09:50 am	:	Speech by **Mr. Hisashi Mitsuhashi,** Asian Development Bank
09:50 - 10:00 am	:	Speech by **Mr. Md. Azizul Haque**, Director General, BWDB
10:00 - 10:30 am		Project outline and presentation on National Road Map for Flood Early Warning System (FEWS) Development in Bangladesh by **Mr. Toshio Okazumi,** ICHARM **and Mr. Dick van den Bergh,** Deltares
10:30 - 11:20 am	:	Open Discussion On way forward for implementing National Road Map, utilization of NRM effectively and sharing of experiences
11:20 - 11:30 am	:	Speech by Mr. Mollah Rahul Alam, Additional Director General (Planning), BWDB
11:30 - 11:35 am	:	Way forward by Mr. Toshio Okazumi, ICHARM
11:35 - 11:45 am	:	Closing address by Mr. Salim Bhuiyan, Chief Planning, BWDB
11:45 - am	:	Lunch

List of participants

S.N.	Name	Designation	Organization
1.	Md Sayeedul Islam	CE/Design	BWDB
2.	Major Golam Kibria Khan	DG	BHWDB
3.	I. M. Reazul Hasan	EE, Office of Chief Planning	BWDB
4.	Md. Abdun Rahman Khan	Meteorologist	BMD
5.	MD. Mosaddeque Hossain	SE	BWDB
6.	Dr Anwar Zahid	DD, Ground Water hydrology	BWDB
7.	Md. Abdul Hye	EE/NEMD	BWDB
8.	Netai Dey Sarker	AD (GIS)	DMB
9.	Md. Abul Kausar	EE, Planning-2	BWDB
10.	Md. Mokibur Rahman	EE/River Morphology Processing	BWDB
11.	Fazlur Rashid	EE/Planning-1 Directorate	BWDB
12.	Amanullah	EE, Office of the Chief Planning	BWDB
13.	A.K.M. Wahed Uddin Chai	EE, office of the Chief Planning	BWDB
14.	Md. Sazzad Hossain	SD/FFWC	BWDB
15.	Md. Hosan Jubair	Water Resources Expert	CEGIS
16.	Md. Serfaraz Banda	Sub-Divisional Engineer	BWDB
17.	Md. Ansat Ali Miah	CE, Hydrology	BWDB
18.	H.S. Mozaddul Farruqe		CEGIS
19.	S.M. Shahidue Alaque		BWDB
20.	Saleh Ahmed	XEN, Office of the Chief Planning	BWDB
21.	Md. Enamul Islam	XEN, Office of the Chief Planning	BWDB
22.	Md. Motaleb Hosssain Sarker	Director, Ecology Division	CEGIS
23.	Shahidul Islam		BHWDB
24.	Md. Amirul Hossain	Executive Engineer, FFWC	BWDB
25.	Dr. M.D. Golam Faruque	Principle Specialist	CEGIS
26.	Rabin Kumar Biswas	SDE	BWDB
27.	A.K.M. Saifuddin	SDE	BWDB
28.	Abu Saleh Khan	DED	IWM
29.	Md. Sohal Masud	Senior Specialist	IWM
30.	Faizuna Warda	Assistant Engineer,	BWDB
31.	A.N.M. Teraq Siddiquee	Assistant Programmer, FFWCC	BWDB
32.	Md. Shahjahan Siraj	Executive Engineer, Office of the Chief Planning	BWDB
33.	Dr. Shamal Chandra Das	Executive Engineer, Office of the Chief Planning	BWDB
34.	Md. Sazzad Hossain	Sub-divisional Engineer, FFWC	BWDB
35.	Md. Arifuzzaman Bhuyan	Sub-divisional Engineer, FFWC	BWDB
36.	Ruknana Rahman	Sub-divisional Engineer, FFWC	BWDB
37.	Shaheea Afrose	PRO	CEGIS
38.	Md. Shahidul Islam	Director, RS Division	CEGIS
39.	Md. Mohinddin Ahmed	System Analyst, PFFC	BWDB
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4. Bangladesh Haor and Wetland Development Board (BHWDB)
5. Disaster Management Bureau (DMB)
6. Institute of Water modeling (IWM)
7. International Center for Water Hazard and Risk Management (ICHARM)
8. Center for Environmental and Geographic Information Services (CEGIS)
9. Asian Development Bank (ADB)
10. Deltares, Netherlands

Photographs of Workshop:



Participants of workshop and discussion on draft NRM for FEWS development in Bangladesh

Asian Development Bank

Technical Assistance
for
Supporting Investments in Water-Related Disaster Management
(TA7276)

Final Report
(Volume 3)
Indonesia Component

September 2012

International Centre for Water Hazard and Risk Management
under the auspices of UNESCO (ICHARM)

Public Works Research Institute (PWRI)

Structure of Reports

(TA 7276 for Supporting Investments in Water-Related Disaster Management)

The reports of TA 7276 for Supporting Investments in Water-Related Disaster Management are divided into following volumes:

Volume 1: Main Volume

(i) Development of Index for Water-Related Disaster Risk Management
(ii) Organization of regional knowledge sharing workshops, exchange visit program and capacity development trainings, etc.

Volume 2: Bangladesh Component

(i) Technical support for improvement of current early warning system
(ii) Capacity building of engineers and managers

Volume 3: Indonesia Component

(i) Satellite-based flood alert system
(ii) Capacity building on local disaster management
(iii) Implementation of community based flood disaster risk management

Volume 4: Lower Mekong Basin Component

(i) Supporting Mekong River Commission Secretariat in developing flood vulnerability indices

Volume 5: Philippines Component

(i) Applying Integrated Flood Analysis System (IFAS) to the river basins
(ii) Identifying causes of historical floods
(iii) Training on utilization of IFAS as supplementary information of the existing flood monitoring systems

List of Authors of TA 7276 Final Reports

Overall	Toshio Okazumi, Shigenobu Hibino
Volume 1: Main Volume	Badri Shrestha, Lee Sangeun, Youngjoo Kwak
Volume 2: Bangladesh Component	Badri Shrestha, Mamoru Miyamoto
Volume 3: Indonesia Component	Seishi Nabesaka, Dinar Istiyanto
Volume 4: Lower Mekong Basin Component	Badri Shrestha, Ai Sugiura, Shigenobu Tanaka, Youngjoo Kwak
Volume 5: Philippines Component	Mamoru Miyamoto, Seishi Nabesaka

Asian Development Bank

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Abbreviation

General

ADB	Asian Development Bank
CBDRM	Community Based Disaster Risk Management
CBFRM	Community Based Flood Risk Management
CMORPH	Climate Prediction Center Morphing technique
CRBOM	Center for River Basin Organizations and Management
DRM	Disaster Risk Management
EWS	Early Warning System
FRM	Flood Risk Management
GIS	Geographic Information System
GSMaP	Global Satellite Mapping of Precipitation
HydroSHEDs	Hydrological data and map based on SHuttle Elevation Derivatives at multiple Scales
ICHARM	International Centre for Water Hazard and Risk Management
IFAS	Integrated Flood Analysis System
JAXA	Japan Aerospace Exploration Agency
JSCE	Japan Society of Civil Engineers
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
OS	Operation System
PC	Personal Computer
PWRI	Public Works Research Institute
QMORPH	Quick version of Climate Prediction Center Morphing technique
SRTM	Shuttle Radar Topography Mission
TA	Technical Assistance
UNEP	United Nations Environment Programme
USGS	United States Geological Survey

Indonesia Component Specific

ARR	Automatic Rainfall Recorder
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AWLR	Automatic Water Level Recorder
Bappeda	Badan Perencanaan Pembangunan Daerah [Local Government Development Planning Agency]
BBWS	Balai Besar Wilayah Sungai [River Basin Authority]
BMKG	Badan Meteorologi Klimatorogi, dan Geofisika
BPBD	Badan Penanggulangan Bencana Daerah – Local Government Disaster Management Agency [Local Government Disaster Management Board]

CB	Community Based
DEM	Digital Elevation Map
DEWA	Division of Early Warning and Assessment
DTM	Digital Terrain Map
FFWS	Flood Forecasting and Warning System
GPV	Grid Point Value
GRID	Global Resource Information Database
HH	Household
IDW	Inverse Distance Weighted Method
KML	Keyhole Markup Language
LINMAS	PerLINdungan MASyarakat (Participative Community Security Unit)
MVK	Moving Kalman Filter
NRT	Near Real Time
PJT	Perum Jasa Tirta (Public company for water use management)
PMI	Indonesian Red Cross
PRA	Participatory Rural Appraisal
PSDA	Local Water Resource Management Office
PusAir	Research Center for Water Resource, Ministry of Public Work Indonesia
REG	Regional
RETA	Regional Technical Assistance
RT	Indonesian administrative term for neighborhood group in a village (usually constitutes by about 40 HHs)
RW	Indonesian administrative term for neighborhood group in a village, constitutes by two or more RT
SOP	Standard Operation Procedure
TARDEM	Name of a digital terrain analysis package
WL	Water Level

Summary

The objectives of this component are to improve in flood forecasting system in the Solo river basin shared by the Central and East Java provinces and capacity building on local disaster management. Integrated Flood Analysis System (IFAS) was applied to improve flood forecasting and warning in the Solo river basin through a regional, satellite-supported flood alert system. An application of IFAS for the case of Solo River flood in 2007, which was verified by using Jurug Station's data of river discharge record (catchment area is 3,220km2), has provided an example on the possibility of using IFAS forecasting result as a useful complementary information for the judgment of potential flood warning in a particular case. IFAS software has been installed in BBWS Bengawan Solo for training purpose and ready for application in Bengawan Solo River Basin.

To develop the sense of local ownership of IFAS technology that enable local engineers mastering the operation, data updating and further development of IFAS according to the local requirement, two main training workshops and three additional intensive trainings on IFAS were carried out for local engineers.

The advance technology and enhanced capacity of community and (institution) practitioner were also integrated. The communities were facilitated to be able to evaluate their own risk. A demonstration of community based disaster risk management activity has been also carried out successfully to educate people awareness on flood disaster preparedness, response and mitigation. The actual evacuation drills were performed in a satisfactory fashion with an active collaboration of the local people in two villages Semen Pinggir and Kedung Sumber.

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1. Situation of Bengawan Solo River Basin

The Bengawan Solo River, the longest river on the island of Java, originates from the Sewu Mountain range and flows into the Java Sea to the north of Surabaya. Its length is approximately 600km and its catchment area is 16,100 km^2.

The Bengawan Solo River Basin can be divided into two main reaches – the Upper Solo and Lower Solo River basins – at its confluence with the Madiun River. The former is further subdivided into the Upper Solo and Madiun basins with areas of some 6,072 km^2 and 3,755 km^2 respectively whereby Mt. Lawu is located at its center. Both Upper Solo and Madiun Rivers have their source in the Sewu Mountain range in the south of the basin.

The Upper Solo and Madiun Rivers flow gathering tributary flows from steep slopes of volcanic cone of Mt. Merapi (2,914 m high), Mt. Merbabu (3,142 m) and Mt. Lawu (3,265 m) in the upper reaches of the river. The tributaries, which flow down carrying continuously a large quantity of eroded volcanic materials, contribute to high sediment load of the Bengawan Solo River.

The downstream of the Bengawan Solo River is called the Lower Solo River with a catchment area of 6,273 km^2 and the steam length of about 300 km from the confluence point with the Madiun River to its estuary. The river flows on a large elongated and low alluvial plain, so the channel slope is prominently low and inundation during floods can be extensive. Figure 1.1 shows the situation map of Bengawan Solo River Basin.

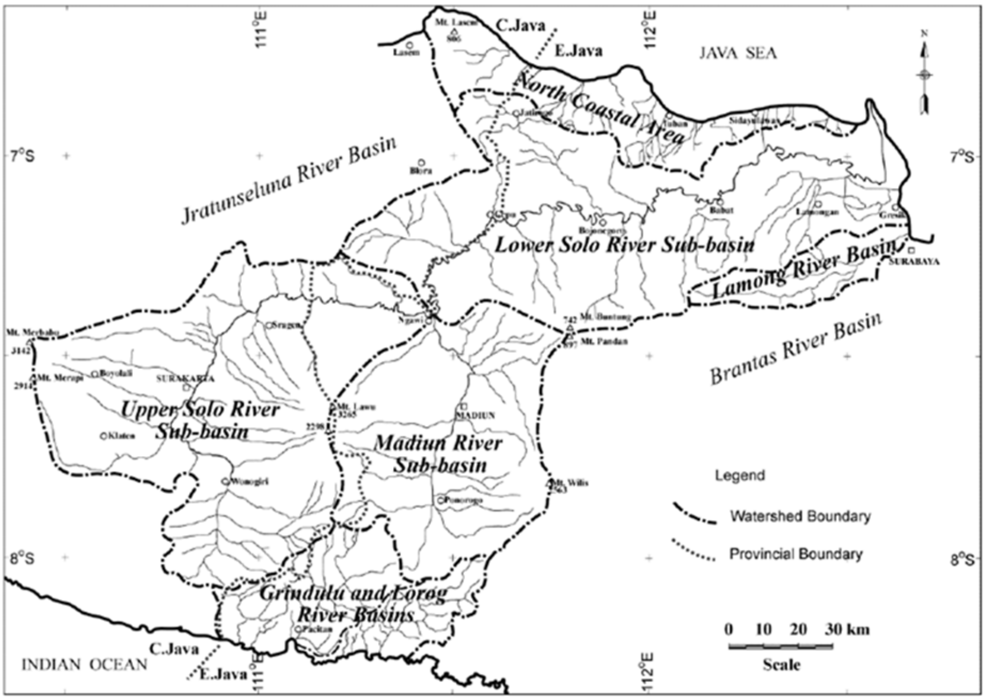

Figure 1.1 The Situation Map of Bengawan Solo River Basin[1)]

[1] Local emergency operation plan with flood hazard map, Material of ICHARM training course.

1.1 Flood and Disaster Situation in Bengawan Solo River Basin

Although construction of Wonogiri Dam was completed and bank levees are progressing, flood damage occurs frequently at the Bengawan Solo River Basin. Table 1.1 shows the serious flood disaster that occurred in Bengawan Solo River Basin since 1966.

Table 1.1 Big Flood Events[1)]

	1966 Flood	1987 Flood	Dec 2007 Flood
Damaged houses	2,400	53,000	138,800
Inundated Crop area (ha)	106,000	78,000	75,780

1.2 Present Flood Management Works

Since the master plan for the Bengawan Solo River Basin was formulated in 1974, several flood control projects have been implemented according to the recommended flood control plan that was one of main components of the master plan. The major flood control projects are listed in Table 1.2. The Wonogiri Multipurpose Dam was constructed in 1982. The Upper Solo River Improvement and Madiun River Urgent Flood Control Projects were completed in 1994 and 1995 respectively. The Lower Solo River Improvement project was carried out from 1994 to 2001. These projects have much contributed to protect vulnerable areas along the mainstream against serious flood disasters. But some areas are still suffering from floods. To reinforce the flood protection system, many future works (mainly structural measures) are under consideration. Figure 1.2a, b, c show for the future improvement plan[2)].

Table 1.2 List of Major Flood Control Projects in the Bengawan Solo River Basin[1)]

	Stage	Project Name	Period
Bengawan Solo River	M/P	Survey and Study for the Development of Solo River Basin	1972-1974
Wonogiri Dam	F/S	Wonogiri Multipurpose Dam Project	1974-1975
	D/D	- ditto -	1976-1978
	C	- ditto -	1977-1982
Upper Solo River	F/S	Wonogiri Irrigation and Upper Solo River Improvement Project	1975-1976
	D/D	Upper Solo River Improvement and Madiun River Urgent Flood Control Project	1983-1985
	C	Upper Solo River Improvement Project	1987-1994
Madiun River	F/S	Feasibility Study for the Madiun River Urgent Improvement Project	1980
	D/D	Upper Solo River Improvement and Madiun River Urgent Flood Control Project	1983-1985
	C	Madiun River Urgent Flood Control Project	1987-1995
Lower Solo River	M/P, F/S	Lower Solo River Development Project	1983-1986
	D/D	Lower Solo River Improvement Project	1992-1994
	C	- ditto -	1996-2001

Note: M/P: Master Plan, F/S: Feasibility Study, D/D: Detailed Design, C: Construction

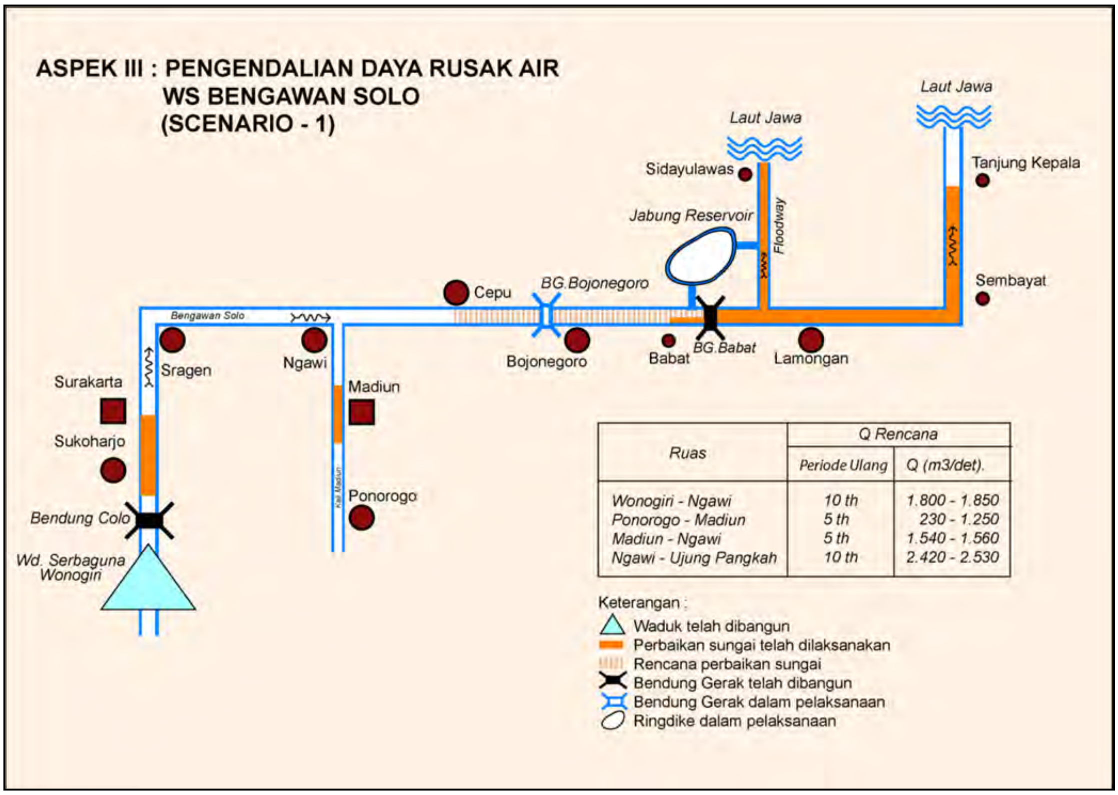

Figure 1.2a Future Improvement Plan of Flood Management Works in Bengawan Solo River Basin[2)]

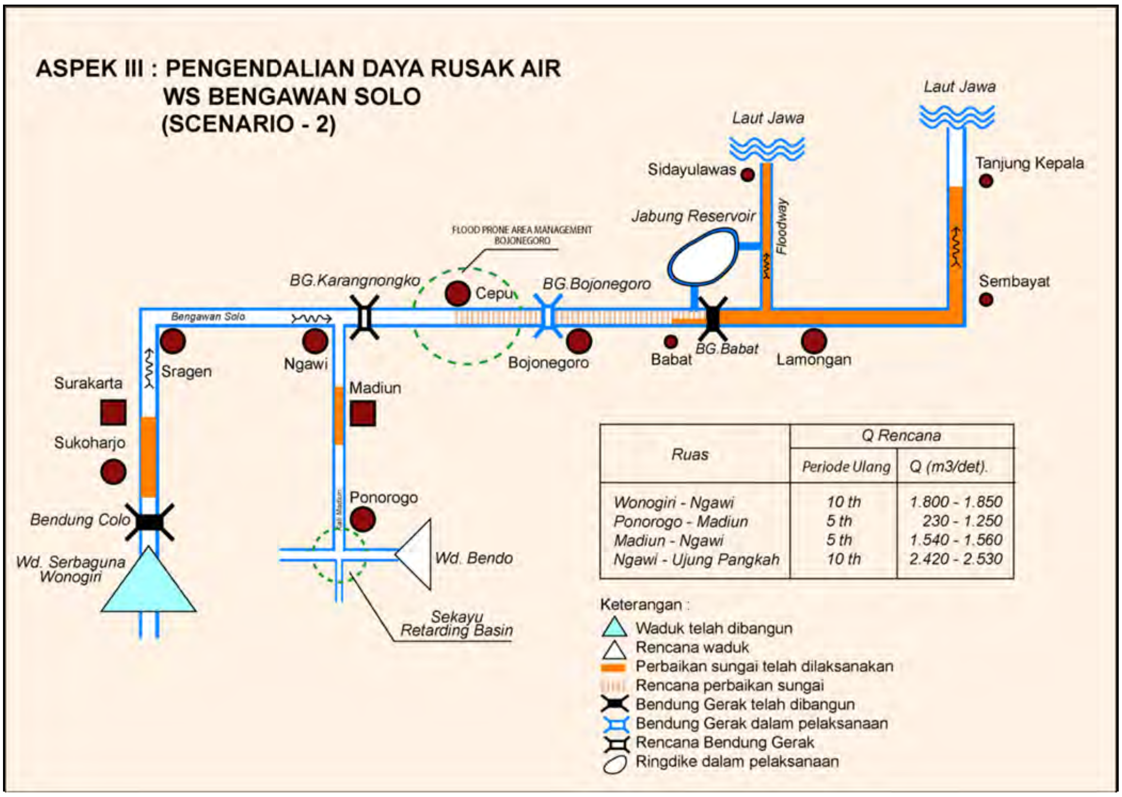

Figure 1.2b Future Improvement Plan of Flood Management Works in Bengawan Solo River Basin[2)]

[2] BBWS Solo, Indonesia

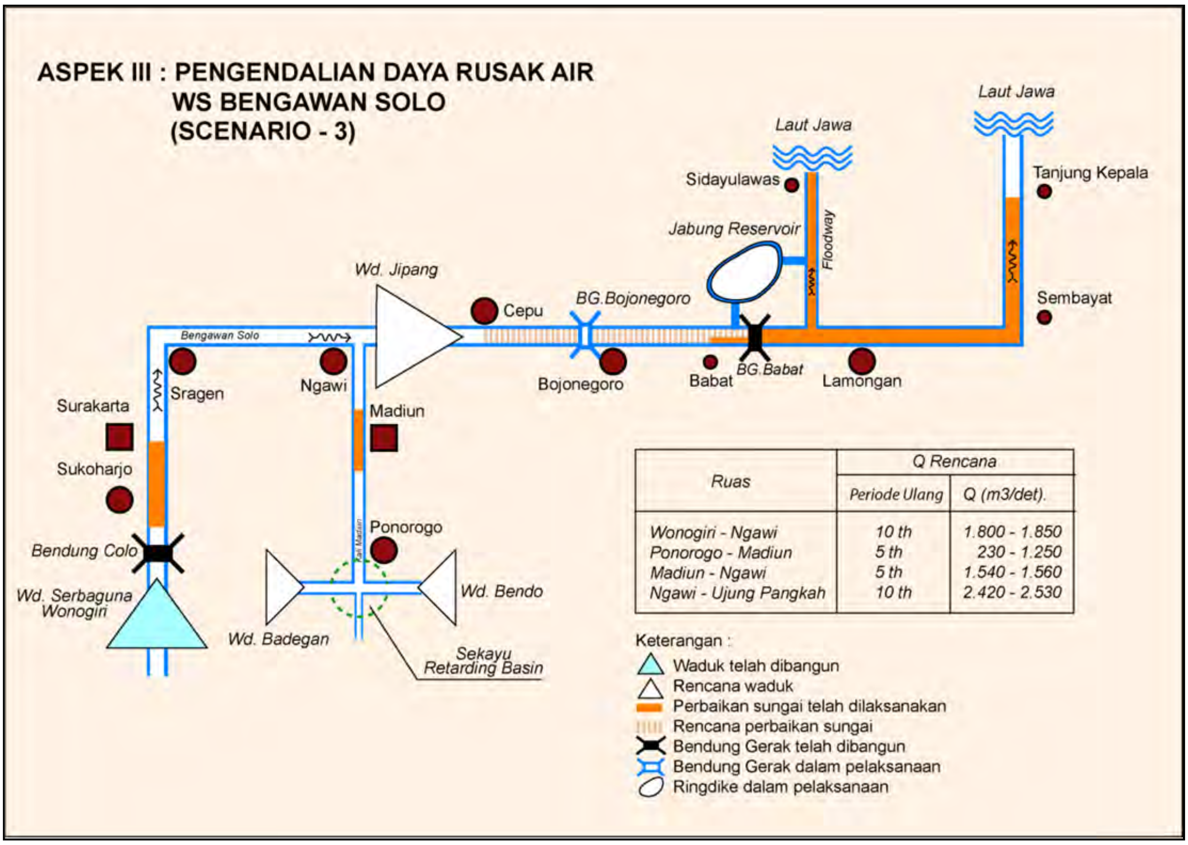

Figure 1.2c Future Improvement Plan of Flood Management Works in Bengawan Solo River Basin[2)]

1.2.1 River improvement works

Table 1.3 is a summary of the river stretches which have so far been or being improved as a result of those projects.

Table 1.3 River Improvement work[1)]

River	Improved Stretches	Protection level	Project Name	Status
Upper Solo	Nguter - Jurug (near Surakarta City, about 37 km)	10-year	Upper Solo River Improvement Project	completed in 1994
Lower Solo	Babat - Tanjung Kepala (Downstream from Babat, about 87km)	10-year	Lower Solo River Improvement Project	on-going
Madiun	Catur Confluence– Kwadungan (near Madiun, about 18 km)	5-year	Madiun River Urgent Flood Control Project	completed in 1995

1.2.2 Dam

The primary flood control facility in the basin is the Wonogiri Multipurpose Dam. The dam was completed in 1982 and controls flood runoff from the uppermost 1,350 km^2 of

the basin. The reservoir provides 220 million m^3 of flood control capacity regulating the peak discharged of 4,000m^3/s to 400 m^3/s.

However, it is reported that there is a serious problem of sedimentation into the dam. In average 2.7 million m3 sediment deposited in the damper year (based on sedimentation data in 1993-2004) by which its retarding capacity was calculated to decrease about 20% in the year of 2004 and may reach about 50% in 50 years later if no significant countermeasure action is taken[4,5).

1.2.3 Flood forecasting system

The existing flood forecasting system was installed in 1982 as supplemental equipment of the Wonogiri Dam to monitor and estimate flood inflow to the reservoir and to provide discharge warning to the downstream reaches as far as Jurug. The system comprised four automatic rainfall stations in the Wonogiri basin, one water level monitoring station at the dam, one transmitter and receiver station, one control station at the Wonogiri Dam office and nine warning sirens along the Bengawan Solo between the dam and Jurug on some 71km downstream.

1.2.4 Flood warning system

At present, an official diagram of the flood warning coordination (before flood) in Bengawan Solo River Basin is hard to find. Nevertheless, it was informed that the flood warning is mainly rely on the river water level observation. Balai Besar Wilayah Sungai (BBWS) Bengawan Solo holds the responsibility of time to time water level monitoring and updates the water level information to the local government offices and other related institution. Based on the water level information, warning of the flood situation will be disseminated to the community by the local government as the authority holder of flood warning dissemination. Diagram in Figure 1.3 shows the organization scheme of flood disaster prevention in Bengawan Solo River Basin, but gives no clear flow on the flood warning dissemination.

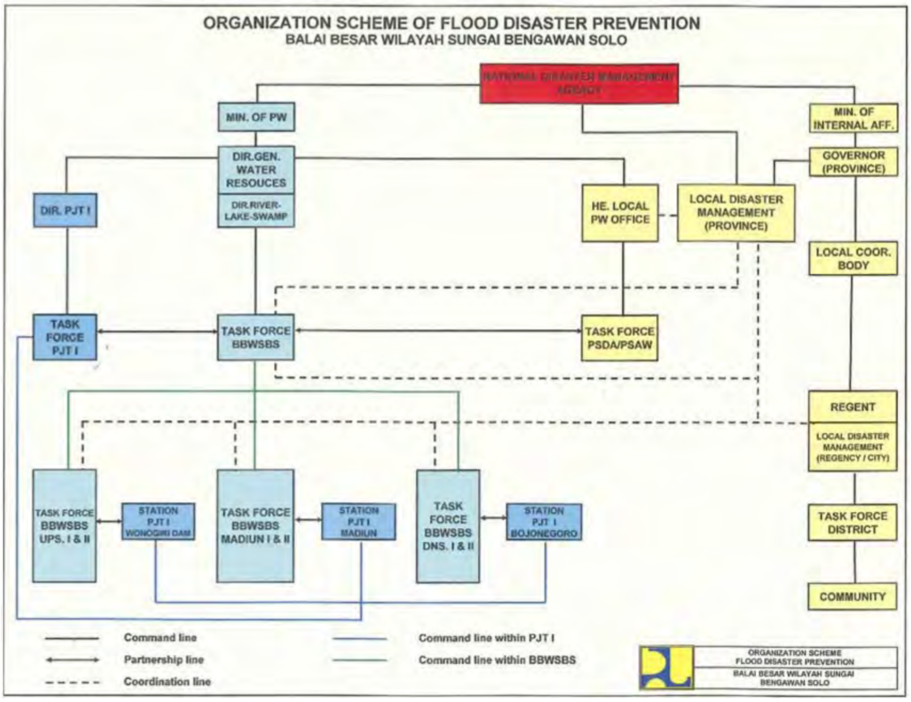

Figure 1.3 Organization Scheme of Flood Disaster Prevention in Bengawan Solo River Basin

1.2.5 Water level observation for flood warning

In principle, the trace of flood waves travelling along the Bengawan Solo River are based on travel times tabulated and graphed accordingly via telephone and email. Water levels from upstream (e.g. Cepu) are communicated to downstream communities (e.g. Bojonegoro), informing them about the approaching of a potentially dangerous flood. During rainy season, water level manual observation is carried out hourly and reported every three hours to BBWS Bengawan Solo flood control office; however when the water level reach warning level (SIAGA level), the data are reported every hour. Out of rainy season, observation is carried out only two times in a day, once in the morning and once in the afternoon.

Figure 1.4 shows the official schematization of the Bengawan Solo River system, reporting relevant peak travel times of the main channel and tributaries, expressed in hours. This official travel time scheme is adopted by all authorities in the Bengawan Solo River Basin.

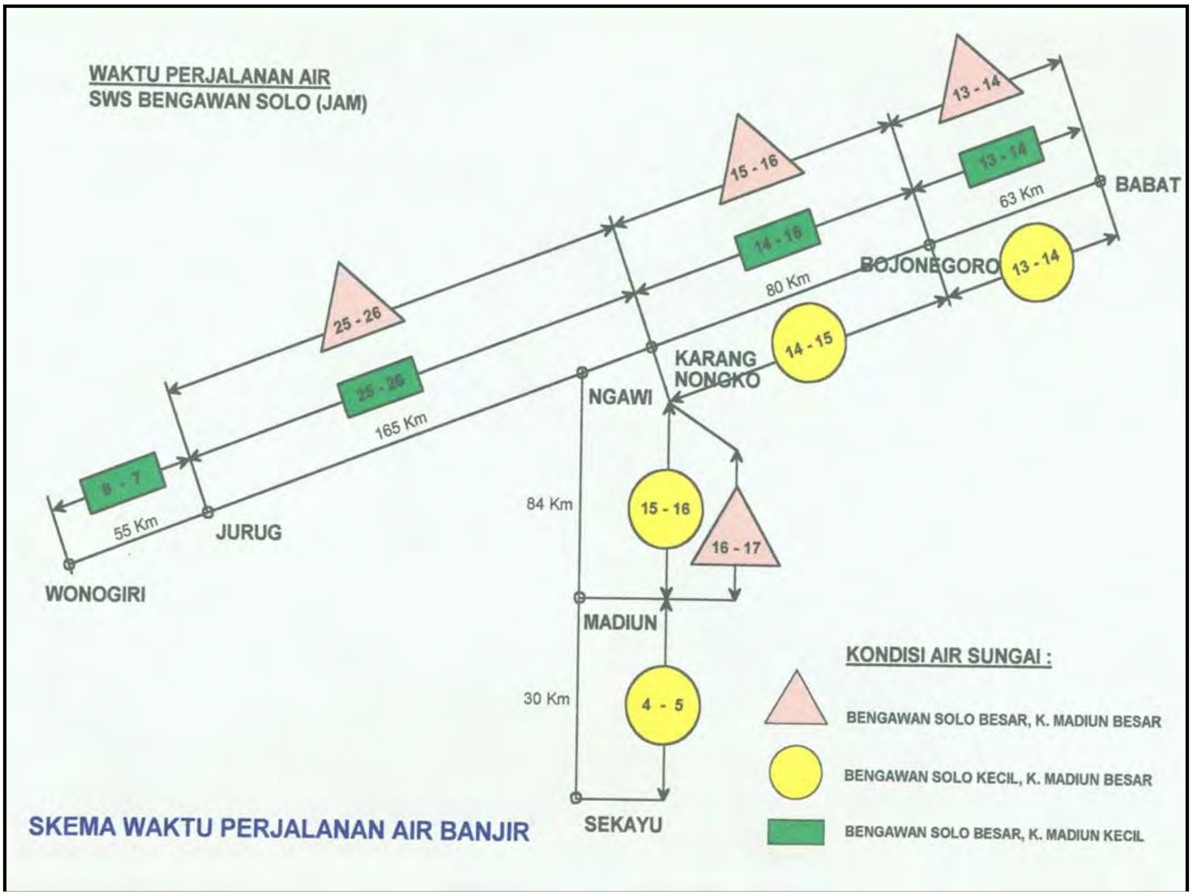

Figure 1.4 Travel Times of Flood Peaks Along the Bengawan Solo River between Wonogiri and Babat (expressed in hours)

1.2.6 Community based flood early warning lamp-siren

Although government is now permanently evacuating people from flood risky areas, 30 early warning stations for 30 different communities are installed by PJT (Perum Jasa Tirta)-I Corporation as a temporary solution. The equipment consists

of three sensors put on the river bank at the outskirt of the village, each of which is attached to the one among three rodswith different colors i.e. blue, yellow and red.Corresponding sensors are attached with different colored lamp and sound producing sirens. The depth of water in the river and therefore corresponding color of rodsand lamps (usually green-yellow-red) were decided by the local people based on their experience and interest. Figure 1.5 shows a typical community based flood early warning lamp-siren in the Bengawan Solo River Basin installed by PJT-I Corporation.

Figure 1.5 A Typical Community Based Flood Early Warning Lamp-Siren in Solo River Basin

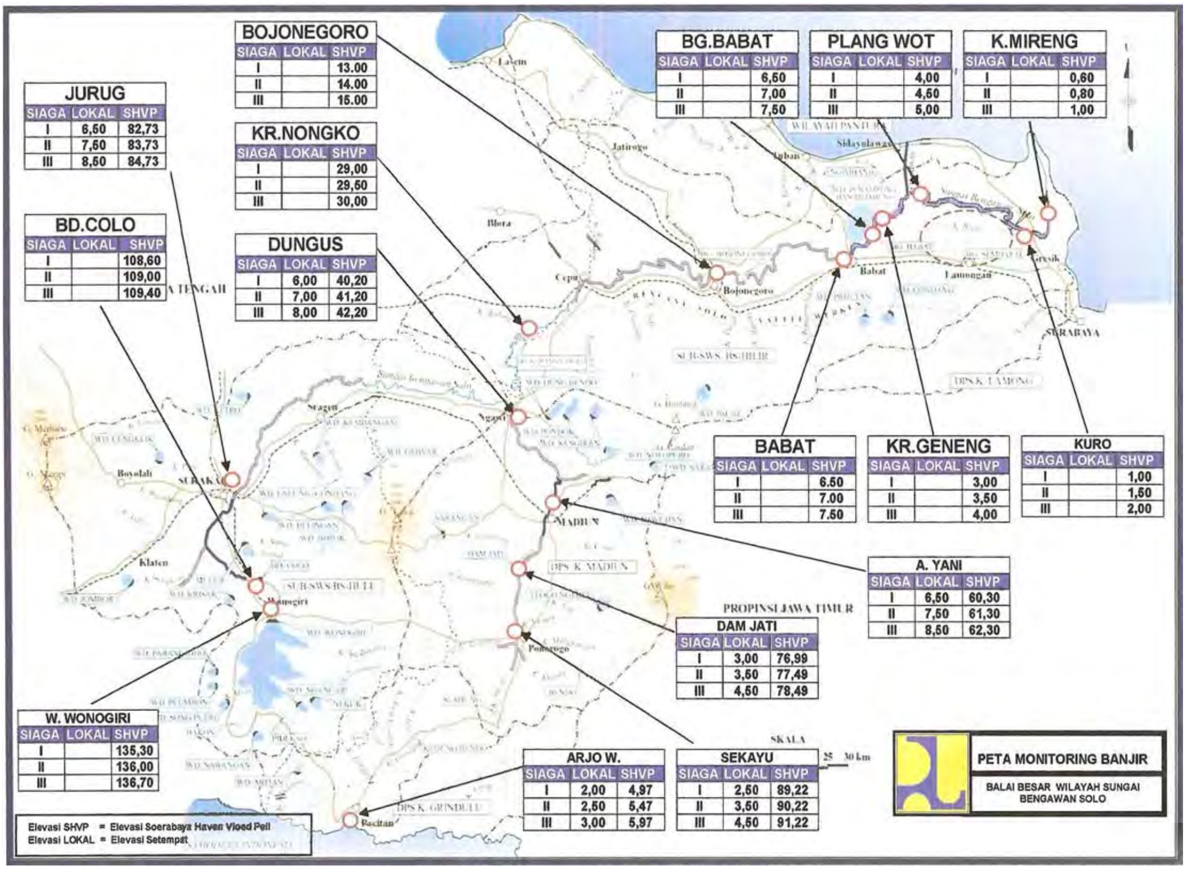

Figure 1.6 Flood Early Warning Station in Bengawan Solo River

Figure 1.6 shows Flood Early Warning Station in Bengawan Solo river basin. There are three stage of Warning against flood water level. Indonesian people called that warning stages as SIAGA I, SIAGA II and SIAGA III.

1.3 Existing Hydrological Observations

The real-time hydrological observation network by 19 rain gauges and 16 water gauges was proposed in 1999. Then, from a viewpoint of a flood forecasting system, reexamination of the real-time hydrological observation network was performed in 2008, and the network as shown in the Table 1.4 was proposed. The implementation of hydrological network, the installation of observation gauges and telemetry system in progress is based on this network. The list of hydrometry station locations that will be improved with telemetering system by latest plan in 2011 can be seen in the Annex 2 of this report.

Table 1.4 Summary of Telemetry Stations Plan in 2008[3)]

Type	Bengawan Solo FFWS & LFMS	MS in Wonogiri irrigation area	Total
Rainfall station	14	0	14
Water level station	11	8	19
Combined station (R & WL)	4	0	4
Combined station (WL & WQ)	4	0	4
Total	33	8	41

R= Rainfall; WL= (River) Water Level; WQ= River Discharge; MS=

1.4 Public Awareness on Disaster

Since the residents along Bengawan Solo River have long experienced with several flood events from year to year, their common knowledge about disaster risks, the factors that lead to disasters and the actions that can be taken individually and collectively to reduce exposure and vulnerability to hazards are supposed to be adequate. However, in fact, there seems no direct effect of level of knowledge and experience to the actual public actions towards the effective reduction of flood disaster along Bengawan Solo River.

The most common fact is the exploitation of flood plain area as residential places. People settle in several flood plain areas despite subjected to regular flood inundationevery year. In several places, even the settlement areas are located behind the existing flood-wall. This in consequence leads to the disobeyance of standard operation procedure of closing the flood-wall gate during the flood, which eventually diminishes the effective flood mitigation efforts. Figure 1.7 shows an example view of residential houses in the flood plain area at Bojonegoro City behind an existing flood-wall.

[3] Design review of Bengawan Solo river flood forecasting and warning system, Design Report, Nippon Koei, Co. Ltd. 2008.

Figure 1.7 An Example View of Residential Houses in The Flood Plain Area at Bojonegoro City Behind The Existing Flood-Wall

Unfortunately, BBWS Bengawan Solo has no authority to deal with such land tenure administration and law enforcement works, which in fact belong to the local government. Nevertheless, in cooperation with the local government of Solo City, several residents are successfully negotiated and encouraged to resettle in safer area inland. Figure 1.8 shows an example of flood plain area that already left by the relocated residents and the new houses series. Those houses constructions were self-managed by the relocated residents with reliable fund support from the government.

Figure 1.8 An example of flood plain area that already left by the residents (left) and the new houses, which their constructions were self-managed by the relocated residents with reliable fund support from the government (right).

2. Rationale and Objectives

2.1 Rationale and Objectives

Based on the description in the previous Chapter, the situation of flood disaster management in Bengawan Solo River Basin shall be concluded as follows:

1) Despite the serious efforts of the Government in improving flood protection infrastuctures, some areas are still suffering from floods.

2) Flood information system, including flood early warning has been helping much the flood disaster mitigation efforts, however insufficient hydrological observation facilities have caused ineffectiveness of flood warning and disable the flood forecasting capability.

3) The low awareness of the community, especially concerning the use of flood plain area as residential area has to some extent caused the disaster impacts remains high. At the same time, the poverty situation of the residents being a high challenge for the local government to execute landuse law enforcement.

The present Asian Development Bank Regional Technical Assistance No. 7276 (hereafter is abbreviated as ADB TA 7276-REG) was design to help prepare and implement flood management investment projects through knowledge and capacity development services that will reduce vulnerability to water-related disasters with in country and regional assistance.

In the country support program – Indonesia component, the objective of the present technical assistance is as follows:

1) Supports improvements in the flood forecasting system in Bengawan Solo River Basin.
2) Supports improvements in capacity building on local disaster management.

Through the enhanced flood forecasting and warning system the preparedness level can be increased and the damage due to flood might be reduced. However, technology intervention does not solve all. The disaster mitigation measures will be not effective without well awareness of the community to perform accurate response.

In the above regards, the Integrated Flood Analysis System (IFAS) - an effective and efficient flood forecasting tool was introduced for its application to Bengawan Solo River Basin. In addition, aiming at developing self-sustainable and flood resilient community, Community Based Disaster Risk Management (CBDRM) demonstration activities were introduced as a way forward to aware and strengthen local community to cope with any flood in its locality.

International Centre for Water Hazard and Risk Management (ICHARM) as the implementing agency for this technical assistance shared role with BBWS Bengawan Solo as the partner agency in Indonesia. A series of IFAS training workshop were conducted to improve the institution capacity. The local ownership of the technology was also improved through the parameter adjustment by the local engineers to find the suitable one for local requirement.

Figure 2.1 shows the concept figure of flood early warning improvement by using IFASapplication in Bengawan Solo River Basin, whereas Figure 2.2 shows the concept figure of institution and community capacity development. The role sharing of ICHARM and BBWS Bengawan SoloBengawan Solo to reach the purpose of this project is shown in Figure 2.3

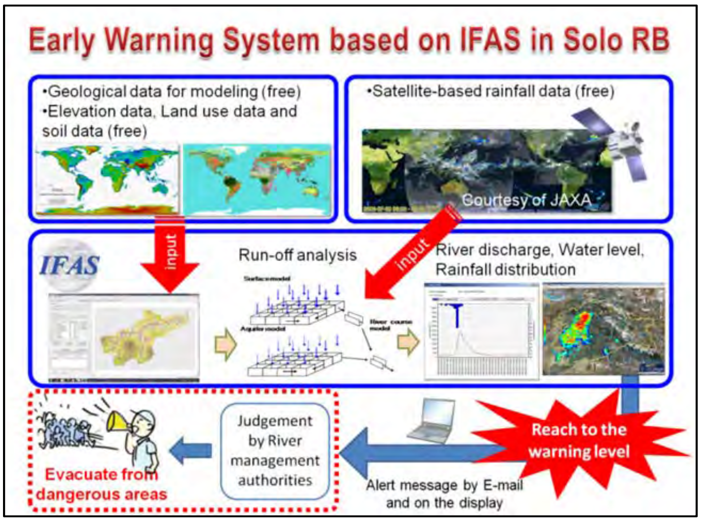

Figure 2.1 The Concept Figure of Flood Early Warning Improvement By Using IFAS Application in Bengawan Solo River Basin

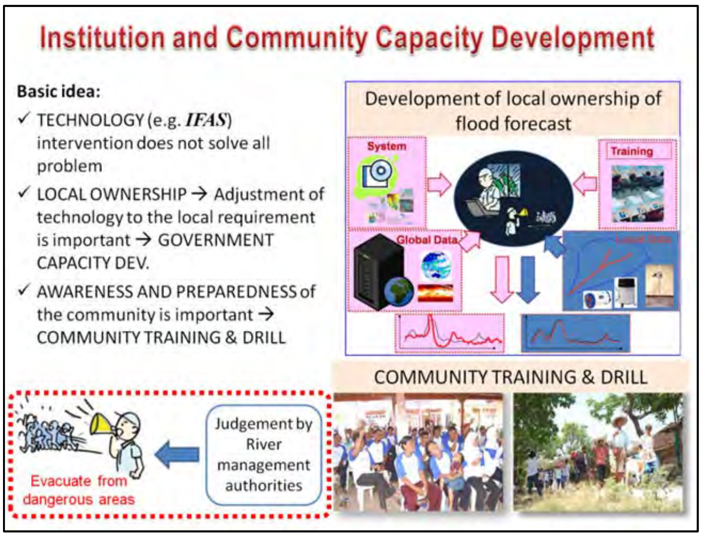

Figure 2.2 The Concept Figure of Institution and Community Capacity Development in Bengawan Solo River Basin under ADB TA 7276-REG

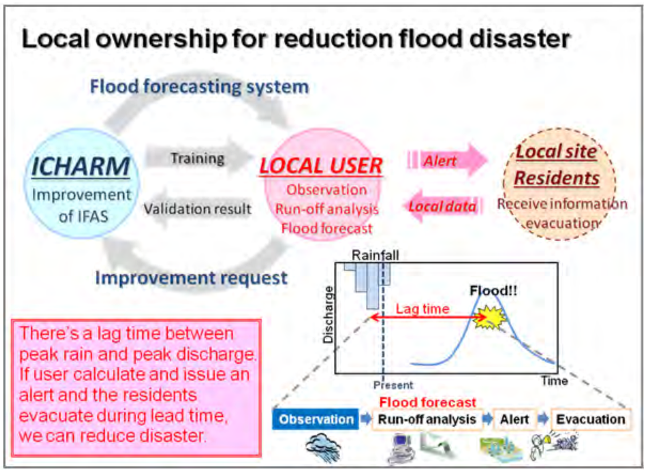

Figure 2.3 Role of ICHARM and BBWS Bengawan Solo to Develop Local Ownership

2.2 IFAS (Integrated Flood Analysis System)

For more effective and efficient flood forecasting in river basin with insufficient observation facilities developing countries, ICHARM has developed a concise flood-runoff analysis system called “IFAS”. IFAS is equipped with many innovative functions. It makes possible the analysis of satellite-based rainfall data (not only ground-based data) and the identification of river channel networks based on Geographic Information System (GIS) data. It can also estimate parameters for a default runoff analysis engine and display output results.

To promote the effective use of IFAS, ICHARM has developed a plan to hold training seminars for potential users and to conduct joint research with governmental agencies and other organizations. ICHARM hopes that IFAS will be used worldwide as a tool which contributes to the development of flood forecasting and warning systems in developing countries and other engaged areas. The following are some of the main features of the system. Figure 2.4 shows the basic scheme of IFAS working flow.

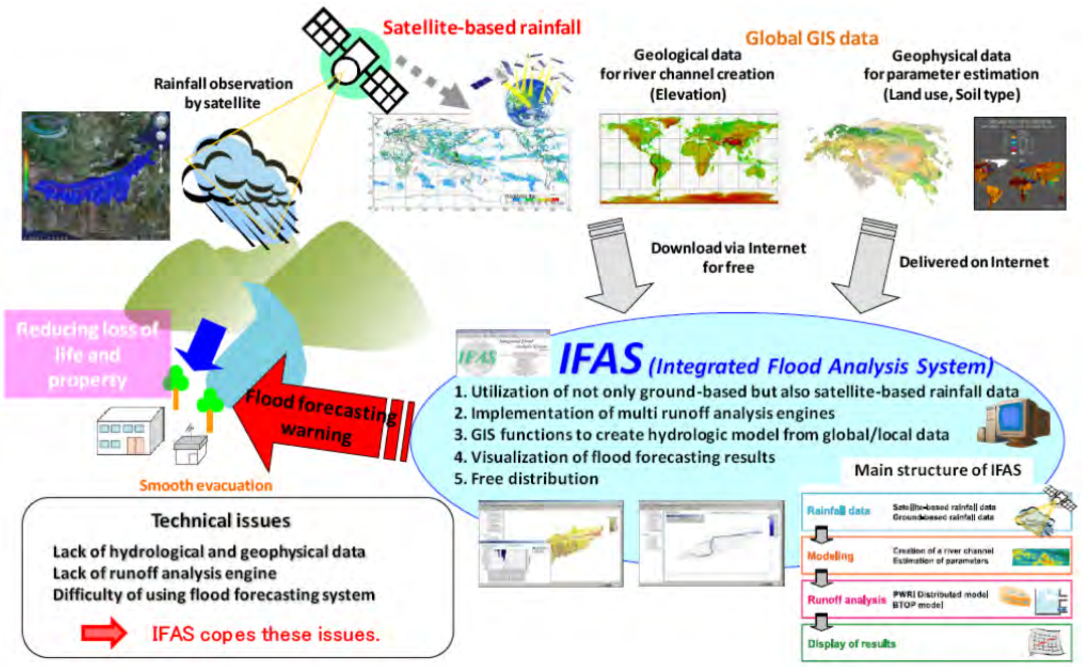

Figure 2.4 Schematic Figure of IFAS

2.2.1 Utilization of satellite-based rainfall as input data

IFAS allows users to use satellite-based rainfall data instead of ground rainfall data. In recent years, real-time or semi real-time satellite-based rainfall data, which cover the almost entire globe, have been provided by National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), Japan Aerospace Exploration Agency (JAXA), and other agencies. These satellite-based rainfall data are easily accessible even with a personal computer through the internet. Furthermore, IFAS also has the function which corrects satellite-based rainfall and enhances observation accuracy for flood forecasting.

2.2.2 Distributed run-off analysis engines based on distributed hydrological models

IFAS has adopted run-off analysis engines based on physics-based distributed hydrological models. Most parameters for a distributed hydrological model are related to

physical basin conditions, such as land use and soil types, and are globally available for public use. In addition, guideline parameters has been also prepared based on past simulation results. Therefore, IFAS is now ready to be easily put into practical use in any insufficient gauged basin.

2.2.3 Model creation function

IFAS has unique functions to create a run-off model and estimate parameters using GIS data including elevation, land use, soil type, etc. With these functions, run-off analysis can be applied to basins with insufficient hydrological and geophysical information.

2.2.4 Visualization of flood forecasting results

IFAS has interfaces to display output results not only in figures and tables but also on a digital map. In this way, users can easily identify flood risks at different locations, looking at visualized simulation results.

2.2.5 Free distribution

ICHARM distributes IFAS executable files to users for free.

2.3 Community Based Disaster Risk Management (CBDRM) Approach

One other disaster risk management strategies that can work in many different communities is a community-based disaster risk management. However, each community may have different culture regarding civil society as well as social conditions and political institutions, which will result in different forms of community based approach.

CBDRM system, or in the field of flood disaster is sometimes called as Community Based Flood Risk Management (CBFRM), under the initiation of local community is based on the knowledge of local residents and therefore may not have scientific soundness. For example, the characteristics of flooding are known to local individuals with a high level of confidence in areas where overbank flooding occurs, whereas characteristic flooding caused by system failure, system aggression or unexpected torrential rain may not be understood by the local residents. In such cases, it is necessary to simulate these events by means of scenario analysis using physical or numerical models.

Therefore, the fusion of technical and indigenous knowledge is required. As a result, river authorities and the local government should participate in CBFRM exercises and play a facilitating role throughout the development process (Figure 2.5). Different participatory appraisal tools can be of great help when developing CBFRM. In addition, scientific methods can be used for CBFRM, but the outcomes must be done adapted in a convincing manner so that the system is suitable for any stakeholders. Especially, high interests are low-tech components, which are less cost-intensive and can be handled by local residents. Additionally, supplementary technical tools, such as simple stage gauge measurement units, a basic rainfall-flood relationship curve (also known as an s-curve), and rain gauge stations can be useful for establishing a community-based early warning system as a part of disaster risk management (DRM).CBFRM should not at any cost be separately dealt with general community development activities.

ICHARM has successfully tested this approach as a pilot study in West Rapti river basin in Nepal. The first phase baseline study already shows the effectiveness of the CBFRM. In this approach community took a key role to describe their risk, to understand

the risk they are facing at present and committed to mitigate the risk through several community based activities. Scientific data and results are simplified to make them understandable to the public, which leads to make community much aware of any possible consequences that may take place after possible dam breach, levee breach or so. ICHARM realize that this knowhow can be disseminated to other countries including Indonesia.

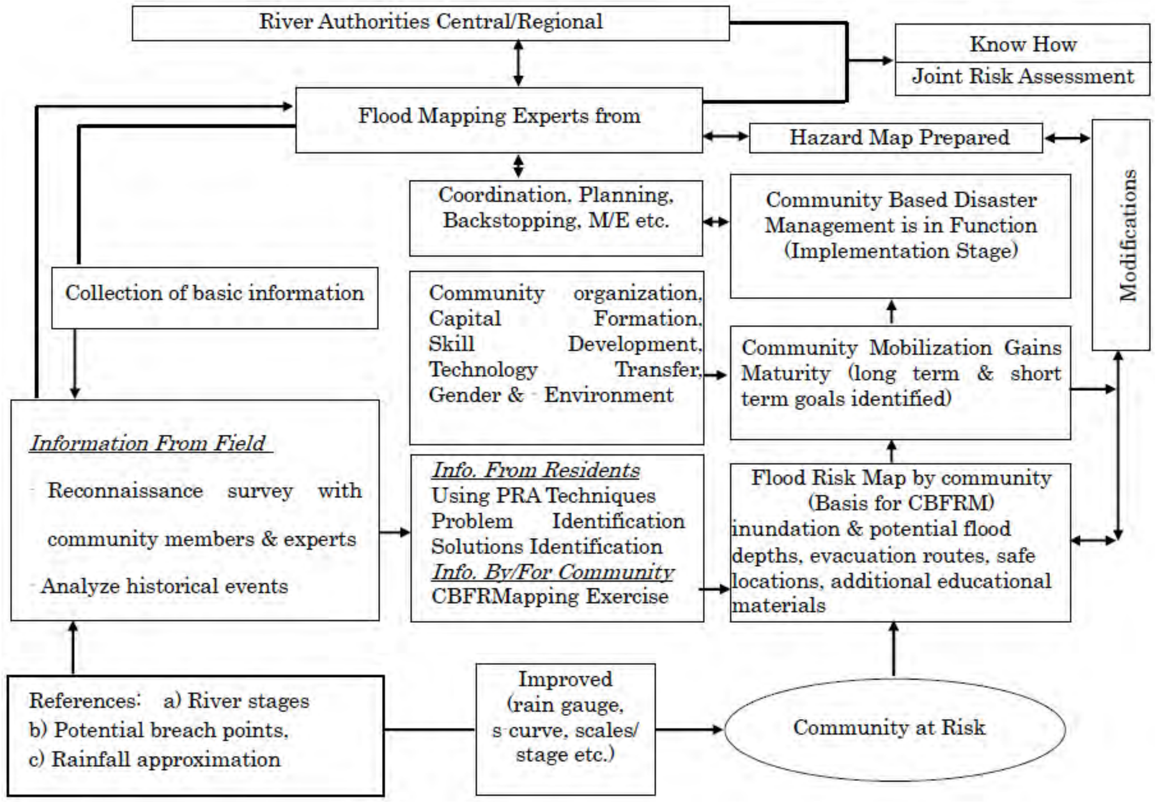

Figure 2.5 Operational Procedure for Implementing CBDRM in Flood Disaster

3. Project Components and Activities

3.1 Outline

The Indonesia component of in-country support program contains supports improvements in a) flood forecasting system in the Bengawan Solo river basin shared by the Central and East Java provinces and b) capacity building on local disaster management.

The activities to gain the objectives include:

(i) A demonstration project to improve flood forecasting and warning in the Bengawan Solo river basin through a regional, satellite-supported flood alert system by using Integrated Flood Analysis System (IFAS) with advanced geophysical data integrating satellite and ground observations;

(ii) Training of personnel of the river basin organizations on the local disaster management;

(iii) A community managed flood risk management interventions for selected communities in the Solo River Basin

The integral goal of ADB TA 7276-REG for Indonesia is the local ownership of the IFAS technology and capacity development of the local river basin organization and the community for the reduction of flood disaster. Thus, the challenge for the present TA implementation in Indonesia is the integration of advance technology and community based disaster management.

3.2 Activities Related to IFAS Installation and Training Workshop

In order to enable successful operation of IFAS by Indonesian engineers for flood forecasting over the Bengawan Solo River Basin, the following items were carried out,

- Model development for the Bengawan Solo River Basin and improvement of IFAS based on local needs and conditions
- Installation of IFAS equipment in local offices
- Workshops to provide a useful opportunity for the local engineers to learn how to forecast flood using IFAS and satellite-based rainfall

Based on the comprehensive consultation and discussion with BBWS Bengawan Solo, the following items were planned and executed.

3.2.1 Data collection

The following data and information on the target basin (Table 3.1) were collected and the topography and detailed hydrological conditions as well as past disaster records and flood countermeasures were sorted out. Figure 3.1 shows the comparison between two types of satellite-based rainfall observation, i.e. National Aeronautics and Space Administration (NASA) 3B42RT and JAXA-GSMaP.

Table 3.1 List of Data Collection

1) To develop the runoff model.	
・Elevation	・River system
・Land Use	・Geology
・Soil classification	
2) To validate the satellite-based rainfall data and runoff simulation results as well as to calibrate parameters	
・Rainfall data at all gauge stations in the target basin since 2002	
・Water level data at all gauge stations in the target basin since 2002	
・Cross-sections and the Height of water level-Quantity of discharge equations at the water level observation points	
・Locations of the gauging stations (plot them on the coordinate plane)	
3) To validate and improve the proposed simulation model (comparison with damage caused in past flood disasters)	
・Photos showing damage conditions	
・Publication such as newspapers	
・Satellite images during flooding	

3.2.2 Selection of target points for flood forecasting

ICHARM set up flood forecast points (target points) based on past flood disaster track record or local opinion.

Significant flood damage is reported in Surakarta, so the suggested target point is Jurug station.

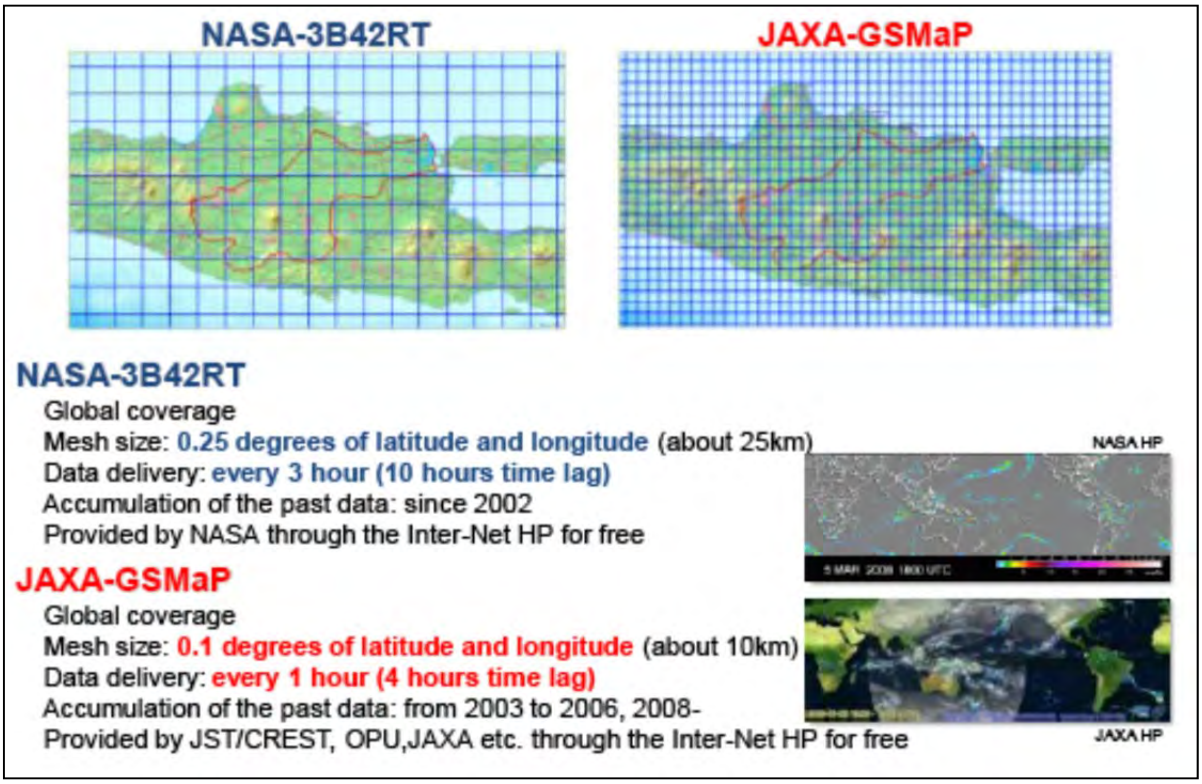

Figure 3.1 Satellite-Based Rainfall Observation

3.2.3 Accuracy validation and improvement of satellite-based rainfall

On the collected ground rainfall, validate the accuracy of both satellite rainfall (GSMaP, 3B42RT) in the Bengawan Solo River Basin and the existing bias correction method (GSMaP) for the following time period and locations. Also, validate the average rainfall in the upstream area in addition to that at each observation point. Improve the existing bias correction method (resetting of the bias correction rate) based on the validation results. Figure 3.2 shows the schematic figure of accuracy improvement works flow.

<u>Target period for validation:</u>

A few flooding events since 2002 or rainy seasons since 2002.

<u>Target locations for validation:</u>

- Each rainfall gauging point
- Bengawan Solo River Basin and upstream area of each water level gauging station

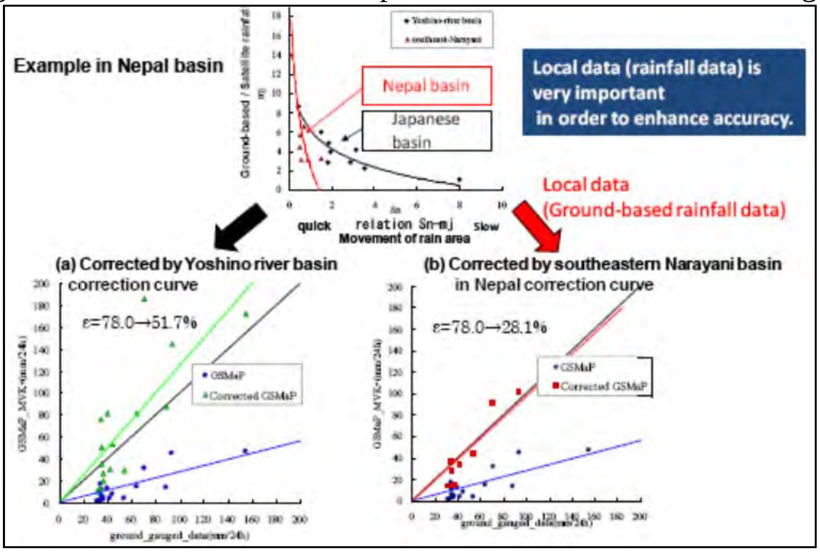

Figure 3.2 Accuracy Improvement

3.2.4 Application of IFAS to the Bengawan Solo River Basin

ICHARM created river channel network of the target basin by using IFAS based on the collected data including the channel cross-sections to conduct runoff simulation and flood forecasting.

Based on past flooding events and rainy seasons, estimate and calibrate parameters for IFAS runoff simulation to apply to several observed discharges or water level gauging stations in the Bengawan Solo River Basin. Validate the simulation results compared with other flooding events and rainy seasons.

Figure 3.3 shows example of IFAS inputs to develop river channel network and parameter based on global GIS data

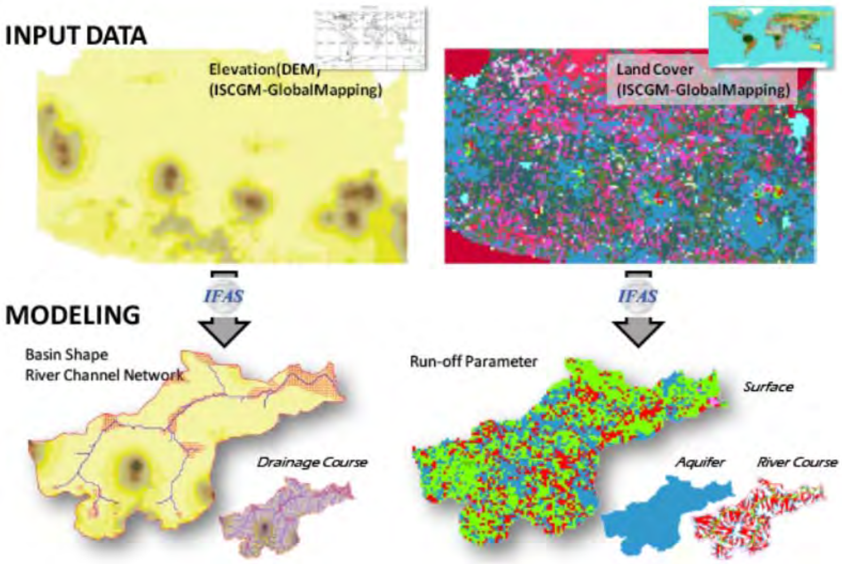

Figure 3.3 River Channel Network and Parameter Based on Global GIS Data

3.2.5 System modification of IFAS

ICHARM improved IFAS to adjust to the local conditions of hydrological observation, power and communication systems so that it can be used for real-time runoff analysis and flood forecasting. ICHARM added the following functions to IFAS for further improvement. Figure 3.4 shows an example of the present version of IFAS display.

1) Improvement of the transmission function based on the local Internet environment to download and save satellite rainfall at regular time intervals
2) Addition of the automatic function to download satellite-based rainfall data (GSMaP, 3B42RT), correct the satellite-based rainfall data (GSMaP) with both the imported ground rainfall data and the bias modification method improved in this project, and save the corrected data.
3) Addition of the automatic function to conduct runoff analysis for the target basin or locations at regular time intervals based on the downloaded satellite rainfall (GSMaP, 3B42RT), the corrected satellite rainfall (GSMaP) and ground rainfall. This function includes automatic displaying, data saving of analysis results and warning for the river management authirities.

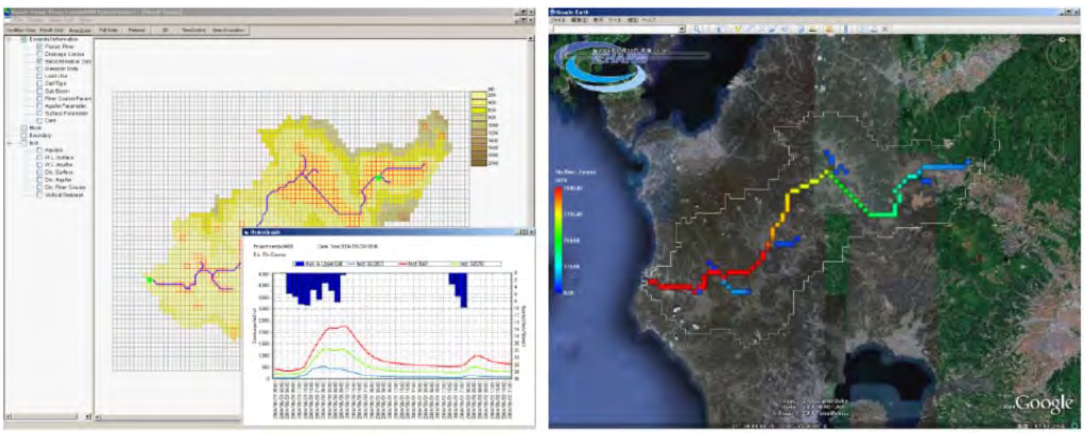

Figure 3.4 IFAS Display

3.2.6 System Installation

ICHARM set up the improved IFAS equipment in this project at three locations in the target basin to put the system into local operation. In addition, ICHARM installed the IFAS software and conducted operation check.

The equipment installation does not include improving installation locations and setting up power and internet connections. Internet access fees are also excluded.

3.2.7 Capacity Building

Originally, three workshops were planned for Indonesian engineers to acquire knowledge and skills necessary for IFAS operation to conduct flood forecasting. But, The General manager of BBWS, Mr. Ir. GRAITA SUTADI, requested to reduce the number of IFAS training workshop three times to two times at the meeting held in March 2010. Because BBWS has a lot of works and projects, so they were very busy (Mr. Graita mentioned). ICHARM informed ADB about the request from BBWS and reduced the number of official workshops. This was already informed by 1st progress report of TA7276-REG. However, the engineers of BBWS wanted to learn how to use IFAS more frequently. They are full of passion to get the skill of runoff analysis using IFAS. So ICHARM tried to hold small scale IFAS training in BBWS during stay in Solo and distance IFAS training from Japan using Skype. But distance IFAS training is not effective, because internet connection in Indonesia is not good. It was too difficult to talk with each other smoothly using Skype. ICHARM also informed ADB about this communicate problem. ADB allowed holding small scale IFAS training in Indonesia frequently. As a result, ICHARM conducted 2 times official IFAS training workshop in Solo including 1 regional workshop, 3 times small scale IFAS training and 5 times IFAS distance trainings using Skype from October 2010 to February 2012. The participants have learned and practiced about analysis methods and data used in the IFAS system. The IFAS training workshops held in Surakarta are listed in Table 3.2.

On the other hand, Bapenas requested to collaborate with Badan Meteorologi Klimatorogi, dan Geofisika (BMKG). This was informed by ADB to ICHARM in March 2011. To respond this request, ICHARM visited to BMKG and discuss with them about application of IFAS in July 2011. Furthermore, ICHARM invited three engineers of BMKG to 2nd IFAS training workshop held in November 2011. All of the lectures were provided in English, and depending on the situation, Dr. Dinar ISTIYANTO and Dr. Ai SUGIURA translated in Indonesian language to explain about detail information.

- Introduction of flood forecast and satellite-based rainfall
- Introduction of IFAS and IFAS exercise
- IFAS exercise using the Bengawan Solo basin model

Table 3.2 IFAS training workshop held in Indonesia

River basin	period	title	contents	Organization	participants
Sendai-gawa river basin	2-4 March 2010	1st IFAS training workshop with BBWS Solo	IFAS trainning (introduction, demo, practice)	ADB, BBWS	25
Bengawan SOLO river basin	16-17 December 2010	IFAS training	IFAS training(introduction, demo, plactice)	ADB,BBWS, CRBOM	15
Bengawan SOLO river basin	10-12 July 2011	IFAS training	IFAS training(introduction, demo, plactice)	ADB,BBWS	15
Bengawan SOLO river basin	23-25 November 2011	2nd IFAS training workshop	IFAS training(introduction, demo, plactice)	ADB, BBWS, PU, BMKG, Pusair, CRBOM	34
Bengawan SOLO river basin	27-28 February 2012	IFAS training	IFAS training(introduction, demo, plactice)	ADB, BBWS	-

3.3 Activities Related to the Community-Based Disaster Risk Management (CBDRM)

3.3.1 Key-activities

In order to establish a well functioning CBDRM system at the target community as illustrated in Figure 2.5, considerable time and resources should be mobilized, which may be difficult within defined project period. Therefore, only selected activities under CBDRM can be conducted under the planned ADB TA 7276-REG project for the demonstration purpose. These demonstration activities include the preparation of community based hazard map, establishment of community based early warning system, and conduction of evacuation drills and exercise. It is hope that the Indonesian counterpart will learn from the experience and will continue promoting such activities in a long run. Following are the key activities

- Facilitate to carry out participatory hazard and risk assessment and mapping activities at the community.
- Facilitate in preparing risk maps, Flood Risk Management (FRM) action plans and the manual for early warning system and evacuation plan
- Support community in technical aspects for carrying out emergency drills and exercises as a part of community awareness program
- Conduction of awareness raising and skill development workshops and training at the community level

These activities will be started from the selection of community to be intervened. It is required to understand the behaviors of community and check the suitability or modification of the proposed approach. The first step of starting CBDRM will be the mobilization of community members, understanding their problems by interacting with them. This can be done by social mobilizers who are strong at convincing and treating the community. After the community is said to be convinced, community will re-organized in a systematic manner so that any decision making can be done in an effective manner. Community members will be able to evaluate their risk at their own, where experts and social mobilizer will facilitate the process.

3.3.2 Approach to Community-Based Disaster Risk Management

Methodologies to be used for the implementation of the Community Based Disaster Risk Management (CBDRM) are subject to a series of commonly accepted steps and sets of rules. A possible and complete list of steps is given in the following paragraph. Given the time constraints of TA-7276-REG, only a subset of the steps will in fact be addressed.

Step 1. Awareness raising. Usually community and social workers build up the relation with local people and emphasize the importance of preparedness in the face of the specific hazards (e.g. floods and flash flood in the Bengawan Solo River case). Real movies or movies recorded of similar hazards at different locations can be used as tools to give community members impressions of the hazard risk they are facing. In the present effort this step will be skipped due to time constraints, and because awareness of the flood issue is already high in the area of interest.

Step 2. Community mobilization. The next step is the mobilization of the community under six different CBDRM principles and one guiding principle. This is the most time-consuming part, which is fundamental for the implementation of CBDRM. However, details are omitted here as they cannot be addressed due to time constraints in TA-7276-REG. Therefore capacity already existing in the community will need to be building upon.

A) <u>Organization</u>: all community members are bound in a formal community organization. For example in a community of 50 households (HHs), five organizations comprising 10 houses each (a so-called “common problem group”) will be formed. From each such organization, representatives will from an ad-hoc committee on DRM activities. In the specific case of TA-7276-REG the ad-hoc committee may include the BPBD (Badan Penganggulangan Bencana Daerah – Local Government Disaster Management Agency), which represents the central government at the district level.

Small-scale community organizations often meet and discuss important flooding issues affecting them and take decisions accordingly. The scope of these meetings can in principle be wider, but within TA-7276-REG the communities will be requested to focus exclusively on emergency responses to floods.

B) <u>Build-up of capital</u>: This process will not be analyzed in detail, as it exceeds the scope of TA-7276-REG. Capital accumulation concerns flood banking, micro-credit and so on, instruments to make capital available to a flood affected community for recovery and resumption of economic activities. This process, although important, will be skipped in the TA due to time constraints.

C) <u>Skills:</u> local people need to be trained in three different categories of skills

- skills in running (small) organizations,
- income generation including preparedness for hazards
- technical skills, which enable people to basic activities such as how to read rain gauge, interpret rainfall discharge or inundation depth graphs, as well as how to asses hazard risk and which technique to use. This includes also Flood Hazard Mapping, a technique which is especially relevant for CBDRM in TA-7276-REG.

D) <u>Gender equality</u>: this activity is aimed at empowering a group of people who are highly vulnerable based on the ranking of their level of vulnerability. This group includes women, children, handicapped people etc.

E) <u>Disaster mitigation:</u> The community is requested to carry out mitigation activities

on a voluntary basis. The extents of the individual contributions are irrelevant at large, as long as they contribute to advance the socialization of CBDRM activities beyond mere and sporadic actions by individuals.

F) Technology: This aspect is concerned with the development of appropriate risk mitigation and assessment tools based on advanced technology. This includes promotion of indigenous technology supported by advance science. Examples are issues such the use of rain gauges and/or water level gauges that are readable for the local community, how to simplify tools in a way that the tools can be operated by locals, what is the meaning of model results for community, etc. Key is to merge science with local knowledge and to develop technologies that fit the specific context.

G) Principle of Cultural Asset Preservation: This aspect includes the respect for local cultural heritage as a guiding principle. In essence all the activities reported from A to F should be implemented without disturbing/harming the social structure and local cultural heritage.

Step 3.Vulnerability analysis. All Participatory Rural Appraisal (PRA) techniques will be applied to assess the specific degree of vulnerability of a community with respect to the typology of floods mainly occurring. The community will identify key activities that are closely affected by the hazard. These generally include economic activities such as agriculture, education, trade etc.

Time lines (e.g. daily and seasonal activities), and Venn type interactive diagrams are used to show the (non)governmental presence and trust level from the community's perspective. During this phase guiding parameters for follow-up activities, e.g. drawing of Community-based (CB)-Flood Hazard Maps are developed.

Step 4a. Community-based flood hazard map (inundation map). The community will prepare a map based on their experience or perception with the means they have available. A community-based flood hazard map can also consist in simple sketches or similar.

Step 4b.A hydrological/hydraulic analysis. Aim is to derive a flood hazard map on the basis of scientific knowledge. The scientific hazard map will be developed by using state-of-the-art tools such as digital terrain models and GIS tools for example. More complex scientific maps can also be based on the use of computer models.

Step 5a. Community-based vulnerability map. The community will prepare a vulnerability map using in reference to the community-based hazard map prepared in step 4a. They will analyze the degree of exposure, physical as well as social (including capacity) vulnerability and identify the levels of vulnerability of individual houses or local economic sectors (e.g. agriculture, education, commercial etc.) to flood.

Step 5b.Scientific vulnerability analysis. Similar steps will be applied by the TA-7276-REG team using damage trend maps if available. In case of unavailability they will be derived at least on the basis of satellite imaginary and/or local surveys.

Step 6a. Community-based flood risk mapping. The community will discuss and make decision on the areas or sectors of the community which are exposed to high flood risk. They will compare the hazard context of particular areas, developed in step 4a within the community and the vulnerability as discussed in step 5a.

Step 6b.Scientific flood risk mapping. The same as in step 6a can be done in parallel for the scientific maps by the TA-7276-REG team.

Step 7. Show the different scenario flood hazard maps. Aim of this step is to convince the community about possible extreme situations. Only if agreed by the community, community-based flood hazard maps which had been prepared in step 4a will be revised. In case they are changed, the community will be asked to change their risk maps developed in steps 6A and 6B while the vulnerability situation may remain unchanged.

Step 8. Flood hazard maps which have been revised in agreement with the community lead to flood emergency response mapping. Response mapping has the following meaning:

1. Preparation of CB flood emergency response map that shows evacuation shelters, escape routes, etc.
2. Rules and regulations for emergency situations, community-based standing order for disaster such as documentation on emergency situation management and regulation guidelines.

During the execution of Steps 6 to 8 technical facilities such as the IFAS system and/or a set of precipitation/stream gauging stations should have been set up. A selected group of community members should have been already trained to i) operate the instruments and/or ii) initiate orderly disaster risk management e.g. in case an IFAS based flood alert is issued.

Step 9. The community will conduct a first drill exercise based on the outcome of Step 8. Lessons should be drawn from the drill exercise, major shortcomings identified as well as limitations and/or problems pointed out. All activities should be witnessed by BPBD or representatives of local authorities.

Step 10. Revision of step 8, so new flood emergency response map will be prepared and rules and regulations will be revised thoroughly.

Step 11. A second round of evacuation drills will be conducted on the basis of revised response mapping.

The activities foreseen by the TA ends here, whereby it is assumed that the BPBD and other responsible authorities will keep monitoring the community activities regularly and will also extend the knowhow to other adjacent communities.

4. Project Outputs Related to IFAS Installation and Training Workshop

4.1 Collection and Analysis Results of Data Other than Rainfall

4.1.1 Flood disaster record from BBWS Bengawan Solo

BBWS Bengawan Solo produced an inundation map in Bojonegoro area and annual report about flood disaster in Bengawan Solo River Basin in 2007, 2008, 2009. These books have useful information for creating run-off analysis model using IFAS.

BBWS Bengawan Solo has been publishing annual flood reports which include following items since 2007;

- Daily rainfall at every station.
- Daily water level at every station.
- Inundation map.
- Affected data (ex: the number o inundated houses, casualties etc.).

They reported 3 times so far as follows;

- 2007-2008 (2007 rainy season (October) to 2008 rainy season (May)).
- 2008-2009 (the same as above).
- 2009-2010 (the same as above).

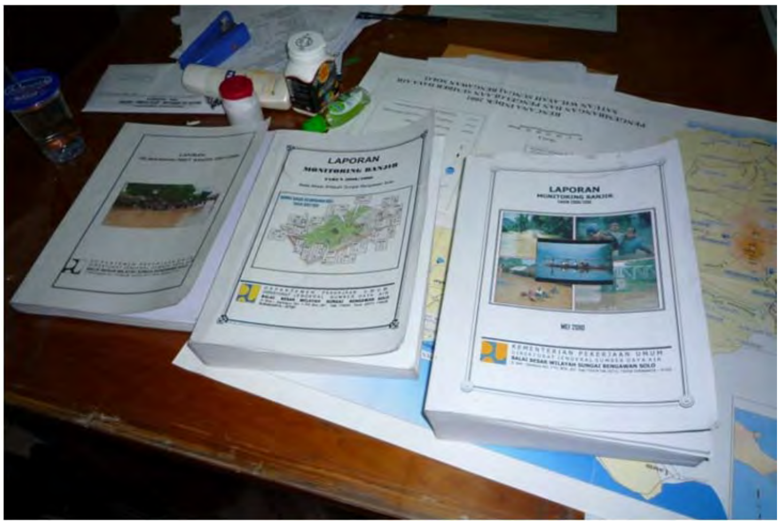

Figure 4.1 Annual Flood Report (Laporan Monitoring Banjir)

Based on these reports, it is known as follows:

- The return period of flood in 2007 exceeded once in 100 years.
- Flood alert system is expected to let people prepare for the flood (ex: let the properties and livestock put in higher locations beforehand).

Figure 4.1 shows the picture of Annual (2007 – 2009) Flood Report Book prepared by BBWS Bengawan Solo.

4.1.2 Basin Boundary Data

ICHARM has created run-off analysis model using IFAS. ICHARM examined some data sources to create the run-off analysis model in Bengawan Solo river basin.

First, ICHARM tried to create river channel network using only digital elevation map, but it’s difficult to create river channel network in the flat plain area. Figure 4.2 shows a result of creating river channel network using only Global Digital Elevation Map (DEM). So it is necessary to make a basin boundary data at first. Creating basin boundary process is shown as follows.

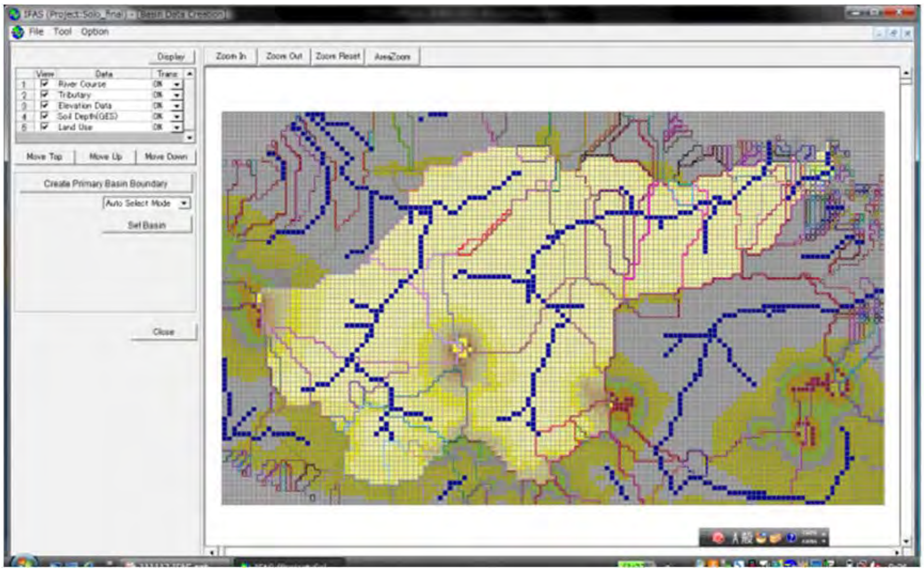

Figure 4.2 River channel network using only DEM

National consultant prepared the basin boundary data, but a part of the basin was missing. ICHARM repaired this data combining with Hydrological data and map based on SHUTLE Elevation Delivatives at multiple Scales (HydroSHEDS) to create run-off analysis model in IFAS training.

Concerning the basin boundary data of Bengawan Solo River Basin, two data sets were obtained. One is the data from local consultant and another is the data of “HydroSHEDS” from United States Geological Survey (USGS) as shown in Figure 4.3.

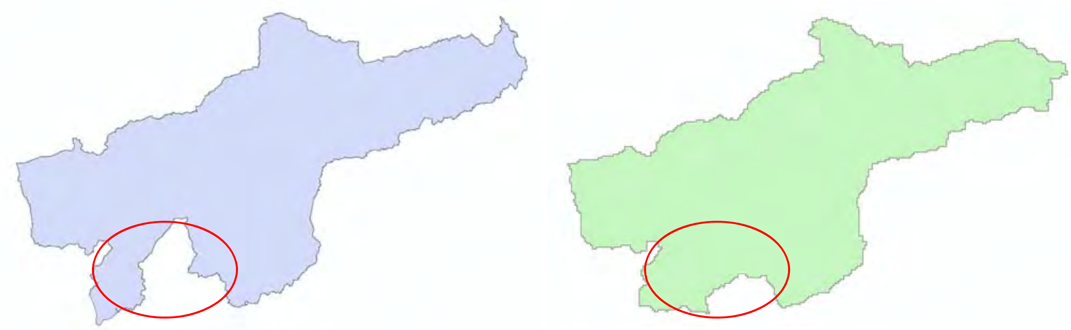

Figure 4.3 Differences of Basin Boundary Data
(Left: Data from Local Consultant, Right: HydroSHEDS)

To reveal the actual river basin, the river flow data developed by BBWS Bengawan

Solo was referred, as shown in Figure 4.3. According to this river flow, it is clear that the basin boundary data was lacking in part of Bengawan Solo River Basin.

ICHARM produced the combined basin boundary data which seemed to be feasible to model actual basin boundary. The combined data is based on the data from local consultant and the missing area was replaced with HydroSHEDS by USGS as shown in Figure 4.4 and Figure 4.5. This combined basin boundary data were used in the flood forecasting system in Bengawan Solo River Basin.

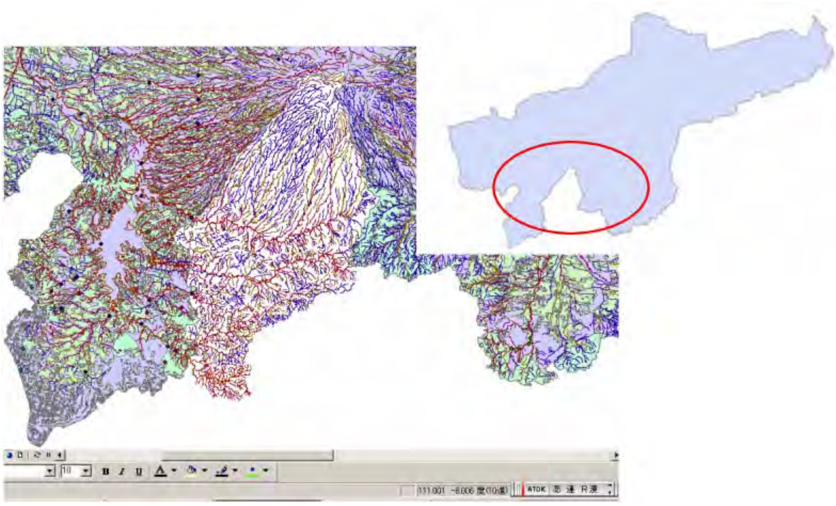

Figure 4.4 River Flow in Southwest Part of Bengawan Solo River Basin

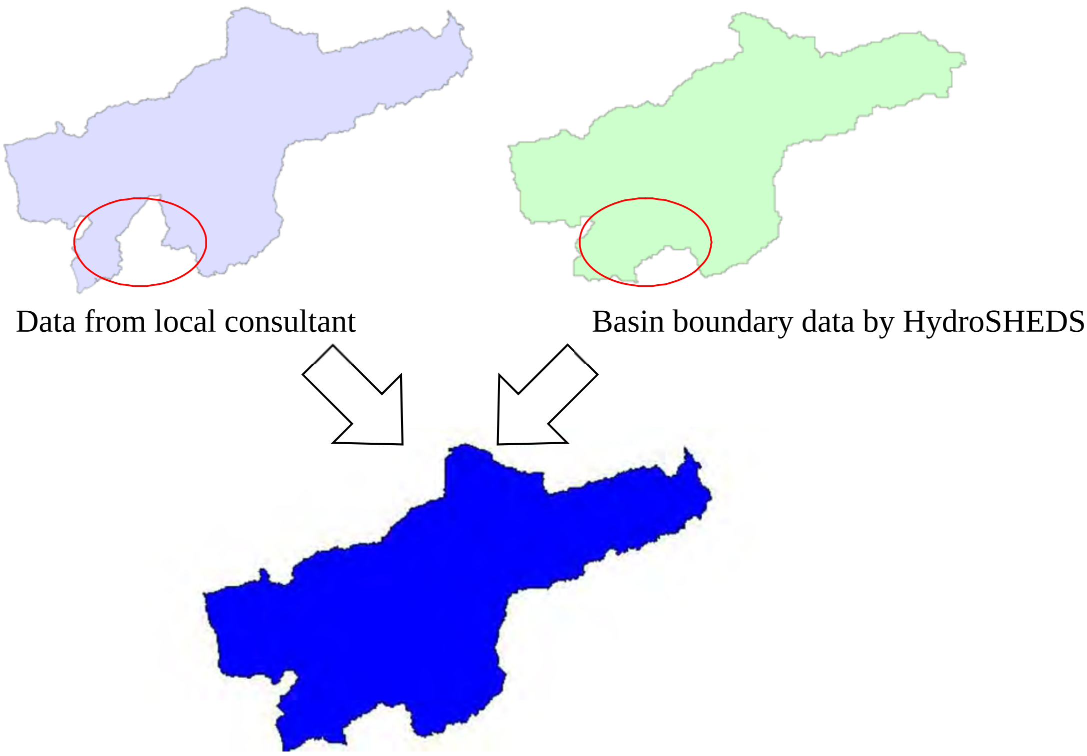

Figure 4.5 Combined Basin Boundary Data of Bengawan Solo River Basin

1) Basin Boundary of Bengawan Solo River and Tributaries Based on Shuttle Radar Topography Mission (SRTM) [90m*90m]

   International consultant made a sub-basin boundary data using digital elevation map namely SRTM 90m*90m, which is measured by Space shuttle.

2) Flow Direction

   International consultant identified a flow direction in Bengawan Solo River Basin. ICHARM used this data for creating river channel network by revising elevation and comparing results.

3) ICHARM revised basin boundary data again using data collected by international consultant and national consultant.

4) Elevation Data

   Figure 4.6 shows basin boundary data and flow accumulation in Bengawan Solo River Basin Analyzed using SRTM, whereas Figure 4.7 shows the revised basin boundary data of Bengawan Solo River Basin.

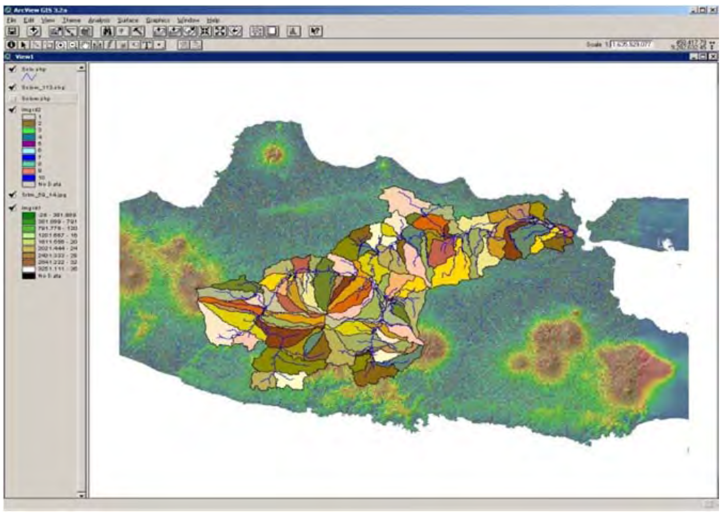

Figure 4.6 Basin Boundary Data and Flow Accumulation in Bengawan Solo River Basin Analyzed using SRTM

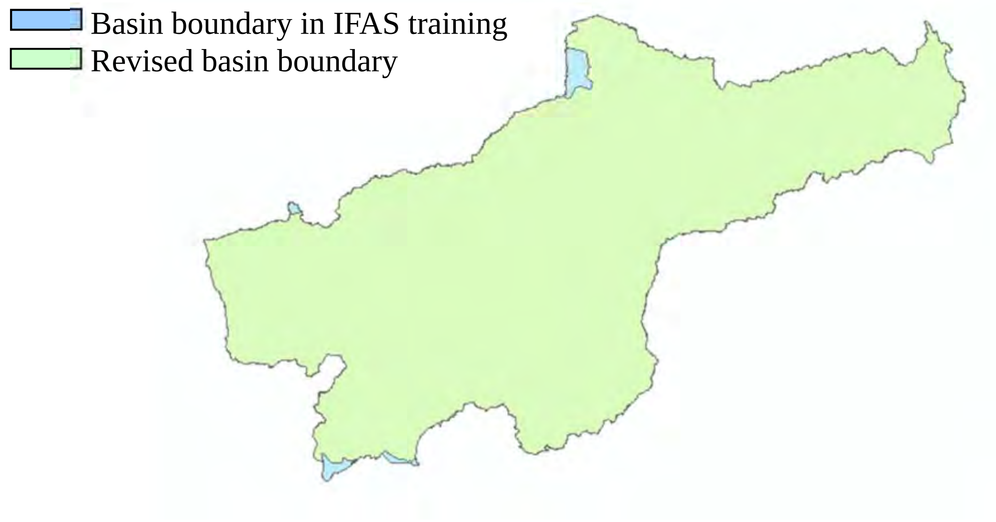

Figure 4.7 Revised Basin Boundary Data of Bengawan Solo River Basin

ICHARM collected 4 types of digital elevation data. And ICHARM selected Global map. Then, ICHARM revised elevation data to delineate appropriate river course. Figure 4.8 shows river course in Bengawan Solo river basin. ICHARM delineate river course tracking on Google Earth. And IFAS exported river channel network to Google Earth. ICHARM compared these two river course as drawn in Figure 4.9.

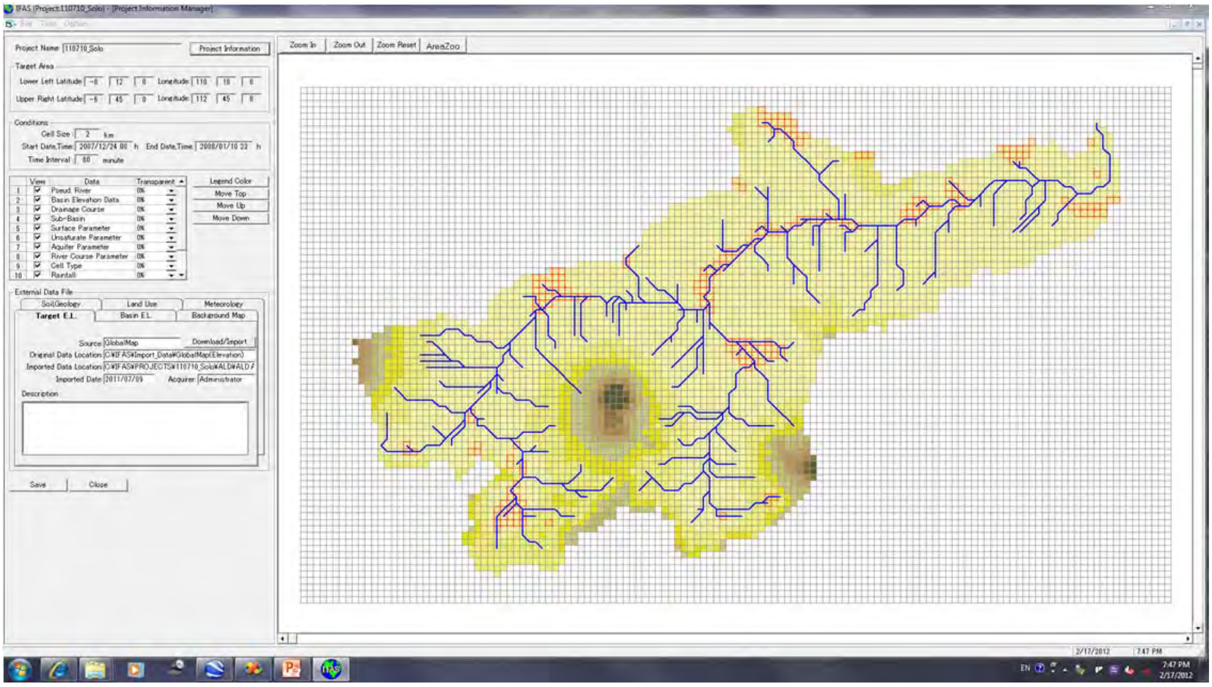

Figure 4.8 River channel network of Solo river using IFAS

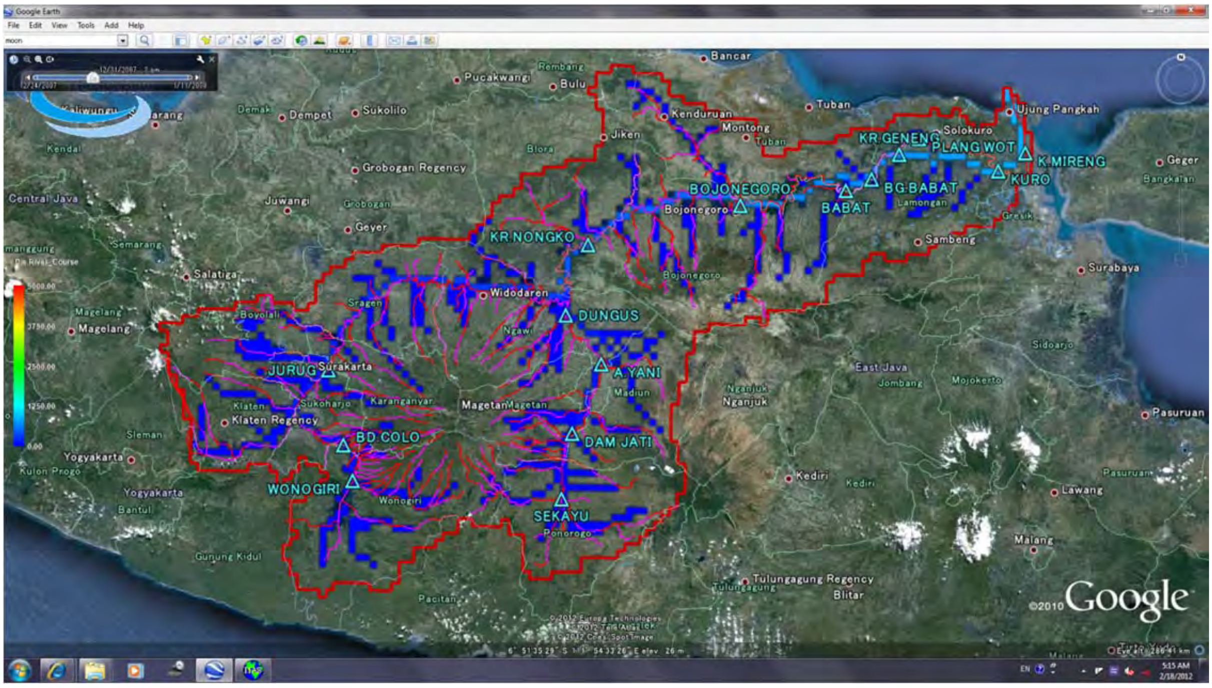

Figure 4.9 Comparison of river course between on Google Earth and IFAS model

4.1.3 Meander of Bengawan Solo river

Bengawan Solo river has so much meander, but created river channel network looks like a straight open canal. This means IFAS model might be short cut the length of the river course. ICHARM compared the length of IFAS model to length of actual Bengawan Solo river. ICHARM tuned parameter of River Length Coefficient (RLCOF) in the parameter manager. Table 4.1a, 4.1b shows the comparison of length of the river course.

Table 4.1a Comparison result of meander of Bengawan Solo river

		Actual distance (km)	IFAS			Calcurated co.	Average	sub-basin No.
			Orthogonal	Diagonal	distance (km)			
Solo river	1	20	5	1	12.8	1.5625		1
	2	20	1	1	4.8	4.1667		2
	3	20	4	3	16.4	1.2195	1.1909	10
		20	0	6	16.8	1.1905		
		20	3	4	17.2	1.1628		
	4	20	3	4	17.2	1.1628		12,13,15
	5	20	2	0	4	5.0000		16
	6	20	4	0	8	2.5000		17
	7	20	3	1	8.8	2.2727		18
	8	20	5	0	10	2.0000		19,21,126
	9	20	4	2	13.6	1.4706		28
	10	20	3	2	11.6	1.7241		30,33,34
	11	20	1	4	13.2	1.5152		38
	12	20	2	2	9.6	2.0833		40
	13	20	1	2	7.6	2.6316		70
	14	20	2	1	6.8	2.9412		74
	15	20	5	0	10	2.0000		77
	16	20	4	2	13.6	1.4706	1.6612	78
		20	4	1	10.8	1.8519		
	17	20	5	2	15.6	1.2821		79,80
	18	20	1	4	13.2	1.5152		83,84
	19	20	3	3	14.4	1.3889		86,87,89
	20	20	3	5	20	1.0000		90,91,111
	21	20	3	3	14.4	1.3889		93
	22	20	4	4	19.2	1.0417		95,99
	23	20	5	2	15.6	1.2821		100,102,104

Table 4.1b Comparison result of meander of Madiun river

		Actual distance (km)	IFAS			Calcurated co.	Average	sub-basin No.
			Orthogonal	Diagonal	distance (km)			
Madiun	24	20	3	2	11.6	1.7241		41
	25	20	3	7	25.6	0.7813		47
	26	20	3	4	17.2	1.1628		49,51,52
	27	20	4	2	13.6	1.4706		54,55,56,58
	28	20	3	3	14.4	1.3889	1.2897	59
		10	0	3	8.4	1.1905		

ICHARM calculated river discharge using these parameters for lower part of Bengawan Solo river. Measured discharge is calculated using H-Q rating curve provided by BBWS Solo. Figure 4.10 shows analysis result by using tuned parameters.

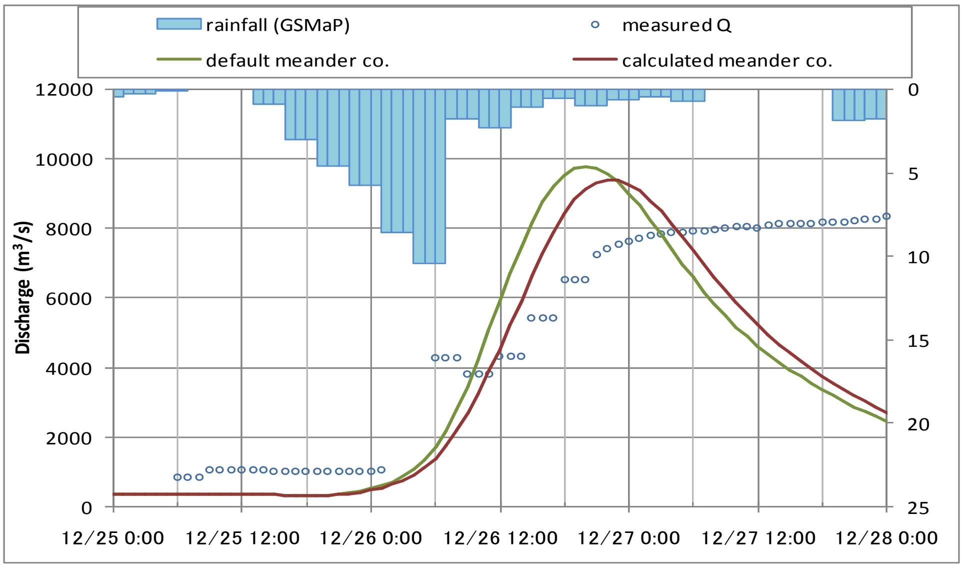

Figure 4.10 Result of run-off analysis at Bojonegoro

4.1.4 Land Use Data

According to Globalmap, Landcover data in Bengawan Solo river basin is shown on Figure 4.11. ICHARM select the Globalmap (Landvcover) as Land use data for IFAS modeling and parameter estimation. IFAS already has convert function Land use data to parameter data for initial value of the model parameters. Table 4.2 shows a classification list from Globalmap (Landcover) data to IFAS parameter classification of surface tank and Legend of landcover and Legend of classification. Each classification has parameter sets as default values. Figure 4.12 shows Classification of Surface tank parameters in Solo river basin.

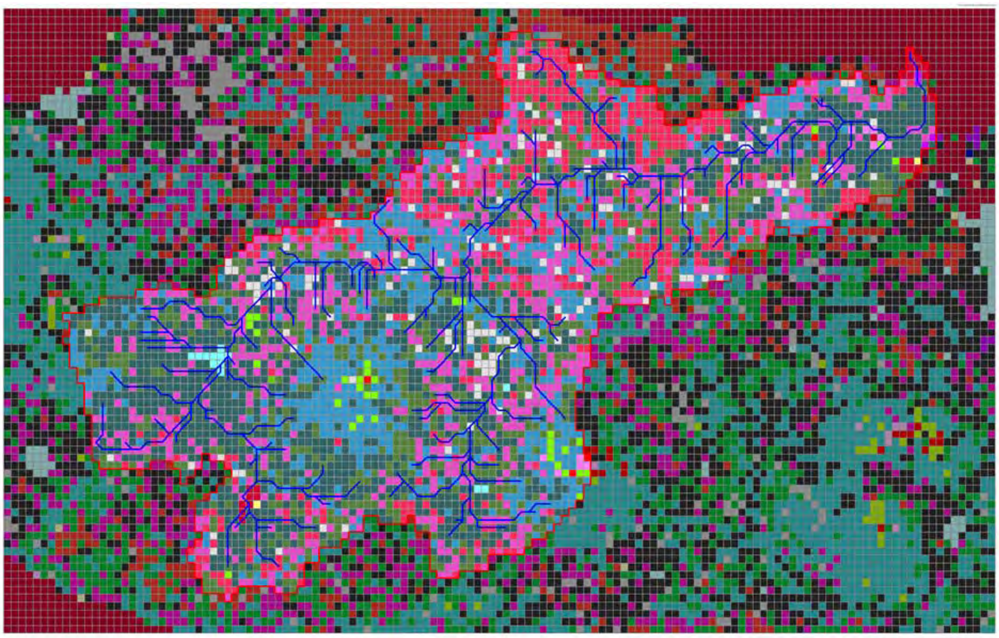

Figure 4.11 Land cover data in Solo river basin (data source : Global map)

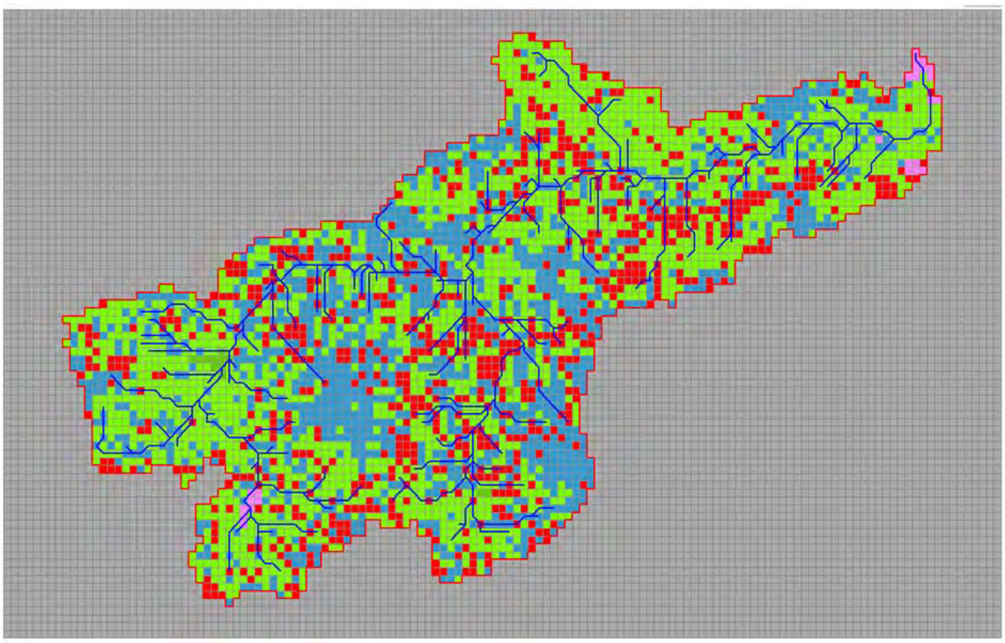

Figure 4.12 Classification of Surface parameters in Solo river basin

Table 4.2 Classification of Global map Land cover data

Classification	Description	Code value	Class in IFAS
Broadleaf Evergreen Forest	The main layer consists of broadleaved evergreen closed to open trees. The crown cover is between 100 and 40%. The height is in the range of >30 - 3m.	1	1
Broadleaf Deciduous Forest	The main layer consists of broadleaved deciduous closed to open trees. The crown cover is between 100 and 40%. The height is in the range of >30 - 3m.	2	1
Needleleaf Evergreen Forest	The main layer consists of needleleaved evergreen closed to open trees. The crown cover is between 100 and 40%. The height is in the range of >30 - 3m.	3	1
Needleleaf Deciduous Forest	The main layer consists of needleleaved deciduous closed to open trees. The crown cover is between 100 and 40%. The height is in the range of >30 - 3m.	4	1
Mixed Forest	The main layer consists of broadleved or needleleaved closed to open trees. The crown cover is between 100 and 40%. The height is in the range of >30 - 3m.	5	1
Tree Open	The main layer consists of open trees. The crown cover is between 40% and (20-10)％. The height is in the range of >30 - 3m.	6	1
Shrub	The main layer consists of closed shrubland. The crown cover is more than 15%.The height is in the range of >0.3 - 5m. Plantation and orchard classified to shrub are included.	7	2
Herbaceous	The main layer consists of closed herbaceous vegetation. The crown cover is more than 15%. The height is in the range of 3 - 0.03m.The main layer consists of open herbaceous vegetation.	8	2
Herbaceous with Sparse Tree/Shrub	The main layer consists of closed herbaceous vegetation. The crown cover is more than 15%. The height is in the range of 3 - 0.03m.	9	2
Sparse vegetation	The main layer consists of sparse herbaceous vegetation. The crown cover is between (20-10) and 1%. Grass height between 3-0.03 meters and trees are 7-2 meters.	10	2
Cropland	Land covered by herbaceous crops. This cover excludes paddy field.	11	3
Paddy field	Land covered by graminoid crops. Flat surfaces with irrigation channels. The main cover type is rice paddy.	12	3
Cropland / Other Vegetation Mosaic	Primarily vegetated areas containing more than four percent vegetation during at least two months a year. The vegetative cover is characterized by the removal of the (semi)natural vegetation and replacement with a vegetative cover resulting from human activities.	13	3
Mangrove	The main layer consists of closed to open woody vegetation. The crown cover is between 100 and 15%. The height is in the range of 7 - 2m. Water is saline (more than 10000 ppm TDS).	14	3
Wetland	The main layer consists of closed to open woody vegetation. The crown cover is between 100 and 15%. The height is in the range of 7 - 2m. Water is either fresh (less than 1000 ppm TDS) or brackish (between 1000 and 10000 ppm TDS).	15	3
Bare area,consolidated(gravel,rock)	The land cover consists of consolidated material(s).	16	2
Bare area,unconsolidated (sand)	The land cover consists of unconsolidated material(s).	17	2
Urban	The cover is artificial and a result of human activities.	18	4
Snow / Ice	The snow/ice covers the surface for more than 9 months each year in all years.	19	5
Water bodies	The land cover consists of artificial water bodies or natural water bodies.	20	5

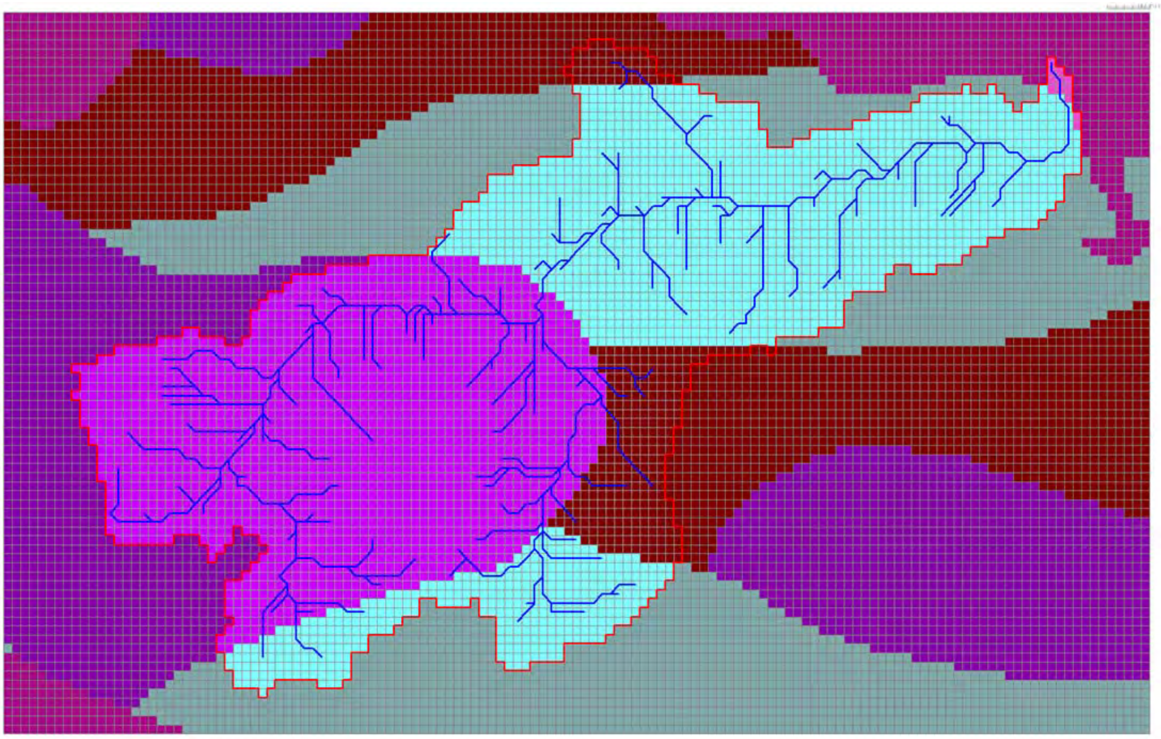

Figure 4.13 Geological data in Solo river basin (data source: CGMW)

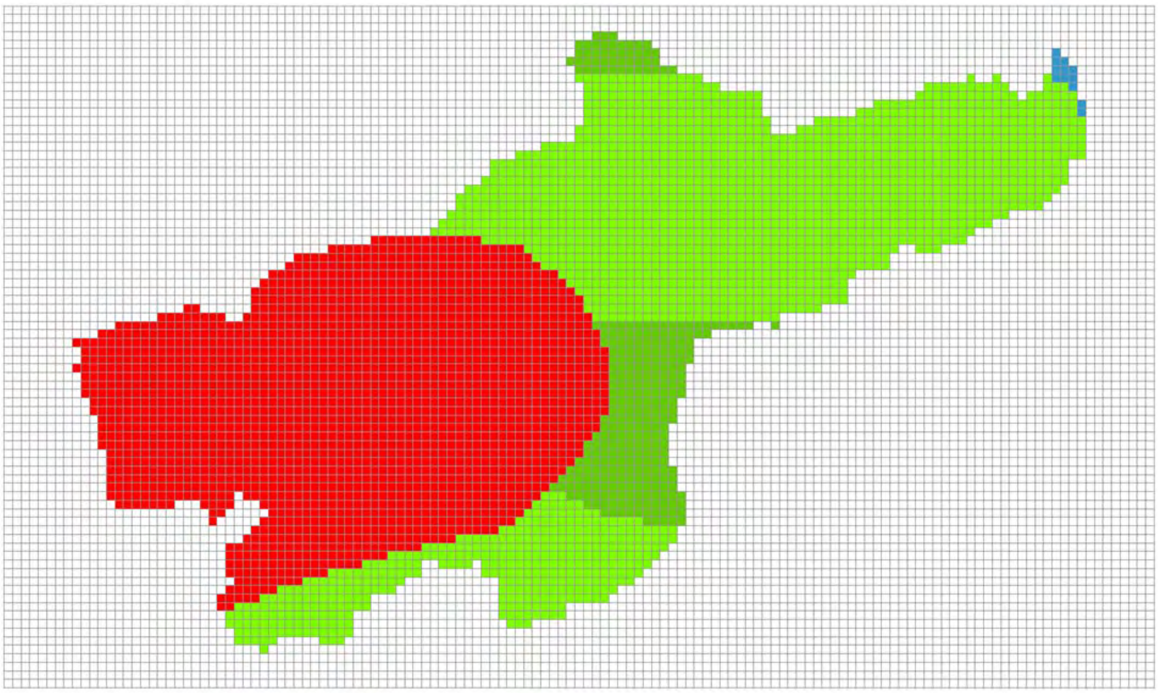

Figure 4.14 Classification of Aquifer parameters in Solo river basin

4.2 Model calibration

4.2.1 Sensitivity analysis

ICHARM conducted sensitivity analysis for parameter tuning. Input data are GSMaP_NRT modified by ICHARM and 3B42RT. Jurug has selected as an evaluation point. ICHARM repeated changing parameters and comparison with measured discharge.

a) Hydraulic conductivity

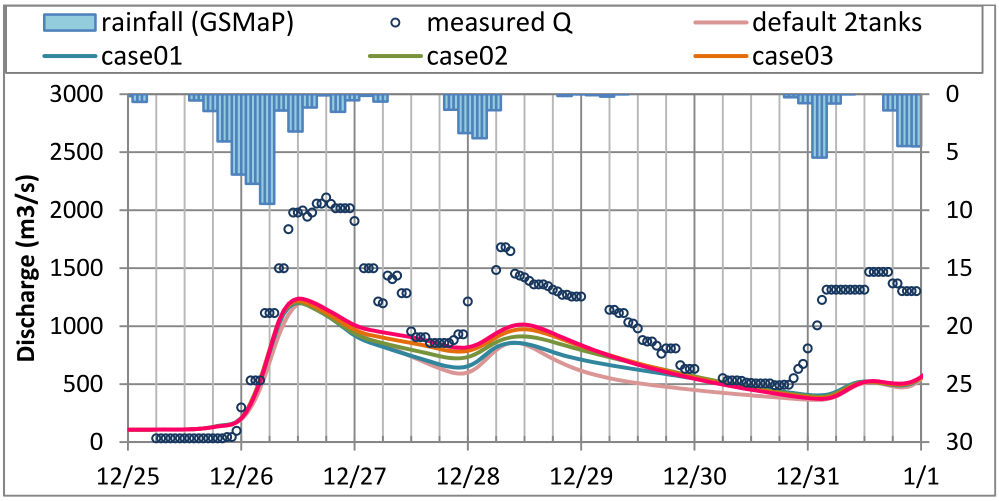

Figure 4.15 Sensitivity analysis of hydraulic conductivity at Jurug

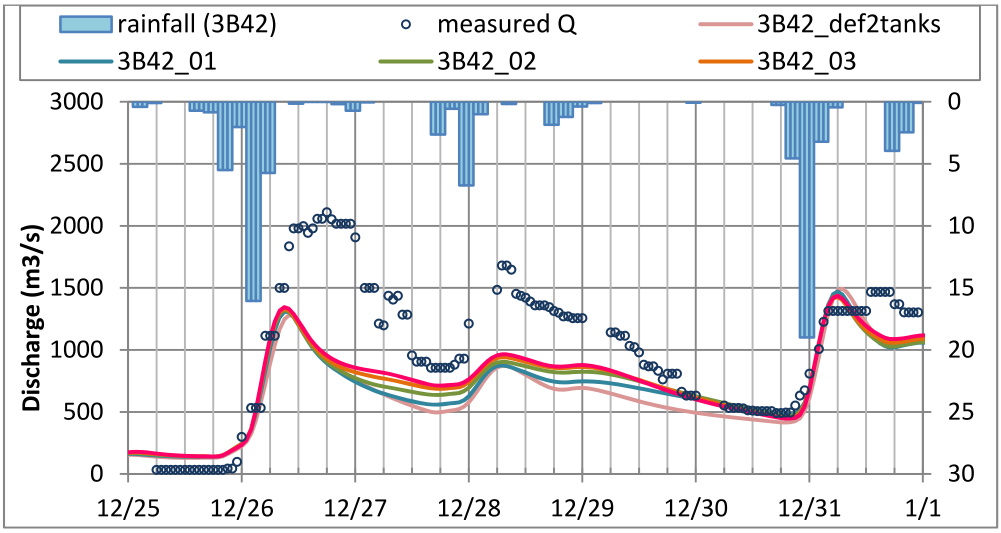

Figure 4.16 Sensitivity analysis of hydraulic conductivity

Table 4.3 Result of sensitivity analysis of hydraulic conductivity

		unit	Default	case01	case02	case03	case04
SKF	Land use type 1	cm/s	0.0005	0.001	0.0015	0.002	0.0025
	Land use type 2		0.00002	0.00004	0.00006	0.00008	0.0001
	Land use type 3		0.00001	0.00002	0.00003	0.00004	0.00005

b) Hydraulic conductivity

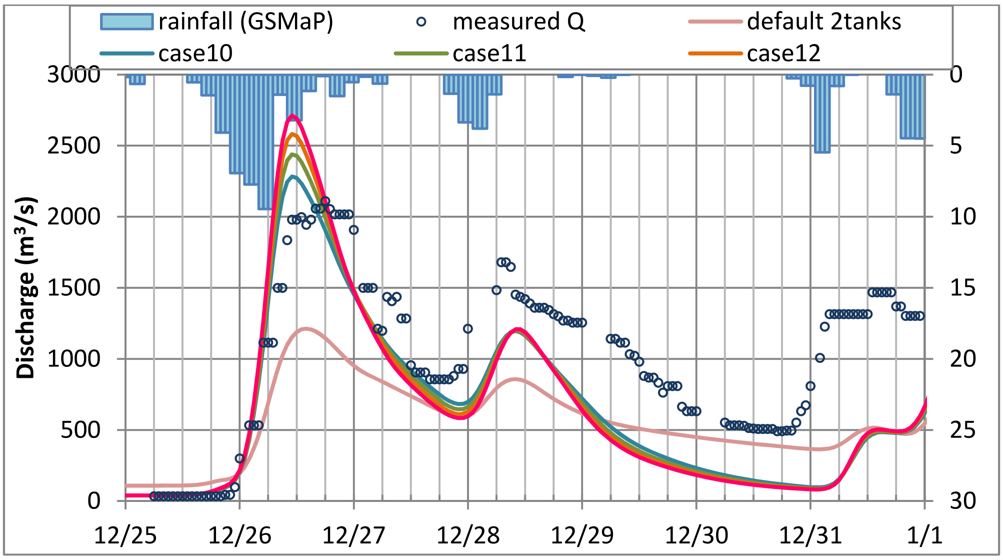

Figure 4.17 Sensitivity analysis of hydraulic conductivity

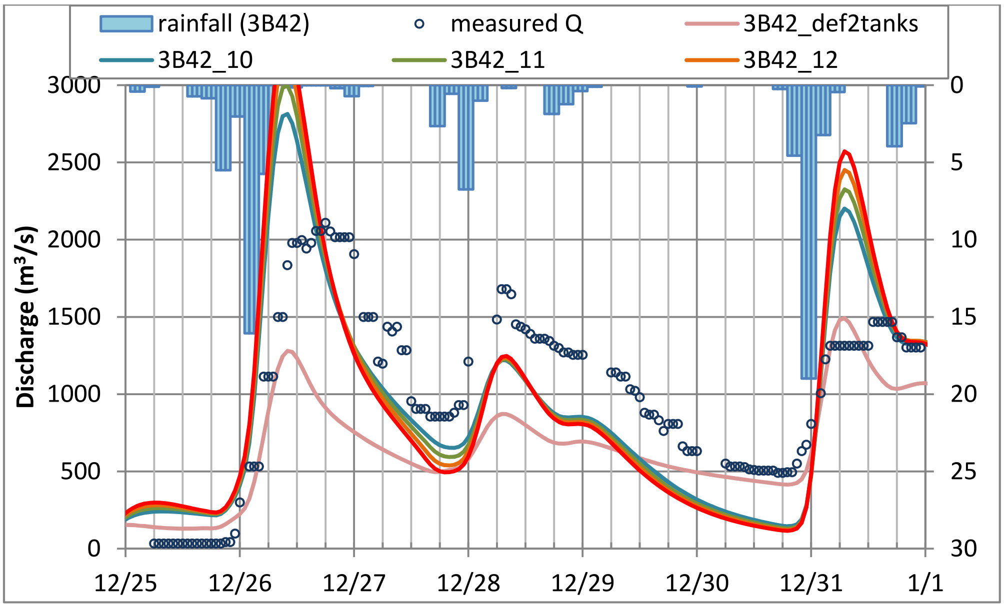

Figure 4.18 Sensitivity analysis of hydraulic conductivity

Table 4.4 Result of sensitivity analysis of hydraulic conductivity

		unit	Default	case10	case11	case12	case13
SKF	Land use type 1	cm/s	0.0005	0.0025	0.003	0.0035	0.0040
	Land use type 2		0.00002	0.0001	0.00012	0.00014	0.00016
	Land use type 3		0.00001	0.00005	0.00006	0.00007	0.00008

c) Run-off coefficient of unconfined groundwater

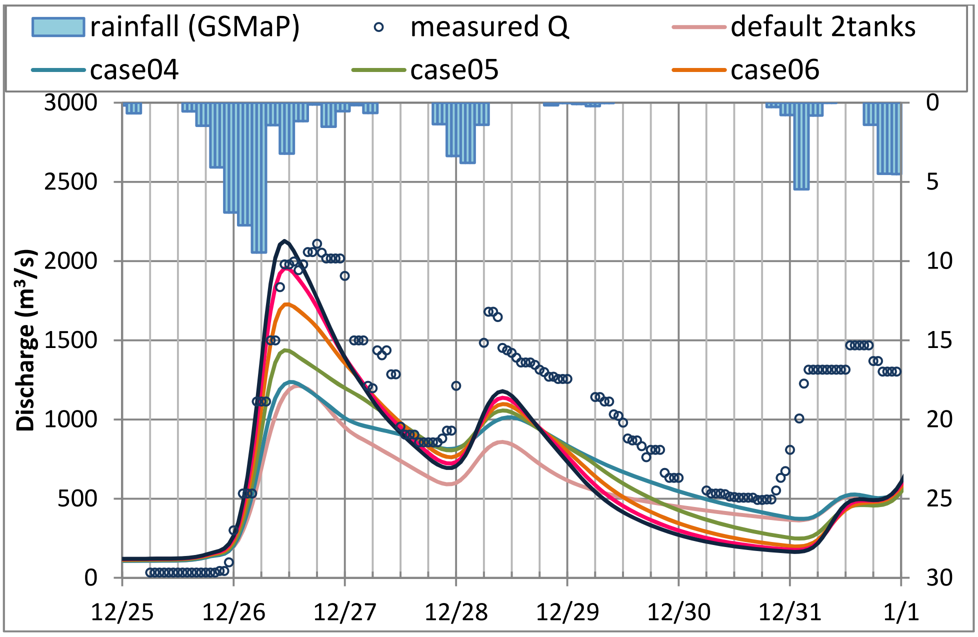

Figure 4.19 Sensitivity analysis of Run-off coefficient of unconfined groundwater

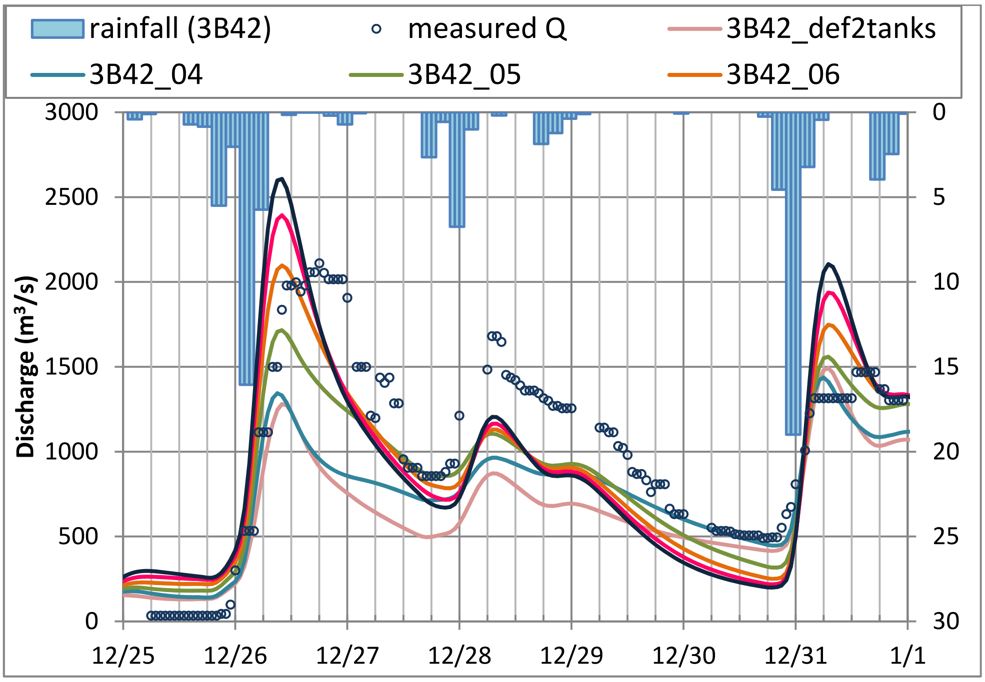

Figure 4.20 Sensitivity analysis of Run-off coefficient of unconfined groundwater

Table 4.5 Result of sensitivity analysis of unconfined groundwater

	Default	case05	case06	case07	case08
AUD	0.1	0.2	0.3	0.4	0.5

d) Run-off coefficient of confined groundwater

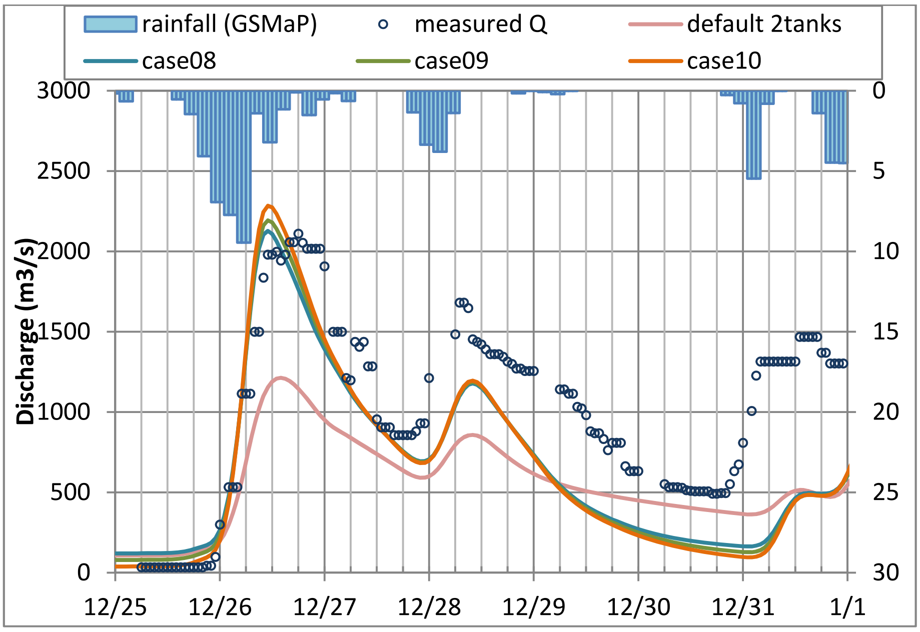

Figure 4.21 Sensitivity analysis of Run-off coefficient of confined groundwater

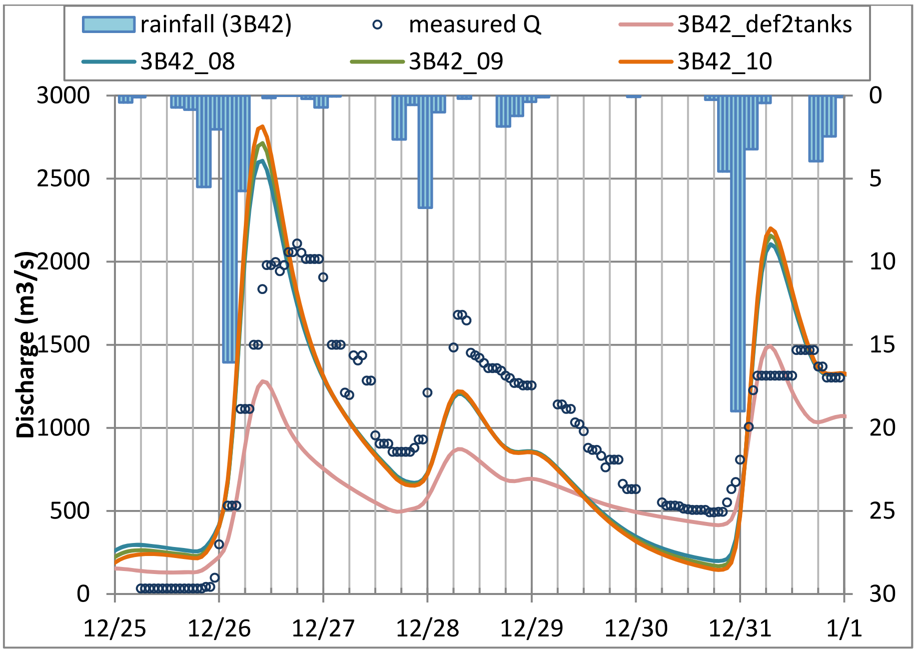

Figure 4.22 Sensitivity analysis of Run-off coefficient of confined groundwater

Table 4.6 Result of sensitivity analysis of confined groundwater

	Default	case08	case9	case10
AGD	0.003	0.003	0.002	0.001

ICHARM decided the parameter of IFAS in Table 4.7. But, this is current estimation. In the future, parameter tuning and implementation of ground observation gauges should be continued by local engineers. This is the most important point to be better flood disaster management.

4.2.2 Calibration

ICHARM conducted sensitivity analysis of model parameters.

Table 4.7 Result of sensitivity analysis

	parameter	Unit	Default	tuned	case01	case02	case03	case04	
Surface	SKF	cm/s	0.0005	0.009	←	←	←	←	
			0.00002	0.00036	←	←	←	←	
			0.00001	0.00018	←	←	←	←	
Aquifer	AUD	-	0.1	0.3	←	←	←	←	
	AGD	1/day	0.003	0.001	←	←	←	←	
	HIGD	m	2	←	←	←	←	←	
River	RLCOF	-	1.4	1.4	Measured (Google Earth)	Measured (Google Earth)	Measured (Google Earth)	Measured (Google Earth)	Upper area
			1.4	1.4	Measured (Google Earth)	3.0	4.0	5.0	Lower Solo

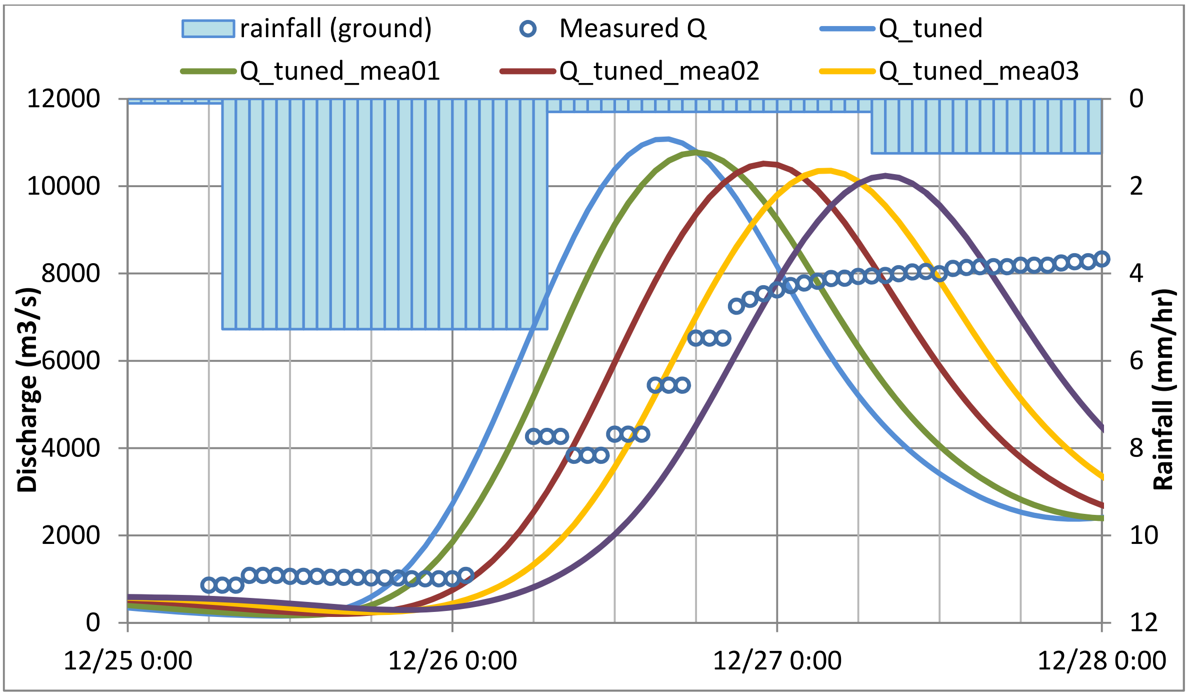

Figure 4.23 Sensitivity analysis of Run-off coefficient

4.3 Coefficient of Modification Equation for Satellite Based Rainfall Data in Bengawan Solo River Basin

4.3.1 Concept of rainfall data used for flood forecasting system

In Bengawan Solo River Basin, BBWS is installing several hourly rainfall stations.

This result shows the number of hourly rainfall data (the density of rainfall observation stations) is not enough for flood runoff analysis.

Table 4.8 Hourly Rainfall Stations in Bengawan Solo River Basin

Name	lat/long	Dry Season						Rainy Season							
		Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09	Jan-10	Feb-10	Mar-10	Apr-10	May-10
Colo	○								○	○					
kalijambe	○								○	○					
klaten	○								○	○	○				
nepen	○								○	○	○				
tawangmar	○								○	○	○				
pabelan	○		○	○	○	○	○	○	○	○	○				
Jatisrono											○	○	○	○	○
Madiun											○	○	○	○	○

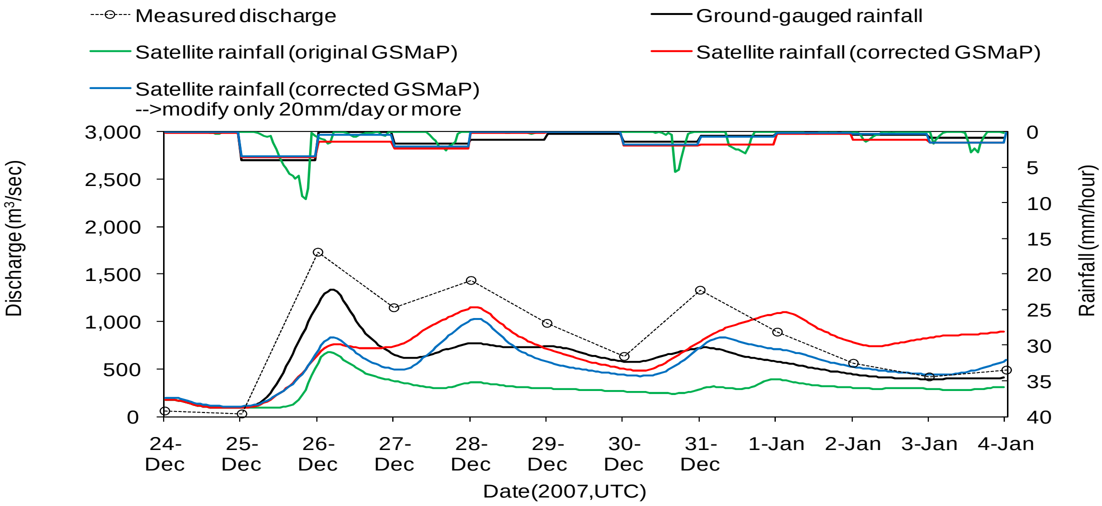

Figure 4.24 Runoff Analysis Results by Using Hourly Rainfall (Jurug)

For ungauged basins which do not have sufficient hydrological information data such as rainfall, satellite-based rainfall data is effective to conduct flood runoff analysis. For example, Global Satellite Mapping of Precipitation (GSMaP) provides "hourly" global rainfall distribution in 0.1 degree (approximately 10km mesh) with 4 hour data latency after observation. This temporal and spatial resolution can be effective for flood forecasting. However, the accuracy of satellite-based rainfall data is often underestimated comparing with ground-based rainfall data. To improve the accuracy, there are two possible approaches as follows;

a) "Real-Time Merging Satellite-Based and Ground-Based Rainfall Data"

Satellite-based and ground-based rainfall data can be merged in real time by using real-time ground-based rainfall data which can be obtained through a telemetric system (if it's already installed). In this case, Thiessen polygon based, Inverse Distance Weighted Method (IDWM) or Co-kriging method can be applied to

merge them. Inverse Distance Weight Method was applied to calculation result in Figure 4.24. However, the accuracy of the result was not enough for flood forecasting. Although other methods (IDW and Co-kriging) should be validated, the number of hourly rainfall stations is insufficient even in other methods.

b) Statistical Modification Method for Satellite-Based Rainfall Data by Using Past Rainfall Data

By using the relation between satellite-based and ground-based rainfall data, modification coefficient can be obtained. In ICHARM, modification method for GSMaP[1), 2)] has developed in ICHARM. If there are some past data of GSMaP and ground-based rainfall, the relation between them can be found. This method focuses on the relation between the accuracy of GSMaP and the speed of rainfall area movement which can be obtained from GSMaP.

In case of application of “Real time merging method”[4], real time ground-based rainfall data are necessary. In BBWS Bengawan Solo, two rainfall data (observed at Jurug and Cepu) are provided in real time. However, these rainfall data could not be confirmed and collected in this project. Furthermore, the density of ground rainfall is not enough for flood forecasting as shown in Figure 4.25. It’s still under implementing by BBWS Bengawan Solo. As a result, “Real time merging method” is impossible for application. (If higher density of real time rainfall data can be obtained, the validation using the merged rainfall data should be conducted.)

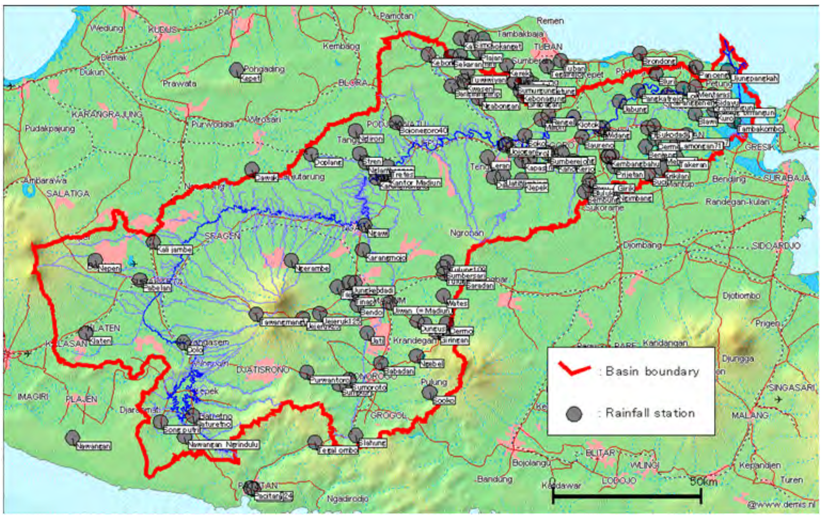

Figure 4.25 Rainfall Observation Stations in Bengawan Solo River Basin

On the other hand, several past hourly and daily rainfall data have been collected. By using these data, “Statistical modification method”[5] can be conducted. In this project, the validation of this modification method is applied and the modification method in Bengawan Solo River Basin was developed and

[4]The proposal of correction method using the movement of rainfall area on satellite-based rainfall information by analysis in the Yoshino River Basin, Yoshiki Shiraishi, Kazuhiko Fukami and Hironori Inomata, Annual Journal of Hydraulic Engineering, JSCE, Vol.53, 2009, February pp.385-390 (in Japanese)

[5]Applicability of GSMAP correction method to typhoon “Morakot” in Taiwan Go Ozawa, Yoshiki Shiraishi Hironori Inomata and Kazuhiko Fukami, Annual Journal of Hydraulic Engineering, JSCE, Vol.55, 2011, February (submitted)

finally the effect of the modification method on the accuracy improvement was revealed in following sections. Both hourly and daily rainfall data which have been recorded in this basin follows this procedure.

Table 4.9 Collected Daily Rainfall Stations Utilized for Validation

No.	Station Name	No.	Station Name	No.	Station Name	No.	Station Name	No.	Station Name
1	Babadan	27	Gaplok	53	Kedungpring	79	Ngawi	105	Sooko
2	Babat	28	Giringan	54	Kembangbahu	80	Ngebel	106	Stren
3	Balen	29	Gondang	55	Kendung	81	Ngerambe	107	Suci
4	Bangilan	30	Gondang	56	Kepet	82	Ngimbang	108	Sugihan
5	Baru / Girik	31	Gondang	57	Kerek	83	Nglambangan	109	Sukodadi
6	Baturetno	32	Grabagan	58	Kerjo	84	Nglirip	110	Sumberejo
7	Baureno	33	Jabung	59	Klaten	85	Ngliron	111	Sumbersari
8	Belikanget	34	Jati	60	Klepek	86	Ngolahan	112	Sumoroto
9	Bendo	35	Jatiblimbing	61	Klotok	87	Pabelan	113	Sumurgung
10	Benjeng	36	Jejeruk	62	Kr.binangun	88	Pacitan	114	Sungkur
11	Blawi	37	Jejeruk	63	Krikilan	89	Pacitan	115	Taji
12	Bluluk	38	Jiwan(= Madiun)	64	Kuro	90	Panceng	116	Takeran
13	Bluri	39	Jojogan	65	Kwasen	91	Pangkatrejo	117	Tambakombo
14	Bojonegoro	40	Jungke	66	Lamongan	92	Plajan	118	Tawangmangu
15	Bojonegoro	41	Kali jambe	67	Lamongan	93	Prijetan	119	Tegal ombo
16	Boropetung	42	Kanor	68	Leran	94	Purwantoro	120	Tegalrejo
17	Brondong	43	Kantor Madiun	69	Lowayu	95	Purwodadi	121	Tinap
18	Cau	44	Kapas	70	Maibit	96	Rengel	122	Tretes
19	Cawak	45	Karangbinangun	71	Mekuris	97	Saradan	123	Tuban
20	Cerme	46	Karanggeneng	72	Menganti	98	Sekaran	124	Tulung
21	Cermo	47	Karangmojo	73	Mentaras	99	Sembung	125	Tulung
22	Colo	48	Karangnongko	74	Montong	100	Sidayu	126	Tuwiwiyan
23	Dander	49	Kare	75	Nawangan	101	Simo	127	Ujungpangkah
24	Doplang	50	Kayenjoho	76	NawanganNgrindulu	102	Slahung	128	Wates
25	Duduksamp.	51	Kebonagung	77	Nepen	103	Soko	129	Widang
26	Dungus	52	Kebonharjo	78	Ngabongan	104	Song putri		

*Although several station names are duplicative since they are managed by different institute, location is different from each other.

4.3.2 Data Collection

e) Ground-Based (Gauged) Rainfall Data

In Bengawan Solo River Basin, there are several organizations to manage the basin and hydrological data such as rainfall, water level and so on. Especially, ICHARM collected rainfall data to develop the modification method for GSMaP and selected rainfall data which have coordinate information (Lat/Lon) of each station and eliminated if they do not have coordinate information. We also selected the period from December 2007 to December 2009 (latest data) since satellite-based rainfall data, GSMaP has been provided since December 2007.

To develop modification method for GSMaP (satellite-based rainfall data), 129 points of daily rainfall data in December 2007 to December 2009 were utilized. The data utilized in this project are attached in Annex-3.

Concerning the daily rainfall data, following three kinds of data with coordinate information (Lat/Lon) were collected;

(1) Daily rainfall in Bengawan Solo River Basin (28 points) managed by BBWS Bengawan Solo.
(2) Daily rainfall managed by Bojonegoro UPTPSA WS Bengawan Solo (78 points).
(3) Daily rainfall in Madiun River Basin (23 points).

Some of category (1) daily rainfall data have global coordinate (Lat/Lon) and the other have local coordinate (Indonesian coordinate). By combining Indonesian coordinate and coordinate (lat/lon), of observation points can be detected. Thus, 28 stations were able to be detected and utilized for validations.

Concerning category (2) daily rainfall data, 78-station data have each coordinate (Lat/Lon) and they are utilized for validations.

Concerning category (3) daily rainfall data, they have coordinate (Latitude/Longitude). These coordinate are described as degree, minute and second.

However, all points are located in strange location if it is based on these coordinate. On the other hand, all points are located in appropriate location if it is based on the coordinate in "degree" as shown in Figure 4.26. Thus, 23 of 3 daily rainfall data which have coordinate (Not as in degree, minute and second but as in degree) were utilized for validations.

Finally, daily rainfall data of 129 stations in Bengawan Solo River Basin are utilized for validations.

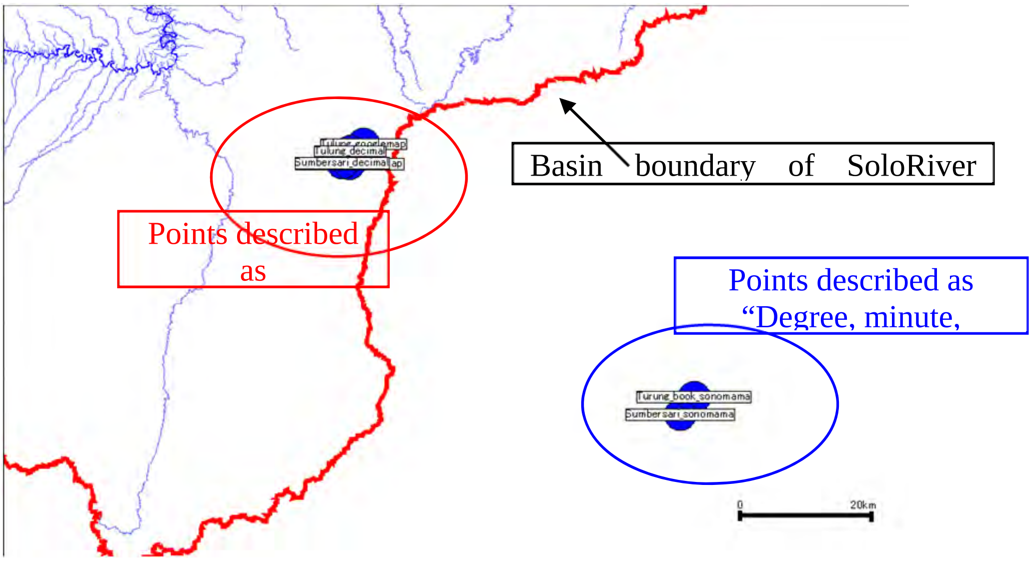

Figure 4.26 Difference of Coordinate in "Degree" and "Degree, Minute, Second"

f) Satellite-Based Rainfall Data

In this project, we planned to build up "the flood forecasting system using not only ground based but also satellite-based rainfall data". This needs to input "real time" satellite-based rainfall data

We use two satellite-based rainfall data, 1) GSMaP_NRT which is near real time satellite-based rainfall data delivered by Japan Aerospace Exploration Agency (JAXA) for free and 2) 3B42RT which is also near real time satellite-based rainfall data delivered by National Aeronautics and Space Administration (NASA) for free.

Table 4.10 Description of GSMaP_NRT and 3B42RT

Product name	3B42RT		GSMaP	
Builder	NASA/GSFC		JAXA/EORC	
Coverage	60N～60S			
Spatial resolution	0.25°		**0.1°**	
Time resolution	3 hours		**1 hour**	
Delay of delivery	10 hours		**4 hours**	
Coordinate system	WGS			
Date archive	Dec. 1997~		**Dec.2007~**	
Date source (Satellite/Sensor)	TRMM	TMI	TRMM	TMI
	Aqua	AMSR-E	Aqua	AMSR-E
	DMSP	SSM/I	DMSP	SSM/I
	NOAA	AMSU-B	DMSP	SSMIS
	IR		IR	

GSMaP_NRT is delivered by JAXA every 1 hour with 4-hour data latency. 3B42RT is delivered by NASA every 3 hours with 10-hour data latency. Then, it's called "Near real time satellite-based rainfall data". Figure 4.27 shows the image of GSMaP_NRT. We can know global rainfall distribution in near real time for free.

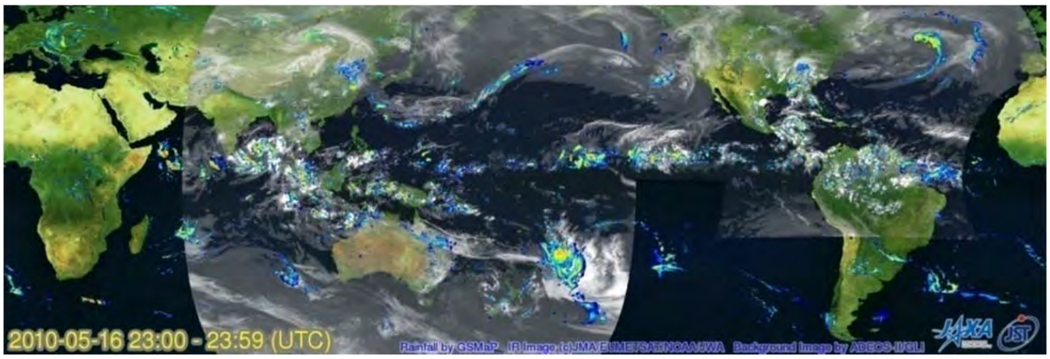

Figure 4.27 Image of Satellite-Based Rainfall Data, GSMaP_NRT

Courtesy of JAXA

For more information about GSMaP_NRT, refer to following JAXA web-site,

http://sharaku.eorc.jaxa.jp/GSMaP/documents.htm

For more information about 3B42RT, refer to following NASA web-site,

ftp://trmmopen.gsfc.nasa.gov/pub/merged/3B4XRT_doc.pdf

g) Validation Period

As mentioned above, data from December 2007 to December 2009 were collected. This period includes the biggest devastated flood in December 2007 and also includes both dry season and rainy season. The flood forecasting system is focusing on "flood". This means we have to concentrate on only rainy season except dry season which doesn't have heavy rainfall.

In this project, we validated by using rainfall data in only rainy season period, from 1 October to 30 April as shown in Figure 4.28

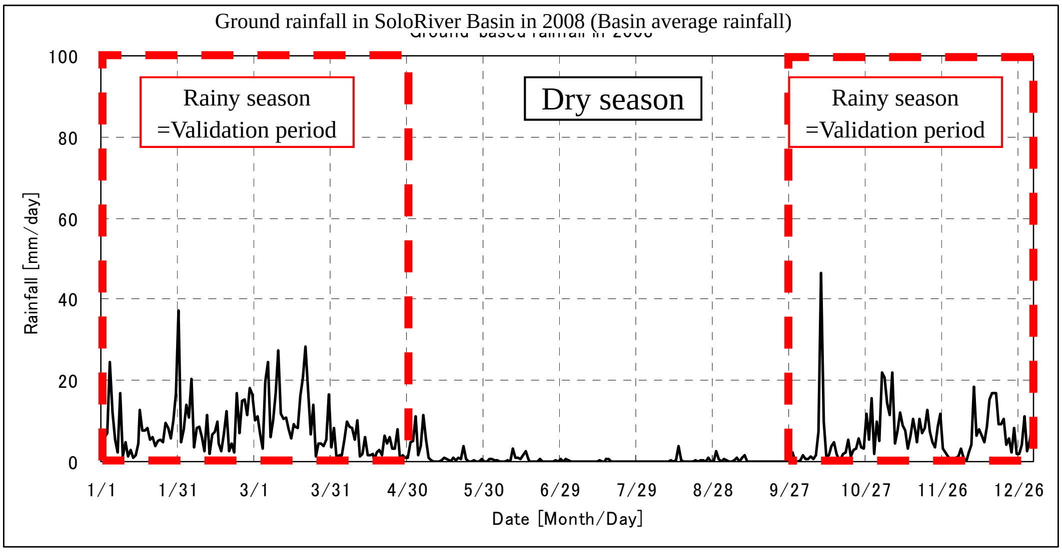

Figure 4.28 Selected Period for Validation

4.3.3 Validation Result of Satellite-Based Rainfall

In this project, we plan to build up "the flood forecasting system using satellite-based rainfall data".

By using collected rainfall data, we have conducted following items;

(1) Compare satellite-based (GSMaP_NRT) and ground-based rainfall data.
(2) Reveal the relation between the speed index of rainfall area of GSMaP and modification coefficient in Bengawan Solo River Basin necessary for modification method.
(3) Develop the modification method in Bengawan Solo River Basin
(4) Validate the accuracy of modified GSMaP

Concerning 3B42RT, no one has developed modification method for it yet. As a result, 3B42RT will be used for flood forecasting system directly without modification method. Since this session describes about modification method, the validation for development of modification method will be conducted only on GSMaP.

a) Hourly Rainfall

As mentioned above, items from (1) to (4) should be conducted to develop the modification method for GSMaP_NRT which is necessary for flood forecasting system in Bengawan Solo River Basin.

Concerning the modification method, this calculates the speed index of rainfall area as a basin average value. Since several hourly rainfall data are observed in Upper Solo River and Madiun River Bain, the modification method is attempted to be developed as a basin average value of upstream area (Upper Solo River and Madiun). In this basin, several hourly rainfall stations have been built as shown in Figure 4.29. In this section, rainfall data of these hourly rainfall stations are used for validations.

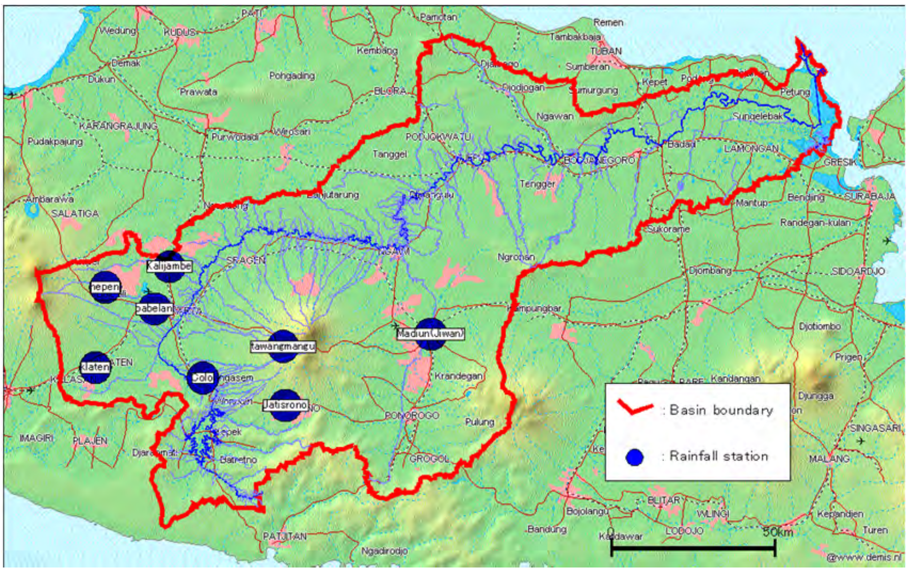

Figure 4.29 Locations of Hourly Rainfall Stations

(1) Validation of hourly rainfall data in Upper Solo River Basin

In this section, GSMaP and hourly ground rainfall are compared in terms of hourly rainfall intensity.

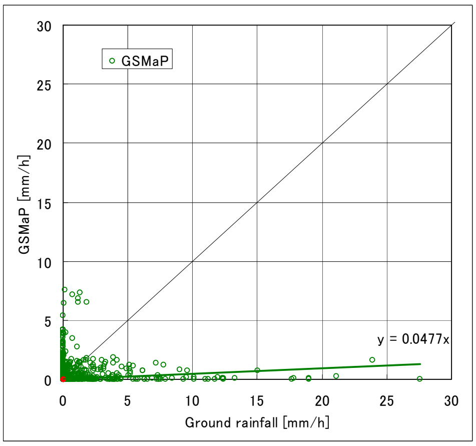

Figure 4.30 Relation between Hourly Ground Rainfall and GSMaP [mm/h] in Upper Solo River

Figure 4.30 shows the low relation between ground rainfall and GSMaP. The reasons of this low correlation can be considered as follows;

- Convective rainfall which occurs frequently in this basin is difficult to be represented by GSMaP.
- This implies the temporal resolution and spatial resolution of GSMaP is not enough to represent convective rainfall since temporal and spatial resolution of convective rainfall is very short and local.

Even though we found little correlation between ground rainfall and GSMaP, we can develop modification equation. However, we cannot find any

correlation in this figure. This result shows the hourly modification equation cannot be obtained and as a result the hourly flood forecasting is difficult to be conducted by using hourly GSMaP. Even though we use hourly GSMaP, the accuracy of flood forecasting result using hourly GSMaP should be low.

We validated following accumulated GSMaP to 3-hour, 12-hour and 24-hour rainfall to find better correlation between ground rainfall and GSMaP. Then, better correlation should be found since temporal resolution is enlarged. The result is shown in Figure 4.31.

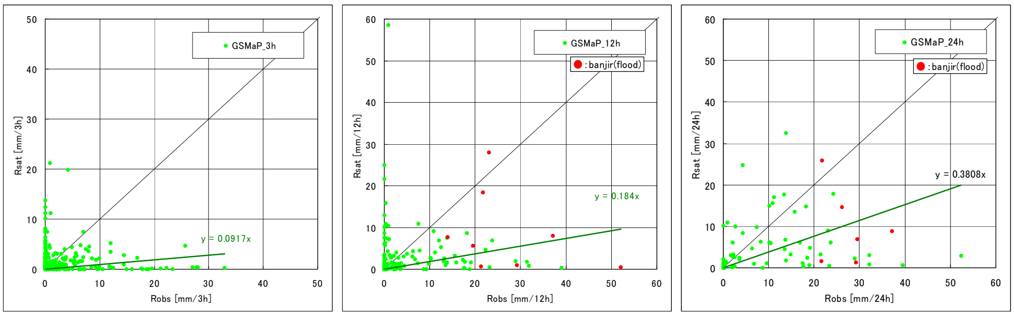

Figure 4.31 Validation Result of GSMaP and Modified GSMaP in Upper Solo River Basin

This result implies longer temporal resolution acquires better correlation between ground rainfall and GSMaP/modified GSMaP. This shows GSMaP cannot represent actual rainfall distribution in accurate time and place in from 3 hourly to 12 hours since rainfall in Indonesia is almost convective rainfall and it rains locally and torrentially.

Concerning the 24-hour rainfall, "Daily rainfall data" should be able to be substitute for 24-hour rainfall data and Daily rainfall data are more sufficient (approximately 130 stations in 16,000km^2). This can provide better accuracy of ground rainfall.

In next section, daily rainfall data are validated.

b) Daily Rainfall

As mentioned in section 4.2.2.1 Ground-based (gauged) rainfall data, daily rainfall data at 129 stations were collected. These data are used for validations.

(1) Validation of daily rainfall data in Bengawan Solo River Basin

In this section, GSMaP and daily ground rainfall are compared in terms of daily rainfall intensity. GSMaP is hourly rainfall data so it is accumulated to 24-hour, daily data to compare daily ground rainfall. Figure 4.32 shows the relation between daily ground rainfall and GSMaP data from December 2007 to December 2009 for 2 years. And Figure 4.33 shows the same relation as Figure 4.32 and plotted data are limited to heavy rainfalls which bring flood reported as a "Banjir (="Flood" in English)" in Disaster report "Laporan Pelaksanaan Piket Banjir " written by BBWS Bengawan Solo.

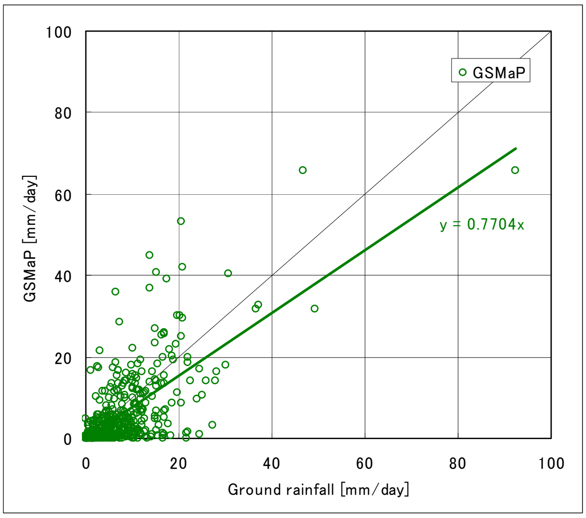

Figure 4.32 Relation between Daily Ground Rainfall and GSMaP [mm/day] in Bengawan Solo River Basin

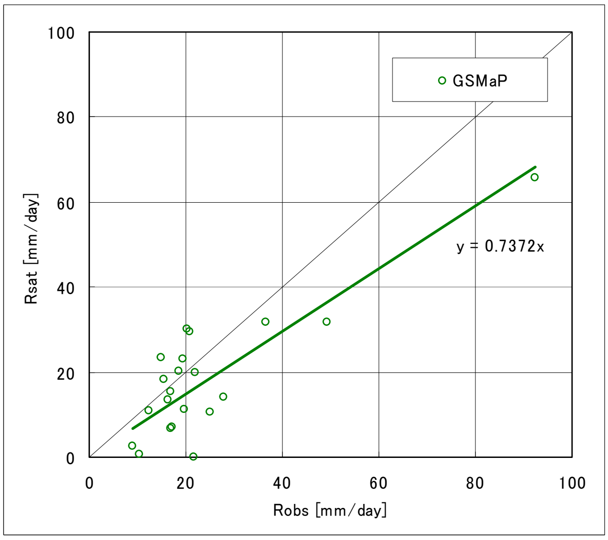

Figure 4.33 Relation between Daily Ground Rainfall and GSMaP [mm/day] in Bengawan Solo River Basin (Only Flood Events)

Table 4.11 Flood Events from December 2007 to December 2009 [mm/day]

No.	Flood(Banjir) date(y/m/d)	Ground rainfall	GSMaP	No.	Flood(Banjir) date(y/m/d)	Ground rainfall	GSMaP
1	2007/12/26	92.5	65.9	12	2009/2/2	21.7	0.1
2	2008/12/8	18.5	20.2	13	2009/2/3	20.2	30.1
3	2008/12/15	17.0	6.9	14	2009/2/18	16.2	13.6
4	2008/12/16	16.8	15.3	15	2009/2/22	19.6	23.0
5	2009/1/1	12.3	10.8	16	2009/2/23	19.8	11.1
6	2009/1/9	25.2	10.5	17	2009/2/24	20.7	29.5
7	2009/1/10	9.0	2.4	18	2009/2/25	36.7	31.8
8	2009/1/19	10.4	0.7	19	2009/2/26	27.8	14.3
9	2009/1/26	17.3	7.1	20	2009/3/4	15.0	23.4
10	2009/1/27	15.6	18.2	21	2009/3/5	21.9	19.8
11	2009/1/31	49.2	31.9				

Figure 4.32 shows the relation between ground rainfall and GSMaP and can be concluded as follows;

- Some of light rainfall up to 20 [mm/day] can be represented properly.
- A few of light rainfall up to 20 [mm/day] are overestimated.
- Most of heavy rainfall over 30 [mm/day] are underestimated.

The relation limited in flood events shown in Figure 4.33 can be concluded as follows;

- Most of light rainfall up to 20 [mm/day] can be represented properly.
- Heavy rainfall over 20 [mm/day] are all underestimated.

For flood forecasting using GSMaP, modification of GSMaP is necessary to improve its accuracy in heavy rainfall since it is underestimated especially in heavy rainfall which is main target in flood forecasting.

4.3.4 Application of Modification Method to Bengawan Solo River Basin

As mentioned above, modification method is necessary for heavy rainfall on GSMaP.

Concerning the modification method, the modification formula has already developed in Japanese river basin. At first this Japanese modification formula is applied to Bengawan Solo River Basin and secondly Solo modification formula is applied after development.

a) Overview of Modification Method for GSMaP Produced by ICHARM

According to Shiraishi et al.[1], GSMaP_ MVK+ can be modified by using ground wind speed because of the correlation found among rainfall events between the error rate and lateral wind speed. They selected the moving speeds of rainfall areas in the study basin, which were deemed to have a high correlation with ground wind speed and can be derived from GSMaP data. Finally, they modified GSMaP based on the moving speeds of rainfall areas. Related equations are described as follows; (See Shiraishi et al.[1)] or Ozawa et al.[2] for further information on their GSMaP modification method.)

$$S_i = \sqrt{\frac{1}{4}\sum_{j=1}^{4}\left(R_i - Rs_j\right)^2} \quad (4.1)$$

R_i: Hourly average of the GSMaP 3-hour rainfall at a given grid i.

Rs_j: Hourly average of the 3-hour rainfall at the surrounding 4 grids (southeast, southwest, northeast and northwest) of the given grid i.

Si: Speed index of rainfall area in river basin for a single grid.

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[1]The proposal of correction method using the movement of rainfall area on satellite-based rainfall information by analysis in the Yoshino River Basin, Yoshiki Shiraishi, Kazuhiko Fukami and Hironori Inomata, Annual Journal of Hydraulic Engineering, JSCE, Vol.53, 2009, February pp.385-390 (in Japanese)

[2]Applicability of GSMAP correction method to typhoon “Morakot” in Taiwan, Go Ozawa, Yoshiki Shiraishi Hironori Inomata and Kazuhiko Fukami, Annual Journal of Hydraulic Engineering, JSCE, Vol.55, 2011, February

$$S = \frac{1}{f}\sum_{i=1}^{f} Si \qquad (4.2)$$

S: Bain average of speed index of rainfall area

f: Number of GSMaP grids in the study basin (Yoshinogawa River basin: f = 35)

$$M = -2.6777 Ln(S) + 6.2234 \qquad (4.3)$$

(*These parameters are in case of Yoshino River Basin in Japan)

$$R_{cor}(t) = M \times R_{sat}(t) \qquad (4.4)$$

M: Modification coefficient for GSMaP.

$R_{sat}(t)$: 3-hour total GSMaP at a given time [mm/h].

$R_{cor}(t)$: Modified 3-hour total GSMaP [mm/h].

b) Application of Japanese Modification Formula to Bengawan Solo River Basin

At first, Japanese modification formula is applied to Bengawan Solo River Basin. Figure 4.34 shows the result of application of Japanese modification formula. It shows that Japanese modification formula cannot work properly and overestimates ground rainfall too much. This is because the difference of moving speeds of rainfall areas between Japan and Indonesia. This modification method is based on the moving speeds of rainfall areas and the moving speed is clear around Japan area. However, it is not clear around Indonesia and the rainfall areas are produced locally since the rainfall is not a typhoon or frontal rainfall but mainly convective rainfall.

Thus, the Japanese modification formula cannot be applied to Bengawan Solo River Basin directly and necessary to be develop Bengawan Solo River Basin original modification formula.

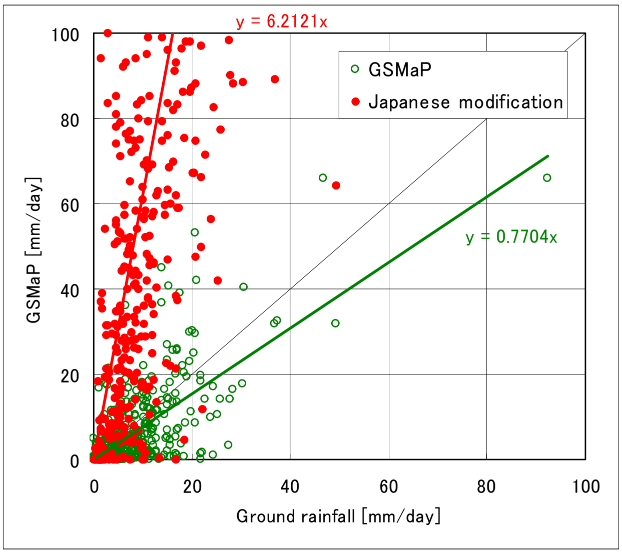

Figure 4.34 Relation between Ground Rainfall and Original and Japanese modified GSMaP [mm/day]

c) Development of Bengawan Solo River Basin Original Modification Method

In section 4.2.3.2, heavy rainfalls which cause flood events were focused on. This section also focuses on heavy rainfalls which actually caused flood events last 2 years from December 2007 to December 2009 shown in Table 4.11. The relation between Speed index "S" for modification method which was described in sub sub section 4.2.1.2 and modification coefficient for GSMaP "M" also described in sub sub section 4.2.1.2 is shown in Figure 4.34. As a result, following formulas can be derived from this figure;

$$\begin{cases} M = 4 & (S \leq 0.33) \quad (4.5) \\ M = 0.8563*S\text{^}(-1.3439) & (0.33 < S \leq 1.2) \quad (4.6) \\ M = 1.2 & (S > 0.8) \quad (4.7) \end{cases}$$

M: modification coefficient

S: speed index of rainfall area

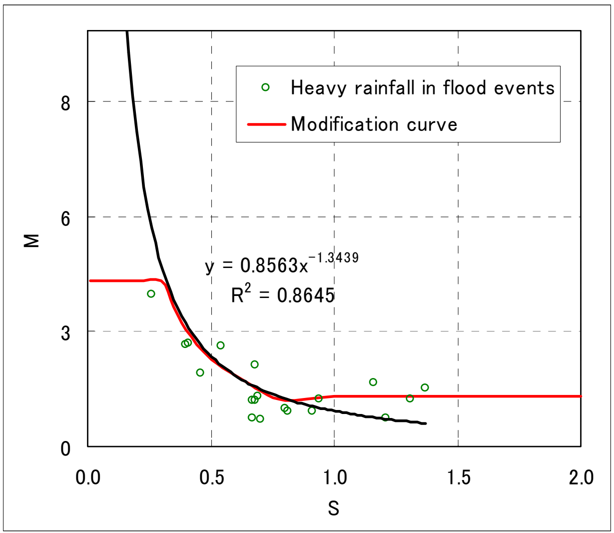

Figure 4.35 Relation between Speed Index "S" and Modification Coefficient "M"

d) Application of Solo Modification Method

In this section, developed modification formula in section c) is applied to heavy rainfall in flood events. Figure 4.35 shows the result of application of Solo modification method to Bengawan Solo River Basin in flood events. The modification method works properly and heavy rainfall events are properly modified.

However, in case of application of this Solo modification formula to all rainfall events including both light rainfall and heavy rainfall, light rainfall modified overestimated as shown in Figure 4.37. This modification method works properly in heavy rainfall which causes flood event. On the other hand, as shown in Figure 4.36, this method does not work properly in light rainfall since it is overestimated. Overestimation in flood forecasting system brings down false flood forecast. It is necessary to take care about the reasonability of the forecasts at each flood forecasting results using modified GSMaP.

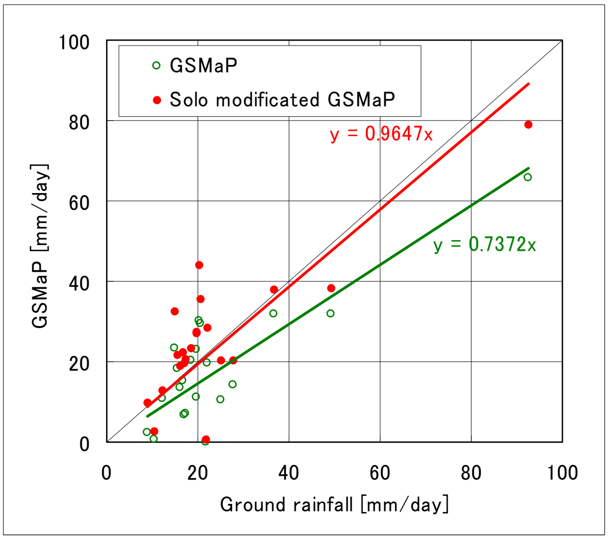

Figure 4.36 Relation between Ground Rainfall and Modified GSMaP Limited in Flood Events [mm/day]

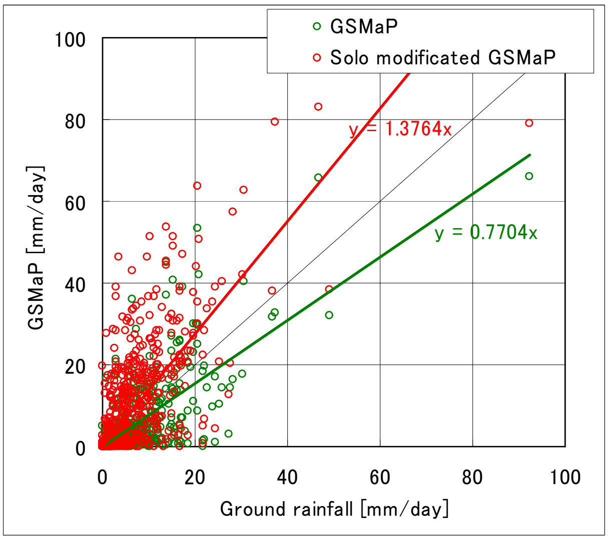

Figure 4.37 Relation between Ground Rainfall and Original and Modified GSMaP [mm/day]

e) Advanced Modification Method in Bengawan Solo River Basin

To avoid the overestimation in current modified GSMaP, there is a one solution. As mentioned above, it is necessary to take care about the reasonability of the result of modified GSMaP. To take care of it, utilization of real time ground rainfall data is effective (if it is available). The characteristic of this modification formula is that it overestimates the light rainfall and whether it is light or heavy rainfall can be found by using real time ground rainfall data. Thus, advanced modification method using real time ground rainfall data can be defined as follows;

If real time ground rainfall exceeds 20 mm/day, following formulas defined in section c) should be applied to GSMaP.

If not, these formulas should be neglected and M should equal to 1 which

means no modification. Then, overestimation for light rainfall can be improved as shown in Figure 4.38 for heavy rainfall in flood events and Figure 4.39 for all rainfall including both light and heavy rainfall. After utilizing real time ground rainfall data, this advanced modification method improved accuracy especially in light rainfall. Thus, it is recommended to be applied for more accurate forecasting.

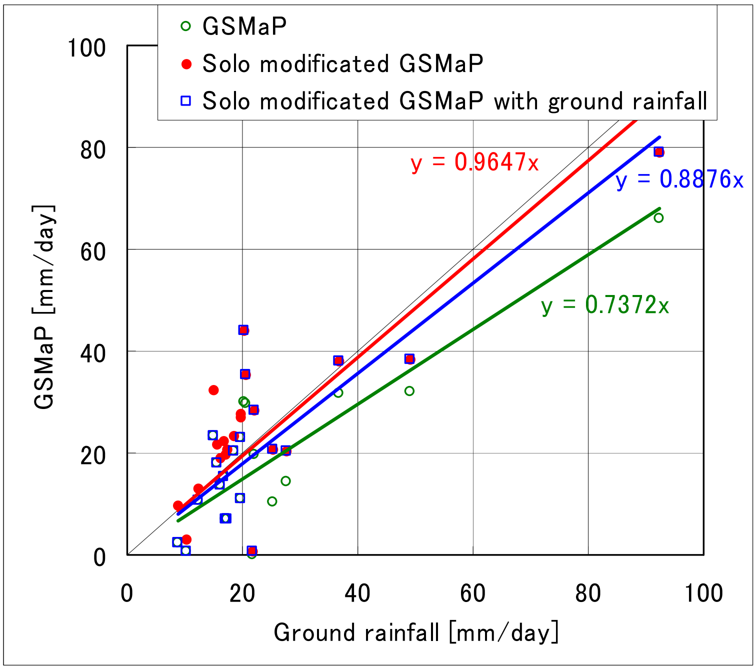

Figure 4.38 Relation Between Ground Rainfall and Modified GSMaP

Relation Between Modified GSMaP with Ground Rainfall [mm/day] in Flood Events

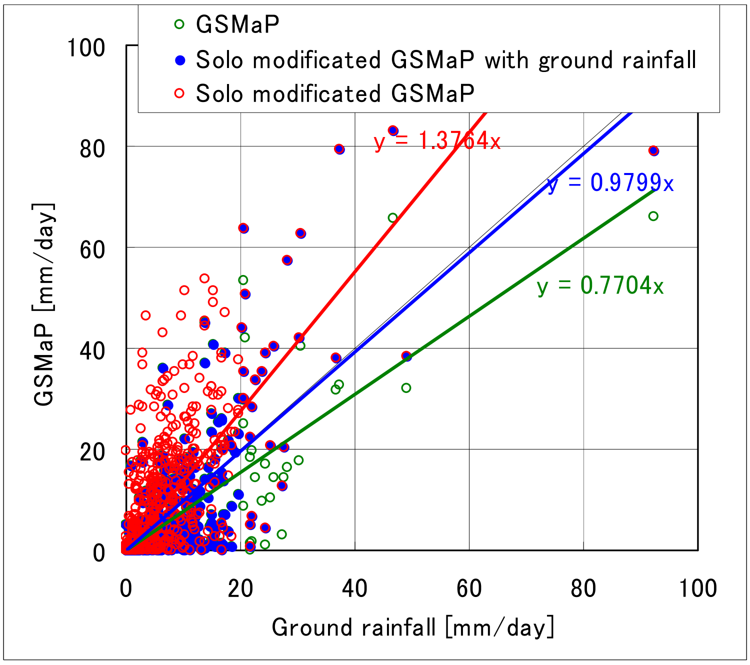

Figure 4.39 Relation between Ground Rainfall and Modified GSMaP,

Relation Between Ground rainfall and Modified GSMaP [mm/day] with all Ground Rainfall

4.4 Flood Forecasting Advantage in Early Warning and IFAS Application

Flood warning system is developed to provide accurate warning on the potential flood risk to the subjected community. The purpose of flood warning is alerting the community to do advance preparation before the hazard to minimize the scale of disaster. The earlier the warning the more the time available for better preparation and accurate action.In this regard, the concept of early warning becomes relevant.

The existing flood warning system in Bengawan Solo River Basin is based on the river water level monitoring. Based on the water level information, warning of the flood situation will be disseminated to the community. The government setup three levels of warning as well as their respected commanded response in relation to the river water level situation and its potential inundation.In fact, usually people start to evacuate only after sure that the highest level of warningwas reached. Analysis on the river water level data ofJurug Station (inside Solo City) during the flood in 2007 resulted that the river started overflowing and inundatingabouttwo hours after the highest warning level. Consequently, people only have two hours for preparation and evacuation before the inundation flow starts.

In fact, an earlier warning can be provided based on the analysis of the rainfall data to calculate the respected river discharge. This flood forecasting is useful to provide warning several hours earlier than the warning based on the water level observation. Furthermore, the flood-fighting groups may get advantage of enough time for preparation. Figure 4.40 shows the concept of flood forecasting advantage in early warning.

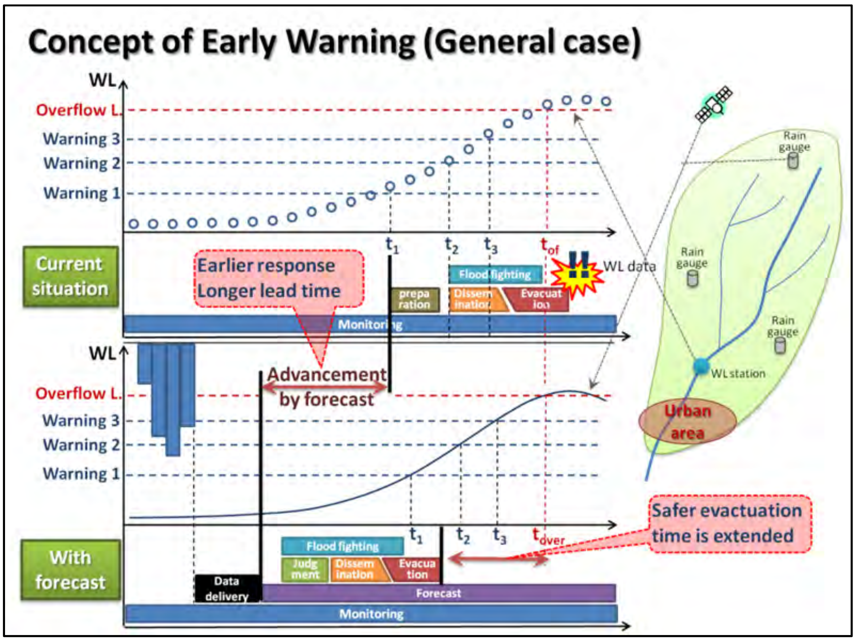

Figure 4.40 Illustration on the concept of flood forecasting advantage in early warning

4.4.1 IFAS application for flood warning in Bengawan Solo River Basin: a case study on 2007 Flood

Flood forecasting by using rainfall data requires reliable raingauge station network within the river basin to get accurate data and finally to provide reliable results. Flood forecasting is almost impossible for the basin with insufficient raingauge station network. However, the recent advance in satellite and radar technology for rainfall data acquisition has enabled the coverage of lack of data in insufficient or ungauged basin.

IFAS was developed for the purpose of flood forecasting or flood warning system especially for countries which have insufficient ground based rainfall data. This software uses GSMaP_NRT rainfall as an input. It seems useful for Bengawan Solo River Basin which has limited data.

By using IFAS simulation model with the rainfall data as an input and the land use data as parameters will provide the water discharge. The timing of the increasing peak discharge is the most significant information to take a decisionregarding flood warning.

IFAS simulation for Bengawan Solo River Flood 2007

The flood event of 25 to 27 December 2007 inBengawan Solo River Basinwas analyzed for the present case study and the hourly water level data of Jurug Station is used in the simulation. This station is located in the upstream of Bengawan Solo River Basin.

Figure 4.41 shows the run-off calculation by IFAS modeling, using satellite rainfall data and the parameters tuned with the Jurug station 2007 flood event data. IFAS calculate water discharge based on the GSMaP satellite rainfall data.

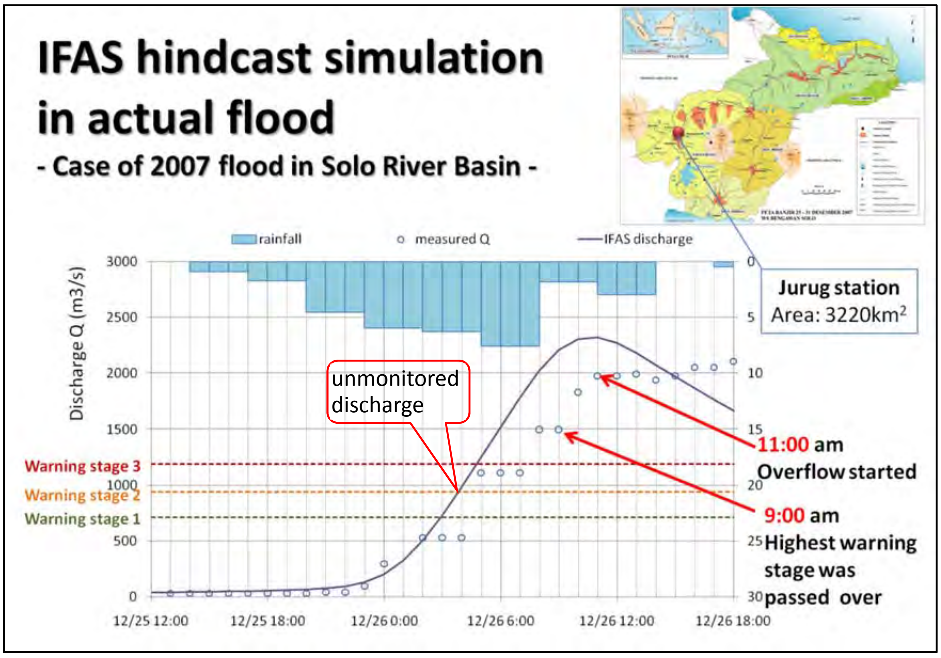

Figure 4.41 Hydrograph of IFAS simulation in Jurug station of Bengawan Solo River for the flood event of Dec 25th – 27th, 2007

The peak discharge of the flood event recorded for this station is on 26 December 2007. Observed hourly discharge data shown in the hydograph started rising at 23:00 on

25 December 2007 (refer to Figure 4.41), and the discharge overflow at 26 December 2007 at 11.00 A.M. The increase of discharge was really fast and rose sharply. The monitoring process could not recognize when the discharge crosses the second warning stage.

Figure 4.41 shows that IFAS simulated the hydrograph of 2007 flood of Bengawan Solo River. By using IFAS, the rising discharge can be notified and being significant complementary data to the monitoring work.The well monitoredrising discharge will help the government to make an accurate decision to mitigate flood disaster.

IFAS runoff forecast at the flood time of Bengawan Solo River Flood 2007

Figure 4.42a and Figure 4.42b show the hydrograph of Jurug Station on Dec 26, at 5:00 a.m. and 8:00 a.m. respectively. In each figure, the left side shows the observed discharge data (empty circle graph), while the right side is the result of IFAS simulation. IFAS simulations were carried out for two cases input rainfall data. The first case used only the satellite data GSMaP (blue graph), whereas the second case used GSMaP data plus assumed rainfall intensities to fill the last 4 hours data gap of GSMaP (red graph).

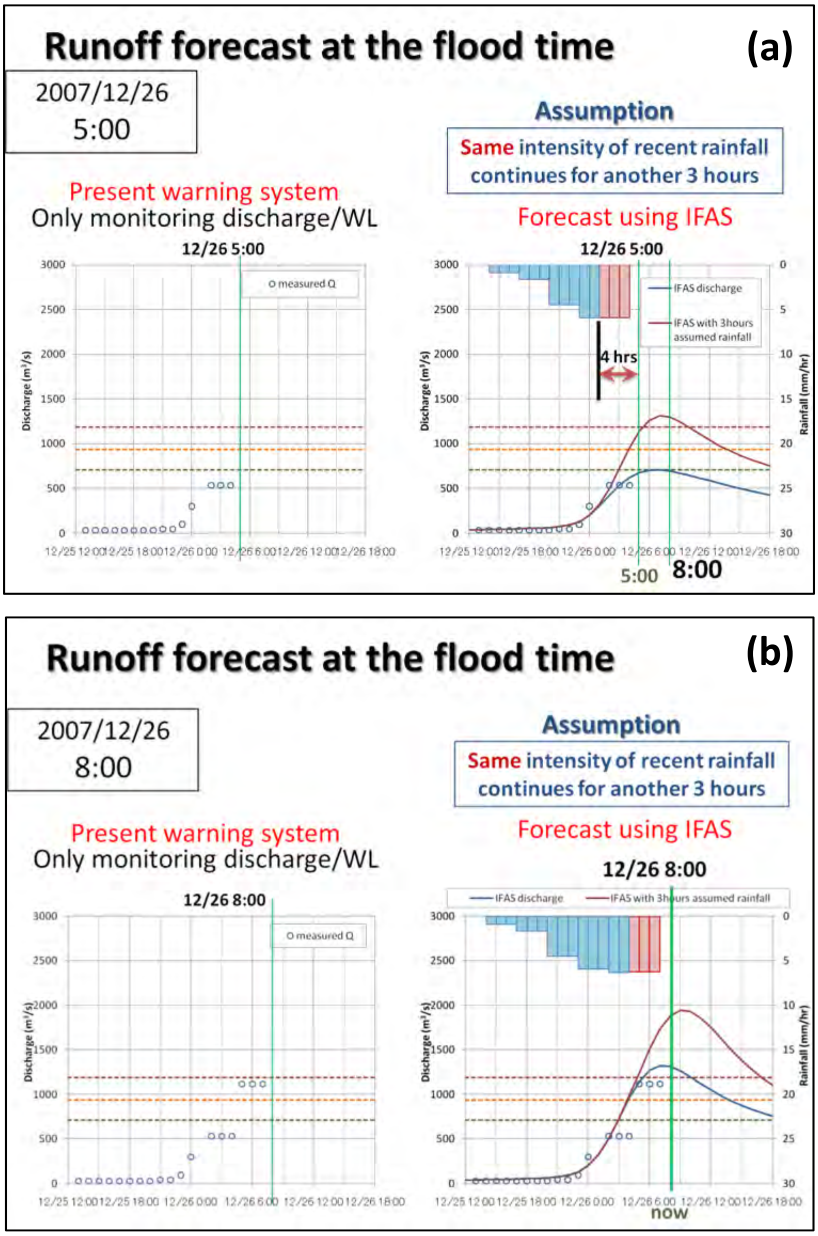

Figure 4.42 The hydrographs of Jurug Station on Dec 26, at (a) 5:00 a.m. and (b) 8:00 a.m. respectively. In each figure, the left side shows the observed discharge data (empty circle graph), while the right side is the result of IFAS simulation.

In reference to Figure 4.42a, on Dec 26, at 5:00 a.m., the existing warning system could not identify the trend of runoff by the available discharge observation data only. IFAS simulation by using only the satellite data GSMaP (blue graph) provided useful information on the trend of discharge in the next hours. However, GSMaP provided only data until 1:00 a.m. (at present, GSMaP can only provide data of 4 hours delay). It means that the discharge was due to the rainfall up to 1:00 a.m. To forecast more reliable discharge, rainfall effect between 1:00 a.m. to 5:00 a.m. should be considered. Since no ground data were available, an approximation was made by assuming that after 1:00 a.m. same rainfall intensity consecutively poured for three hours. Accordingly, IFAS simulated that there was a potential of river discharge exceedence over the highest warning level in

between 6:00 a.m. to 8:00 a.m. This forecast result is quite consistent to the complete observed discharge data shown in Figure 4.42a. The same process of forecasting calculation was carried out if the monitoring was made at 8:00 a.m. as it is shown in Figure 4.42b.

The hydrograph from the IFAS simulation above shows the relation between the satellite rainfall and the water discharge. Due to the delay time of transfer data given by the satellite, in fact the satellite rainfall data cannot provide very accurate forecast of discharge.

The purpose of the rainfall assumption is to predict the discharge earlier. By assuming the rain comes, it can be used to identify the rising discharge earlier so that can be used as a reference for the Government to make coordination with all the function which has responsibility to make an action plan to against the flood disaster.

In this study, the assumption of rainfall in flood forecast has one hour interval. To get accurate information, the shorter interval would be better for forecasting. The assumption rainfall must represent the near real time rainfall.

By using IFAS and real time ground gauge rainfall data as inputs, the accuracy of flood warning system is potentially improved. The simulation results of IFAS therefore can be very much useful as a flood forecasting tool by assuming rainfall data with has the near real-time intensity.

4.5 System Modification of IFAS

ICHARM developed IFAS as activity result of study under Public Works Research Institute (PWRI). New IFAS can be used with Windows Vista and Windows 7 64bit operating system. And it has automatic alert function for appropriate evacuation.

Figure 4.43 shows a relationship between calculation time and period using IFAS ver 1.2. If user set long period of calculation or high spatial resolution, it is necessary too much time to calculate river discharge. If user changes the calculation period, IFAS delete the all of imported rainfall data. Therefore, users have to import rainfall data from starting time to present time again. This means it is necessary to take too much time to get the result of run-off analysis every time step. ICHARM improved IFAS to shorten calculating time with automatic function.

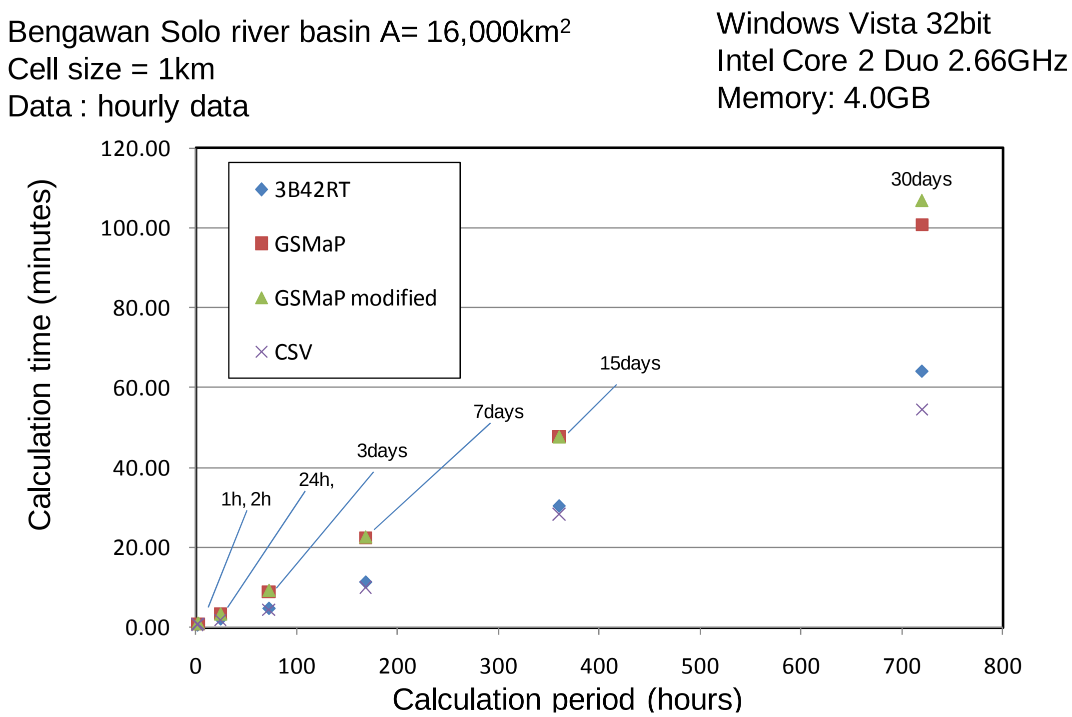

Figure 4.43 Relationship between Calculation Time (Calculating) and Period (Target Period)

4.5.1 Automatic Executing Function

As shown in Figure 4.44, ICHARM developed new IFAS which has automatic functions such as automatic download, automatic import, automatic modification, automatic calculation and automatic alert as research result under PWRI. User should set short period to calculate river discharge, in order to shorten the calculation time. ICHARM will use new IFAS, for creating Early Warning System for Bengawan Solo River Basin.

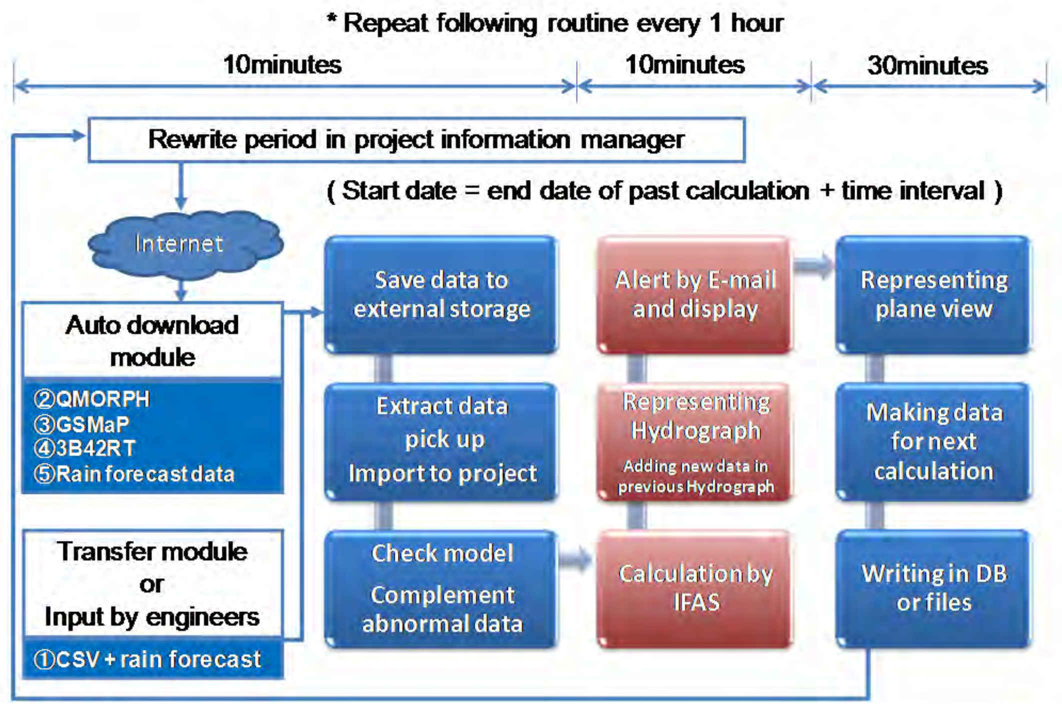

Figure 4.44 Schematic Image of Automatic Alert Function

4.5.2 Automatic Download Function for Satellite Based Rainfall Data

ICHARM had developed new IFAS which has automatic download function. In BBWS, internet connection is not good. Download capacity is 140kbs is required, satellite based rainfall data is about 800kb/1file for hourly data. Too much time is required to download long period satellite based rainfall data. To avoid this, ICHARM developed automatic download function for downloading satellite based rainfall data one by one every 1 hour.

User can download satellite based rainfall data by setting, GSMaP_NRT (hourly), GSMaP_NRT (daily(0-23)), GSMaP_NRT(daily(12-11)), 3B42RT(V6), Quick version of Climate Prediction Center Morphing technique (QMORPH), Climate Prediction Center Morphing technique (CMORPH) and Grid Point Value (GPV) (Figure 4.45).

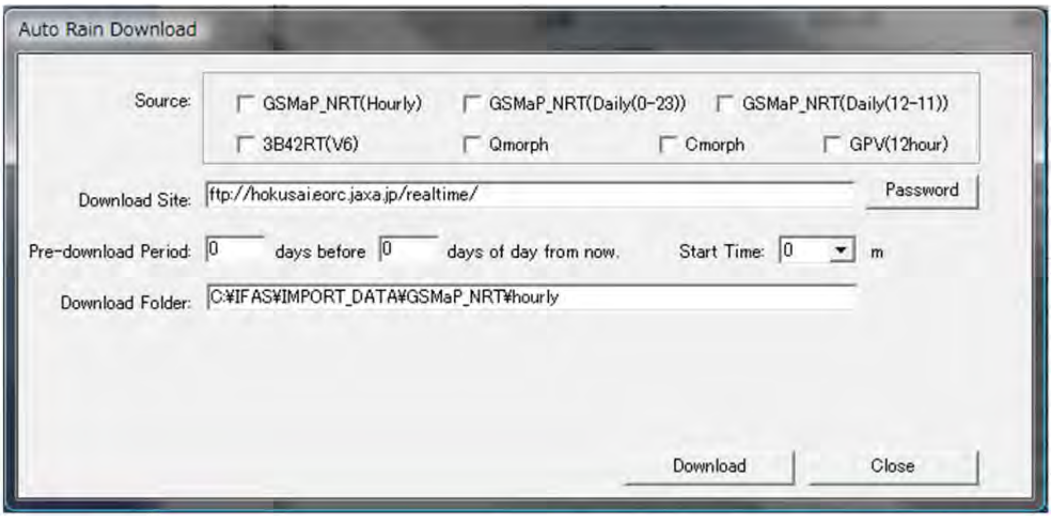

Figure 4.45 User Interface of Automatic Download Function

4.5.3 Automatic Data Import Function and Improved Import Rainfall Data Function and Modification Function for GSMaP

IFAS ver1.2 has rainfall data importing function. If calculation period will be changed according to time advancing in IFAS ver 1.2, IFAS delete all of imported rainfall data. IFAS ver 1.2 doesn't have adding function of rainfall data as input data. User has to import rainfall data from starting time to present time again. In flood situation, user wants to get result of run-off analysis as soon as possible for conducting appropriate early warning. Shortening of calculation time is one of the most important things for decision making. Then ICHARM improved import function and modifying function to realize more efficient early warning for appropriate evacuation. Differences in the functions of two versions are shown in Figure 4.46

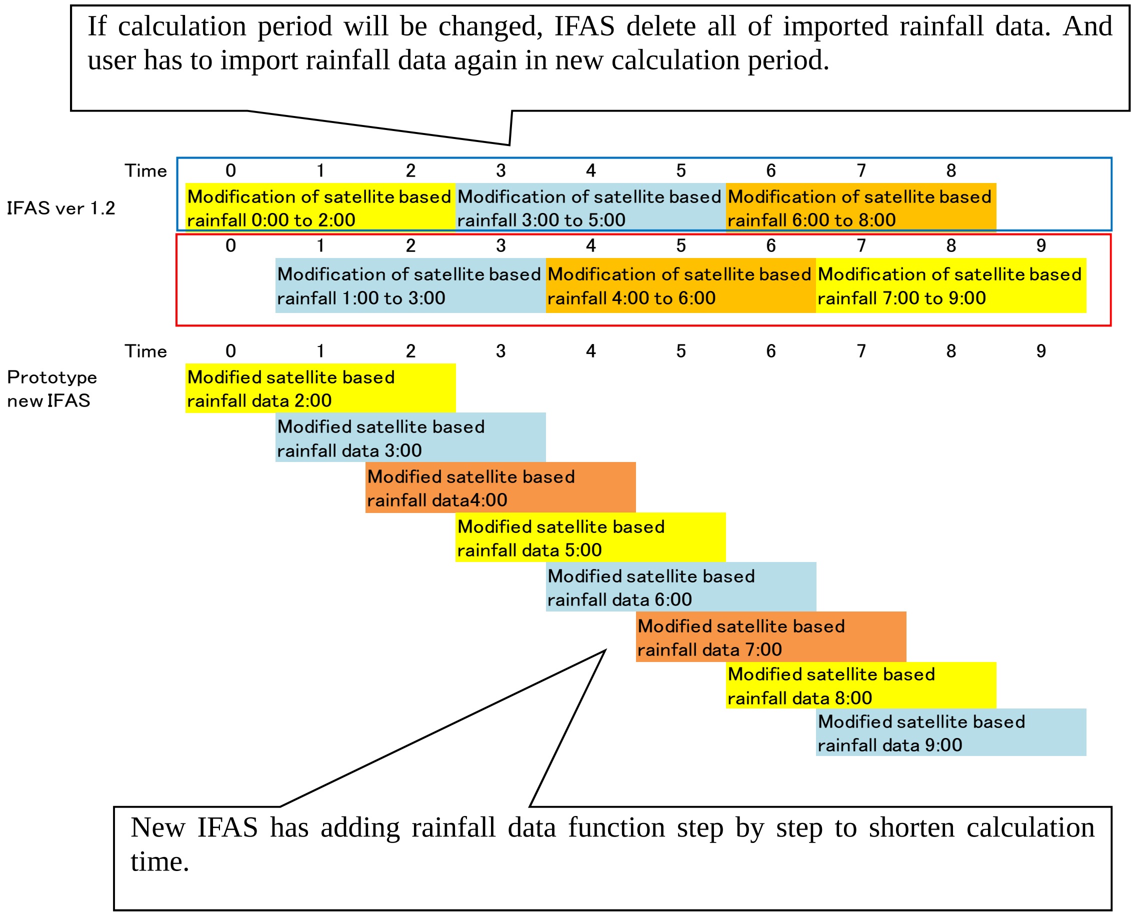

Figure 4.46 Comparison of Modification Method between IFAS ver 1.2 and New IFAS

4.5.4 Automatic Calculate and Display Function

User can set calculation period in setting interface of new IFAS. IFAS repeat calculation during the calculation period by time interval. User can get the result of calculation automatically. Figure 4.47 shows the hydrograph of automatic calculation. Horizontal yellow line shows threshold of the first level of warning. Horizontal pink line shows threshold of thesecond level of warning. Horizontal pink line shows threshold of the third level of warning.

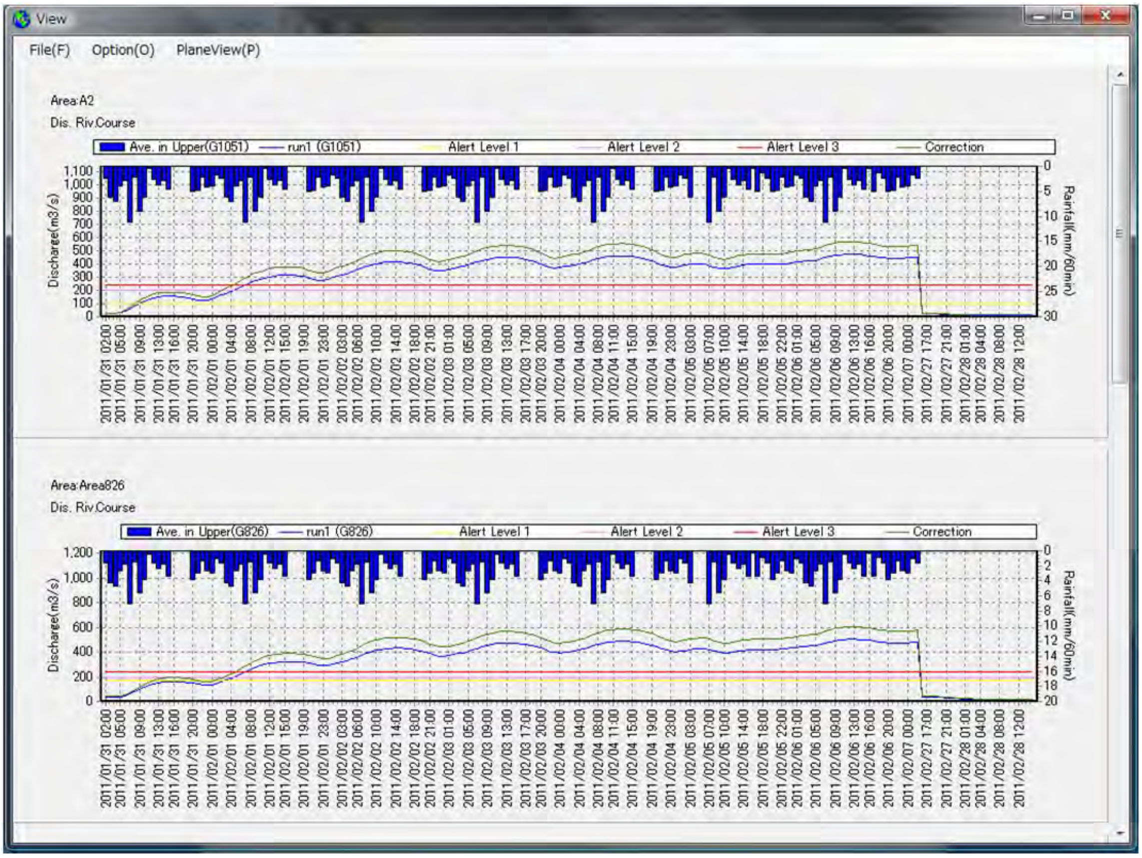

Figure 4.47 Calculated Discharge Display Function Using Automatic Function

4.5.5 Automatic Alert Function

User can set threshold of alert in each target area. New IFAS can set three levels of thresholds for alert. If calculated discharge exceeds the threshold, IFAS shows the alert message on screen and send alert e-mail (Figure 4.48).

1) Period Setting

   User can set past days as a starting point of calculation, and user also can set future date as ending point of calculation. If flood situation will be long, user can set long period of calculation. But if calculation period is long, calculation time will be so long. If user set high spatial resolution as calculation, calculation time will be long.

2) Alert Setting

   This function has alert location setting and alert threshold setting. User wants to know when dangerous is, where dangerous is. New IFAS is implemented automatic alert function.

3) Modified Discharge and its Displaying Function

   This function is displaying and setting function of modified discharge. Modified discharge function means final modify of the amount of water from rainfall. All of the value has error every time. This function is matching function in discharge point.

4) Alert Display Setting

This function is alert displaying function on Personal computer screen. Operator can get the alert information about flood as a result of run-off analysis using IFAS. If calculated discharge exceeds the threshold of alert, IFAS represents the alert by the step of 3 levels. User can set alert level at each location.

5) Rainfall Data Setting

User can select rainfall data products as input data into IFAS. These rainfall products are near real time data and rain forecast data. These data is useful for run-off analysis. But, satellite based rainfall data has delay time, therefore user have to be careful of the target area setting. Satellite based rainfall data is not useful under 2,000km^2 basin.

6) KML Exporter Setting

User can see the rainfall distribution and time series of river discharge as a result of calculation. KML (Keyhole Markup Language) file is format of Google Earth.

7) Alert Mail Setting

Alert mail setting function has text box to set sentence of alert e-mail. User can get the alert information by E-mail, when calculated discharge exceeds the threshold of flood alert. New IFAS has the function of sending E-mail for user.

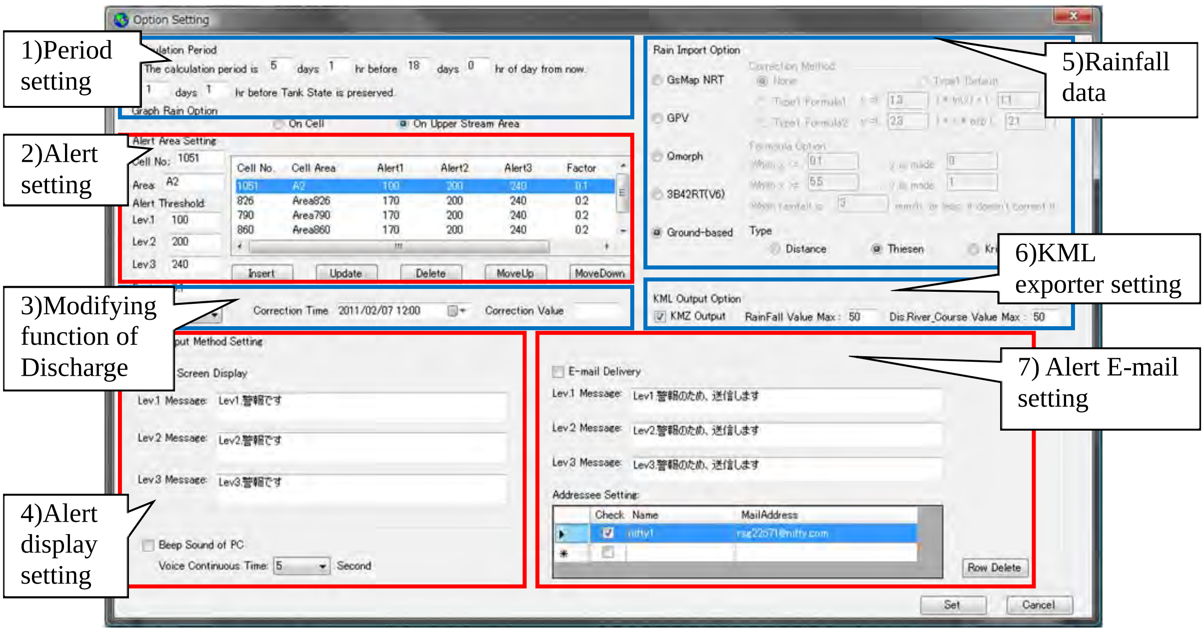

Figure 4.48 User Interface Alert, Rainfall Data and Modification of Discharge

4.5.6 Modification Function of Calculated Discharge Data

Main target of IFAS is insufficiently gauged basins. Satellite based rainfall data is not accurate enough. If user can get discharge data, new IFAS can represents modified discharge according to the error rate compared with measured discharge data (Figure 4.49).

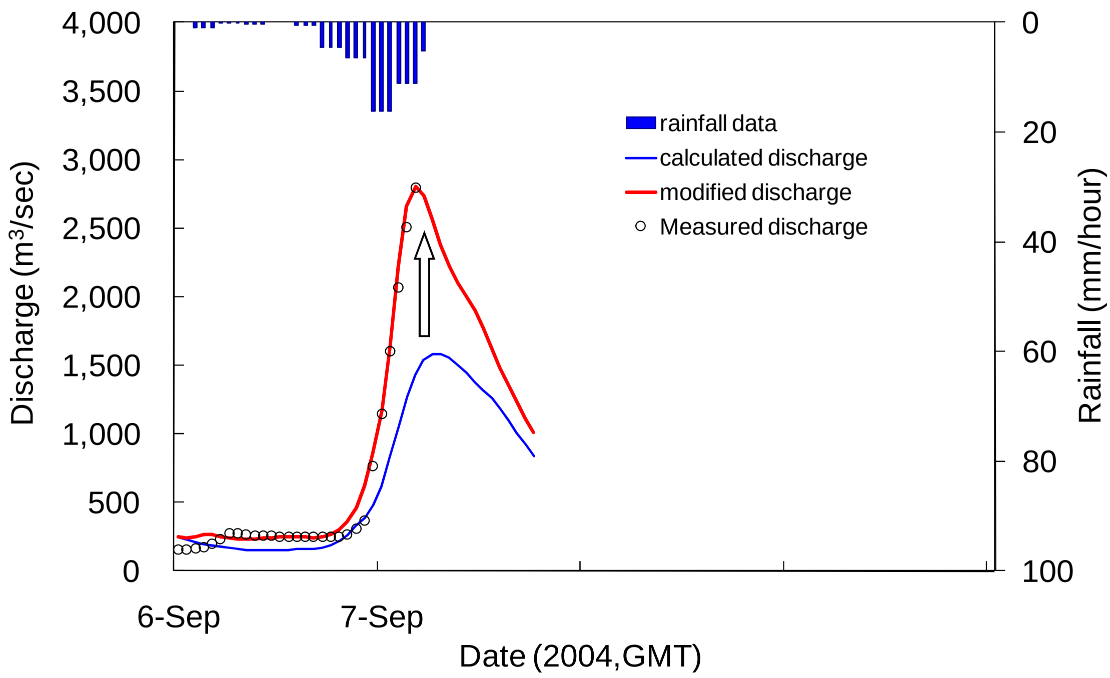

Figure 4.49 Modification Function for Calculated Discharge

4.5.7 Application of IFAS for 64bit Operating System, Windows XP, Vista 7

In the past IFAS training, some participants brought PC which is managed by 64bit Operating System. But, IFAS ver 1.2 could be used in only 32bit Operating System. Some participants couldn't follow the IFAS training. ICHARM improved IFAS, and new IFAS also can be used in 64bit Operating System, Windows XP, Vista and Windows 7.

5. Project Outputs Related to CBDRM Activity

5.1 Selection of the Pilot Community

Because this component is time-intensive and requires the mobilization of local resources, two pilot target areas in the basin were selected and the approach is pursued for small target communities. Execution of CBDRM activities in the selected locations were kind of demonstration activities, in which the local government officer learned directly from their involvement in the activity. It is expected that the local government officer hold the capacity to carry out the similar activity in other relevant locations afterward.

The general criteria for this selection is that the pilot location must be frequently subjected to serious flood and there is open possibility to integrate the application of advance technology and community based disaster risk management.

Two field visits and meeting with the local disaster management officers and local community leaders were carried out for the selection purpose. One is to the Bengawan Solo River in the vicinity of Bojonegoro, and the second one is to the area of Eromoko upstream of Wonogiri Dam in the vicinity of Solo. The two field visits have led to important insights into the genesis of floods in the respective areas and into the organizational structure of the affected community.

Through the help of the BPBD officials (local disaster management office) a series of potential flood prone locations were identified and earmarked. Table 5.1 shows the potential flood prone locations in these two areas that are affected by different types of flood problems (i.e. flash floods and backwater effects from the Bengawan Solo River).

Table 5.1 Potential flood prone locations surrounding Bojonegoro and Eromoko

Administrative unit						
District	**Sub-district**	**Village**	**Location**	**Flood type**	**Position**	**Visited**
Bojonegoro	Padangan	Kuncen	Rejo/Kebun Agung/ Sonorejo	Flood	N/A	No
Bojonegoro	Trucuk	Banjarsari	Guyangan/ Sranak	Flood& Flash Flood	7˚, 8’, 29” S 111˚, 52’, 51” E	Yes
Bojonegoro	Semen Pinggir	Semen Pinggir	Balai/Pacal River	Flood& Flash Flood	7˚, 11’, 15” S 111˚, 56’, 7.” E	Yes
Bojonegoro	Semen Pinggir	Kapas	Semen Pinggir/ Pacal River	Flood& Flash Flood, backwater	07˚, 10, 28 S 111˚, 56’, 19 E	Yes
Bojonegoro	Semen Pinggir	Bogo	Brangkal / Pacal river	Flood& Flash Flood	N/A	Yes
Bojonegoro	Temayang	Kendung Sumber	Sugihan	Flash Flood	7˚, 23’, 55.” S 111˚, 52’, 37” E	Yes
Wonogiri	Eromoko	Ngadirejo	Sumber Harjo	Flash Flood	7˚, 58, 88” S 110˚,51’,19” E	Yes

5.1.1 Bojonegoro Area (Downstream)

In the vicinity of Bojonegoro the Bengawan Solo River is characterized by strong meandering. Several areas east and west of Bojonegoro, including areas right in the middle of the municipality (situated right in on a bend of the Bengawan Solo River) suffer

from direct inundation from the Bengawan Solo River as well as from flash flooding.

The flash floods are mainly caused further away from the Bengawan Solo River along smaller tributaries, such as the Pacal River. During a rain period, the tributaries may carry significant discharges. At the location, where the tributaries flow into the Solo, backwater effects propagate upstream thus causing reduced or even inverted flow in the respective tributary. This effect, in combination with strong localized runoff attributable to intense rainfall causes flash flooding in several villages in the Bojonegoro District (Kabupaten Bojonegoro). The map depicted in Figure 5.1 shows the flood hotspots in various administrative districts.

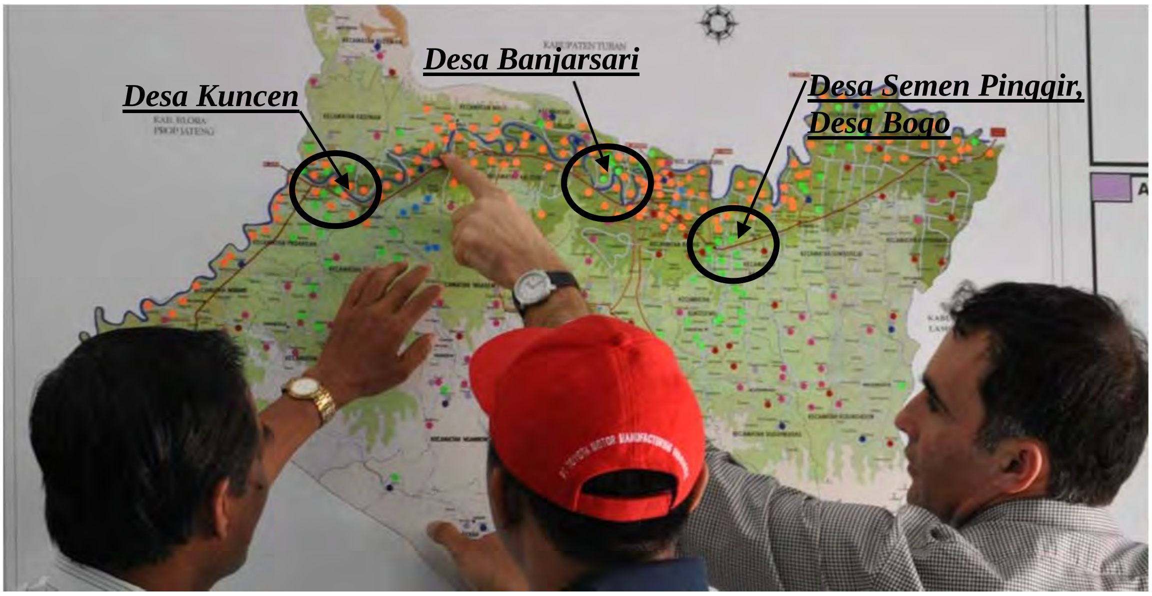

Figure 5.1 Map of the Bojonegoro district, showing flood hotspots. The orange dots indicate areas affected by direct flooding from the Bengawan Solo River, while the green dots indicate areas affected by flash floods. The encircled areas include the villages earmarked for local inspections.

Two sites have been earmarked for the CBDRM: 1) The area in the villages *Semen Pinggir* and *Bogo*, east of Bojonegoro, and 2) the sub village *Sugihan* in the village *Kedung Sumber*.

In the first case the floods are a combined effect of flood from the Bengawan Solo River and flash flood effects from the Pacal River. In the second case the community is isolated and exposed mainly to flash floods from a smaller upstream tributary to the Pacal reservoir.

5.1.2 Eromoko Area (Upstream)

Some parts of the village of Ngadirejo are exposed to flash floods from the smaller tributary. Water heights up to 1m have been reached in the area, causing damage to houses, agriculture and other economic activities. It is evident that the smaller rivers causing the flash floods are controlled by small irrigation reservoirs. In this context it is important to know the status of the reservoir and what causes the heavy runoff, the size of the watershed area of the river. The national consultant PusAir (Research Center for Water Resource, Ministry of Public Work Indonesia)will be requested to carry some investigations into the matter.

An aerial photograph of the village Eromoko and local area around Ngadirejo is

shown in Figure 5.2. As can be noticed, the small creek, which is causing flash flooding in the area, has its headwaters in the hills on the west side of the lake. Also visible is the small reservoir which could potentially have an impact on the discharge of the creek.

At the village level efforts are underway to relocate inhabitants from the lowest areas into higher-lying sectors of the village.

Figure 5.2 Flood-prone area in the village Eromoko, village Ngadirejo

5.1.3 The selected location for CBDRM demonstration

Finally it was decided that two sites have been earmarked for the CBDRM demonstration location: 1) The area in the villages *Semen Pinggir*, east of Bojonegoro, and 2) the sub village *Sugihan* in the village *Kedung Sumber*. Figure 5.3 shows the location of villages for CBDRM demonstration.

The 1st pilot village – Semen Pinggir Village:

✧ The floods are a combined effect of flood from the Bengawan Solo River and flash flood effects from the Pacal River (tributary). Under conditions of bank-full discharge in the Bengawan Solo River, the backwater effects in the Pacal River cause the villages to be inundated with water depths reaching up to 1.5 meters.

✧ Usually this community initiates evacuation following an evacuation alert from the government authority.

✧ To support the self-help capacity of the community, utilization of IFAS forecasting result as complementary flood information was introduced in addition to the usual evacuation alert from the government authority. By this additional flood potential information, the citizens are expected to have more additional time for evacuation preparedness.

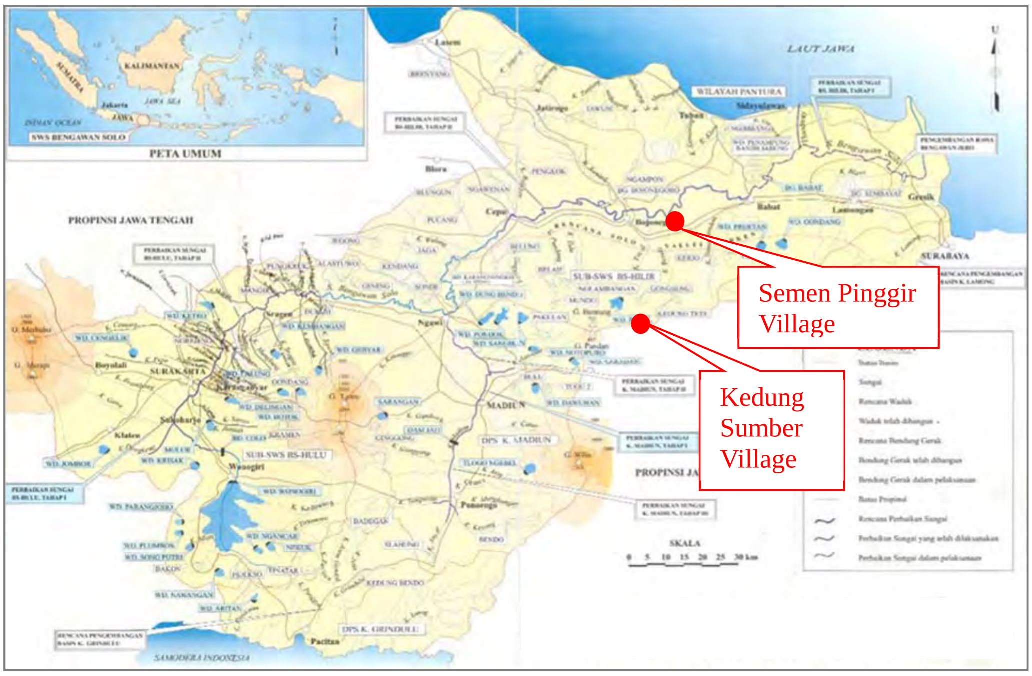

Figure 5.3 Location of villages for CBDRM demonstration.

Figure 5.4 Aerial view of the confluence between the Bengawan Solo River and the Pacal river. The Location of the village Semen Pinggir, target area of CBDRM activities is also indicated.

The 2nd pilot village - sub village Sugihan, Kedung Sumber Village:

✧ The community is isolated and exposed mainly to flash floods from a smaller upstream tributary to the Pacal reservoir.

✧ The community is essentially reliant on itself in case of flooding situations.

To support the self-help capacity of the community, a rain gauging station was installed in the upper part of the Pacal River catchment to provide additional early warning to the village from flash flooding due to runoff generated in the upstream catchment area. The instrument is set to be able to record precipitation at short time intervals and send a warning via SMS to a series of cellular phones in case the precipitation exceeds a predefined intensity threshold.

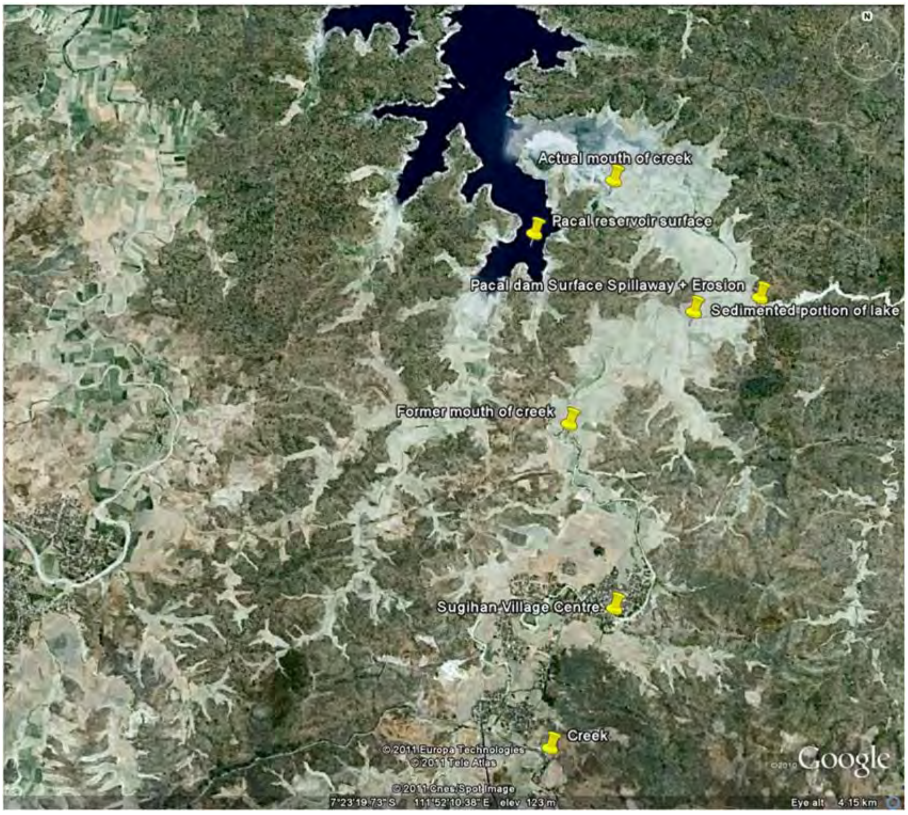

Figure 5.5 The Pacal Dam with sedimented reservoir portions and the village Sugihan

5.2 Scientific Analysis of the River Basin for CBDRM

Steps 4 and 5b in the approach to CBDRM in Sub Section 3.3.2, including the drafting of scientific hazard maps, requires an analysis of the physiographic characteristic of the basin. For this purpose digital terrain information must be analyzed to extract river courses and drainage areas. In addition, precipitation and discharge data need to be analyzed to be able to draw conclusions about rainfall-runoff behavior.

5.2.1 Digital terrain analysis

Essentially three sources of digital terrain information are available: the SRTM 90x90m and 30x30m digital terrain maps (DTM) and the 30x30m Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) digital terrain map. However, all three maps contain bias due to presence of vegetation, which remains an important hurdle when focusing on micro-topographic features. Moreover all three maps are affected by errors, as an extensive ground truthing on these products has only been performed for selected areas, which do not include the area of interest for this project. As a first approach the 90x90 SRTM map of the Solo basin has been analyzed. The map was processed with a digital terrain analysis package (TARDEM) to extract basin boundaries, drainage areas and the channel network.

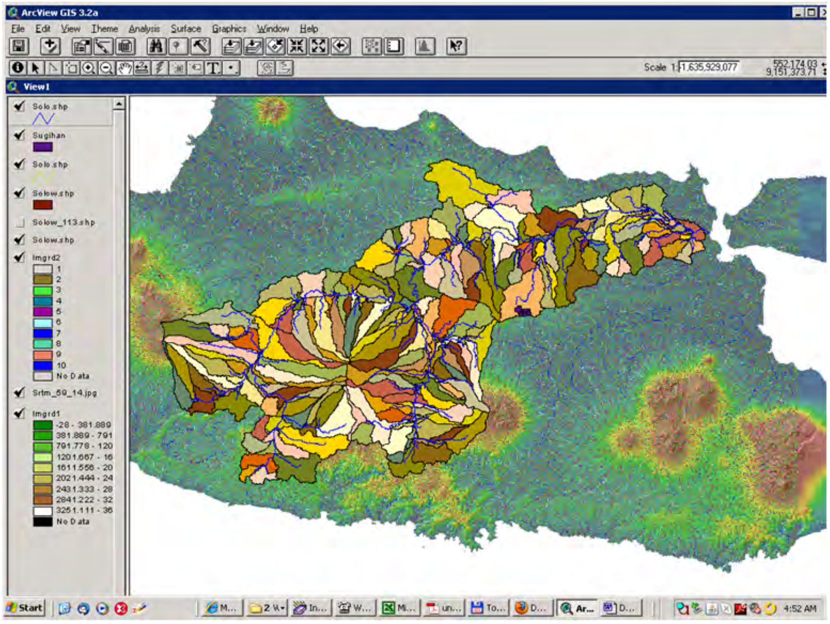

Figure 5.6 Analysis of the SRTM 90x90 Digital Terrain Map of the Bengawan Solo River Basin. The basin has been subdivided into a series of sub-basins.

The quality of the data was sufficient to allow the DTM processing algorithms to converge. The results of the analysis are presented in Figure 5.6. In the figure the subdivision of the Solo basin into sub-catchments is visible. The area of the catchment analyzed from the digital terrain information has been estimated at about 16000 km^2. The analysis also reveals the Bengawan Solo River course in the project area in vicinity of Bojonegoro. The river bends in correspondence of the town of Bojonegoro and the confluence of the Bengawan Solo River with the Pacal River are clearly identifiable. The same can be said for the Pacal River, which is affecting the two target communities Semen Pinggir and Kedung Sumber.

Next we performed an analysis of the catchment area upstream of Pacal reservoir, whose presence causes inundation of the Sugihan village. The drainage area lies directly on the boundaries of the Solo basin and has a surface area of 23 km^2. The watershed area includes two villages: Kedung Sumber and Gondang (containing the upstream village Pajeng). Figure 5.7shows an image of the watershed area upstream of the Pacal reservoir subdivided into three sub-basins.

The surface area will be used for the application of a synthetic hydrograph approach for the determination of the maximum discharge. For this purposes precipitation data from a nearby station will need to be analyzed. A precipitation gauge (Pos Kedung Pingit) is in fact installed at the basin boundary on the road which connects Bojonegoro to Nganjuk via the Pacal Reservoir.

5.2.2 The GIS-based Flood Hazard Maps

Another aspect of scientific analysis which is needed to identify scientific flood hazard maps consists in the drafting of inundation maps for the affected areas. These are supposed to be compared with the community-based flood hazard maps. Such an approach requires the availability of a high resolution DTM, which is sufficiently accurate to account for the local micro-topography in an area of a few hectares. Micro-topographic features, including smaller dykes and roads, play an important role as to the distribution of the flood waters.

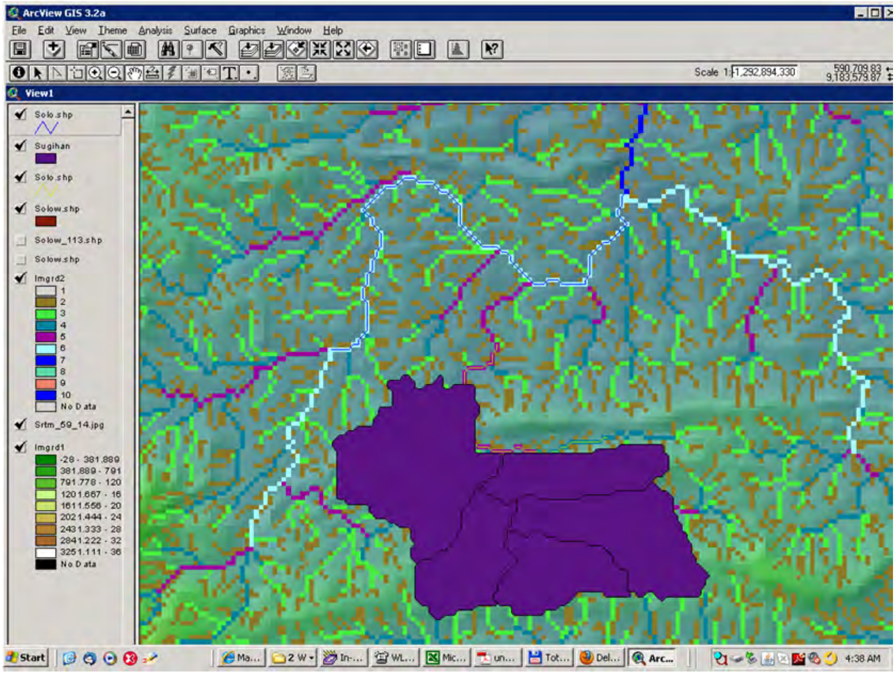

Figure 5.7 Analysis of the watershed area upside of Sugihan. The drainage area causing the flooding in the village is about 23 km^2. We note that the reservoir is not present in the digital terrain data, but is situated along the light blue drainage line.

For this purpose an SRTM DTM (30x30 m) has been processed and was used to derive the hazard maps for Semen Pinggir and Sugihan on the basis of simple GIS-based inundation modeling. The GIS-based modeling has been performed by coloring water levels at 50 cm intervals in different blue tones. Darker blue corresponds to larger water depths than light blue. The results are shown in Figure 5.8 and Figure 5.9 for the inundation area in Kedung Sumber Village (Sugihan) and Semen Pinggir Village respectively.

While this GIS-based modeling approach is static and exclusively uses topographic data, it gives a good impression of the areal extent of the inundation and which areas are inundated first. Commonly the lowest-lying depressions in a flood-prone area are filled up first.

The GIS-based hazard maps very much coincide with the impressions on inundation extend areas perceived by the respective community. The GIS-based physical inundation maps also clearly indicate the areas that should serve as safety zones in case of an evacuation, including the most obvious route to reach them in case of an emergency.

5.2.3 Kedung Pingit precipitation data analysis

Next the precipitation data at Kedung Pingit gauging station have been examined. The position of the Kedung Pingit precipitation gauge is 07°30' 48" S and 111°54' 30" N.The data were supplied in electronic format by PUSAIR. The precipitation gauge is a totalizing device, which records accumulated precipitation over monthly intervals. The precipitation is accumulated in a bucket, which is manually emptied at regular intervals by an operator of the meteorological service. The volumes stored in the bucket are summed up to obtain monthly total precipitation volumes.

This type of station is commonly found in Indonesia and allows recording reliably average precipitation volumes (e.g. daily, weekly or monthly averages). Totalizing precipitation gauges however cannot be used to record instantaneous precipitation

intensities, which requires a tipping-bucket measuring device.

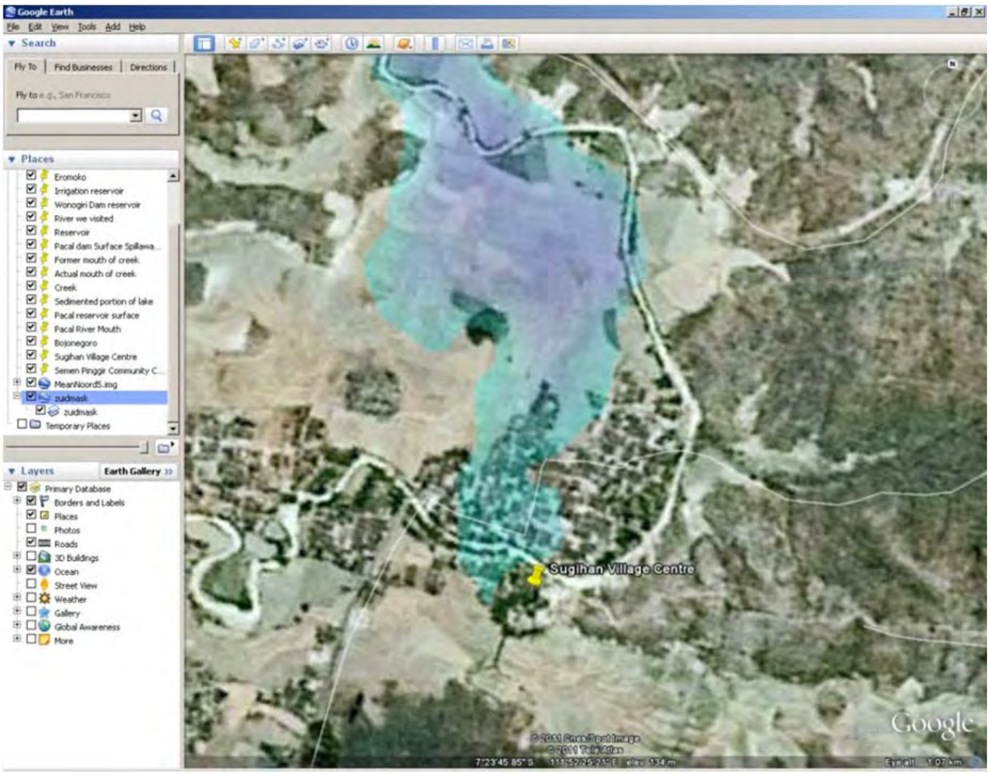

Figure 5.8 The GIS-based modeling of the Inundation area in Sugihan

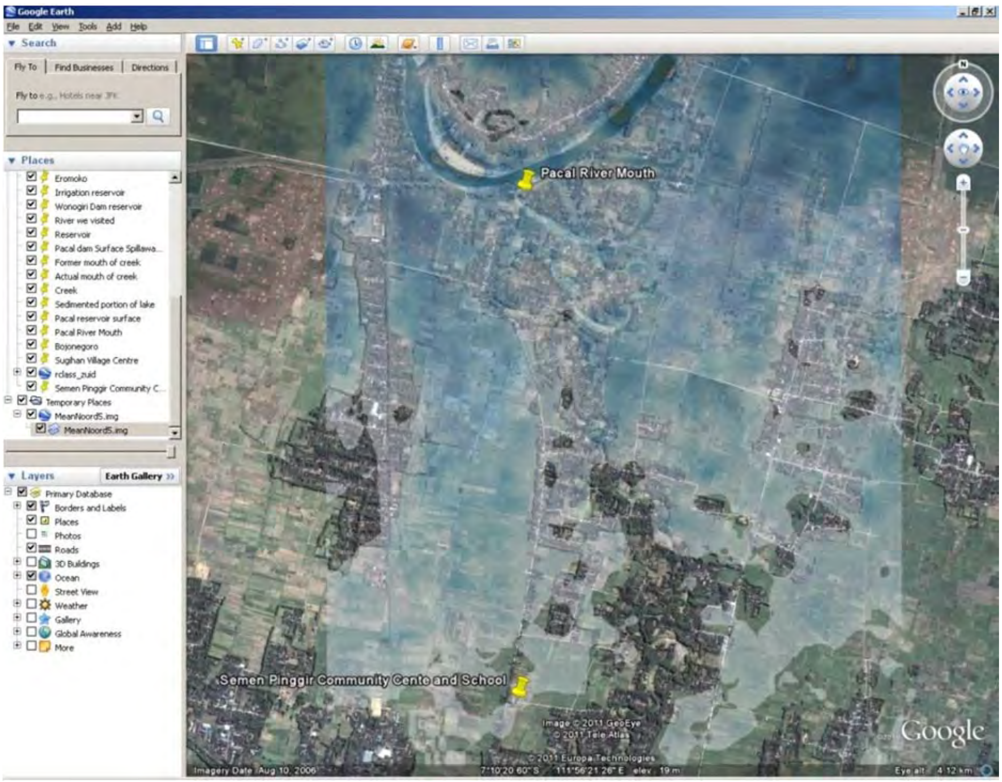

Figure 5.9 The GIS-based modeling of inundation at Semen Pinggir

In Table 5.2 the monthly precipitation for the years 1994-2007, including basic statistics such as annual totals, maximum, minimum and the average precipitation for each year are reported. It can be noted that the maximum annual precipitation recorded is 2920 mm/year. The maximum monthly average precipitation is recorded December until March, while the driest period of the year is June until October. The daily data recorded at the Kedung Pingit Station are shown in Figure 5.10.

Table 5.2 Monthly precipitation recordings at Kedung Pingit for the period 1996-2007.

YEAR	MONTH												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total (mm/thn)
1994	461	243	397	114	41	0	0	0	0	0	81	214	1551
1995	398	249	556	282	27	36	22	0	0	139	265	164	2138
1996	178	282	205	148	0	0	0	40	0	216	246	308	1623
1997	221	270	67	229	121	0	0	0	0	0	49	292	1249
1998	373	597	450	402	0	238	182	36	108		257	277	2920
1999	450	159	303	140	74	0	0	7	0	59	459	304	1955
2000	211	159	358	199	171	75	0	0	0	192	195	217	1777
2001	238	188	233	197	59	76	0	0	0	119	305	263	1678
2002	476	102	444	142	103	0	0	0	0	0	43	424	1734
2003	505	353	53	81	89	48	0	0	0	0	226	356	1711
2004	482	280	437	101	16	60	7	0	21	0	290	547	2241
2005	394	308	178	443	42	0	0	0	0	48	82	590	2085
2006	353	303	143	242	200	0	0	0	0	0	14	482	1737
2007	99	245	245	378	0	31	0	0	0	29	176	537	1740
Max	505	597	556	443	200	238	182	40	108	216	459	590	2920
Average	346	267	291	206	67	40	15	6	9	62	192	355	1867
Min	99	102	53	81	0	0	0	0	0	0	14	164	1249

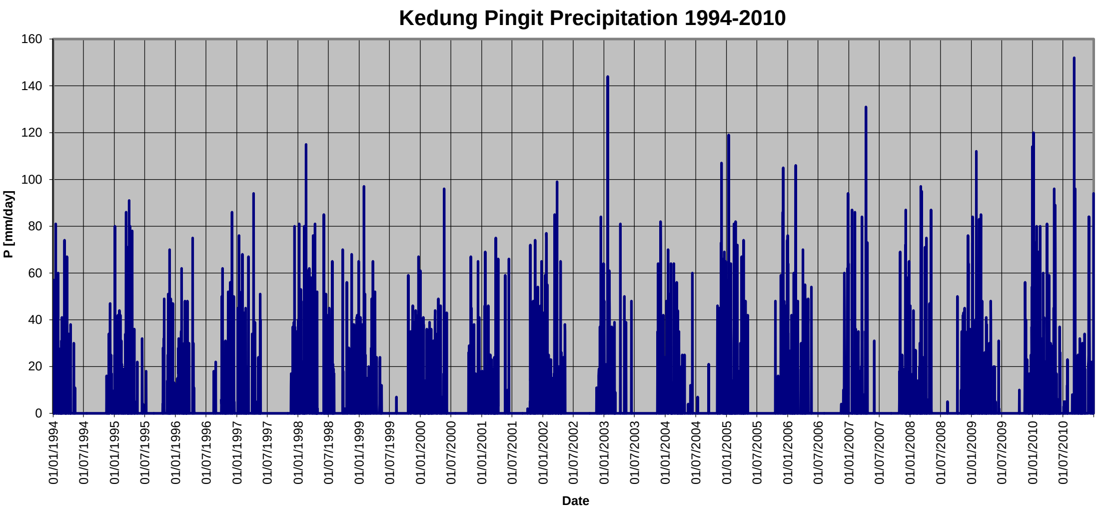

Figure 5.10 Daily precipitation recorded at Kedung Pingit Station (1994-2010)

5.2.4 Discharge estimation at Kedung Sumber Village (Sugihan)

The daily precipitation data can be used to give a rough discharge estimate at the village of Sugihan. Given that the upstream watershed area is known, and the slope can be estimated form the digital terrain data, it is possible to apply a synthetic hydrograph formula to get the possible peak discharge. The rational method allows calculating the peak discharge as follows:

$$Q_p = 2.78CiS \qquad (5.1)$$

where C is a runoff coefficient, i is the intensity in mm/hour and is S the basin surface in hectares. From the analysis of the digital terrain map (see Figure 5.7) it has been

calculated that the drainage area upstream of Sugihan is 2300 hectares (23 km^2). The runoff coefficient for a lowly urbanized area is assumed as 0.3.

The maximum recorded daily precipitation is 140 mm/day. Nearly every year a maximum precipitation of 100 mm/day has been reached. If we assume that this precipitation is falling within 4 hours in a day, this results in a rainfall intensity of 25 mm/hour. By introducing these values in the rational formula, on obtains the following peak discharge at Sugihan:

$$Q_p = 2.78 \cdot 0.3 \cdot 25 \cdot 2300 \approx 48 m^3/s$$

The time to peak can be calculated also by means of a simple formula, such as the Kirpich formula:

$$T_c = 0.01947 L^{0.77} S^{-0.385} \tag{5.2}$$

where L is the length of the main river in meters and S is the dimensionless slope. For the basin in question the length of the channel passing through Sugihan and originating further upstream is estimated form the analysis of the digital terrain information at about 5000 m. The slope of the channel is 0.0138. By inserting these values in the formula one obtains:

$$T_c = 0.01947 \cdot 5000^{0.77} \cdot 0.0138^{-0.385} \approx\sim 70 \min$$

thus the concentration time or time to peak at Sugihan is slightly longer than one hour. This confirms that the flood type observed in Sugihan can be classified as flash-flood. The time to take mitigating actions for the inhabitants of the village is very short. This confirms the importance of having a high-frequency recording gauging station installed in Pajeng, which is about 5 km upstream.

5.3 Raingauge Installation at Pajeng

In reference to the request by ADB, a rain gauging station was installed in the upper part of Pacal River catchment to provide early warning to the community at village of Sugihan from flash flooding due to runoff generated in the upstream catchment area. The upper part of the catchment belongs to the village of Gondang.

The location is the backyard of the village community centre. The station position is 07°25' 23" S and 111°53' 14" N.

The instrument should be able to record precipitation at short time intervals (in the order of 5 to 10 minutes) and send a warning via SMS to a series of cellular phones in case the precipitation exceeds a predefined intensity threshold. It was also agreed that a rain gauge for cumulative precipitation measurements was not suitable as flood warning instrument for flash floods in Sugihan, because the catchment area is too small and the runoff in the Pacal River is rising quickly in response to rainfall.

The rain gauging station was ordered and installed in Pajeng on July 15th, 2011. The particular flash flood warning application required the embedded software of the instrument to be modified by Hydrosix in the factory before delivery. The SMS warning message should only be sent after the precipitation threshold was reached (e.g 40 mm/hour). For electricity a solar panel and battery pack were needed.

The choice for the tipping bucket rain gauging station has been made for the following reasons:

- The flash flood regime requires fast warning, when the precipitation intensity over time exceeds a certain limit. Intensity can only be gauged with a tipping bucket station and not with a totalizing instrument.
- The station needs to be equipped with a telemetry system, to send SMS warning messages to interested parties.
- The station should be compatible with the BBWS observing station, which is made by the same manufacturer and be able to feed into the BBWS data server. This compatibility was a requirement for the station to be maintained in the future by BBWS.

During the installation in July 2011 the civil engineering works were carried out and a fence erected. The station was placed according to WMO guidelines and went online immediately. Figure 5.11 shows a technical drawing of all elements, including the pillars for the installation of the rain gauge and the metal box containing the electronic equipment as well as the 2.5 inch galvanized steel pole supporting the solar panel. The whole equipment location is protected by a fence aimed at preventing vandalism. The design of the civil works is fully compatible with WMO standards and has also been adopted by JICA in the Brantas basin.

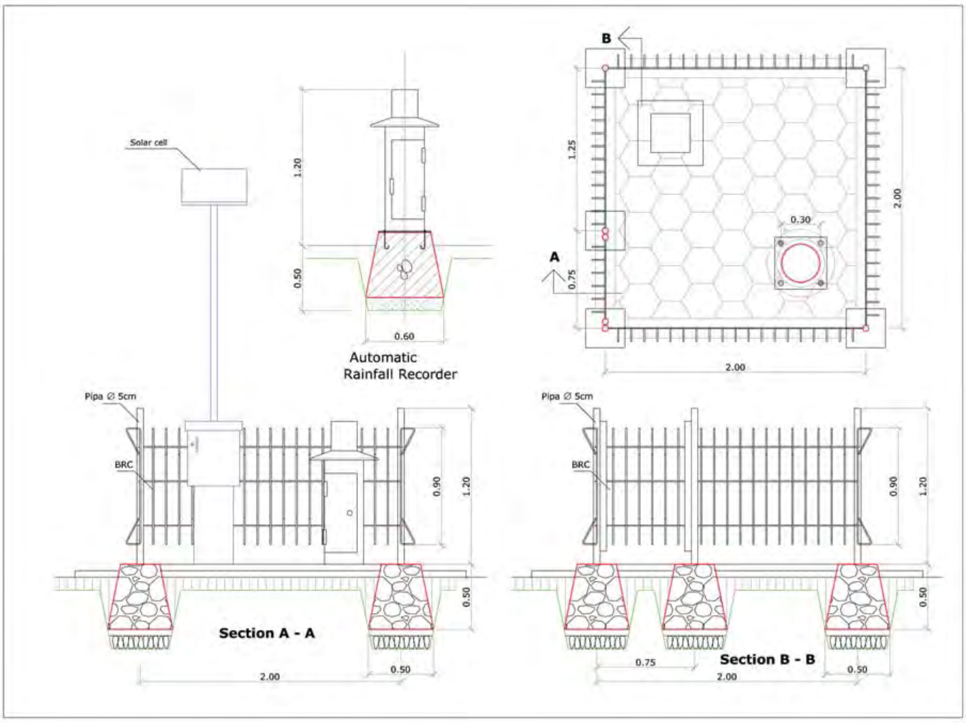

Figure 5.11 Schematic view of the civil works for the placement of the rain gauge

After installation the rain-gauge was connected to the local GSM network. The rain-gauge was subsequently connected. The rain gauge station has two basic functionalities:

1) In case of high rainfall intensity the system is directly transmitting a warning signal (via SMS) to six pre-defined receivers (persons)

2) Every hour the station is transmitting the cumulative rainfall data in 5 minutes intervals

to PusAir institute. PusAir is transferring the signal automatically to the dataserver of Tech4water. They publish the recorded data on a public website (see Figure 5.12)

Subsequently, the instrument was tested. However, it turned out that the software which is designed to send SMS text messages to selected cell phones in Sugihan and BNPD needed to be adapted to handle the narrow data transmission bandwidth.

This adaptation required further software development at Hydrosix headquarters. The software update was performed on the 19th of September by a Hydro6 technician. The station is currently able to transmit a warning SMS to six people when a threshold of 40 mm/hour is reached. One of the persons receiving a warning SMS is Mr. Didi Saputra, village chief of Sugihan. Another receiver is a duty mobile phone at BNPD in Bojonegoro.

At the moment of writing this report the precipitation station is connected to the central server at the Centre for Water Resource Management (PUSAIR) in Bandung. The station data is accessible online through a web server on the URL: www.tech4water.com.

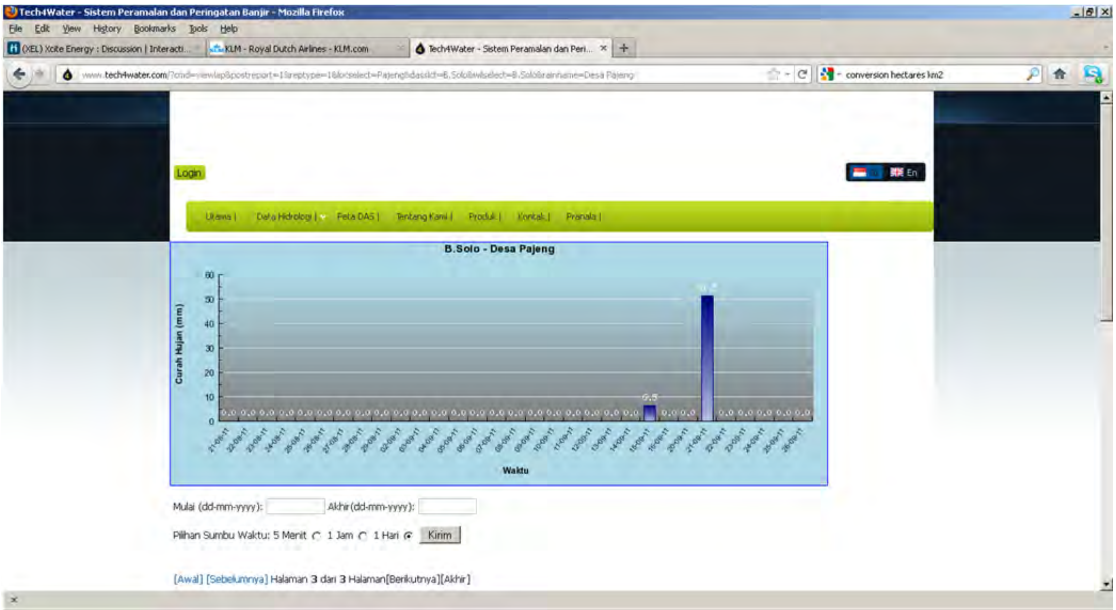

Figure 5.12 Tech4Water.com web interface to the rainfall data recorded at Pajeng gauging station

Calibration

After some weeks of testing the people from the village receiving the messages noticed that the instrument issued warnings when there was no flooding imminent and failed to issue timely warnings in when the inundation actually occurred.

These issues were addressed and found to be related to the implementation of the software. The software only sent out warning messages when the precipitation threshold was exceeded on the hour, but as it would reset its readings could not issue a warning when part of the high rain would fall before the hour and part after the hour (e.g. 30 mm before 5 pm and 20 mm after 5 pm).

The instrument was thus recalibrated and reprogrammed after the visit to Pajeng at the end of February 2012. The recalibration was performed at the factory in Bandung, and the registering device with new software installed was shipped to Pajeng, to replace the

component already present on site.

The software in the rain gauge has been updated to send a message after a period of 20 mm or more rain is recorded over the preceding 30 minutes (using a moving window). After a message the instrument will pause for 30 minutes before sending a next message to prevent double counting of a certain 5-minute period. The message that is sent in Bahasa Indonesia is now as follows:

Tanggal 09/03/2012 jam 15:15:10 WASPADA BANJIR ! SELAMATKAN HARTA BENDA DAN SIAPKAN BARANG BAWAAN.
Selama 30 menit berlalu: curah hujan = 23.00 mm.

Translation:

Date 09/03/2012 time 15:15:10 Be aware of flood ! Store your valuables and prepare goods to take with you. In the last 30 minutes the rain was 23 mm.

The rain gauge (tipping bucket) was re-calibrated in the lab as well as in the field. The messaging was tested on site and it was indeed sent at the right moment to the right people.

Finally the antenna of the GSM device was raised to 11,50 meter and as a result the response time of the SMS improved significantly. The new situation and message were explained to the chiefs in both villages. The village chief of Sugihan (Mr. Didi Saputra) was very satisfied with the functioning of the warning system. The lead time before actual flooding in the village has now been extended to approximately one hour. This is seen as a major improvement by all inhabitants of the village.

5.4 Drafting of Community-Based Hazard Map

In each pilot village, a local hazard map was drafted by community participation. In the sub village of Sugihan ten representative inhabitants, including the village chief, were drafting the hazard map, whereas in Semen Pinggir Village about 20 inhabitants, including the village chief, joined and were drafting a hazard map.

The map is drafted in three steps: 1) a social map outlining the birds-eye view of the village, individual houses, roads, the river, dykes and the use of open land areas (crops, forest), 2) a hazard map, in which three types of inundated areas are highlighted: a) areas flooded with < 50 cm of water, b) areas covered between 50 cm and 100 cm of water and c) areas with water depths > 100 cm, 3) the drafting of the evacuation map on which potential evacuation routes are highlighted. The drafting of the three maps and a question and answer session about flood damages took about 5 hours.

5.5 Evacuation Drills Demonstration

5.5.1 Coordination with the local government and community leaders.

The demonstration evacuation drills at Bojonegoro was successfully conducted because of great contribution and participationof many organizations including local administrative bodies, BBWS Bengawan Solo, Center for River Basin Organization Management (CRBOM), Deltares Consultant, PusAir and the CBDRM experts team of Gadjah Mada University.

An active collaboration of the local government and community has been developed through an intensive interaction and communication between project staff and the government as well as community members in efforts to understand local problems and facilitate the communities to become able to evaluate their risks by themselves. This active involement of the officers from various government organizations have benefited them to be able to carry out the similar activie in to other relevant area.

Main points of coordination with the local administrative bodies included:

(1) Courtesy visit and explanation about the evacuation drill activitiesto the Regent of Bojonegoro Regency. The Regent welcome very well that the evacuation drills is carried out in the selected villages within Bojonegoro and he ordered the Vice Regent to provide full support and to attend the inauguration ceremony of the drills.

(2) Visit to the local disaster management agency (BPBD) to explain about the evacuation drill activities, discussion and idea sharing on the drill scenarios, including determination of locations, dates, necessary equipments, and number of participant. BPBD expressed that the community agree and are ready to be empowered on flood risk management. Also tents, rubber boats, and others equipments are ready to mobilize.

(3) Visit to the local Water Resource Management Office (Balai PSDA) of Bengawan Solo River Region to explain about the evacuation drill activities, discussion on the existing local practices conducted by local community in managing flood disaster and developing scenario of adopting the existing practice in the evacuation drills.

(4) Coordination with the local community leaders of the pilot villages for the arrangement of place of gathering, mobilization of village residents, equipment preparation, logistics, etc.

5.5.2 Evacuation drill demonstration implementation.

The evacuation drill was conducted through several phases, which are lecture, disaster mitigation game, development of SOP (Standard Operation Procedure), establishment of disaster preparedness organization, determination of evacuation scenario based on proposed Early Warning System (EWS) and drill implementation.

5.5.2.1 Lecture

The lecture material was elaborated as follows:

Lecture 1: Introduction on the disaster risk reduction program based on community collaboration

- Rainfall monitoring for flood forecast
- Relationship between rainfall intensity and flood or flash flood occurrence
- Development of community-based flood early warning system (EWS)
- Exploring the flood disaster potential in Kedung Sumber Village and Semen Pinggir Village

Lecture 2: Community-based evacuation drill against flood disaster

- Disaster risk reduction strategy
- How to design an evacuation drill program
- Success story of evacuation drill at Mt. Merapi area
- Development of SOP, evacuation map, and disaster preparedness organization
- Evacuation drill scenario with different warning level

Figures 5.13 and 5.14 show the lecture activity in both villages.

Figure 5.13 Lecture at Kedung Sumber Village on 14 July 2011

Figure5.14 Lecture at Semen Pinggir Village on 15 July 2011

5.5.2.2 Disaster Mitigation Game

In order to reduce disaster risk, integrated and participative steps with local community as the main actor are needed. Therefore, a collborative program with local community as the target should be developed. The aim of the program is to improve the local community’s awareness on disaster management by improving understanding on the natural hazards they may face (i.e floodings) and knowledge on strategic steps and risk reduction techniques when disaster happens with local community as the target. The game is addressed at transferring the materials in more interactive way among the local people, relaxand fun, but meet the target of raising the local communities’ capacity managing the disaster.

(1) Pick Up Priority Game

The purpose of this game is to find out the tendency and understanding of the participants on the items to bring for evacuation. In this game, the participants were divided into three groups. Each group will choose one by one the items that they will take when flood occurs according to the priority scale. Then, every group, represented by their coordinator will give explanation on the reason why they choose to take those items.

From this game, it can be concluded that the people in Sugihan Sub-Village consider important documents as the first item to be saved when flood occurs as they think that the documents are very important for the future of their family.

Other than important documents, the participants also chose money and jewelry, communication means, flashlight, medicines, and dried/instant food as the next items to take. Meanwhile, a group felt that it was necessary to take lifejacket and another group felt that cattle should be brought when evacuating.

In Semen Pinggir Village, each group chose different items. A group chose important documents for the main priority as they consider them important for the future; another group chose communication means as they think that they need it for communicating with their relatives/friends who may help them; and the last group chose baby kit as they consider them important for the babies, who are in vulnerable group and should be evacuated first. The next items were medicines, money and jewelry, primary food, clothes, lifejackets, and cattle.

At the end of the game, the participants are expected to have awareness on the importance of self-preparation in facing flood disaster. The preparation begins with preparing the necessary items to bring for evacuation since flood warning alert is received. Figure 5.15 shows the activities during pick-up priority game at Semen Pinggir Village and Kedung Sumber Village.

(a)

(b)

Figure 5.15 The activities during pick-up priority game at (a) Kedung Sumber Village and (b) Semen Pinggir Village

(2) Cross Road Game

Crossroad Game was originally set for disaster education, building awareness, and willingness, by presenting dilemmatic situation during emergency, in order to make people aware what should be prepared in such situation. Through the discussion after making the decision, the participants (villagers/communities) will be able to extract basic essentials of disaster risk management, in this case is the impact of climate change.

Crossroad game is not a tool to solve the problem, but to find out and to understand or describe the conflicting situation as the obstacle of establishing awareness on climate change impact, especially related to water resources management, in related to daily basic need or income/livelihood. The essence of Crossroad is not to judge who or how many the minorities or majorities are. Sometimes the minorities' opinions can also help to open the minds of other participants for the reasons of doing another possible action. That is why there is no Right or Wrong answers, all opinions are correct. Figure 5.16 shows cross-road game at Kedung Sumber Village and Semen Pinggir Village. Meanwhile, the cross-road game evaluation is shown in Annex-4, Table A4.1 and Table A4.2.

Figure 5.16 Cross-road game at (left) Kedung Sumber Village and (right) Semen Pinggir Village

5.5.2.3 Develop Standard Operating Procedure (SOP) and Disaster Preparedness Organization

This evacuation drill is one of the efforts to improve the capacity building of the local community in flood disaster mitigation in Bojonegoro Regency area. The local community is expected to be able to conduct self-evacuation in the end. The preparedness training for local community in anticipating flood disaster was conducted in two days for the selected locations. The training was carried out in several phases, namely a lecture on disaster materials, establishment of Standard Operating Procedures (SOP) and establishment of Disaster Preparedness Organization. Evacuation map was made previously involving several village officials and village/sub-village key persons/focal points. From the SOP, the steps or procedures to be taken in each flood level can be found or known.

(1) Develop SOP and Disaster Preparedness Organization in Sugihan Sub-Village, Kedung Sumber Village, Temayang District

The people of Kedung Sumber Village in general have understood that the area that they reside in is a flash flood prone area. The knowledge that they have inherited from their ancestors to anticipate flash flood is actually effective as their capital in flash flood disaster preparedness. They naturally know when and where they have to evacuate when flash flood hits, how they response the functions of sub-village officials, how they save their precious items including cattle, and when they decide to leave their houses and evacuate. Consequently, they are easier to be asked to involve in formulating SOP and Disaster Preparedness Organization in sub-village level in accordance to their necessity. Figure 5.17 shows the development of SOP and Disaster Preparedness Organization. Figure 5.18 shows the organizational structure in Sugihan Sub Village, Kedung Sumber Village while the SOP in anticipating flash flood is shown in the Annex-4 Table A4.3.

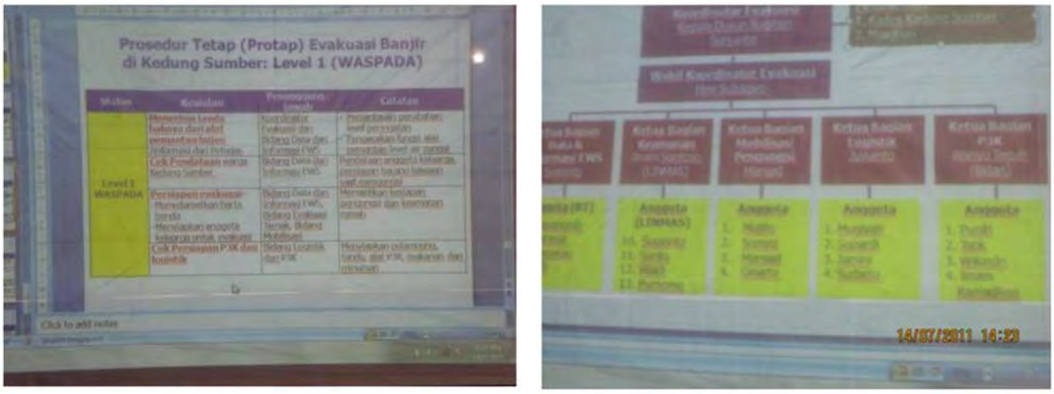

Figure 5.17 The development of SOP and Disaster Preparedness Organization at Sugihan Sub-Village, Kedung Sumber Village

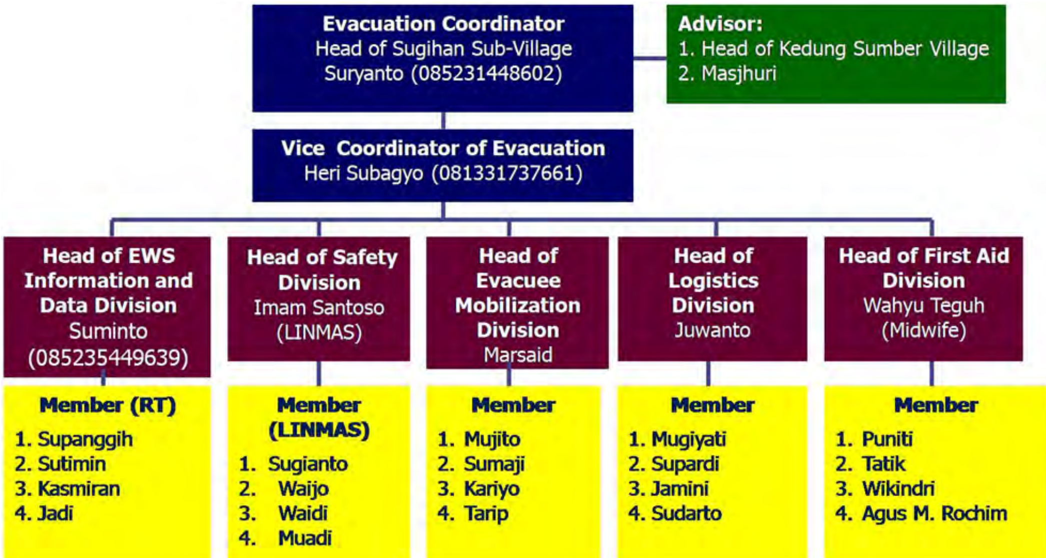

Figure 5.18 Disaster Preparedness Organization of Sugihan Sub-Village, Kedung Sumber Village

(2) Development of SOP and Disaster Preparedness Organization in Semen Pinggir Village, Kapas District

Disaster preparedness training for local community was carried out on 15 and 16 July, 2011. On the first day, other than delivering a lecture on disaster materials, disaster games were also conduced, and SOP for flood disaster evacuation and disaster preparedness organization were established. The training was attended by the representatives of three sub villages, i.e. Pinggir, Semen, and Pagak. Pagak is the most affected sub-village by the flood.

Semen Pinggir Village is a village affected by two types of flood, namely flash flood and flood occurring every year. Consequently, with this training, the community of Semen Pinggir Village is expected to improve their preparedness in anticipating flood disaster. Figure 5.19 shows the development of the SOP and Figure 5.20 shows organizational structure in Semen Pinggir Village. The SOP in anticipating flood disaster is shown in Annex-4 Table A4.4.

Figure 5.19 The development of SOP and organizational structure at Semen Pinggir Village

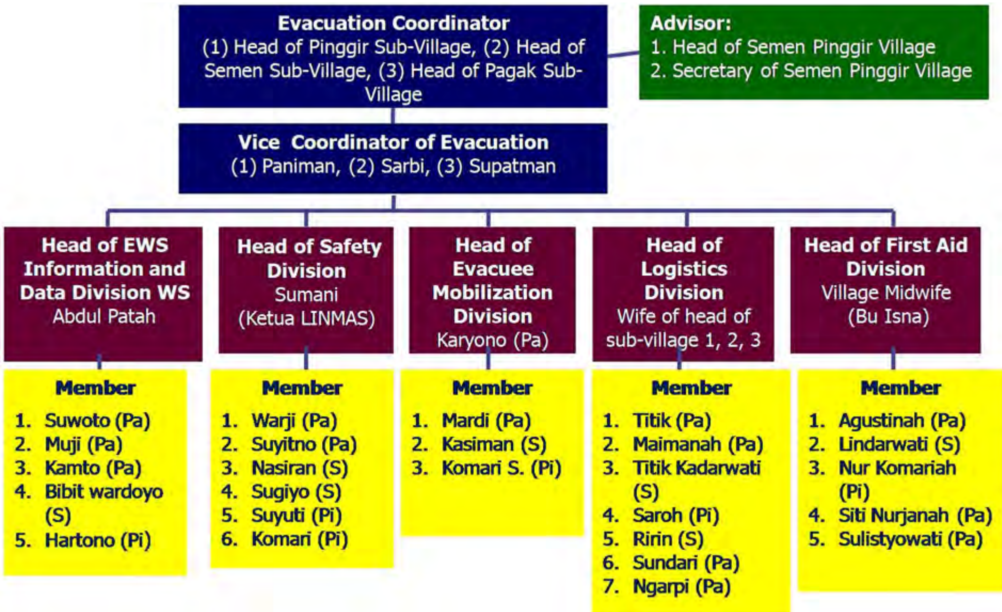

Figure 5.20 Disaster Preparedness Organization of Semen Pinggir Village

5.5.2.4 Evacuation simulation

(1) Evacuation simulation at Semen Pinggir Village

The scenario for the evacuation drill is in line with the previously established SOP. The simulated warning level was Siaga 2 Level (Packing) and Siaga 3 Level (Evacuating). All participants performed their roles respectivelyaccording to the SOP. A house of an inhabitant located on a higher ground was used as the evacuation shelter.

Each key actor well performed hisrole, exceptthose who did not attend the training on the day before.Their absent in the pre training affected their ability to convey a clear message or instruction in each step of evacuation, which leadto confusion and inaccurate follow up actions.

In general, the items in the SOP were carried out entirely. The transfer of

information on flood warning level was quite smooth, however, in the realization, some mistakes were made and some officers were still confused on their job descriptions. This is understandable due to the limited time for the preparation. Furthermore, the disaster preparedness organization that includes three sub-villages was not optimal in implementing the evacuation drill as it was conducted only in Pagak Sub-Village. Figure 5.21 shows the evacuation simulation at Pagak Sub-Village, Semen Pinggir Village.

Figure 5.21 Evacuation simulation at Semen Pinggir Village

(2) Evacuation simulation at Sugihan Sub-Village, Kedung Sumber Village

The simulated warning level is Siaga 2 (Warning) and Siaga 3 (Evacuating). All participants conducted evacuation drill according to their job descriptions in the SOP. Almost all of the evacuation key-actors understood their tasks. The evacuation drill went smoothly and all items in the SOP were conducted due to the strong leadership of the head of Sugihan Sub- Village. Fortunately, this pilot village carried out intensive supervised preparation for several days prior to the implementation of the drill, thus, issues that might arise during the drill had been discussed and solved before the implementation of the drill. During the drill, speakers in the mosque were also used to give information to the local community. The local school which is located on the higher ground was used for the evacuation shelter. Figure 5.22 shows the evacuation simulation at Sugihan Sub-Village, Kedung Sumber Village.

Figure 5.22 Evacuation Drill at Sugihan Sub-Village, Kedung Sumber Village

Figure 5.23 Evacuation Drill Evaluation at Semen Pinggir Village (left) and Kedung Sumber Village (right)

5.5.3 Evaluation and Recommendations

5.5.3.1 Evaluation of the evacuation drill implementation

An evaluation meeting was held with community members and observers from the local government offices right after each evacuation drill and discussed actual evacuation actions deviated from the SOP, difficulties found in the implementation of the SOP, the improvement of SOP, and general views and opinions for future activities. Figure 5.23 shows the evacuation drill evaluation in Semen Pinggir Village and Kedung Sumber Village.

Some important points arisen in the evaluation are given as the following:

1) The establishment of SOP, evacuation map, and disaster preparedness organization should involve key persons, village officials, LINMAS, etc. so that the materials can be understood and easily implemented by local people.
2) The determination of warning level has an important role in the establishment of SOP and determination on when the local people should pack and evacuate.
3) The information flow from head of village → head of sub-village → head of division → members of division → villagers should be elaborated, i.e. timing, media to be used, and information to be delivered.
4) The participation of all of local people/villagers is highly expected to improve their capacity in anticipating disaster.
5) Preparation for evacuation drill should take a longer time and should be more structured.
6) Evacuation drill should be implemented regularly with supervision from related parties.
7) This kind of activity should be coordinated with similar activities in the regency/provincial level through communication with BPBD, Bappeda Bojonegoro, PMI (Indonesian Red Cross), SAR, Police and army.

5.5.3.2 Recomendations for Future Sustainability of the Disaster Management Program

1) It should be borne in mind that the awareness and capacity of community in the anticipating the disaster of flooding and flash flood in Semen Pinggir and flash flood in Kedung Sumber need to maintained in such that sustainability is met.
2) Frequent similar drills have been requested by both local people and local authorities. Since this enthusiasm came from the local communities, means that this is a kind of 'strength' that should be considered designing the strategy for future activities. Otherwise, local community would be having little trust and spirit to develop their capacity.
3) A sufficient strategic method to develop action plan for the disaster management in a community level is therefore essential, at least for short term period (e.g. three years action plan).
4) The utilization of advance technology of monitoring system such as IFAS system for Semen Pinggir and real time Automatic Rainfall Recorder (ARR) in Kedung Sumber should be made more obvious that local community understand exactly what information they may get and how sufficient the beneficial is.
5) Immediate action regarding the establishment/improvement of such system need to be considered, since the system is not yet function properly at thhe meoment. Similarly, for the utilization of water level monitoring system and its warning criteria in the form of what they should do when tha water level reach with line of green, yellow and red seems to be evaluated, based on the local community experience so far. The appropriate warning criteria may not be established unless sufficient data (length and accuracy) is provided.
6) Discussion regarding some short of EWS performance evaluation with the local community should be conducted frequently that make the system

gradually improved from time to time and contribute more beneficial to community.

7) It is expected that lesson and practical learned from this evacuation drill demonstration can be used by the government officer to implement the similar thing to other relevant locations.

8) In order to improve the quality of local CBDRM in the future, the potential linkage to the utilization of IFAS simulation forecast as a supplementary source of warning alert should be seriously elaborated.

6. Conclusions and Recommendations

6.1 Conclusions

1. IFAS technology has been transferred to BBWS Bengawan Solo through two main training workshops and three additional intensive trainings.
2. IFAS software has been installed in BBWS Bengawan Solo for training purpose and ready for application in Bengawan Solo River Basin.
3. IFAS software has been improved to be able to do flood forecasting and sending warning alert and successfully simulated the case of the 2007 flood in Solo River Basin.
4. A demonstration CBDRM activity has been carried out successfully to educate people awareness on flood disaster preparedness, response and mitigation.

6.2 Recommendations and the way forward

1. To improve the accuracy of IFAS application in Bengawan Solo River Basin, improvement of parameter (land use, soil data, etc.) with the latest local data and increase number of ground based observation facilities (rain gauge, water level gauge, discharge gauge, Height of water level – Quantity of river discharge rating curve) are significant.
2. A person in charge of IFAS operation and parameter update should be specifically assigned to maintain the sustainability of IFAS operation in Bengawan Solo River Basin.
3. The demonstration activities of CBDRM should be followed up by BBWS Bengawan Solo and local government periodically to sustain the awareness and preparedness of the community. This activity should also be tried to implement in other community area to develop local community capacity in disaster management.
4. The performance of the rain gauge installed at Kedung Sumber Village for supporting CBDRM activities must be monitored and improved to reach the objective of its installation; the monitoring include: correlation between rainfall intensity and river water level, the alert function of the rain gauge. In this relation operation and maintenance cooperation among stakeholders in Bengawan Solo River Basin should be well coordinated.
5. Collaboration with other organizations, such as BMKG, PusAir, PJT-I, etc. are very important towards more effective application of IFAS.

Acknowledgement

This final report of Indonesia Component is prepared under in-country project support program of Asian Development Bank, Technical Assistance for Supporting Investments in Water-Related Disaster Management (TA7276). The Deltares, Netherland also contributed to prepare Chapter 5 of this report. We, International Centre for Water Hazard and Risk Management (ICHARM), Public Works Research Institute (PWRI), Japan, would like to express our acknowledgement to Deltares, Netherland for their contribution. We highly appreciate for their contribution in Chapter 5 of this report.

We would also like to express our gratitude to Mr. Katsuhito Miyake, Senior Disaster Risk Management Specialist, the World Bank and Mr. Kimio Takeya, Visiting Senior Advisor, Japan International Cooperation Agency for their kind support to prepare initial implementation plan of Indonesia Component and for their suggestions when they have been assigned to ICHARM and ADB respectively.

Annex 1: Collected data

Division	Name	Creator	Grid size	Coordinate	Data format
DEM	GTOPO30	USGS	Horizontal grid (1km mesh)spacing is 30 arc seconds	Horizontal direction WGS84 Vertical direction, meter unit from average sea level	8 files are providedfor each 33 tiles
	Hydro1k	USGS	Horizontal grid (1km mesh)	lambert Azimuthal Equal Area	af_dem.bil ,as_dem.bil, au_dem.bil, eu_dem.bil, na_dem.bil, sa_dem.bil as 6 files
	Global Map	ISCGM	Horizontal grid (1km mesh)spacing is 30 arc seconds	Horizontal direction WGS84 Vertical direction, meter unit from average sea level	Data of each tile are provided in bil format
	SRTM	USGS	Horizontal grid (1km mesh)spacing is 3, 15 ,30arc seconds	Horizontal direction WGS84 Vertical direction, meter unit from average sea level	Bil
Land Use	GLCC	USGS	1km grid	Spatial coordinate -ITRF94 Elipsoid-GRS80	Raster data (img),binary data
	Global Map (Landuse)	ISCGM	Horizontal grid (1km mesh)spacing is 30 arc seconds	Horizontal direction WGS84 Vertical direction, meter unit from average sea level	Data of each tile are provided in bil format
	Global Map (Landuse)	ISCGM	Horizontal grid (1km mesh)spacing is 30 arc seconds	Horizontal direction WGS84 Vertical direction, meter unit from average sea level	Data of each tile are provided in bil format
Soil, Geology etc.	Soil classification	UNEP/DEWA/GRID	1 degree	Origin point of 90 degrees North latitude and 180 degrees West longitude	Bil
	Soil depth	GES DISC,NASA	1 degree（111km）		bil、sol
	Soil water holding capacity	UNEP/DEWA/GRID	1 degree	Origin point of 90 degrees North latitude and 180 degrees West longitude	Bil
	Geological classification*	CGMW		Mercator image method	Bsq CD（Arc Info format）
	Geological Map of Jawa and Madura	Geological Survey of Indonesia	-	Horizontal direction WGS84	Paper format
River system	HydroHEDS Flow accumlation	USGS (Analyzed by Deltares)	Horizontal grid spacing is 3 arc seconds	Horizontal direction WGS84 Vertical direction, meter unit from average sea level	Bil
	Track on the Google Earth	ICHARM	-	-	-
	River system	Ministry of Public Works, Indonesia	-	-	Picture
Cross section	Field measurement data	Ministry of Public Works, Indonesia	-	-	AutoCAD format

Ground gauged rainfall data, water level and river discharge data (including H-Q relation curve) have been collected from BBWS. Collected data are shown in Table A1.1 to A1.6.

Concerning the rainfall data, the data can be used for following items;

- Validation of satellite-based rainfall data(especially, GSMaP)
- Development of modification formula for GSMaP localized to Bengawan Solo River Basin.
- Runoff analysis

Concerning the water level, H-Q (Water level and river discharge) relation curve and river discharge data, we can conduct the validation of runoff analysis at the water level observation point which has a river discharge data or water level and H-Q relation curve. These validation points are shown as light blue box in each table. Each "hourly" water level data in 2010 can be transformed to discharge data by using H-Q relation curve in 2009 or 2008. However, the H-Q curve is preferable to be developed in 2010 in terms of its accuracy.

Rainfall

Table A1.1 Collected "Daily" rainfall data

area	station name	Positional information: Indonesian coordinate (x,y)*	Positional information: coordinate latitude longitude	Observation time (@ ? o'clock)	-2000	2000	2001	2002	2003	2004	2005	2006	2007 (flood)	2008	2009	2010	
Lower solo	Bojonegoro	○		7				○	○	○	○	○	○	○	○ (orange)		
	Doplang	○		7				○	○	○	○	○	○	○	○ (orange)		
	Karang binangun		○	7				○	○	○	○	○	○	○	○ (orange)		
	Mundu		○	7				○	○	○	○	○	○	○	○ (orange)		
	Nglirip		○	7				○	○	○	○	○	○	○	○ (orange)		
	Sembung		○	7				○	○	○	○	○	○	○	○ (orange)		
	Bojonegoro Kantor			7				○	○	○	○	○	○	○	○ (orange)		
	Gondang	○		7				○	○	○	○	○	○	○	○ (orange)		
	Lamongan	○	○	7				○	○	○	○	○	○	○	○ (orange)		
	Ngadasan			7				○	○	○	○	○	○	○	○ (orange)		
	Ngliron		○	7				○	○	○	○	○	○	○	○ (orange)		
	Tunder			7				○	○	○	○	○	○	○	○ (orange)		
Upper Solo	Baturetno		○ (red)	7				○	○	○	○	○	○	○	○ (orange)		
	Kali jambe	○	○	7				○	○	○	○	○	○	○	○ (orange)		
	Nawangan		○ (red)	7				○	○	○	○	○	○	○	○ (orange)		
	Pabelan	○	○	7				○	○	○	○	○	○	○	○ (orange)		
	Purwantoro	○	○ (red)	7				○	○	○	○	○	○	○	○ (orange)		
	Tawangmangu	○	○	7				○	○	○	○	○	○	○	○ (orange)		
	Colo		○	7				○	○	○	○	○	○	○	○ (orange)		
	Klaten	○	○	7				○	○	○	○	○	○	○	○ (orange)		
	Nepen	○	○	7				○	○	○	○	○	○	○	○ (orange)		
	Parangjoho			7				○	○	○	○	○	○	○	○ (orange)		
	Song putri		○ (red)	7				○	○	○	○	○	○	○	○ (orange)		
Madiun River	Nglandangan			7				○	○	○	○	○	○	○	○ (orange)		
	Jiwan	○		7				○	○	○	○	○	○	○	○ (orange)		
	Ngawi	○		7				○	○	○	○	○	○	○	○ (orange)		
	Ngerambe	○		7				○	○	○	○	○	○	○	○ (orange)		
	Slahung	○		7				○	○	○	○	○	○	○	○ (orange)		
	Tulung	○		7				○	○	○	○	○	○	○	○ (orange)		
	Jejeruk	○		7				○	○	○	○	○	○	○	○ (orange)		
	Nawangan Ngrindulu	○		7				○	○	○	○	○	○	○	○ (orange)		
	Ngebel			7				○	○	○	○	○	○	○	○ (orange)		
	Pacitan			7				○	○	○	○	○	○	○	○ (orange)		
	Sooko	○		7				○	○	○	○	○	○	○	○ (orange)		
Madiun River Paper	approximately 100 points		△	7							○	○	○	○			
Madiun River CD				7	▲										○ (green)		
??? excel (Klimatologi)	BALONGGPANGGANG		○	?					○	○	○	○	○	○	○		05/18sent
	PADANGAN		○ (blue)	?					○	○	○	○	○	○	○		
upper&lower Solo & Madiun of GIS data from Oky	Wd. Ngancar		○ (blue)														
	Wd. Ketro		○ (blue)														
	Wd. Cengklik		○ (blue)														
	Kd. Uling		○ (blue)														
	Secang		○ (blue)														
	Banjarhardjo		○ (blue)														
	Sumbergadu		○ (blue)														
	Gabel		○ (blue)														
Bojonegoro UPTPSA WS_BSolo	BOJONEGORO-23points		○	?	○	○	○	○	○	○	○	○	○	○	○	○	05/19sent
	GRESIK-14points		○	?	○	○	○	○	○	○	○	○	○	○	○	○	
	LAMONGAN-22points		○	?	○	○	○	○	○	○	○	○	○	○	○	○	
	TUBAN-32points		○	?	○	○	○	○	○	○	○	○	○	○	○	○	

*In case of Bojonegoro, x=596,764, y=9,209,360

*lat-lon can be calculated by this coordinates but lc

○ (red):These data were taught by a man in Workshop March 2010.

△:some of data include their coodinate data.

▲:some of data include several data period (e.g., 1975to1991 etc.)

○ (green):data in 2009 are provided by CD through Dr.Dinar from Suzanti

○ (blue):Location data provided by Oki as GIS data.

○ (orange):data in 2009 are provided by CD from Suzanti during IFAS training in 2010DEC.(Folder_name:Beng. Solo IFAS data¥Rainfall 2009)

Table A1.2 Collected "Daily" rainfall data provided by Bojonegoro PSA

				Indonesian coordinate		Based on Tawangmangu		-> estimated lat&lon		riginaly defined by BBW	
Bojonegoro UPTPSA WS_Bsolo*				X	Y	X	Y	latitude(S)	longitude(E)	latitude(S)	longitude(E)
TUBAN	1	Widang								-7.098033	112.175167
TUBAN	2	Sekaran								-6.882667	111.714483
TUBAN	3	Kerek								-6.908333	111.883267
TUBAN	4	Plajan								-6.863333	111.796667
TUBAN	5	Sumurgung								-6.960883	111.906450
TUBAN	6	Ngolahan								-6.879200	111.742767
TUBAN	7	Maibit								-7.072433	111.987967
TUBAN	8	Bangilan								-6.972000	111.715567
TUBAN	9	Montong								-6.957200	111.906900
TUBAN	10	Tuban								-6.893933	112.047150
TUBAN	11	Simo								-6.822033	111.776933
TUBAN	12	Soko								-7.122420	111.938880
TUBAN	13	Rengel								-7.058667	112.010833
TUBAN	14	Tegalrejo								-6.910883	112.005283
TUBAN	15	Tuwiwiyan								-6.928133	111.764483
TUBAN	16	Klotok								-7.066517	112.087283
TUBAN	17	Belikanget								-6.827450	111.810433
TUBAN	18	Boropetung								-6.964067	111.961389
TUBAN	19	Grabagan								-7.004430	111.936930
TUBAN	20	Kebonagung								-6.986750	111.924917
TUBAN	21	Jojogan								-7.147950	111.882167
TUBAN	22	Gaplok								-6.947083	111.942300
TUBAN	23	Kwasen								-6.957000	111.752650
TUBAN	24	Ngabongan								-7.008000	111.797133
TUBAN	25	Kepet								-6.922933	111.062783
TUBAN	26	Kayenjoho								-6.827867	111.742767
TUBAN	27	Kebonharjo								-6.876033	111.645000
LAMONGAN	28	Kedungpring								-7.187170	112.192550
LAMONGAN	29	Blawi								-7.056500	112.456070
LAMONGAN	30	Karanggeneng								-6.999400	112.371820
LAMONGAN	31	Kuro								-7.046370	112.513720
LAMONGAN	32	Jabung								-7.018030	112.225910
LAMONGAN	33	Baru / Girik								-7.259530	112.134530
LAMONGAN	34	Ngimbang								-7.289250	112.215820
LAMONGAN	35	Kembangbahu								-7.183570	112.192550
LAMONGAN	36	Bluluk								-7.272930	112.134530
LAMONGAN	37	Bluri								-6.934220	112.337130
LAMONGAN	38	Kr.binangun								-7.012530	112.502890
LAMONGAN	39	Takeran								-7.188140	112.398780
LAMONGAN	40	Babat								-7.101490	112.166550
LAMONGAN	41	Gondang								-7.176010	112.006100
LAMONGAN	42	Sukodadi								-7.094150	112.329740
LAMONGAN	43	Pangkatrejo								-6.986620	112.284080
LAMONGAN	44	Lamongan								-7.129300	112.398760
LAMONGAN	45	Prijetan								-7.215930	112.208530
LAMONGAN	46	Brondong								-6.871133	112.287750
GRESIK	47	Tambakombo								-7.077520	112.573320
GRESIK	48	Mentaras								-6.974900	112.456200
GRESIK	49	Ujungpangkah								-6.925000	112.554817
GRESIK	50	Krikilan								-7.222400	112.352480
GRESIK	51	Lowayu								-6.978590	112.419420
GRESIK	52	Cerme								-7.131430	112.333460
GRESIK	53	Sidayu								-6.998810	112.509260
GRESIK	54	Menganti								-7.176990	112.359200
GRESIK	55	Benjeng								-7.156010	112.305060
GRESIK	56	Duduksamp.								-7.099160	112.312280
GRESIK	57	Wringinanom								-7.176990	112.351900
GRESIK	58	Panceng								-6.913400	112.458330
GRESIK	59	Suci								-7.238020	112.315210
BOJONEGORO	60	Ngerambe								-7.501313	111.229305
BOJONEGORO	61	Sugihan								-7.242060	111.522690

Table A1.3 Collected "Hourly" rainfall data

	lat/long	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09	Jan-10	Feb-10	Mar-10	Apr-10	May-10
		Dry Season						Rainy Season							
Colo	○								○	○					
kalijambe	○								○	○					
klaten	○								○	○	○				
nepen	○								○	○	○				
tawangmar	○								○	○	○				
pabelan	○		○	○	○	○	○	○	○	○	○				
Jatisrono											●	●	●	●	●
Madiun											●	●	●	●	●

○ already sent by Suzanti-san
● sent_on_20100616

Water Level and river discharge data

Table A1.4 Collected "Daily" water level and river discharge data (1)

Daily		Latitude Longitute	Ovservation Time (Local time)		2002	2003	2004	2005	2006	2007	2008	2009	2010
Lower Solo	K.SOLO-BABAT	○	?	Water Level								○	
				H-Q								○	
				Discharge									
	K.CAWAK-KD.LEREP	○	?	Water Level								○	
				H-Q									
				Discharge								○	
	K.CELEBUNG-BUBULAN	○	?	Water Level								○	
				H-Q								○	
				Discharge								○	
	K.GEMBUL-BECOK/MERAKURAK	○	?	Water Level								○	
				H-Q								○	
				Discharge								○	
	K.GANDONG-STREN	○	?	Water Level								○	
				H-Q								○	
				Discharge								○	
	K.GANGSENG-KEDUNGSARI	○	?	Water Level								○	
				H-Q								○	
				Discharge								○	
	K.KENING-KD.JAMBANGAN		?	Water Level								○	
				H-Q									
				Discharge									
	K. SOLO-KALIKETEK	○	?	Water Level								○	
				H-Q								○	
				Discharge								○	
	K. SOLO-KARANGGENENG	○	?	Water Level								○	
				H-Q								○	
				Discharge								○	
	K.KERJO-PEJOK	○	?	Water Level								○	
				H-Q								○	
				Discharge								○	
	K. KLERO-GENAHARJO/TUBAN	○	?	Water Level								○	
				H-Q									
				Discharge								○	
	K.LOHGUNG-	○	?	Water Level								○	
				H-Q									
				Discharge									
	K. NGLIRIP-MULYO AGUNG	○	?	Water Level								○	
				H-Q								○	
				Discharge								○	
	K. SOLO-PADANGAN	○	?	Water Level								○	
				H-Q									
				Discharge								○	
	K.PRUMPUNG-SIDOMULYO	○	?	Water Level								○	
				H-Q									
				Discharge								○	
	K .KENING-SELOGABUS	○	?	Water Level								○	
				H-Q								○	
				Discharge								○	
	K. SOLO-SEMBAYAT	○	?	Water Level								○	
				H-Q								○	
				Discharge								○	
	K.PACAL-SENGANTEN	○	?	Water Level								○	
				H-Q								○	
				Discharge								○	
	Waduk Pacal-	○	?	Water Level								○	
				H-Q									
				Discharge									

(cyan box) : Discharge data can be used for the validation of runoff analysis

Table A1.4 Collected "Daily" water level and river discharge data (2)

Daily		Latitude Longitute	Ovservation Time (Local time)		2002	2003	2004	2005	2006	2007	2008	2009	2010
Upper Solo	JARUM		7:00 AM	Water Level	△	△	△	△	△	△	○	○	
				H-Q									
				Discharge									
	JURUG	○	7:00 AM	Water Level	○	○	○	○	○	○	○	○	
				H-Q		○	○	○	○	○	○		
				Discharge								○	
	PEREN		7:00 AM	Water Level	○	○	○	○	○	○	○	○	
				H-Q									
				Discharge									
	KAJANGAN	◎	7:00 AM	Water Level	○	○	×	○	○	○	○	○	
				H-Q						○	○		
				Discharge								○	
	SERENAN		7:00 AM	Water Level	○	○	○	○	○	○	○	○	
				H-Q		○	○	○	○	○	○		
				Discharge								○	
	Kr. NONGKO		7:00 AM	Water Level	○	○	○	○	○	△	△		
				H-Q									
				Discharge									
	NGADIPIRO		7:00 AM	Water Level	×	×	×	×	○	○	△	○	
				H-Q									
				Discharge									
	NGREMBANG		7:00 AM	Water Level	○	○	○	○	○	○	○	○	
				H-Q									
				Discharge									
Lower Solo	BLAWI		7:00 AM	Water Level	○	○	△	○	△	△	△	△	
				H-Q									
				Discharge									
	BOJONEGORO	○	7:00 AM	Water Level	○	○	○	○	○	△	△	○	
				H-Q									
				Discharge								○	
	BRANGKAL	○	7:00 AM	Water Level	○	○	○	○	△	△	○	○	
				H-Q									
				Discharge									
	CEPU (Automatic Water Level Record)	◎	7:00 AM	Water Level	○	○	○	○	○	○	○	○	
				H-Q		○	○	○	○	○	○		
				Discharge								○	
	KULURAN	○	7:00 AM	Water Level	○	○	○	○	○	△	○	○	
				H-Q									
				Discharge									
	NAPEL (Automatic Water Level Record)	◎	7:00 AM	Water Level	○	○	○	○	○	○	○	○	
				H-Q		○	○	○	○	○	○		
				Discharge								○	
	Karang Nongko	◎	7:00 AM	Water Level								△	
				H-Q									
				Discharge									
Madiun	KETONGGO	◎	7:00 AM	Water Level	○	○	○	○	○	○	○	○	
				H-Q		○	○	○					
				Discharge								○	
	SEKAYU (Automatic Water Level Record)	◎	7:00 AM	Water Level	○	○	△	△	○	○	○	○	
				H-Q		○	△	△	○	○	○		
				Discharge								○	
	BENDO	○	7:00 AM	Water Level	○	○	△	○	○	○	○	○	
				H-Q									
				Discharge									
	BADEGAN	◎	7:00 AM	Water Level	○	○	○	○	○	○	○	○	
				H-Q									
				Discharge									
Out of Solo	ARJOWINANGUN	○	7:00 AM	Water Level	○	○	○	○	○	○	○	○	
				H-Q									
				Discharge								○	
	BOBOH-LAMONG		7:00 AM	Water Level	△	△	△	△	△	△	△	△	
				H-Q									
				Discharge									
	Pacitan (Automatic Water Level Record)	◎	7:00 AM	Water Level									
				H-Q						○	○		
				Discharge									

: Discharge data can be used for the validation of runoff analysis

Table A1.5 Collected "Hourly" water level in 2010

Hourly	Site name	Latitude Longitute	Ovservation Time		2010 Jan	Feb	Mar	Apr	May
Upper	Jurug		Local time	Water Level	○	○	○	○	○
Lower	Cepu		Local time	Water Level	△	△	△	△	△
Madiun	Ketonggo		Local time	Water Level	○	○	○	○	○
Madiun	Sekayu		Local time	Water Level	○	○	○	○	○
Other	Pacitan		Local time	Water Level	○	○	○	○	○

(shaded box) : Discharge data can be used for the validation of runoff analysis

Annex 2: Location of New Installation of Automatic Rainfall Recorder (ARR) and Automatic Water Level Recorder (AWLR) in Bengawan Solo River Basin

Table A2.1
LOKASI PEMASANGAN ARR (*LOCATION OF ARR INSTALLATION*)

No	No. Stasiun *(Station Code)*	Stasiun *(Name of Station)*	Alamat *(Location's address)*	Jarak Dari Kota Solo *(Distance from Solo City)*
1	63 HU	Pos Hujan Song Putri	Songputri Kec.Eromoko Kab. Wonogiri	70 Km ke arah Selatan *(70km to the South)*
2	6.a HU	Pos Hujan Parangjoho	Gedong RT. 003 RW. 007, Kel. Eromoko, Kec. Eromoko, Kab. Wonogiri	60 Km ke arah Selatan *(60km to the South)*
3	3 a HU	Pos Hujan Wd. Nawangan	Nawangan Kidul RT.001 RW. 007, Kel. Platarejo, Kec. Giriwoyo, Kab. Wonogiri	80 Km ke arah Selatan *(80km to the South)*
4	111a HU	Pos Tritis	Ds.Tritis, Kec. Colomadu. Karanganyar	10 Km ke arah barat *(10km to the West)*
5	63 HU	Pos Hujan Klaten	Dukuh Sobrah Gede RT. 03 RW. 010, Kel. Buntelan, Kec. Klaten Tengah, Kab. Klaten	40 Km ke arah Barat daya. *(40km to the South-west)*
6	86 HU	Pos Hujan Tawangmangu	Tawangmangu RT. 04 RW. 06, Kel. Tawangmangu, Kec. Tawangamangu, Kab. Karanganyar	60 Km ke arah Timur *(60km to the East)*
7	192 HU	Pos Hujan Kalijambe	Kalijambe Kec. Kalijambe, Kab. Sragen	20 Km ke arah Utara *(20km to the North)*
8	6 KM	Pos Hujan Purwantoro	Dusun Jetak RT. 05 RW. 01, Kel. Bangsri, Kec. Purwantoro, Kab. Wonogiri	80 Km ke arah tenggara *(80km to the South-east)*
9	25 HU	Pos Hujan Giriwoyo	Desa Giriwoyo Kec. Giriwoyo, Kab. Wonogiri	
10	152 HU	Pos Hujan Nepen	Magangrejo RT. 9 RW. 2, Desa Nepen, Kec. Teras, Kab. Boyolali	30 Km ke arah Barat *(30km to the West)*
11	135 HU	Pos Hujan Grompol	Desa Balong Kec. Batu Jamus Kab. Karanganyar	30 Km ke arah Timur *(30km to the East)*
12	193 HU	Pos Hujan Ketro	Desa Ketro Kec. Tanon Kab. Sragen	30 Km ke arah Utara *(30km to the North)*
13	187.HU	Pos Hujan Ngrambe	Dusun Pule RT.002 RW.001, Desa Ngrambe, Kec.Ngrambe, Kab. Ngawi 63263	70 Km ke arah Timur *(70km to the East)*
14	29. KM	Pos Hujan Jejeruk	Candirejo RT. 04 RW. 04,	120 Km ke arah Timur

			Desa Candirejo, Kec. Magetan, Kab. Magetan 63351	*(120km to the East)*
15	61.KM	Pos Hujan Tulung	Ngepeh RT. 009 RW. 005, Desa Ngepeh, Kec. Saradan, Kab. Madiun 63155	120 Km ke arah Timur *(120km to the East)*
16	24 KM	Pos Hujan Ngebel	Ngebel Kec. Mlilir Kab. Ponorogo	130 Km ke arah Timur *(130km to the East)*
17	12 GD	Pos ARR Pacitan	Desa Mangunharjo, Kec. Pacitan, Kab. Pacitan	120 Km ke arah Selatan *(120km to the South)*
18a	2 GD	Pos Hujan Nawangan/Pacitan	Dusun Krajan RT. 01 RW. 01, Desa Sembu, Kec. Nawangan, Kab. Pacitan	150 Km ke arah Selatan *(150km to the South)*
18b	4 KM	Pos Hujan Soko	Dukuh Dalangan RT. 02 RW. 02, Kel. Sooko, Kec. Sooko, Kab. Ponorogo	150 Km ke arah Timur *(150km to the East)*
19	1 KM	Pos Hujan (ARR) Slahung	Dukuh Krajan RT. 02 RW. 01, Kel. Menggare, Kec. Slahung, Kab. Ponorogo	130 Km ke arah Timur *(130km to the East)*
20	12 a GD	Pos ARR Kebonagung	Desa Kebonagung, Kec. Kebonagung, Kab. Pacitan	130 Km ke arah Selatan (10 Km timur kota Pacitan) *(130km to the South; 10km East of Pacitan)*
21	204 HU	Pos ARR Ngawi	DesaKarangansri, Kec. Ngawi, Kab. Ngawi	80 Km ke arah Timur (5Km timur kota Ngawi) *(80km to the East; 5km East of Ngawi)*
22	29 HI	Pos Hujan Padangan	Desa Padangan, Kec. Padangan, Kab. Bojonegoro	110 Km ke arah Timur laut *(110km to the North-east)*
23	63 HI	Pos Hujan Nglirip	Dusun Krajan Desa Tangkis, Kec. Singgahan, Kab. Tuban	250 Km ke arah Utara *(250km to the North)*
24	6 HI	Pos Hujan Doplang	Kel. Doplang, Kec. Jati, Kab. Blora	200 Km ke arah Utara *(200km to the North)*
25	22 b HI	Pos Hujan Balong Panggang	Mojopuro Kel. Babatan, Kec. Balongpanggang, Kab. Gresik 61173	275 Km ke arahTimur *(275km to the East)*
26	41 HI	Pos Hujan Lamongan	Kantor Dinas Pengairan Lamongan Kec. Lamongan, Kab. Lamongan 62251	240 Km ke arah timur *(240km to the East)*

27	22 HI	Pos Hujan Waduk Gondang	Desa Gondang Lor, Kec. Sugio, Kab. Lamongan	210 Km ke arah timur *(210km to the East)*
28	3 a HI	Pos Hujan Sembung	Desa Sembung, Kec. Sukorame, Kab. Lamongan	240 Km ke arah timur *(240km to the East)*
29	2 HI	Waduk Pacal	Wd.Pacal. Kec.Temayang Kab.Bojonegoro	230 Km kearah timur *(230km to the East)*
30		DPS Kali Lorog	Desa Sudimoro Kec. Lorog Kab. Pacitan	
31	4	Pos Klimatologi Colo	Pengkol Desa Pengkol, Kec. Nguter, Kab. Sukoharjo	25 Km ke arah Selatan *(25km to the South)*
32	1	Pos Klimatologi Batu Retno	Ds.Boto Kel. Gambiranom, Kec. Baturetno, Kab. Wonogiri	60 Km ke arah Selatan *(60km to the South)*

Table A2.2

LOKASI PEMASANGAN ALAT AWLR DAN PEMBANGUNAN POS AWLR*(LOCATION OF AWLR INSTALLATION)*

No	**No. Stasiun** ***(Station Code)***	**Stasiun** ***(Name of Station)***	**Alamat** ***(Location's address)***	**Jarak Dari Kota Solo** ***(Distance from Solo City)***
1	1 A	Pos Duga Air Ngadipiro	Ngadipiro Kel. Ngadipiro, Kec. Nguntoronadi, Kab. Wonogiri	50 Km ke arah Selatan *(50km to the South)*
2	3	Pos Duga Air Serenan	Bulakan Kel. Bulakan, Kec. Sukoharjo, Kab. Sukoharjo	30 Km ke arah Selatan *(30km to the South)*
3	5	Pos Duga Air Jarum	Jambal Desa Tumpukan, Kec. Karangdowo, Kab. Klaten	30 Km ke arah Selatan *(30km to the South)*
4	11	Pos Duga Air Bendo	Dukuh Bendo Kel. Ngindeng, Kec. Sawoo, Kab. Ponorogo	140 Km ke arah Timur *(140km to the East)*
5	12	Pos Duga Air Pacitan	Desa Arjowinangun, Kec. Pacitan Kab. Pacitan	120 Km ke arah Selatan *(120km to the South)*
6	14 A	Pos Duga Air Napel	Dusun Nape Desa Kerek, Kec. Ngawi, Kab. Ngawi	90 Km ke arah Timur *(90km to the South)*
7		Pos Duga Air (AWLR) A. Yani	Desa Pangongangan Kec. Mangunharjo Kab. Madiun	

8	10	Pos Duga Air (AWLR) Badegan	Dukuh Keden Kel. Watubonang, Kec. Badegan, Kab. Sukoharjo	90 Km ke arah Timur *(90km to the East)*
9	17	Pos Duga Air Brangkal	Kel. Brangkal, Kec. Parengan, Kab. Tuban	210 Km ke arah Tumur laut *(210km to the North-east)*
10	16	Pos Duga Air Bojonegoro	Dusun Kalisari RT. 001 RW.001, Desa Banjarsari, Kec. Trucuk, Kab. Bojonegoro	180 Km ke arah Timur laut *(180km to the North-east)*
11	14	Pos Duga Air Karangnongko	Desa Luwihaji, Kec. Ngraho, Kab. Bojonegoro	100 Km ke arah timur laut *(100km to the North-east)*
12	20	Pos Duga Air Karanggeneng	Desa Karanggeneng, Kec. Karanggeneng Kab. Lamongan	230 Km ke arah Timur laut *(230km to the North-east)*
13		Pos Duga Air (AWLR) Babat	Desa Babat Kec. Babat Kab. Lamongan	
14		Pos Duga Air (AWLR) Pidekso	Desa Pidekso Kec. Giriwoyo Kab. Wonogiri	

Annex 3: Photos showing damage conditions

Photos showing damage conditions provided by BBWS Solo

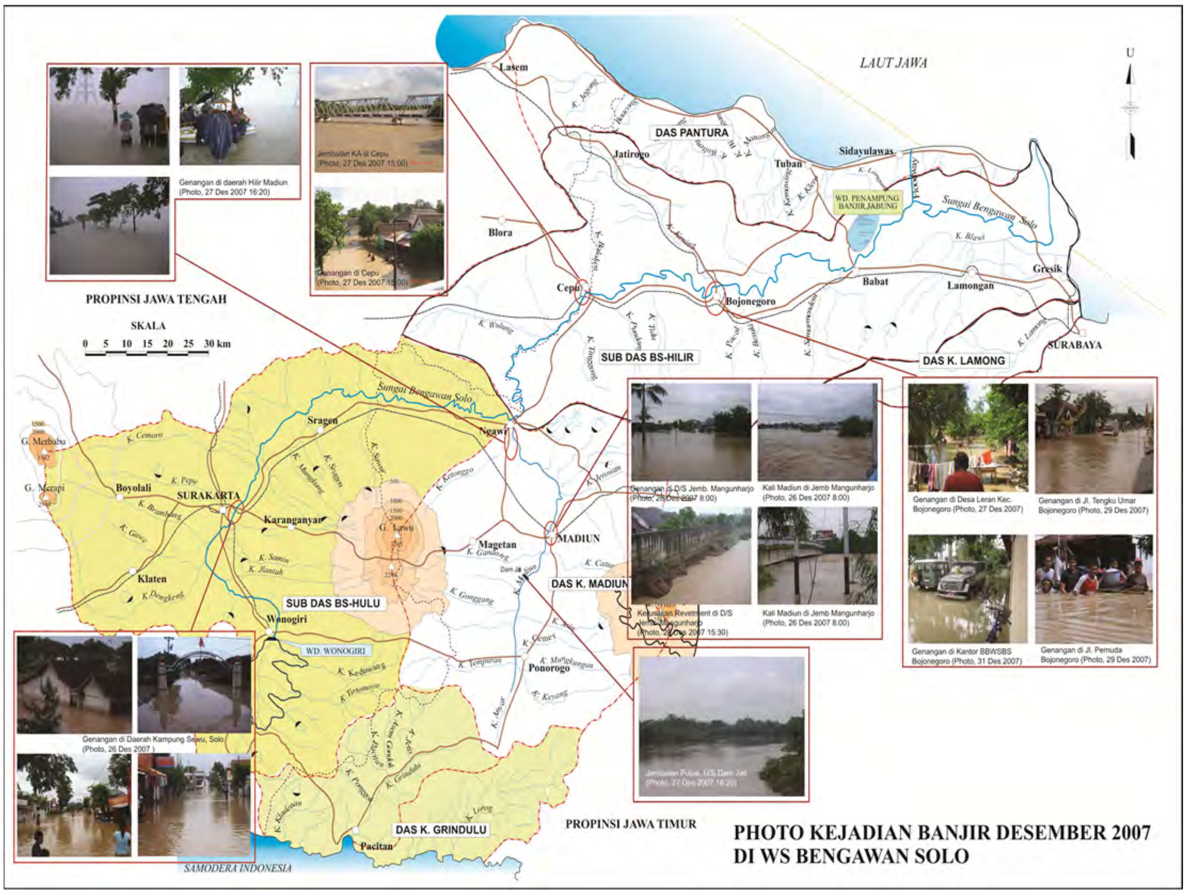

Figure A3.1 Flood situation in 2007 flood

Figure A3.2 Flood situation around Solo river

Figure A3.3 Flood situation in JAGALAN

Figure A3.4 Flood Situation in KAMPUNG SEWU

Figure A3.5 Flood Situation on 29 DESEMBER 2007

Figure A3.6 Flood Situation in GANDEKAN

Publications

Photos showing damage conditions on Newspapers provided by BBWS Solo in the 1st IFAS training Workshop


REKAMAN LENSA

Banjir & longsor melanda, warga Soloraya berduka

Figure A3.7 Flood photograph in Newspaper


EVAKUASI—Tim SAR mengevakuasi warga yang terjebak di Gereja GPPS Mahanaim, Jagalan, Jebres, Solo.

MACET—Ratusan bus, truk dan mobil umum terjebak kemacetan di jalan Solo-Sragen, Kebakkramat, Karanganyar, Rabu (28/12) pagi.

BERTAHAN DI ATAP—Sejumlah warga di Kampung Sewu, Solo, bertahan di atap rumah mereka yang terendam.

POSKO PENGUNGSI—Suasana Posko pengungsi banjir di daerah Joyonsakan, Solo, Rabu (28/12). Mereka membutuhkan pakaian, makan dan tenda.

Figure A3.8 Flood Photograph in Newspaper

Satellite image during flooding

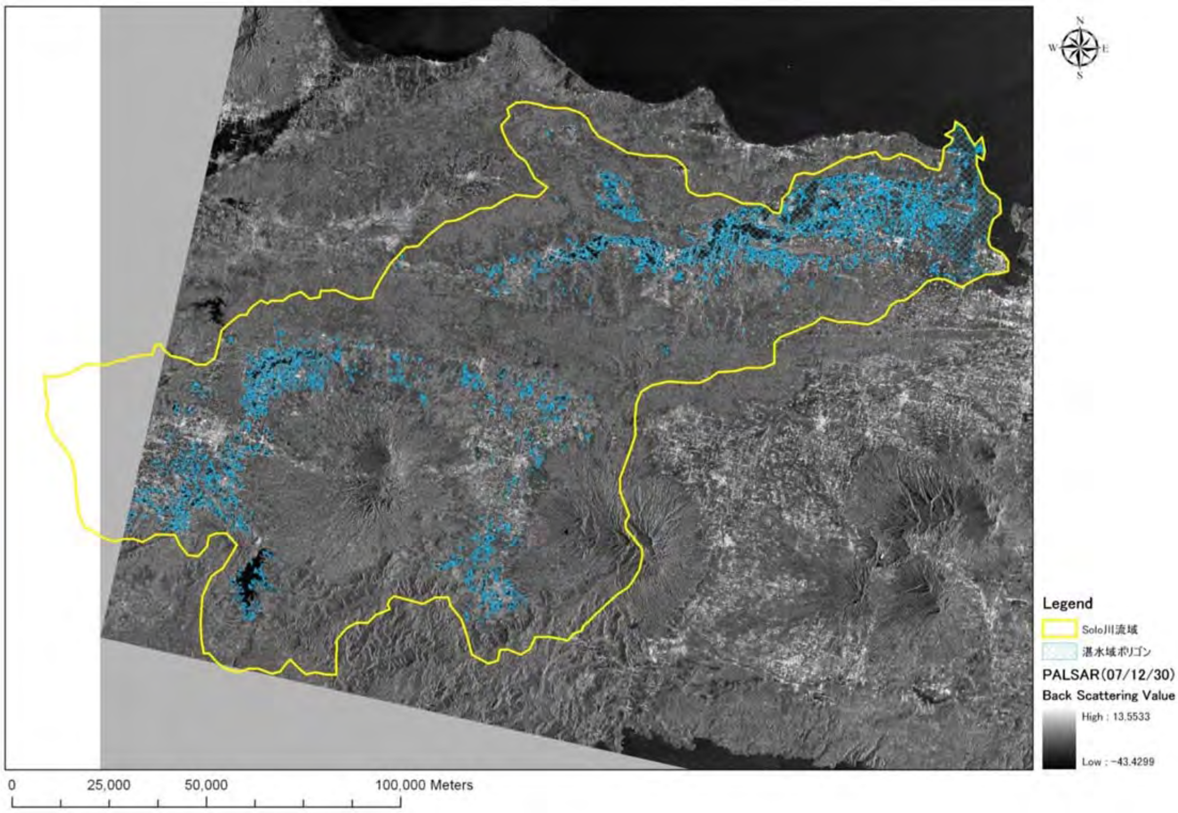

Figure A3.9 Flood Situation in Bengawan Solo river basin

Annex 4: Tables Related to Evacuation Drill Demonstration

Table A4.1
Questions used in the Cross road game in Sugihan Sub-Village, Kedung Sumber Village, Temayang District, Bojonegoro Regency

Question 1: You live in a flood prone area. The weather in your area is currently good, however, you receive news from your friend that in the upstream, it is very cloudy and heavy rain may occur. You choose to prepare for evacuation without waiting for official notice from the government.

No.	ANSWER : YES	ANSWER : NO (Minority)
	Reason	**Reason**
1	Based on the previous experience, when it rains hard in the upstream, this area seems to be unaffected but in a couple of hours, flash flood hits without warning.	It is only news without proof.
2		Wait for official notice from the authority
3		Flood is only water. We still have time to run.

Question 2 : Your area is hit by flood that rises very quickly and has reached 30 cm high. You decide not to evacuate and wait for the water level to reach 50 cm.

No.	ANSWER : YES	ANSWER : NO (Minority)
	Reason	**Reason**
1	The flood, which reaches 50 cm, usually occurs for a short period. To anticipate it, we should build/make "ajag-ajag" (a higher building to save ourselves when flood hits)	We have hit by flood so many times so we are already prepared when the water level reaches 20 cm. When the water has reached 30 cm, we will have definitely packed our things and evacuated
2	The flood frequently reaches only 1m at our area, so we do not need to evacuate	Since our house is located in a low area, water reaches our house faster than other houses in our RT. Therefore, when water has reached areas near the house, we will immediately pack our things
3	We are busy packing (there are a lot of things to do)	We will pack and will evacuate soon

Table A4.2
Questions used in the Cross road game in Semen Pinggir Village, Kapas District, Bojonegoro Regency

Question 1: You live in a flood prone area. The weather in your area is currently good, however, you receive news from your friend that in the upstream, it is very cloudy and heavy rain may occur. You choose to prepare for evacuation without waiting for official notice from the government.

No.	ANSWER : YES (Minority)	ANSWER : NO
	Reason	**Reason**
1	Even though the water has not reached our houses, we choose to evacuate ourselves.	The vulnerable persons should be evacuated first (elderly and children), the father should stay and watch the house.
2	30 cm is a common flood water level, therefore, we cannot decide whether we should evacuate or not. When water has reached 50-100 cm, then, we should evacuate.	Flood of 30 cm high occurs frequently. We should not evacuate until it reaches higher level.

Question 2: Your area is hit by flood that rises very quickly and has reached 30 cm high. You decide not to evacuate and wait for the water level to reach 50 cm.

No.	ANSWER : YES	ANSWER : NO (Minority)
	Reason	**Reason**
1	If it rains hard, the water may reach this area.	If the weather here is clear/good, then flood will not reach this area.
2	Houses situated along the river should be prepared.	It may not be correct and only a rumor.
3		Even though it rains very hard in the upstream, when there is no official notice from the authority, we should not evacuate.

Table A4.3
Standard Operation Procedure (SOP) of Flood Evacuation in Sugihan Sub-Village, Kedung Sumber Village, Temayang District – Bojonegoro

Status	Routine Activity	Person In-Charge	Remark
Routine Activity	Evacuation Officers **Coordination**	Evacuation Coordinator, Head of RT/RW	Preparation of SOP, Disaster preparedness organization, and job description
	Data collection of Sugihan Sub-village people, Kedung Sumber Village	Division of EWS Data and Information	Data collection of family members, vulnerable group, and location distribution
	Socialization/Information on the danger of flood and evacuation procedures	Head of EWS Data and Information Division	Information on flood level, SOP, evacuation route, evacuation shelter and houses/ neighborhood safety
Level 1 CAUTION (Water has not reached the monitoring equipment)	**Receiving warning sign from rain monitoring equipment** /information from the related officer	Evacuation Coordinator and EWS Data and Information Division	-Monitoring on the change in warning level -Checking the function of river water level monitoring equipment
	Checking data collection of Kedung Sumber people	EWS Data and Information Division	Collecting data of family member. Preparing the necessary items for evacuation
	Evacuation Preparation: -Saving the possessions -Preparing family member for evacuation	EWS Data and Information Division, Evacuation Division, Cattle Division, Mobilization Division	Ensuring the preparedness of the evacuees and safety of the houses
	Check the preparation of first aid kit and logistic	Logistics and First Aid Kit Division	Preparing life jacket, sedan chair, first aid kit, food and beverage

Table A4.3 (Continuation)
Standard Operating Procedure (SOP) of Flood Evacuation in Sugihan Sub-Village, Kedung Sumber Village, Temayang District – Bojonegoro

Level 2 WARNING (water reached the monitoring equipment at GREEN)	**Receiving warning sign from rain monitoring equipment (GREEN)** /information from the related officer	Evacuation Coordinator and EWS Data and Information Division	Collecting information, visual observation on water level monitoring equipment, transfer of information transfer
	Evacuation preparation : Delivering information to the people to save their possessions and prepare family member for evacuation	EWS Data and Information Division, Mobilization Division	Ensuring the preparedness of the evacuees and safety of the houses
	Evacuating Vulnerable Group to Evacuation Shelterand **Other group depending on the situation**	Mobilization Division	Helping vulnerable group to evacuate to the Evacuation Shelter
	Safety Monitoring	Security Division	Monitoring the neighborhood's safety
	Preparing First Aid Kit and Logistics in the evacuation shelter	Logistics Division and First Aid Kit Division	Preparing lifejacket, first aid kit, food, and beverage
Level 3 EVACUATING (water reached the monitoring equipment at YELLOW)	**Receiving warning alert from water level equipment (YELLOW)** /information from the officer	Evacuation Coordinator and EWS Data and Information Division	Collecting information, visual observation on water level monitoring equipment, information transfer
	Evacuating all people to the Evacuation Shelter	Mobilization Division	Everyone leaving the Evacuation Shelter must gain permission from the head of the sub-village
	Collecting data in the Evacuation Shelter	EWS Data and Information Division	
	Safety Monitoring	Safety Division	Ensuring the safety of the neighborhood

Table A4.4
Standard Operating Procedures (SOP) for Flood Evacuation in
Semen Pinggir Village, Kapas District– Bojonegoro

Status	Routine Activity	Person In-Charge	Remark
Routine Activity	Evacuation Officers **Coordination**	Evacuation Coordinator, Head of Sub-village and RT/RW	Preparation of SOP, Disaster preparedness organization, and job description
	Data collection of Sugihan, Semen Pinggir Village	Division of EWS Data and Information	Data collection of family members, vulnerable group, and location distribution
	Socialization /information on flood danger and evacuation procedures	Head of EWS Data and Information Division	Information on flood level, SOP, evacuation route, evacuation shelter and houses/neighborhood safety
SIAGA 1 PREPARING (water level of Bengawan Solo River starts to rise)	**Receiving information** on water level/information from the related officer	Evacuation Coordinator and EWS Data and Information Division	- Monitoring on the change in warning level - Checking the function of information flow from the related officials
	Checking data collection of Semen Pinggir people	EWS Data and Information Division	Collecting data of family member. Preparing the necessary items for evacuation
	Checking the evacuation preparation: evacuation officers coordination, SOP, Evacuation Map, preparing necessary items to take for evacuation and save the possessions	EWS Data and Information Division, Mobilization Division	Ensuring the preparedness of the evacuees and safety of the houses
	Check the preparation of first aid kit and logistic	Logistics and First Aid Kit Division	Preparing life jacket, sedan chair, first aid kit, food and beverage

Table A4.4 (Continuation)
Standard Operating Procedures (SOP) for Flood Evacuation in
Semen Pinggir Village, Kapas District– Bojonegoro

SIAGA 2 PACKING (Possibility of flood occurrence in Bengawan Solo and Pacal River)	**Receiving information** on the Possibility of flood occurrence in Bengawan Solo River/information from the related officers	Evacuation Coordinator and EWS Data and Information Division	Collecting information from the related authority, visual observation, transfer of information
	Evacuation preparation : Informing the people to save their possessions and prepare family member for evacuation	EWS Data and Information Division, Mobilization Division	Ensuring the preparedness of the evacuees and safety of the houses
	Evacuating Vulnerable Group to Evacuation Shelterwhile evacuation for **Other groups depends on the situation**	Security Division	Helping vulnerable group to evacuate to the Evacuation Shelter
	Safety Monitoring	Security Division	Monitoring the neighborhood's safety
	Preparing First Aid Kit and Logistics in the evacuation shelter	Logistics Division and First Aid Kit Division	Preparing lifejacket, first aid kit, food, and beverage
SIAGA 3 EVACUATING (Water from Bengawan Solo and Pacal River starts to overflow)	**Receiving warning alert from the related authority** /information from officers	Evacuation Coordinator and EWS Data and Information Division	Collecting information from the related authority, visual observation, transfer of information
	Evacuating all people to the Evacuation Shelter	Mobilization Division	Everyone leaving the Evacuation Shelter must gain permission from the head of the village/sub-village
	Collecting data in the Evacuation Shelter	EWS Data and Information Division	
	Safety Monitoring	Safety Division	Ensuring the safety of the neighborhood

Asian Development Bank

Technical Assistance
for
Supporting Investments in Water-Related Disaster Management
(TA7276)

Final Report
(Volume 4)
Lower Mekong Basin Component

September 2012

International Centre for Water Hazard and Risk Management
under the auspices of UNESCO (ICHARM)

Public Works Research Institute (PWRI)

Structure of Reports

(TA 7276 for Supporting Investments in Water-Related Disaster Management)

The reports of TA 7276 for Supporting Investments in Water-Related Disaster Management are divided into following volumes:

Volume 1: Main Volume

(i) Development of Index for Water-Related Disaster Risk Management
(ii) Organization of regional knowledge sharing workshops, exchange visit program and capacity development trainings, etc.

Volume 2: Bangladesh Component

(i) Technical support for improvement of current early warning system
(ii) Capacity building of engineers and managers

Volume 3: Indonesia Component

(i) Satellite-based flood alert system
(ii) Capacity building on local disaster management
(iii) Implementation of community based flood disaster risk management

Volume 4: Lower Mekong Basin Component

(i) Supporting Mekong River Commission Secretariat in developing flood vulnerability indices

Volume 5: Philippines Component

(i) Applying Integrated Flood Analysis System (IFAS) to the river basins
(ii) Identifying causes of historical floods
(iii) Training on utilization of IFAS as supplementary information of the existing flood monitoring systems

List of Authors of TA 7276 Final Reports

Overall	Toshio Okazumi, Shigenobu Hibino
Volume 1: Main Volume	Badri Shrestha, Lee Sangeun, Youngjoo Kwak
Volume 2: Bangladesh Component	Badri Shrestha, Mamoru Miyamoto
Volume 3: Indonesia Component	Seishi Nabesaka, Dinar Istiyanto
Volume 4: Lower Mekong Basin Component	Badri Shrestha, Ai Sugiura, Shigenobu Tanaka, Youngjoo Kwak
Volume 5: Philippines Component	Mamoru Miyamoto, Seishi Nabesaka

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Abbreviations

General:

ADB	Asian Development Bank
AMSL	Above Mean Sea Level
BTOP	Block-wise Top Model
FVI	Flood Vulnerability Index
FVIs	Flood Vulnerability Indices
FVI-AF	Flood Vulnerability Indices for Average Flood
FVI-EF	Flood Vulnerability Indices for Extreme Flood
GIS	Geographical Information System
GSMaP	Global Satellite Mapping of Precipitation
ICHARM	International Centre for Water Hazard and Risk Management
IFAS	Integrated Flood Analysis System
IHGM	ICHARM Hydro-Geo Method
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency
Lao PDR	Lao People's Democratic Republic
NASA	National Aeronautics and Space Administration (US)
NGOs	Non-Governmental Organizations
PWRI	Public Works Research Institute
R-CDTA	Regional Capacity Development Technical Assistance
REG/RETA	Regional Technical Assistance
RRI	Rainfall-Runoff-Inundation
SD	Standard Deviation
SRTM	Shuttle Radar Topography Mission
TA	Technical Assistance
TOR	Terms Of Reference
WFP	World Food Program
UTM	Universal Transverse Mercator

LMB Component specific:

ADPC	Asian Disaster Preparedness Centre
FMMP	Flood Management and Mitigation Program
HV	House Value
LMB	Lower Mekong Basin
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
MPWT	Ministry of Public Works and Transport

Summary

Lower Mekong Basin (LMB) is frequently affected by floods, particularly, the low-lying floodplains of Cambodia. Populations living in LMB area of the Cambodian floodplain are vulnerable to flood disasters. These disasters are occurring with increased frequency as a consequence of socio-economic development and land-use development and also due to climate change. It is thus important to identify flood vulnerability in flood-prone area. In this component, flood vulnerability in the Lower Mekong Basin of Cambodian floodplain was identified and developed flood vulnerability indices for the average and extreme floods in order to avoid big damages and cope with flood in their life.

The flood vulnerability was defined in terms of amount of potential damages. The agricultural and house damages were considered to identify flood vulnerability indices, because both are major income and stocks in the area. The agricultural damage was defined as the function of flood water depth during the cultivation period and its duration. The maximum daily water depth and their duration for each grid were calculated and agricultural damages in each grid were calculated according to damage curves. The house damage was defined as the function of maximum flood water depth by relating with average year flood level. The household survey data for 2006 flood from Flood Management and Mitigation Programme (FMMP) of Mekong River Commission (MRC) was used to determine damage ratio curve and probability distribution of house value. The calculated house damages were compared with the statistical data of house damages. The FVIs were developed for agricultural, houses and total damages by normalizing the calculated values of damages. The FVIs were developed for an average flood case and extreme flood case.

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1. Introduction

1.1. Background

The aim of the Regional Capacity Development Technical Assistance for Supporting Investments in Water-Related Disaster Management (TA 7276, 'TA' for short) is to help prepare and implement flood management investment projects through knowledge and capacity development services that will reduce vulnerability to water-related disasters with in-country and regional assistance. The TA has two components: i) in-country project support and ii) program quality support through regional cooperation. The in-country project support will be provided to Bangladesh, Indonesia and to the Mekong River Commission Secretariat.

In Lower Mekong Basin (LMB) component, the TA will support the Mekong River Commission Secretariat (MRCS) in developing flood vulnerability indices, which have been identified as a priority requirement for preparing further investment projects in the LMB region. The TA will help the countries in LMB to develop investment projects and improve the ability of communities to prepare for, respond to, and recover from the negative impact of floods, together with other regional TA (RETA 6456) for flood and drought risk management and mitigation in the Greater Mekong Sub-region. Figure 1.1 shows the map of the Lower Mekong Basin.

Figure 1.1: Map of the Lower Mekong Basin (Source: MRC)

1.2. Objectives of Study

Based on the Term of Reference (TOR) of the TA, the objectives of the Lower Mekong Basin (LMB) Component are described as follows:

(i) Defining flood vulnerability indices relevant to future flood management at the community level (the impact of floods on health, food security, livelihoods, poverty, education, and others), and relating them statistically to the underlying socioeconomic factors.

(ii) Defining and measuring the factors that affect the various flood vulnerability, through supplementary community surveys (at the family level) of flood and impact in flood-prone villages where the basic socioeconomic profile has previously been determined by community surveys of other agencies (typically nongovernment organizations).

Development of flood vulnerability indices is the most important output of this component and can be used for preparing vulnerability maps:

- *Developing a methodology for mapping these indices on a Geographic Information System (GIS) basis and pilot-testing the mapping.*
- *Extrapolating the indices across the flood-prone areas by relating the indices and their underlying factors to national socioeconomic statistics.*

Previous work undertaken on flood risk and flood vulnerability includes the Flood Management and Mitigation Programme (FMMP) of Mekong River Commission (MRC), poverty, drought and flood vulnerability mapping of the World Food Programme (WFP), strengthening of capacity for flood vulnerability reduction of the Asian Disaster Preparedness Centre (ADPC) and several local surveys and mapping activities of various Non-Governmental Organizations (NGOs). Results of these activities have been studied and used for this research whenever applicable. In particular, the results from FMMP (2004-2010) were utilized. FMMP (2004-2010) consisted of five components among which component C2 (Structural Measures and Flood Proofing) and component C5 (Land Management) were of a particular interest.

2. Present Situation of LMB

2.1. Living Situation

Floods are not always bad and people are not vulnerable to all types of floods. Long-term flood-prone populations develop a natural resilience (or acceptable base level of vulnerability) to floods; it is commonly called ‘living with floods’. These people have lived with floods for many generations and have developed traditional coping mechanisms that mitigate the negative impacts. In fact, according to such people, the positive impacts of floods outweigh the negative impacts – at least for ‘normal’ floods. It is only when a flood is ‘abnormal’ – e.g. its onset is early, its duration is longer than expected, its recession is slow - that underlying additional vulnerabilities associated with ‘abnormal’ flooding emerge (Joy, 2009). But what are these underlying additional vulnerabilities? What is meant with vulnerability?

People have adapted to flooding by all sorts of mechanisms, such as living on higher ground or elevated house (Figure 2.1), using boats for transportation, collecting rainwater (many use earthenware jars for collecting rain water) and storing rice. And instead of working on the fields they go out to fish or work in nearby towns. Things can go wrong during bad floods. For instance, during the Focal Group Discussion in Leuk Daek Commune, people told that problems get really serious when the flood is accompanied by strong winds and thunderstorm. People may drown or get killed from lightning strikes. Also a much heard problem is that of the bad water quality. When the floods remain long, the crops are going to rot and the water gets a strong smell/stench. People as well as livestock may get ill. Basic sanitation can become problematic during the flood season, as it is difficult to find clean water. This leads to skin diseases and diarrhea, especially among the children, who drink directly from flooded areas.

The traditional Khmer houses of good quality wood on poles can withstand heavy rains, winds and floods. Since good quality wood is expensive nowadays, more and more people build their houses from cheap bamboo wood just a little above ground level. Strong winds, rain and floods destroy these houses (CARE, 2001). Most people rely on the traditional location of houses in naturally elevated sites. Some households increase the strength of struts and bracing timbers, and may have alternative sites to move to. Some people prepare a boat to be able to move away to safer areas in case of severe flooding. Figure 2.2 shows the elevated houses constructed by using wooden pillars.

Figure 2.1: Photographs of Houses Constructed in Higher Ground in Kampong Cham

Figure 2.2: Elevated Houses by Using Wooden Pillars at Tnaot Nhi Village (Left) and at Preaek Andoung Village (Right) in Kandal Province

2.2. Rice Crop Situation

Rice farming in Cambodia is well adapted to the dynamic character of and the uncertainties in the rainfall pattern and the timing and level of the Mekong's discharge. Farmers normally have plots in at least two different rice ecosystems. In that way farmers spread the required labour force more evenly over the year and prevent the loss of the whole yield at once (De Bruijn, 2005). In Cambodia, about 30% of GDP is from rice production and 60% of Labour Force is for rice production. About 75% of rice production is from wet season rice (Kamoshita, 2009). Figure 2.3 shows the cropping calendar for three different rice growing systems: wet season (rainfed) lowland rice, dry season (recession) rice and deep water rice. Figure 2.4 shows the photograph of rice fields.

These rice systems very much depend on the micro-topography of the floodplain. In the areas that are normally only marginally flooded, people grow ***wet season lowland paddy*** which is planted in shallow flooded areas in May and harvested in November till January. Within this zone, one can distinguish three types of fields, depending on the elevation (Nesbitt, 1997):

- Upper fields, with sandy soils and deepest standing water 20-30 cm, used for early maturing varieties;
- Medium fields, with sandy loam soils and deepest standing water of 20-40 cm;
- Lower fields, with sandy to sandy-loam soils with some silt, deepest standing water 40-100 cm, used for late maturing varieties.

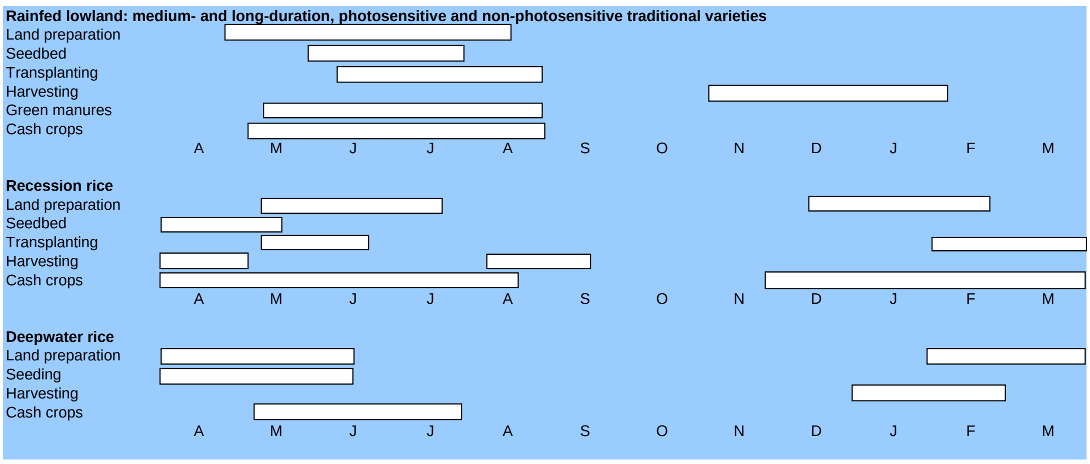


Figure 2.3: Rice Cropping Calendar (source: Nesbitt, 1997)

Figure 2.4: Rice Field at Kandal (left) and at Prey Veng (right)

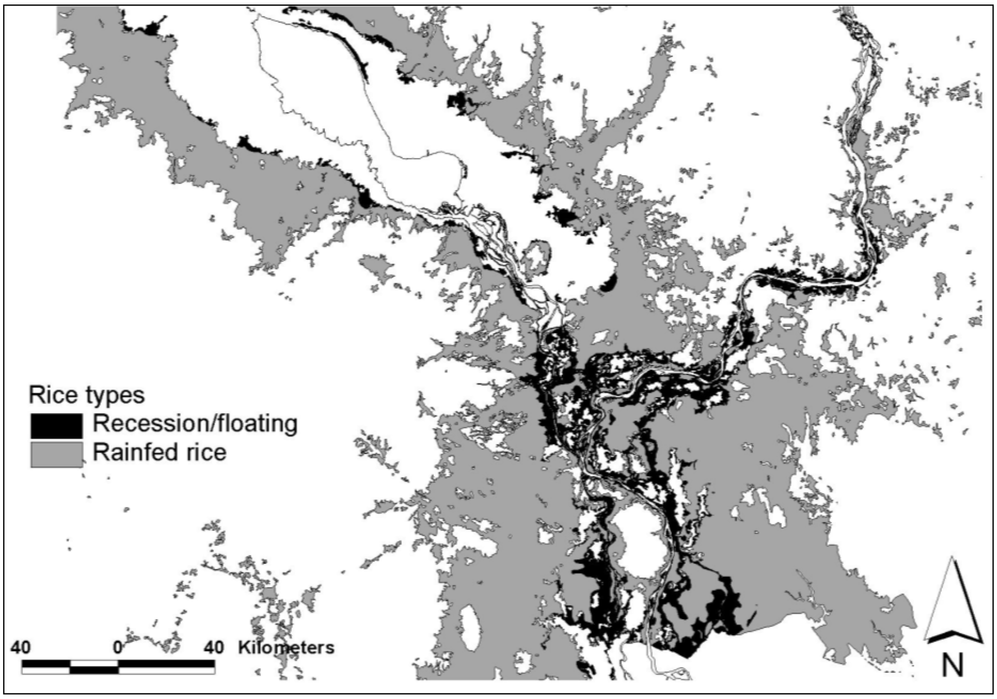


Figure 2.5: Rice Type Distribution in Central Cambodia Based on a Combination of Data (source: De Bruijn, 2005)

The higher fields are least susceptible to flood damage, but the crop is vulnerable to drought. The lower fields have a better soil moisture condition, but the crops are vulnerable to flooding.

In the areas that experience every year flooding, the second important rice system is used: ***dry season rice*** cropping, or ***recession rice***. This makes use of the flood water as a source for moisture. As the water begins to recede, the receding water is blocked off with barriers erected by farmers. Crops are planted along the edges of the flooded areas and as the water recedes during the dry season, water is pumped back onto the crops where possible. A succession of crops follows the edge of the lakes or floodplains as the water recedes, hence the term ‘recession rice’. The soils where recession rice is grown are normally very fertile due to the yearly floods. Recession rice is normally non-photosensitive, and short in duration. The period of transplanting is, therefore, very flexible. Recession rice yields are usually higher than for wet season rice.

Deepwater rice is grown in depressions that accumulate floodwater at a depth of 0.5 m or more for at least one month. Maximum water depth ranges to more than 3.0 m. Most varieties of deep water rice are old traditional varieties that are photosensitive and have very good elongation capabilities. In ideal seasons, these crops receive sufficient local rainfall to allow six or more weeks of growth before mid-July. They are then at an advanced stage of maturity which allows them to elongate fast enough to keep pace with the rising floodwater. Some of these rice varieties can grow 0.2 - 0.3 m/d and grow up to 4 m long. Deep water rice is harvested in January or February. Deep water rice cultivation is decreasing rapidly in favour of recession rice, double cropping or dry season rice. The risk of damage due to abnormal floods or droughts is high. Figure 2.5 shows the rice type distribution in central Cambodia based on a combination of data.

Impacts of floods on agriculture

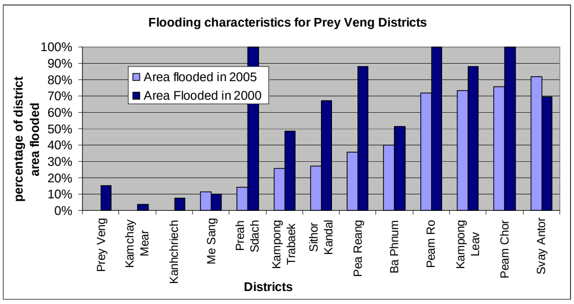
The main losses in agriculture are usually the loss in rice harvest. Flood damage to the wet season paddy crop can be caused by early onset of floods, larger extent and longer duration of flooding. But also dry season rice can be affected. In some areas dry rice is planted in March – April and harvested in July – August. Early floods in July can destroy the entire dry season harvest. Also home gardens with fruit trees and vegetables can damage. Fishing is severely diminished in the bad floods.

In many floodplain areas most people have a rice deficit for one or two months in normal flood seasons, but this may increase to 4 to 6 months in a bad flood season. People try to cope with this through i) reducing daily meals; ii) collecting free sources of food, such as fishing, catching crabs and snails, collection wild vegetables (leafage, plant and etc.), iii) try to find work in the towns, iv) borrow money from neighbour, NGO or money lender; and v) sell part of their assets (e.g. livestock, land).

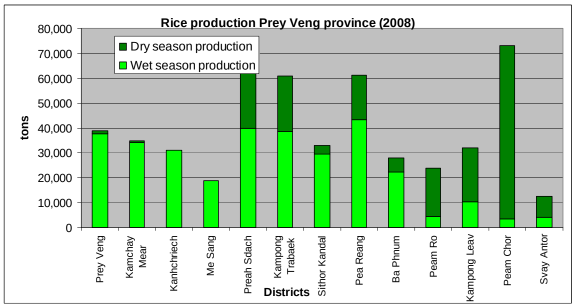
When we look at the relation of flooding and rice production levels at district, we see a clear pattern (see Figure 2.6a, b and d): for the Prey Veng Province all districts that have annual floods practice a combination of dry and wet season rice, with a tendency of dry season dominance. On the other hand, districts with no annual flooding predominantly rely on wet season rice. What is even more important is that in terms of total rice production or per capita rice production there is hardly a difference in performance between annually flooded and normally non-flooded districts. Remarkably, the two districts with the highest per capita rice production, Kampong Leav and Peam Chor also have a very large annual flood extent. This shows the importance of the annual flood for rice cultivation in this province.

With respect to vulnerability to extreme floods, we can compare the district characteristics with the impacts of the 2000 floods, as reported by the Cambodian Red Cross in November 2000 (Figure 2.6c). The following observations can be made:

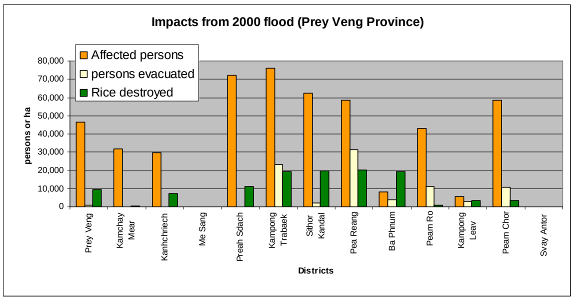
- There is no positive relation between area flooded and number of people affected. It even looks slightly negative: districts that were fully inundated (Preah Sdach, Peam Ro and Peam Chor) do not have the highest number of affected people. The highest number was found in Kampung Trabaek, which was only 50% inundated. The lowest number of affected people was found in Kampong Leav District, which was for more than 90% inundated.
- Districts with predominantly dry season rice production (Svay Anthor, Peam Ro, Kampong Leav and Peam Chor) hardly had their rice destroyed. This sounds very logical since dry season (recession) rice growing is not vulnerable to flooding. Instead, it benefits from it.



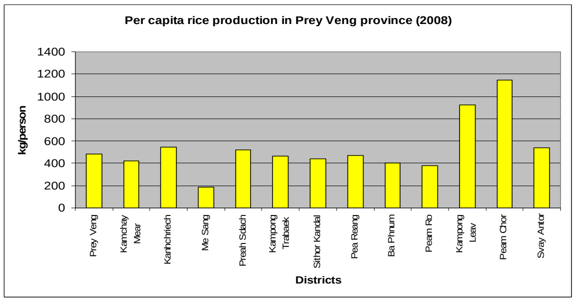
a. Flood characteristics (MRC-GIS)



b. Rice production (NCDD, 2009a)

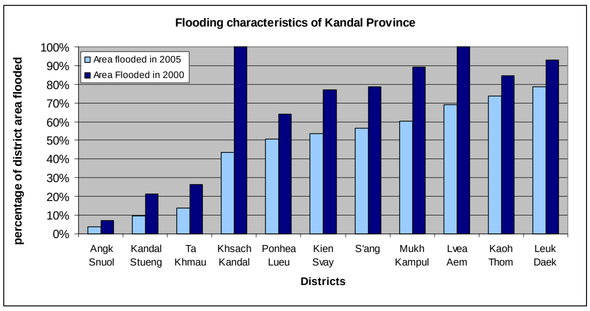


c. Impacts from 2000 flood (CRC, 2000)

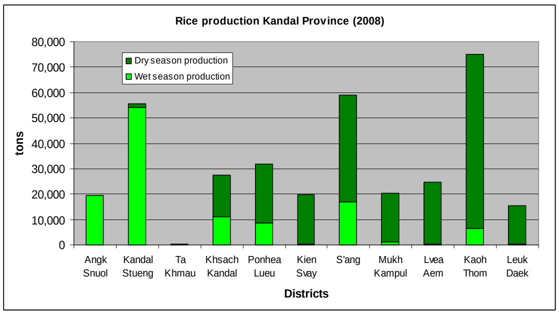


d. Per capita rice production (NCDD, 2009a)

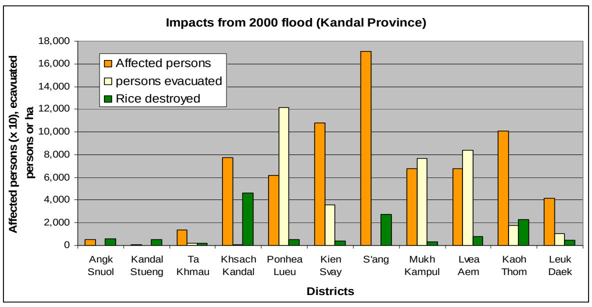
Figure 2.6: Vulnerability Characteristics of Prey Veng Province



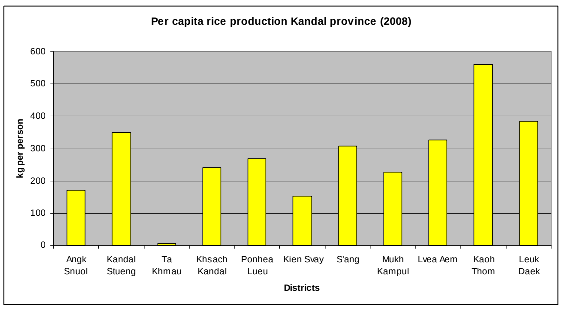
a. Flood characteristics (MRC-GIS)



b. Rice production (NCDD, 2009b)



c. Impacts from 2000 flood (CRC, 2000)



d. Per capita rice production (NCDD, 2009b)

Figure 2.7: Vulnerability Characteristics of Kandal Province

For Kandal province (Figure 2.7) the same general observations can be made. This brings us to the preliminary conclusion that districts which are annually flooded are less affected in their agricultural production by extreme floods than districts that keep normally dry. According to (Assen & De Jong, 1971) ideal circumstances for rice production can be summarized as follows:

- Monthly rainfall is 250 mm from June through October
- Water level reaches 7 m MSL at Phnom Penh in the beginning of July and stays above that level till the end of October
- No sharp increases beyond 8 m above mean sea level

Food insecurity

Generally, there are three broad categories of 'food insecure' people in Cambodia. The largest group are the chronically insecure that include population affected by civil insecurity and displacement. The second group are the 'vulnerable groups' (handicapped, disease victims, orphans etc.). The third group are the 'transitory food insecure', due to factors such as fires, floods, and droughts. After the big flood in 2000, due to the exceptional flooding, the number classified as transient food insecure was estimated at 3 million people, which was a six times increase of the average number (FAO, 2000).

What happened in the year 2000 was that the high flood damaged part of the wet season rice (about 400,000 ha) and national production was about 90% of the year before. But at the same time, conditions for the dry season rice production were more favourable due to the higher level of water available both in the soil and in reservoirs for irrigation. In addition the level of water recession has been much slower than normal, providing farmers with better opportunities to cultivate dry season and flood recession rice more productively. Hence production in 2000/2001 was 104% of that of the previous year. However, this national picture does not show that in the most hit districts of the country large segments of the populations faced per capita rice deficits of 6 months, because they did not have sufficient resources to purchase food from markets (FAO, 2000). Food aid was channelled to 114 communes selected by the following criteria:

- Communes where greater than 50% of the wet season rice was destroyed,
- Where less than 30% of the total rice areas planted was in the dry season, and
- Where greater than 80% of the households were involved in rice farming.

2.3. Flood Damages

The floods are serious problems in LMB area. Every year floods severely damaged agricultural, house and infrastructures. Also the people died and injured caused by floods. The majority of panel households experienced shocks and crises, illness being the most common, followed by crop damage and death of livestock. Better off households were able to mobilise savings and assets to cope with shocks, while poorer households tended to cut consumption or have family members migrate for work, and were disproportionately affected in income lost. Although shocks and life-cycle events are predictable, poorer households do not plan for or insure against them. The main factors driving households into poverty include location in a poorly or moderately performing village, in combination with fewer earners and more dependants, exposure to (multiple) shocks and crises and destructive or risky behaviours by individuals within the household. Importantly, households that fall are often those that have not anticipated crises and shocks, or have not accumulated sufficient assets or savings to weather these events. The internal characteristics, such as ambition and risk-taking, and having more adult earners and better health and education services, do enable families to take advantage of opportunities [such as government interventions, e.g. irrigation and road construction] when they arise, as does having connections and "strong back". The internal characteristics render [the poor] more vulnerable to these external factors [such as natural disasters] than other households.

Table 2.1: Damages and Human Suffering After the 2001 Flood for Selected Districts

2001	Damages in thousand US$ at 2007 prices				Human suffering	
District name	Total damage	housing	Agriculture	Infrastructure	deaths	evacuated
Kampong Trabek	650	67	410	174	7	6,685
Ba Phnum	791	27	362	401	0	12,877
Peam Chor	2,693	51	2,068	574	5	2,181
Peam Ro	1,136	442	493	201	6	13,728
Preah Sdach	898	11	689	198	12	9,310
Angkor Borei	622	8	554	60	2	1,426
Daun Keo	198	48	100	49	0	63
Prey Kabbas	552	43	367	143	0	564
Samroang	589	26	28	319	0	0
Traing	541	0	96	36	0	342
Borei Cholsar	1,299	70	376	61	11	2,742
Bati	309	0	307	2	0	0
Kiri Vong	1,816	0	1,748	68	0	933
Kaoh Andeth	1,595	19	1,306	270	1	9,179
TOTAL	13,689	811	8,903	2,557	44	60,030

Source: (FMMP, 2010) Source: Cambodian Red Cross

Table 2.2: Regression Coefficients between Damage and Human Suffering

R^2	Deaths	Evacuated
Total damage	0.0649	0.0245
Housing damage	0.0775	0.293
Agricultural damage	0.0073	0.0041
Infrastructure damage	0.0058	0.15

From this background it will be evident that where the largest damages are expected we do not necessarily also find the most vulnerable people. Indeed, large damages could even be an indication of relative wealth. Using the 2001 damage data no significant correlation was found between amount of damage and number of affected people (deaths, injuries) or evacuees (see Tables 2.1 and 2.2). The district with the largest damage (Peam Chor) also had large numbers of deaths and injured people, but relatively little evacuated people, where other districts with relatively little damage still had large numbers of affected people (e.g. Ba Phnum or Kampong Trabek).

Excessive flooding can inflict damage on the social infrastructure, disruption of economic activities, loss of human lives and livestock, and destruction of cultivated crops. The 2000 floods resulted in damage to some 370,000 ha of paddy rice, destruction of 6,081 houses, loss of 2,444 livestock, and affected 3.44 million people in 132 districts (CNMC, 2003).

Analysis of the historical floods in 2000, 2001 and 2002 shows that there are differences between 'bad' floods. For instance, the damage in 2000 was much higher than in 2001, although the peak discharge at Kratie was comparable for both years. Therefore, the maximum discharge at Kratie alone is not a good indicator for the damage. Also important

is the timing of the high water levels as well as the total volume in the wet season (De Bruijn, 2005).

Figure 2.8 shows the constructed floating house around Tonle Sap Lake. Figure 2.9 shows the total cost of flood damage in million US$ and damaged crops in hector from year 2000-2009.

Figure 2.8: Constructed Floating Houses around Tonle Sap Lake

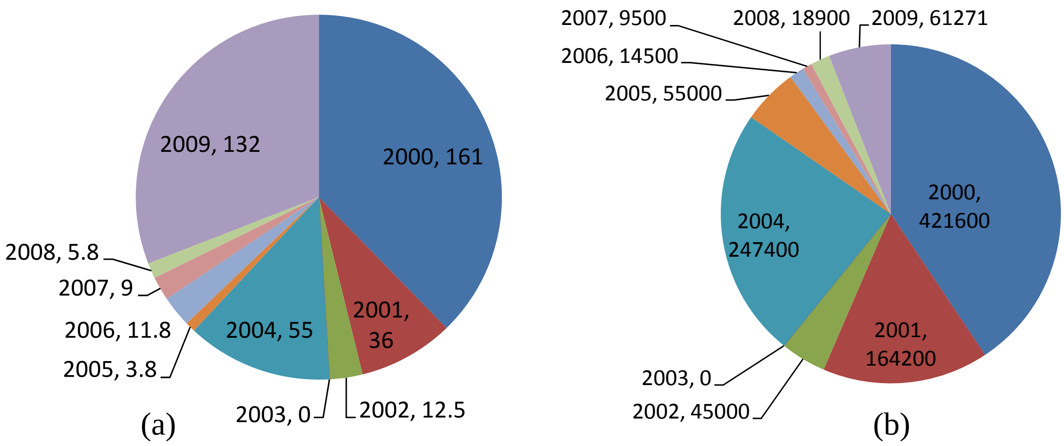


Figure 2.9: (a) Total Cost of Flood Damage in Cambodia in million US$ from Year 2000-2009, and (b) Crops Damaged in Hector from Year 2000-2009

2.4. Characteristics of Flooding in the LMB

2.4.1 Flood Types

There are many different situations through which flooding can occur in the Basin. The Annual Flood Report 2005 (MRC, 2006) distinguishes the following flood types:

- Flash floods or tributary floods
- Mainstream floods
- Combined floods affected by backwater from the main stream
- Floods in the Cambodian Flood Plain, and
- Flood in the Mekong Delta

In our study we distinguish between flash floods and mainstream floods, which are in essence all other sorts of floods, both occurring in the central area and downstream in the Delta. Flash floods are floods caused by heavy or excessive rainfall in a short period of

time, generally less than 6 hours. Flash floods are usually characterized by raging torrents after heavy rains that rip through river beds, urban streets, or mountain canyons sweeping everything before them. They can occur within minutes or a few hours after excessive rainfall. They can also occur even if no rain has fallen, for instance after a levee or dam has failed, or after a sudden release of water by a debris break. Flash floods occur mostly in the steep sloped upper reaches of the basins due to intense rainfall after a long rainy period forcing the catchment to respond quickly to the rainfall. Flash floods are short lived, typically in the order of hours, rise and fall rapidly and the flow velocities are very high. Although most flash floods in the Lower Mekong River Basin occur in Lao PDR, also in Cambodia and Vietnam the phenomenon is not uncommon.

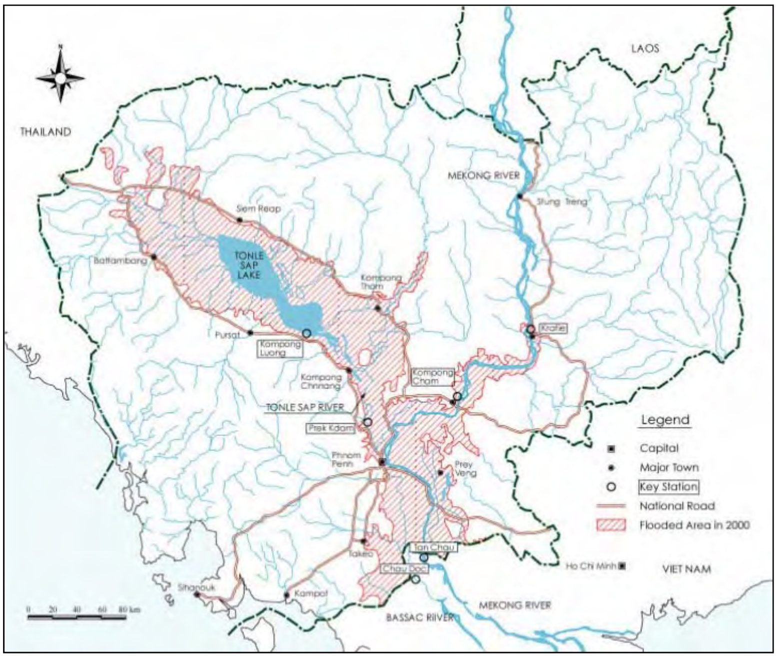


Figure 2.10: The River Network System in Cambodia and Flooded Area in 2000 (source: CNMC, 2003)

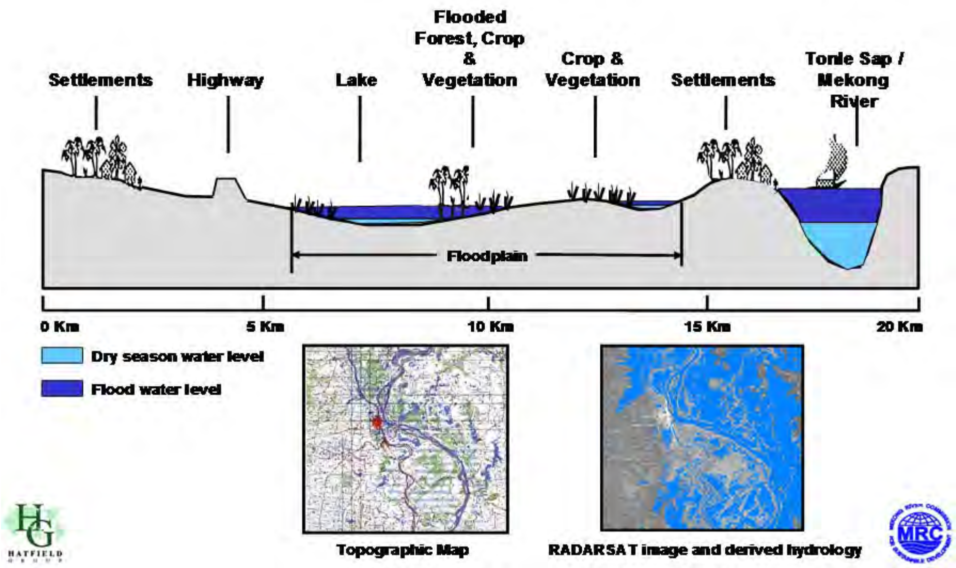


Figure 2.11: Cross Section of Floodplain of the Lower Mekong Basin (Source: MRC)

Mainstream floods in the central area are large floods that result from a combination of runoff from the Mekong and heavy rains around the Tonlé Sap Lake. The waters affect the provinces around the lake, but also flow heavily down the Tonlé Sap River and the lower portion of the Mekong to flood the southern provinces. Floods of this nature occurred in 1996, in 2000 – when the country saw the worst flooding in 70 years – and in 2001. Figure 2.10 shows the River network system in Cambodia and flooded area in 2000.

2.4.2 Flood Extent and Flood Depth

The actual flood extent during high water largely depends on the topography of the floodplain. Figure 2.11 shows a typical cross section of the floodplain in the Lower Mekong Basin.

2.4.3 Good and Bad Floods

It must be remembered that in many parts of the LMB flooding occurs every year, although the extent as well as timing differs annually. 'Normal' floods have many benefits, such as habitats for fish, agricultural production and biodiversity conservation. While floods can impose large economic and social costs on the people of the basin, their economic benefits far outweigh their costs. The average annual cost of flooding in the LMB is 60–70 million US$ a year, while the average annual value of flood benefits is 8–10 billion US$ a year, i.e. some 100 times greater (MRC, 2010). The challenge is to reduce the costs and negative impacts of flooding while maintaining the benefits. Also in the Vietnam part of the Mekong Delta floods have been considered by the people as beneficial to agricultural production. Floods bring sediments to rice fields, help sulphate-dilution and land reclamation, enable the development of aquaculture as well as balance the ecology and promote ecotourism. This 4 million ha region supplies more than 50% of staple food and 60% of fish production for entire Vietnam, accounting for 27 % of the total GDP (Dang, 2003).

There is a general consensus among people living in the LMB about the key characteristics of good and bad (See Box 1). Flooding is an essential aspect of the rice cultivation that dominates the rural economies of the LMB and a good flood is one that rises slowly, recedes quickly and, most importantly, is timed to provide the required amount of water needed for the wet-season crop (FMMP, 2010).

Box 1 Good and Bad Floods

During a focal group meeting in Leuk Daek Commune, Koh Thum District, Kandal province, 'Good flood' was defined when the water level slowly rose at a normal pace to provide water for the rice crop. When floodwater slowly rose and it quickly recedes at low tide so that the rice is not damaged or rots. There is no strong wind or large wave so that the people can continue fishing and other activities without danger or difficulty. The flood brings fertile land / alluvial soil to the rice file and has a lot of fish.

The community defines a 'Bad flood' when a flood quickly rises and remains high for a long time leading to poor quality of water, with a bad stench. Crops become rotten. There is strong wind and large wave that is dangerous to boat transportation. People cannot go out or fishing and some time they died from drowning and lightning strikes. It is very difficult for livestock to find dry places staying and grass fields to graze. When people bathe in the poor quality water they are liable to get skin diseases and rashes.

3. Definitions of Flood Vulnerability and FVI

3.1. Definition of Flood Vulnerability

The vulnerability (V) consists of three main components; exposure, sensitivity and coping capacity (Chavoshian et al., 2009, Turner et al., 2003, Birkman, 2006):

- Exposure (E)
- Sensitivity (also named as susceptibility or basic vulnerability) (S)
- Coping Capacity (C)

We can translate that into: $V = f\,\frac{E \times S}{C}$

In order to facilitate comparison, there is a need to quantify vulnerability. Figure 2.6 and Figure 2.7 of previous chapter exposed vulnerability elements that are able to characterize vulnerability but in a qualitative way; the different elements are of different units and it is difficult to compare them among each other. One way of quantifying vulnerability is to account for it as the "amount of potential damages" (Jones and Boer, 2003). Therefore, here after, "vulnerability" will be quantified as the "amount of potential damages". The amount of potential damages due to flood were then subdivided into two major categories*: livelihood or income* and *assets or property*.

Residential structures account for nearly all main structures in the districts surveyed (FMMP, 2010) and rice land accounts for more than 95% of land use. Indeed, there are two main paddy seasons; wet season rice from May to November and dry season rice from November till April. And wet season rice production system is mainly damaged by flood. Moreover, among the total rice land, more than 50% (nearly 78% for Prey Veng province) are wet season rice land (FMMP, 2010). Thus, the vulnerability is defined by considering amount of potential agricultural damages and house damages. In this study, agricultural damage means potential damages of wet season rice and house damage means potential damages of houses with residential assets. Indeed, comparing the amount of potential damages to the total amount of income or asset is an indicator of the extent of coping capacity and resilience.

3.2. Flood Vulnerability Indices

In this study, two kinds of Flood Vulnerability Indices (FVIs) are developed such as FVIs for average flood and FVIs for extreme flood. The FVIs are developed for agricultural damages, house damages and total damages.

3.2.1 Flood Vulnerability Indices for Average Flood (FVI-AF)

The FVIs mean identification of area which easy to be affected by flood. The results of this FVIs guide well preparedness for flood in agricultural as well as houses and assets. The average flood water depth of flood in 2006 is same as average flood water depth of years 1991-2007. Thus, we evaluated FVI for 2006 flood as average flood. The flood vulnerability index (FVI) of damages for average flood is identified by normalizing the calculated value of damages in each grid. To normalize the value, the calculated value in each grid is divided by the maximum value of calculated damages. The Flood Vulnerability Indices for Average Flood (FVI-AF) in case of agricultural damages are defined as follows.

$$FVI\text{-}AF\ (Agricultural\ damage) = \frac{Value\ of\ agricultural\ damage\ in\ a\ grid\ (2006)}{Maximum\ value\ of\ agricultural\ damage\ (2006)} \quad (1)$$

Similarly, FVI-AF for house damages are calculated as follows;

$$FVI\text{-}AF\ (House\ damage) = \frac{Value\ of\ house\ damage\ in\ a\ grid\ (2006)}{Maximum\ value\ of\ house\ damage\ (2006)} \quad (2)$$

As we defined vulnerability as the amount of potential damages, vulnerability is the result of a given combination of agricultural damages and house damages. However, agricultural and house damages do not have the same impact on a household; indeed, if a household has all its assets damaged, even though it does not suffer any agricultural damages, it is obvious that this household will encounter consequent difficulties to live or survive. However, if a household gets its annual wet season rice harvest damaged but no damages in its assets, then it is also obvious life will be more difficult because wet season rice is main source of income. These were the two extreme general scenarios (refer to Figure 3.1) and all the in between scenarios are to be considered. Indeed, the relative proportion of damages occurring to assets and income will set the ability of a household to recover from a given flood event. And as a result to adaptation to its living environment, the population behavior will tend to minimize the possible damages and build resilience (e.g. building houses on stilts, flood fighting structures, dykes etc.).

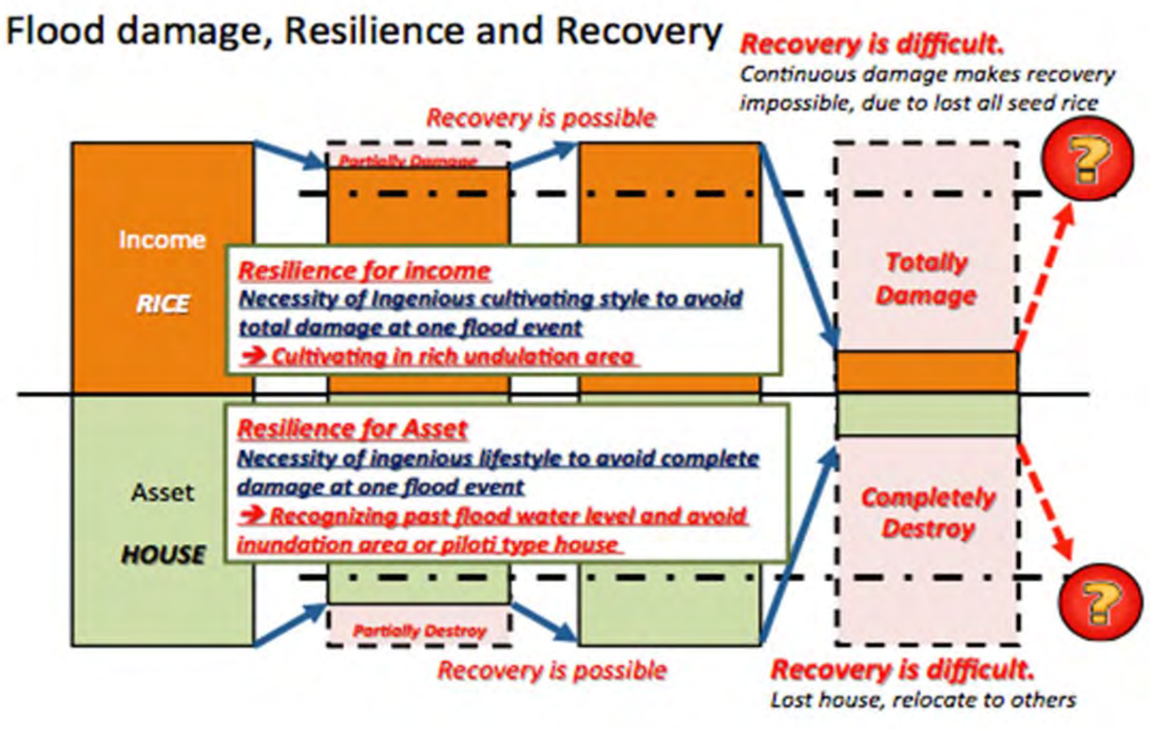


Figure 3.1: Flood Damages, Resilience and Recovery

To calculate total flood vulnerability indices by considering agricultural and house damages, it is not reasonable to give equal weight for agricultural damages and house damages. The farmers in Cambodia flood plain may have higher priority on agricultural production. As our focus of FVI development is rural area, the main source of income of farmers is from agricultural production. They consume some amount of income from agricultural production. However, they also use their saving amount of income from agricultural production to houses or assets. So, amount of house damage also includes

some saving amount of income from agricultural production. Also if we look their expenditure on food with their total expenditure based on Engel's coefficient, their expenditure on food is about 75% of their total expenditure i.e., Engel's coefficient is 0.75 (Source: David et al., 2001). As main source of farmers for food expenditure is consumed from agricultural production, they give high priority on agricultural production. The agricultural damages estimate almost same as income. So, in this study we give the weightage on agricultural damages based on food expenditure and we give 0.75 weightage to agricultural damage based on Engel's coefficient. The house damage includes damages of house and assets. As the total weightage of both agricultural damage and house damage is 1, we give 0.25 weightage to residential (house) damage. Thus, the weighted total potential damages can be described as follows.

$$TD = Wa \times AD + Wh \times HD \tag{3}$$

where,

TD: weighted total potential damages

AD: agricultural damages

HD: residential (house) damages

Wa: weightage factor of agricultural damage (=0.75, based on food expenditure)

Wh: weightage factor of house damage (=0.25)

Then, FVI-AF for total damages is calculated by normalizing the weighted total potential damages by dividing the maximum weighted value as follows

$$FVI\text{-}AF\ (weighted\ total\ damage) = \frac{Value\ of\ weighted\ total\ damage\ in\ a\ grid\ (2006)}{Maximum\ value\ of\ weighted\ total\ damage\ (2006)} \tag{4}$$

The flood vulnerability indices for average flood value has been normalized ranging from 0 to 1, which symbolizes comparatively low or high flood vulnerability between the various spatial scales. The flood vulnerability indices have been defined to low, medium, high and very high vulnerability based on normalized number as shown in Table 3.1.

Table 3.1: Normalized Number and Defined Vulnerability

Normalized value	**Defined vulnerability**
0 - 0.25	Low
0.25 - 0.5	Medium
0.5 - 0.75	High
0.75 - 1	Very High

3.2.2 Flood Vulnerability Indices for Extreme Flood (FVI-EF)

Flood Vulnerability Indices for Extreme Flood (FVI-EF) are defined to identify damage gap area between average flood and extreme flood. The flood gap damage means difference between average flood damage and extreme flood damage. The average flood

brings not so big damages but extreme flood brings big damage. It means serious preparedness for extreme flood is needed in such area. Based on flood observation data from 1991-2007, average water depth of flood in 2000 is higher in the period. Hereafter 2000 flood will be referred as maximum flood year or extreme flood. The average water depth of flood in 2006 is almost same as average water depth of 17 years period (1991-2007). Thus the flood in 2006 is referred as average flood in the Cambodian flood plain. The variations of gap area of flood vulnerability of average flood are identified by relating it with extreme flood as follows. For agricultural damage;

$$FVI\text{-}EF\ (Agricultural\ damage) = \frac{Agricultural\ damage\ (2000) - Agricultural\ damage\ (2006)}{Agricultural\ damage\ (2006)} \quad (5)$$

For house damage;

$$FVI\text{-}EF\ (House\ damage) = \frac{House\ damage\ (2000) - House\ damage\ (2006)}{House\ damage\ (2006)} \quad (6)$$

For weighted total damage;

$$FVI\text{-}EF\ (Weighted\ total\ damage) = \frac{Weighted\ total\ damage\ (2000) - Weighted\ total\ damage\ (2006)}{Weighted\ total\ damage\ (2006)} \quad (7)$$

4. Methodology

4.1. General Flowchart

In ICHARM grid-based distributed methodology, the definition chosen for vulnerability is the amount of potential damages (Jones & Boer, 2003). Therefore in ICHARM methodology, vulnerability is calculated for agricultural damages and house damages. Agricultural damages refer here as damages occurring to wet season rice crops according to (FMMP, 2010). House damages account for damages occurring to household residential assets and were calculated based on 2008 household survey data from FMMP project. Through ICHARM Hydro-Geo Method (IHGM) integrating hydro-meteorological analysis and digital elevation model obtained from SRTM data, flood water depth is calculated as the difference between flood water level and elevation at grid level (3 seconds mesh) (Figure 4.1). Indeed, the backbone of this method is flood water depth and therefore how to calculate damages as a function of this floodwater depth. Then, by integrating damages curves for both crops and houses, both amount of agricultural and house damages are calculated at grid level and their combination is considered for vulnerability level assessment.

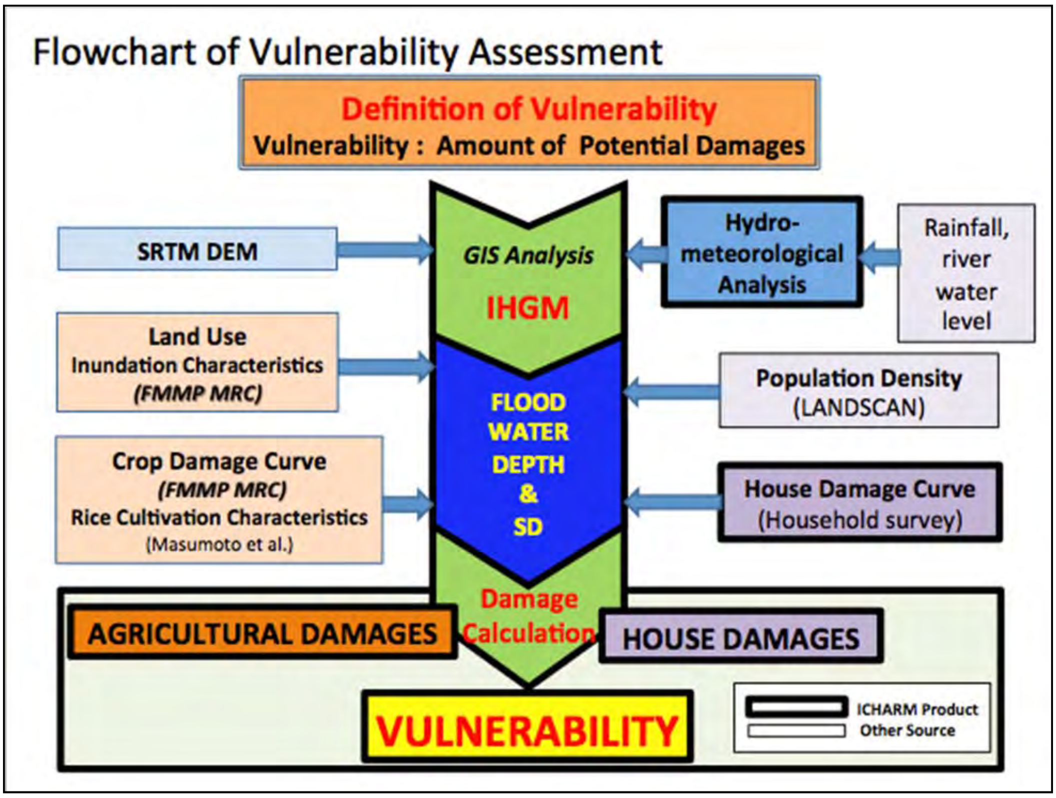


Figure 4.1: Flowchart of ICHARM Methodology for Vulnerability Assessment

4.2. ICHARM Hydro-Geo Method and Water Depth Calculation

ICHARM Hydro-Geo Method: General Process

The widely available and existing data sets are used in the IHGM to calculate flood vulnerability indices. The flowchart of IHGM is shown in Figure 4.2. Data from various sources are considered (refer to each boxes in the flowchart). Geographical Information System (GIS) based analysis is the backbone of this study and the yellow boxes contain

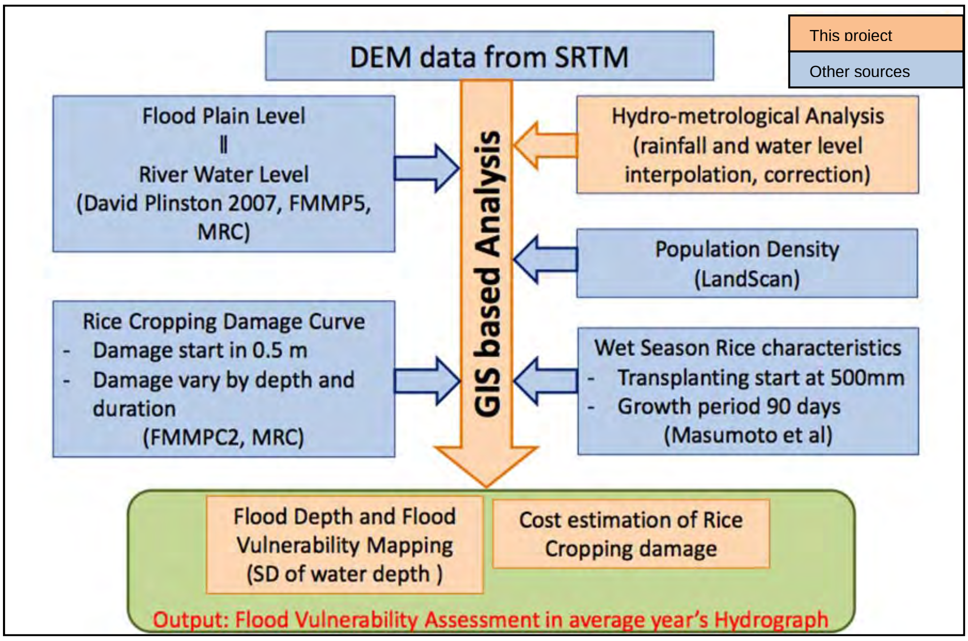


Figure 4.2: Research Flowchart: GIS analysis was carried out using SRTM DEM data for inundation analysis and other information in the flowchart were incorporated to assess vulnerability

our original data whereas we also used data from other sources shown in the blue boxes. Indeed, by using GIS based analysis and globally available datasets (e.g. digital elevation data, satellite based rainfall estimates, population density data etc.), it is possible to apply this method to any river basin (Figure 4.3).

Moreover, GIS based analysis allows updating easily databases status in order to reflect progress in local knowledge. For example, if some improvements are achieved in the digital elevation model, it is easy to replace the former layer by the updated one. It also allows conducting hydro-meteorological forecast by including layers on data reflecting future climatic and/or meteorological conditions (Figure 4.4). This GIS based IHGM is easy to reflect data changes and new knowledge with local ownerships. The future flood projection can be easily re-simulated when new knowledge is ready.

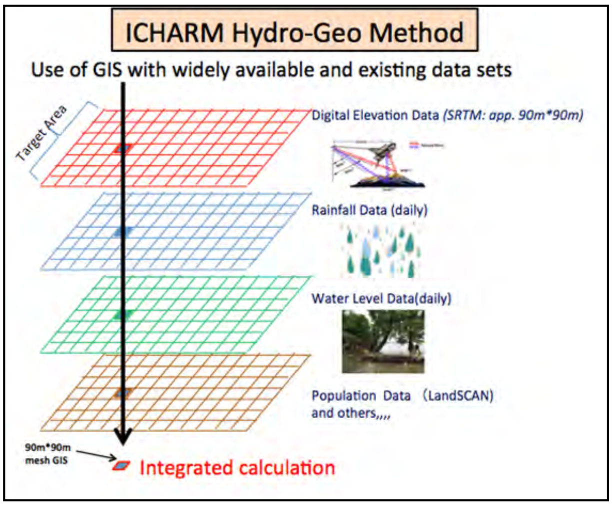


Figure 4.3: GIS Analysis in ICHARM Hydro-Geo Method

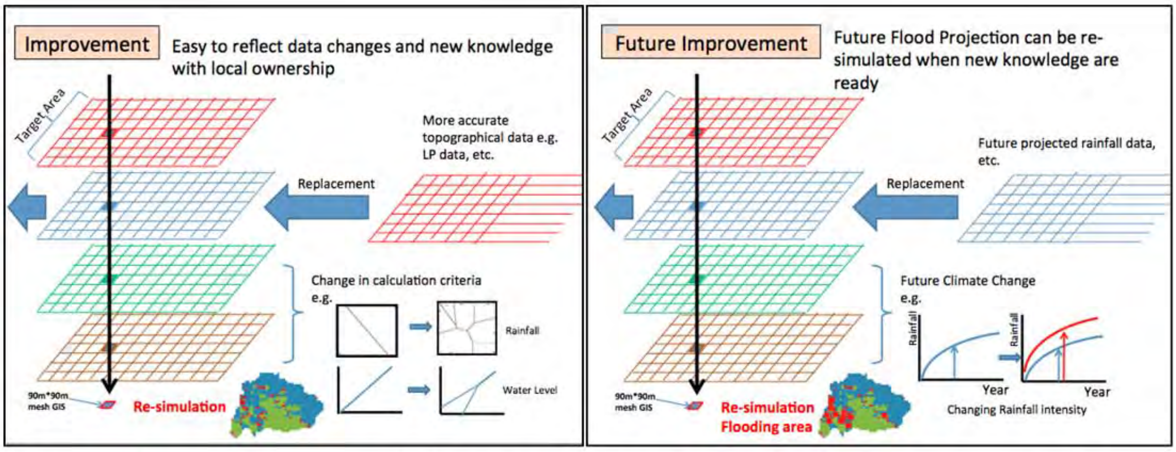


Figure 4.4: GIS Based Analysis and Flexibility in Reflecting Improvement in Local Knowledge

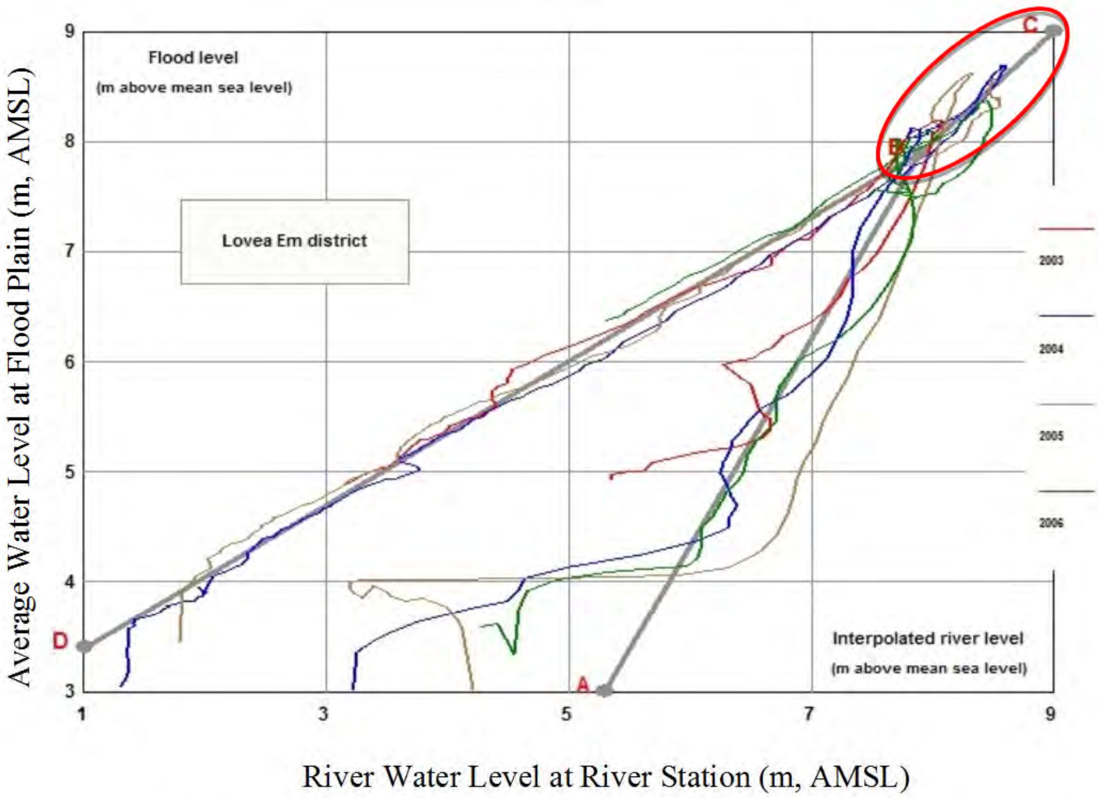


Figure 4.5: Relationship between River Water Level and Flood Water Level (Main River Data: Interpolated Records from the Stations in Phnom Penh and Neak Luong; Village Level Data: Records from Flood Marks in Lovea Em District) (Plinston, 2007)

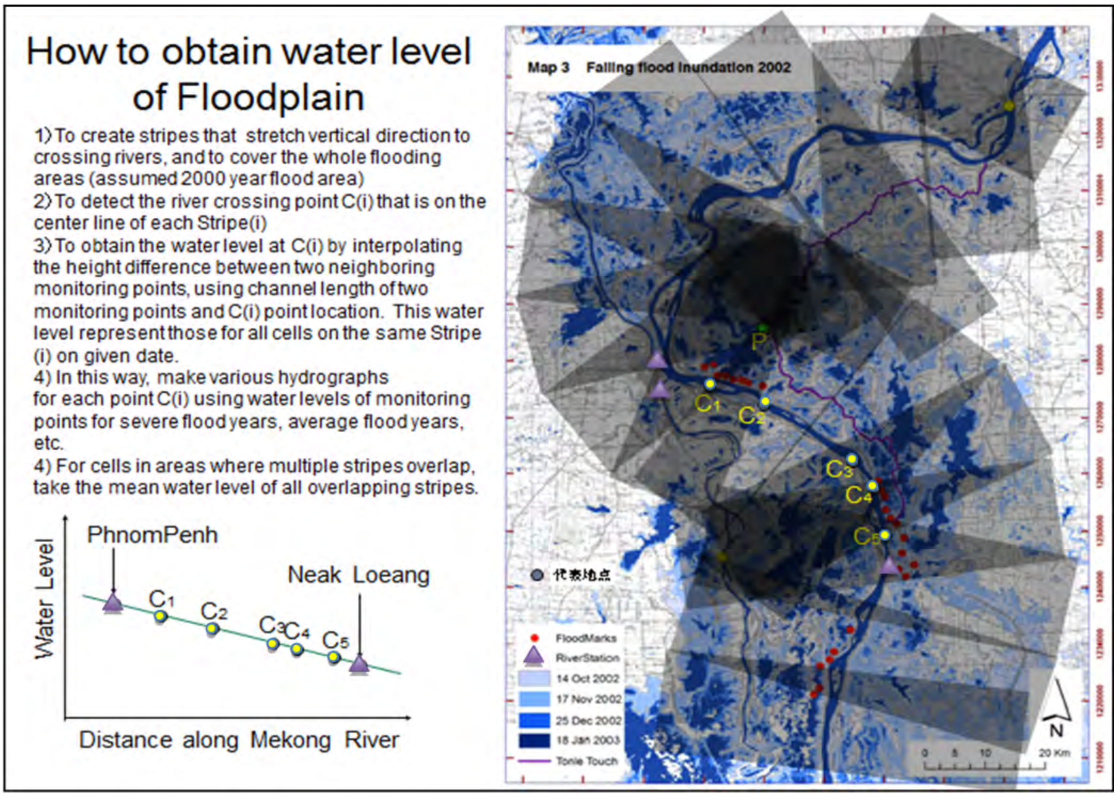


Figure 4.6: Schematic of Water Level Calculation in the Floodplain

Figure 4.7: Location of Rainfall and Water Level of Some Stations

Flood water depth calculation

Plinston (2007) identified that in the Cambodian floodplain, the river water level approached flood plain inundation water level during past floods (Figure 4.5); indeed,

once floods were high enough, flood level and river water level coincided. Water level data from monitoring stations in Mekong River and precipitation data in Cambodian flood plain were then collected to identify floods and natural hydro-climatic phenomenon. Water level in the floodplain or flood level is approached as the river water level at the closest gaging station or by interpolation between two consecutives gaging stations. For example in model calculation, the area between Kampong Cham and Phnom Penh is set, which extends about 168km x 130km. We obtained water stage data (hydrographs) at Kampong Cham and Phnom Penh, this data was interpolated on 31 points on the river between the two stations in order to allocate a water level value to those 31 points, according to the distance of each point from both stations (Figure 4.6 and Figure 4.7). Thus, the floodplain between the two stations was divided into 31 stripes along the river, centered on a point on the river, C_i, and hydrographs were plotted for each stripe from the interpolated water levels for the same flood event. For cells in the floodplain where several stripes overlap, it gets attributed the average water level of all the overlapping stripes (Figure 4.6). Through this process, floodwater depth is hence calculated for each 3 seconds grid (SRTM scale) for the whole Cambodian floodplain. The detail explanation of IHGM is described in Appendix 1.

4.3. Agricultural Damage Estimation

Outline

The IHGM is a grid-based distributed method to calculate the maximum inundation or water depth for each grid on the area of interest. Flood water depth is defined as the depth of water resulting from the subtraction of flood level by elevation. Because the scale of *Shuttle Radar Topography Mission (*SRTM) topographical data considered in this project is 3 seconds, this will be the scale for IHGM and agricultural damages calculations.

Background

Among the different existing rice production systems in practice in Cambodia, wet season rice production is the one particularly damaged by floods. Therefore, the maximum water depth calculated by ICHARM Hydro-Geo method is the one with a damageable effect on wet season rice yield. Indeed, there are specific conditions for floodwater depth to become damaging for wet season rice production and those specific conditions are:

- Wet season rice cannot be damaged if it is not planed. Traditionally farmers in Cambodia start then planting wet season rice as land becomes soft enough to be cultivated which corresponds to the time once accumulated rainfall reaches 500 mm, t_{500mm} (Taniguchi et al., 2009).
- Damages occur during the 90 days following that day t_{500mm} as it is the period during which rice plants are the most sensitive to prolonged submersion.
- During that period of 90 days, damages occur if floodwater depth reaches over 0.5 m as it is the minimum damageable depth of water over which newly planted rice germinations will be impaired (FMMP, 2010).

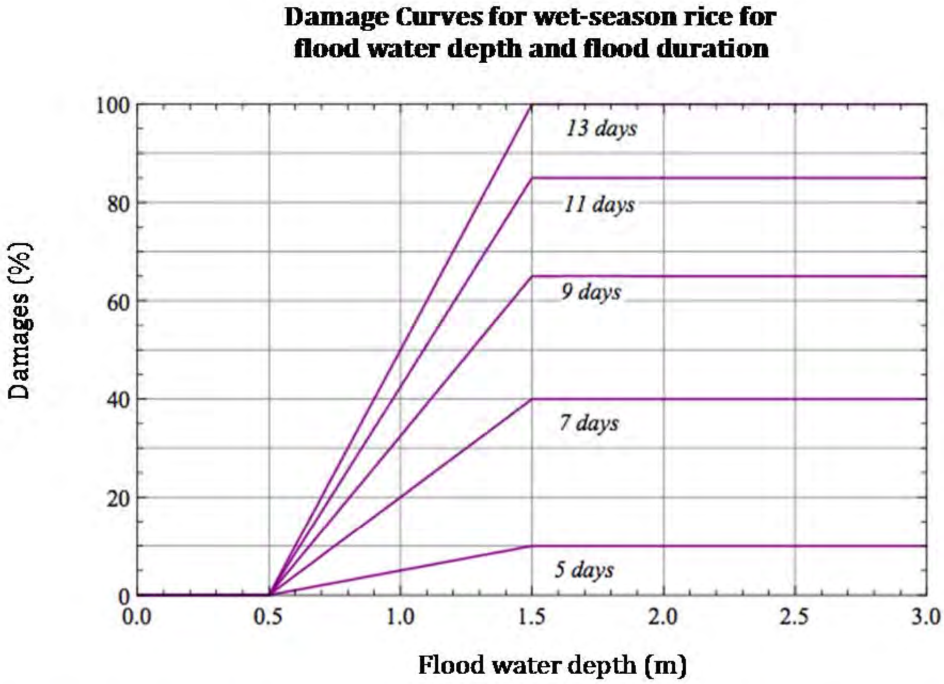


Figure 4.8: Crop Damage Curves According to Flood water Depth and Flood Duration (FMMP, 2010)

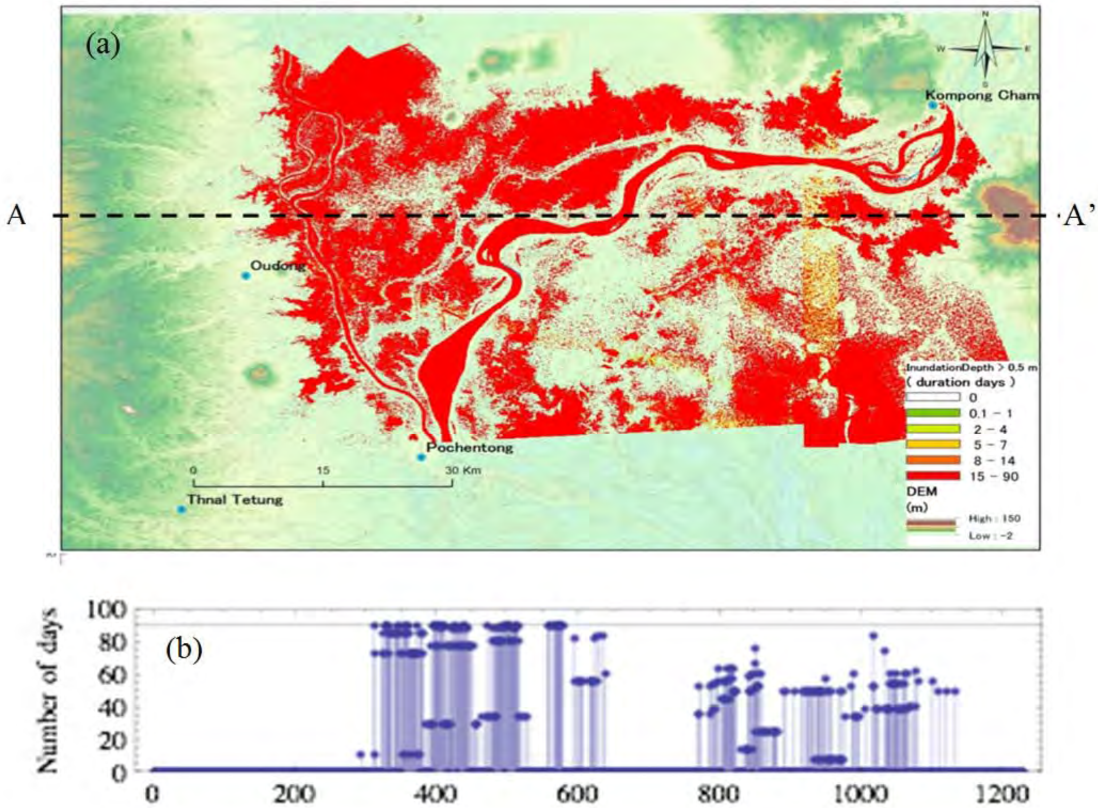


Figure 4.9: (a) Plan view: Number of Days of Flood over 0.5 m During the 90 days Following a Cumulative Rainfall of 500 mm and (b) Cross-Section View AA'

Agricultural damages calculation

According to damages curves for wet season-rice proposed for Thailand, in FMMP (2010), crop damages due to flood were found to be a function of both duration of the flood event and its maximum water depth (Figure 4.8). From IHGM, it is possible to identify the maximum flood water depth and their duration for each 3 seconds cell.

According to FFMP (2010), wet season rice field varies from 0.20 ha to 7 ha with in average on the three provinces of 1.62±0.66 ha which correspond to two grids of 3 seconds in average. Hence, it is possible to assess, for each grid of 3 seconds, the number of days of flood over 0.5 m during the 90 days following the 500 mm cumulative rainfall over the whole Cambodian floodplain (Figure 4.9). However, the whole Cambodian floodplain is not cultivated with wet season rice. Therefore, it is necessary then to identify the 3 seconds grids that would be cultivated with wet season rice in an average year. According to FMMP (2010), crop damages occur once flood water depth reaches 0.5 m during the period of 90 days following plantation. In order to consider cultivation area of wet season rice, an agricultural land use data made by Ministry of Public Works and Transport (MPWT), Cambodia and Japan International Cooperation Agency (JICA) in 2003 was used to consider cultivation land (Figure 4.10).

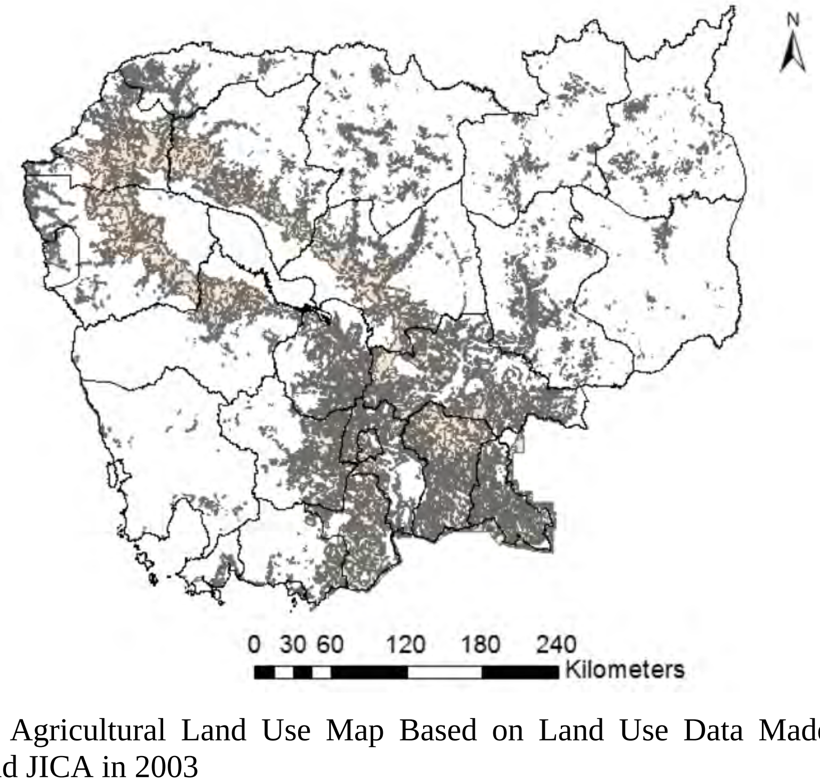


Figure 4.10: Agricultural Land Use Map Based on Land Use Data Made by MPWT, Cambodia and JICA in 2003

The agriculture damage equation was developed and crop damage calculations were then conducted for each grid. The crops damages percentage in cell/grid k, $AD\_percentage_k$, was defined as a function of water depth *h* and flood duration *d* as follows.

$$AD\_percentage_k = (h - 0.5)(-86.875 + 22.5d - 0.625d^2) \qquad (8)$$

This equation is defined for $0.5 \leq h \leq 1.5$m
And if d>13, then d=13.
If h>1.5 then h=1.5.

If AD_percentage≤0, then AD_percentage=0
If AD_percentage≥100, then AD_percentage=100.

Table 4.1: Average Rate of Income from Rice Production per Hectare

Province	**Average value of yield for rice per hectare in 2009 (US$/ha)**
Kandal	522.2
Prey Veng	336.5
Kampong Thom	317.3
Average (for 100% yield)	392.0

Source: Ministry of Planning, Cambodia, 2009

Then by multiplying by the average yield (US$/year) for wet season rice, it is possible to calculate the amount of agricultural damages for each cell/grid. The average value of yield 392.0 US$ per hectare was used to calculate the amount of agricultural damage based on commune data base of Kandal, Prey Veng and Kampong Thom provinces (Data source: Ministry of Planning, Cambodia, 3 provinces, 2009) (Table 4.1). In practice, during the 90 days period once accumulated rainfall reaches 500 mm, for each cell, the number of days during which flood water depth is between 0.5 m and 1.0 m, and the number of days during which flood water depth is over 1.0 m are recorded and Equation 8 was applied. It was assumed that one cell is a plane with same height of wet season rice, i.e. a big paddy with 3 seconds by 3 seconds.

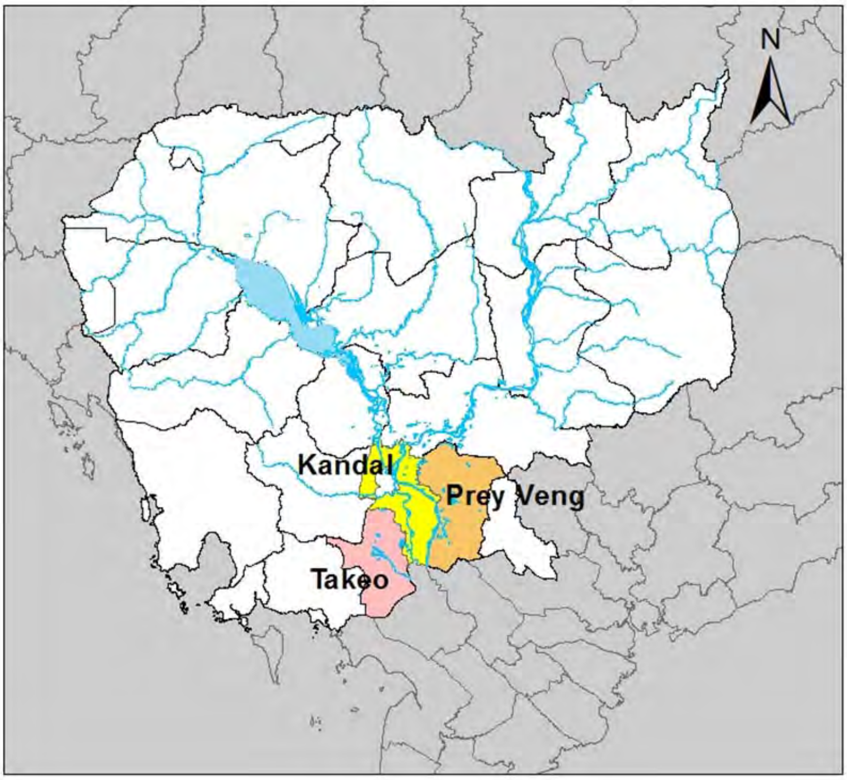


Figure 4.11: Location Map of Three Provinces Takeo, Kandal and Prey Veng

4.4. Household survey

The house damages were calculated based on 2008 household survey data for 2006 flood from FMMP project (FMMP, 2010). The household survey carried for losses and damages from 2006 flood events. The household survey data of village level at three districts Koh Andet in Takeo province, Koh Thom in Kandal province and Kampong Trabek in Prey Veng province were used. The location of three provinces Takeo, Kandal and Prey Veng is shown in Figure 4.11. The provinces Takeo, Kandal and Prey Veng were significantly affected by the 2000 and 2001 mainstream floods. They include communes with high flood vulnerability and drought vulnerability according to WFP (2003). The provinces were included in the focal areas of FMMP, so that recent detailed household survey data are available. Several communes have a flood warning system through flood staffs since 2003. The flash flood events also happened in these provinces in the past 5 years and also these provinces in Cambodia include priority areas for vulnerable population in flood prone areas (based on WFP, 2003). Furthermore, these provinces include focal areas of FMMP.

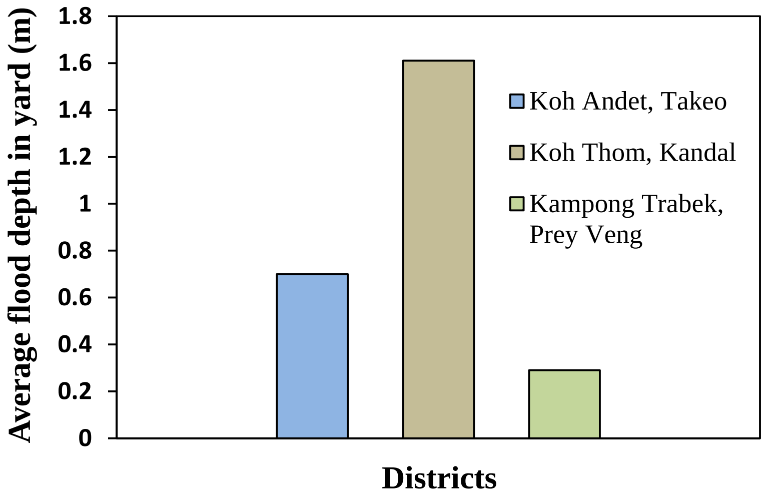


Figure 4.12: Average Flood Depths of 2006 Flood Events in Three Provinces

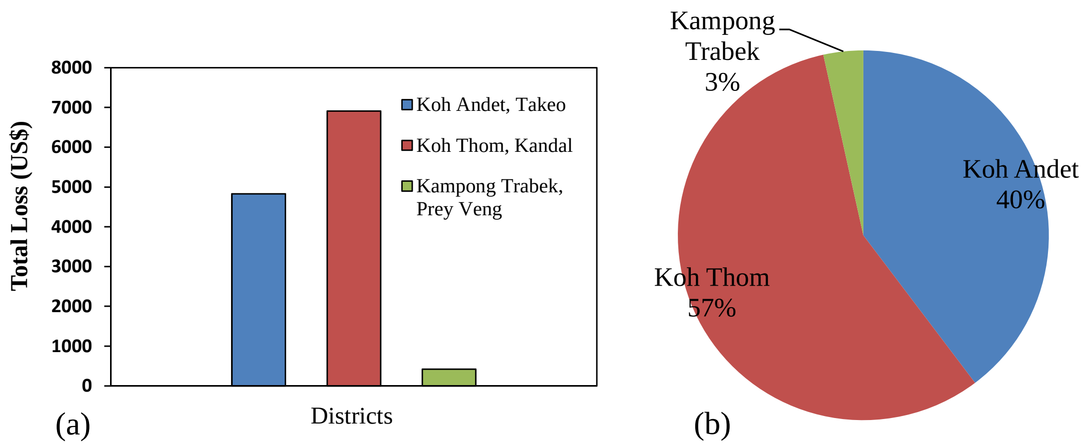


Figure 4.13: (a) Amount of Total Loss due to 2006 Floods, and (b) Percentage Distribution of Total Losses in Three Provinces

The average flood depth of 2006 floods in house yard of three districts are shown in Figure 4.12. The figure shows that the flood depth is higher in Koh Thom district of Kandal province. Figure 4.13 shows the amount of total loss due to 2006 flood. The amount of total loss in Koh Andet and Koh Thom is higher than Kampong Trabek. Because flood depth is low in Kampong Trabek compared with other two districts. In Kampong Trabek district of Prey Veng province, amount of total loss is about 3% only of total losses in three districts. The detail of questionnaire survey is attached in Appendix 2.

4.5. House Damages Estimation

General methodology

Residential damages are the damages encountered at the household level. Here, as rural zone is considered, it is assumed that all the people living in one house are members of one same household. Then, the total residential damages encountered at a greater scale, i.e. villages, communes, districts, provinces or national, are the sum of those households damages. From the literature, flood damages are assessed as a function of floodwater depth (Dutta et al., 2003).

Indeed, water depth and consequent damages are linked in relationships; the unitary damage curves (or at the household level), which can be declined according to socio-economic factors such as type of housing (Prettenthaler et al., 2010). The establishment of those unitary damage curves is based on household survey data (in this project, based on FMMP 2008 survey data). The survey sample included 262 households in three districts in three provinces: Koh Andet district in Takeo province, Koh Thom in Kandal province and Kampong Trabek in Prey Veng province. The average value of the house varied between 5.65 million ±5.1million of Riel (1,500±1200 US$). During the survey, households were asked to quantify the damages resulting from the 2006 flood and also to estimate how much the damages to household would have been if the water level was 0.5, 1.0, 1.5 and 2.0 m higher than in 2006.

As mentioned above, the backbone of ICHARM damage estimation method is flood water depth. Indeed, it was possible to relate also house damages with flood water depth: from household survey analysis, house value was plotting against maximum water depth measured in the house and measured in the yard (Figure 4.14). Based on the household survey data, the gamma distributions well fitted to house value distributions according to water depth in the yard (Figure 4.15). In the Figure 4.15, blue line distribution is the distribution of house value according to water depth measured in the house; red line distribution is the distribution of house value according to water depth measured in the yard; and dashed line distribution is the distribution of house number according to water depth measures in the yard. As gamma distribution function of house value is well fitted according to water depth measured in the yard, we used the gamma distribution function according to water depth measured in the yard. Based on the distribution of house value according to either water depth measured in the house (blue line) or water depth measure in the yard (red line), it can be underline that the peaks of both lines do not coincide and neither do their shape. Indeed, there are more house values concentrated for lower water depth measured in the house than for water depth measured in the yard. This illustrates the fact that most of the houses are constructed on stilts. Therefore, it illustrates an adaptive behavior of the local population.

Figure 4.14: Max Water Depths Measured from Inside the House or from the Yard

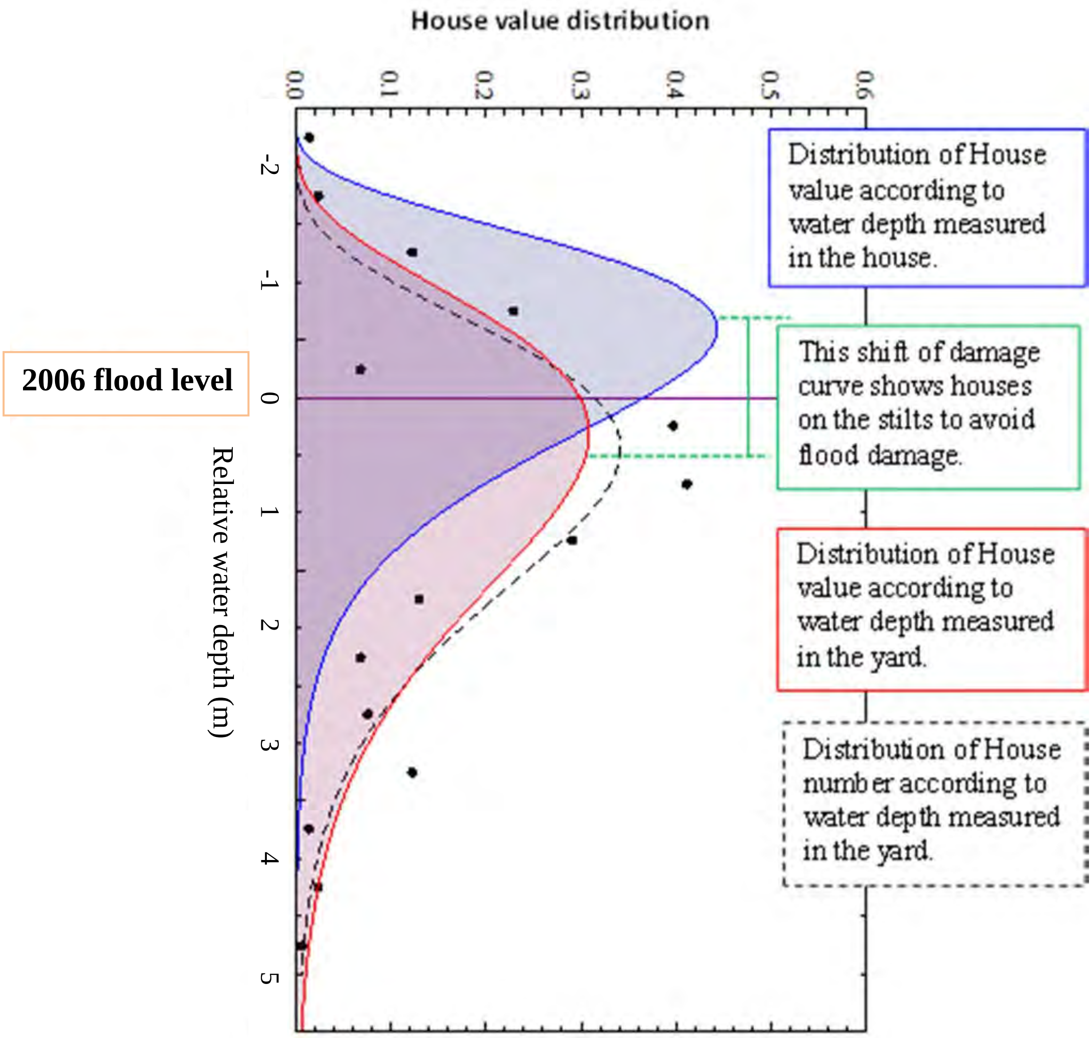


Figure 4.15: Gamma Distributions Fitted to House Value Distributions According to Water Depth in the Yard and in the House

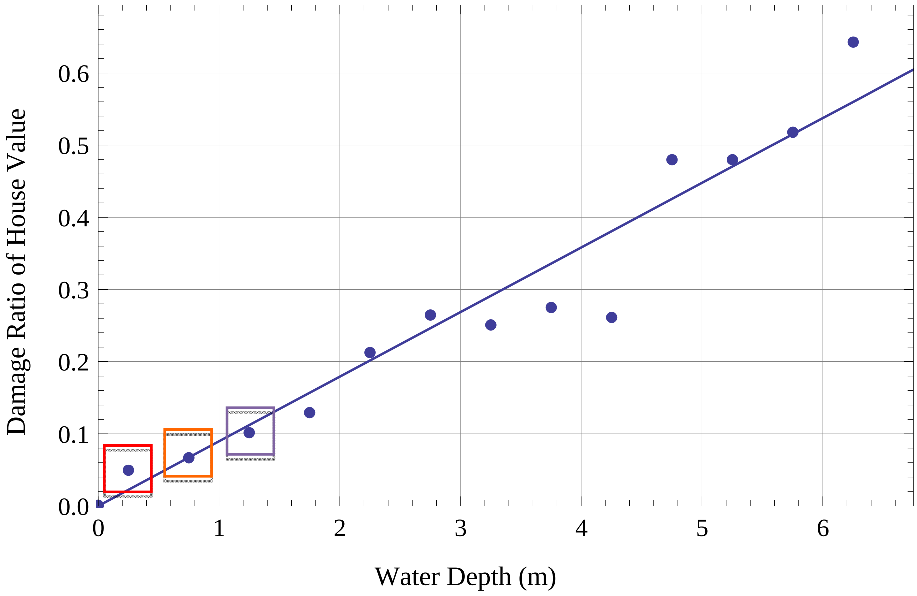


Figure 4.16: Damage Curves Calculated from Actual Damages After 2006 Flood and Potential Damages that Would Have Occurred if 2006 Flood Water Depth Had Been 0.5 m, 1.0 m, 1.5 m and 2.0 m Higher

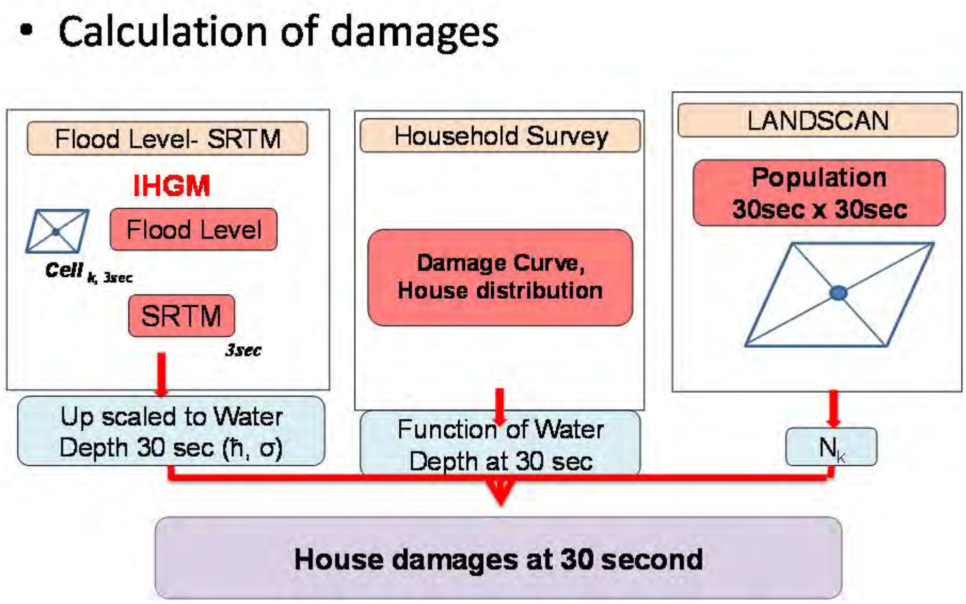


Figure 4.17: Flowchart for General House Damage Calculation Integrating IHGM (ICHARM Hydro-Geo Method), Household Survey Data and LANDSCAN Data

Figure 4.16 shows the damage curves calculated from actual damages after 2006 flood and potential damages that would have occurred if 2006 flood water depth had been 0.5 m, 1.0 m, 1.5 m and 2.0 m higher. In the figure relative water depth means water depth measured from average flood level of 2006 flood. Then by multiplying this damage curve with gamma distribution function, we can get the value of house damages. People living in Cambodian flood plain often experienced average flood. So, they construct elevated houses by using stilts which floor height of houses is higher than average flood level or they constructed houses at higher elevation than average flood level to avoid flood

damages. Thus, house damages are calculated only for water level higher than average flood level.

As flood damages for a given flood water depth at a given scale (here, LANDSCAN's scale) are the sum of the damages at the corresponding flood water depth for each of the household living in the unit of the scale considered, it is necessary to have a good estimate of the number of household at that specific scale. This household or population density data can be obtained either from national survey or from global data set such as LANDSCAN at 30 seconds resolution. Moreover, it is also necessary to assess not only the distribution of the houses but as we are focusing on damages, to also the distribution of house values; i.e. the distribution of the expensive houses and the cheap houses inside each cell/grid. In this project, as only rural zone is considered, all the cells with more than 2,000 inhabitants were dismissed. The spatial unit considered for house damages calculation was set to 30 seconds and the method followed is illustrated in the flow chart Figure 4.17.

Therefore, this method consists in calculating house damages as a function of average year maximum flood water depth (h). Moreover, damage curves are usually differentiated according to socio-economic factors. They can either be a relationship between damage ratio and water depth or damage (currency) and water depth (Figure 4.18). In order to calculate house damages in US$, average house value per person 245 US$ was used based on 2008 household survey data from FMMP project. The detail calculation of house damages is described in Appendix 3.

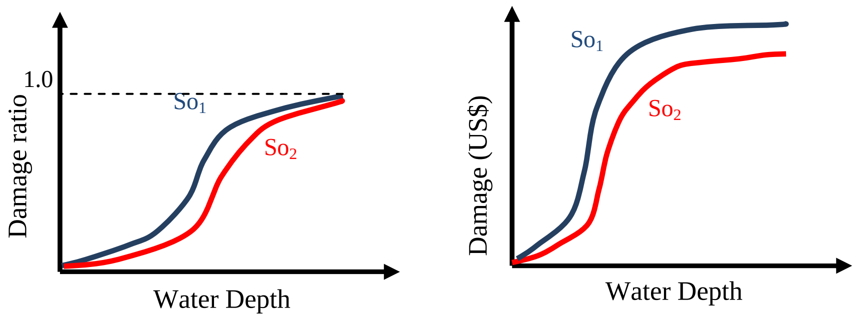


Figure 4.18: Examples of Damage Curves: Damage Ratio as a Function of Water Depth, or Damage ($) as a Function of Water Depth, According to Different Socio-Economic Factors So_j

5. Results and Discussions

5.1. Flood Water Depth and Social Impact

The flood water depth was calculated by subtracting flood water level by elevation at each grid. Figure 5.1 shows the average flood water depth of annual maximum water depth of year 1991 to 2007 (average of 17 years floods) in Lower Mekong Basin. Figure 5.2 shows the maximum flood water depth in 2000. The flood water depth in 2000 is maximum depth in average year 1991 to 2007. Similarly, the maximum flood water depth in 2006 is shown in Figure 5.3. The flood inundation depth in 2006 is almost same as average flood water depth of year 1991 to 2007. Since 2006 flood water depth is same as average flood depth of years 1991 to 2007, 2006 flood is considered as average year flood.

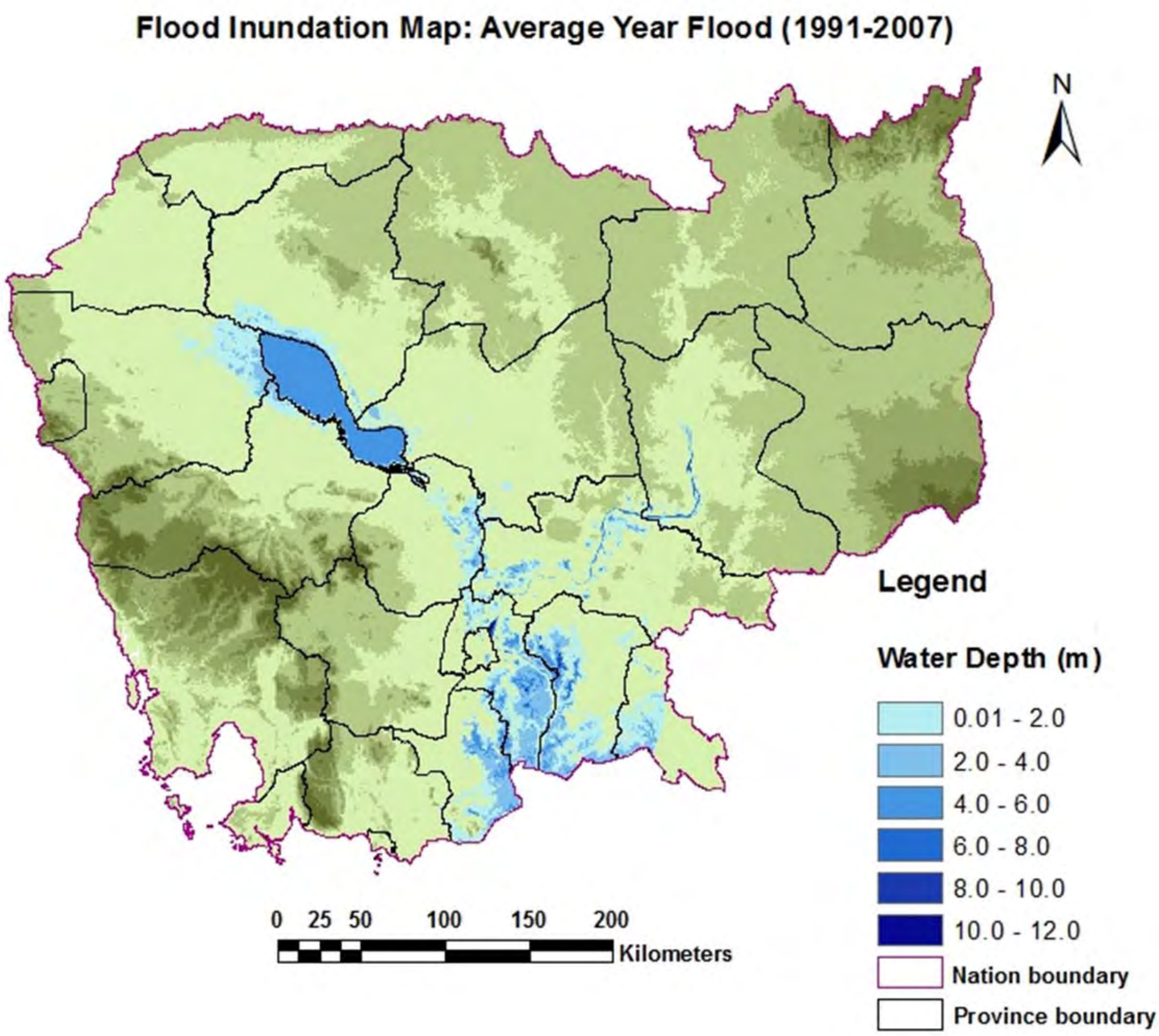


Figure 5.1: Average Flood Water Depth of Years 1991-2007 (average water depth of 17 years flood)

The flood inundation maps are useful tool for flood response, evacuation and mitigation that show flood water extent and depth on the land surface. The flood inundation depth is higher in downstream reach of Lower Mekong Basin in Cambodian floodplain, i.e. in

Takeo, Kandal and Prey Veng provinces. The flood inundation occurred in almost whole part of province in Kandal. Figure 5.4 shows the commune level flood inundation map of Kandal Province for 2006 flood.

The higher flood inundation depth and longer flood duration can cause higher impact on health, food security, livelihoods, poverty, education and others. During the flood events injuries may occur as individuals' attempts to escape from danger or as a result of collapse

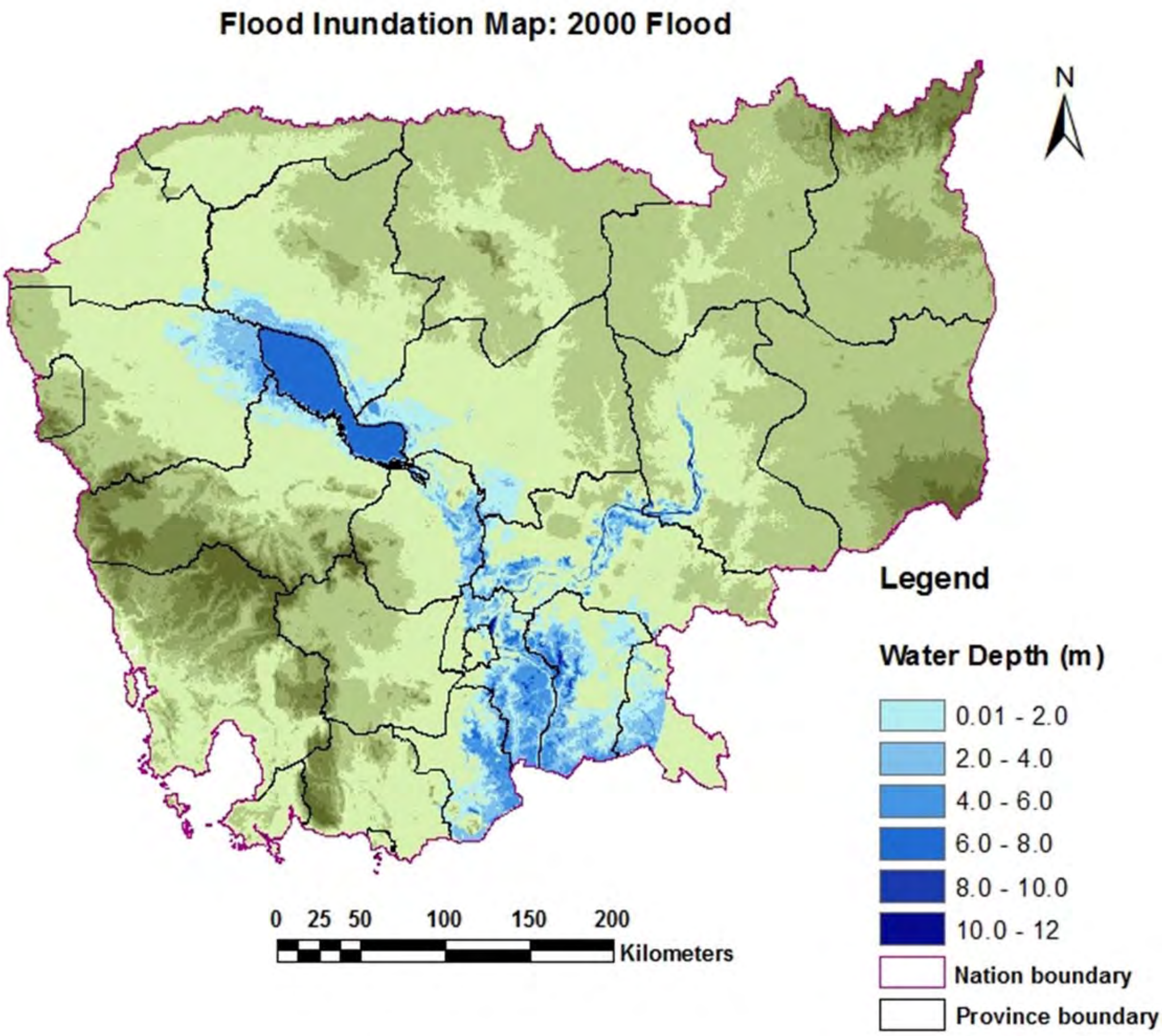


Figure 5.2: Maximum Flood Water Depth in Case of 2000 Flood

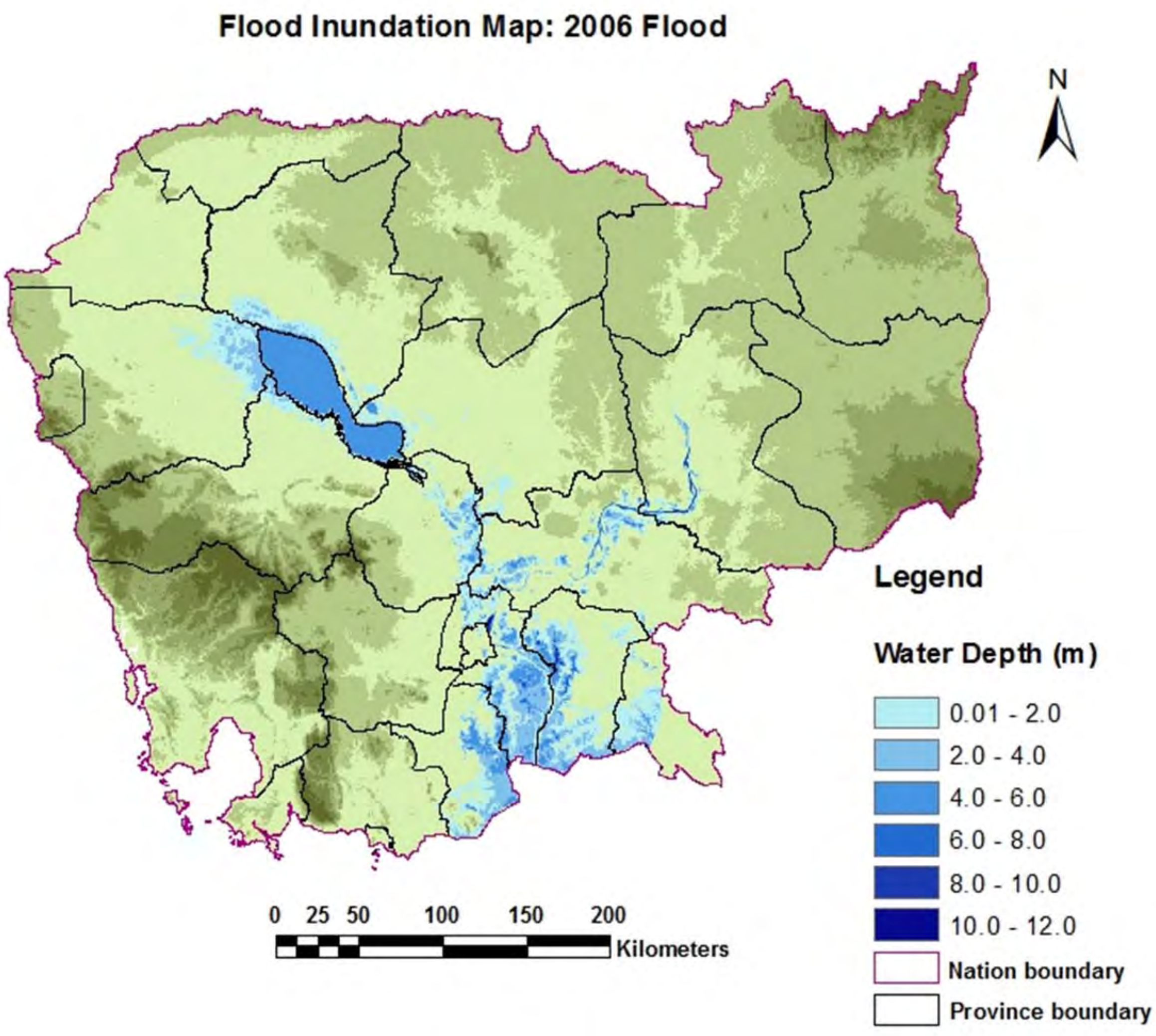


Figure 5.3: Maximum Flood Water Depth in Case of 2006 Flood

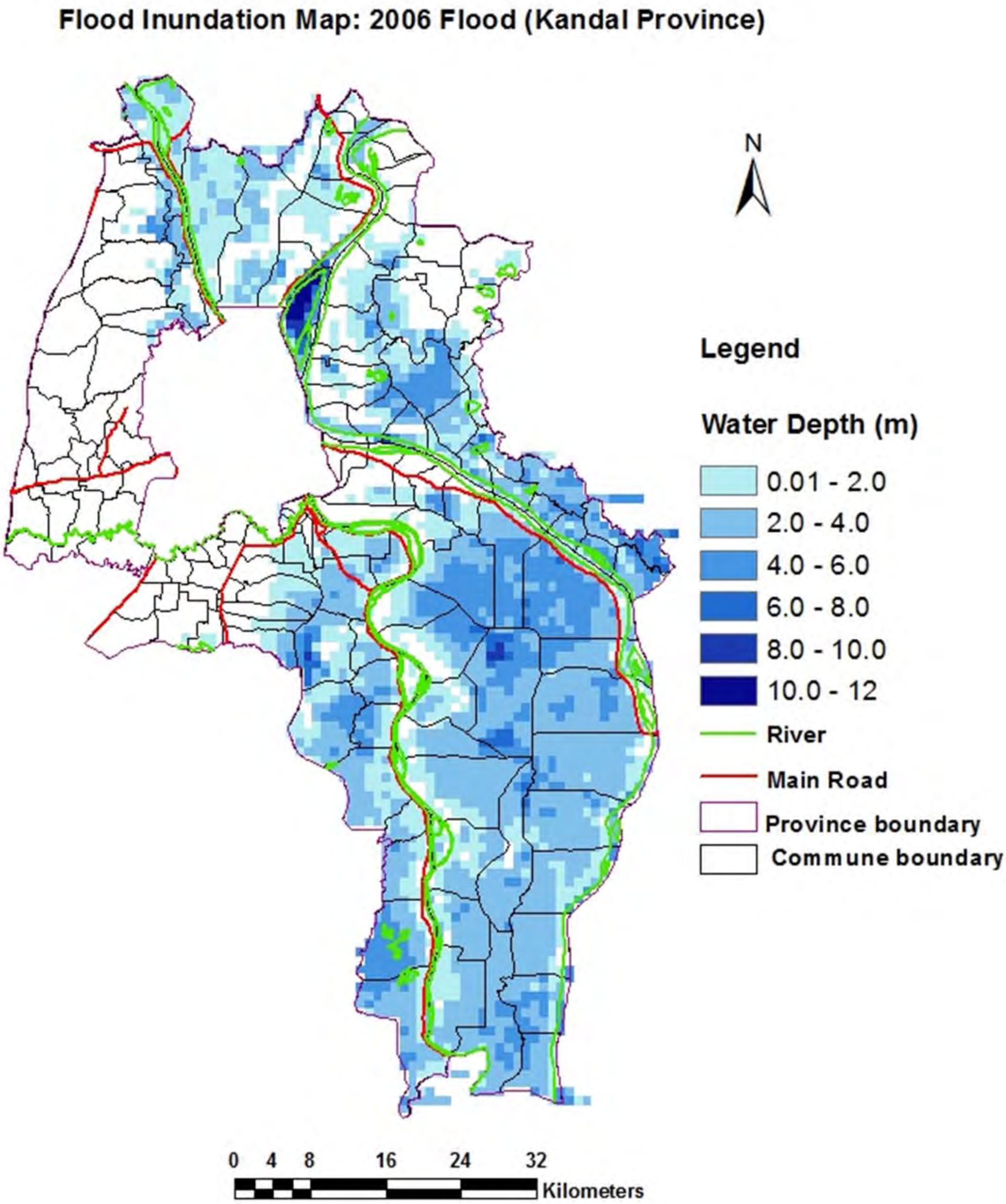


Figure 5.4: Flood Inundation Map of Kandal Province for 2006 Flood (commune level map)

of the building and other structures. If the flood inundation depth is higher, it may take long time for the drawdown of the water depth. In such area, diseases problems may occur such as lack of clean water, overcrowding, nutritional deficiency and poor sanitation are the major contributing factors for spread of diarrheal diseases. Also vector-borne diseases may increase during flooding period and stagnant water also can cause diseases like malaria and dengue. The developed flood inundation maps are very much useful for identifying the area of high chances of water diseases.

During flooding period, it might be difficult to go to health center and also flood inundation may occur inside the health center, which can highly influence on health situation of the people living in the flooding area. Figure 5.5 shows the village center and distance of nearest health center from the village center in the case of Kandal province. The nearest health center from most of the village center is located within less than 3 km distance. If water depth is greater than 0.5 m, it might be difficult for people to go to health center. For more details of map, the village level map of Krang Yov commune in Kandal province is shown in Figure 5.6 as an example of village level map of flood prone area. Figure 5.6 shows the villages center and distance of nearest health center from the village center in Krang Yov commune of Kandal province. In the figure, we can find that villages are concentrated in the place where water depth is low. If the distance of health center is nearest from the villages, people living in the area can access easily to hospital for treatment of diseases during flood and also hospital can be used for evacuation center during the flood. If the distance of health center is far from the village, they have to do preparedness for flood.

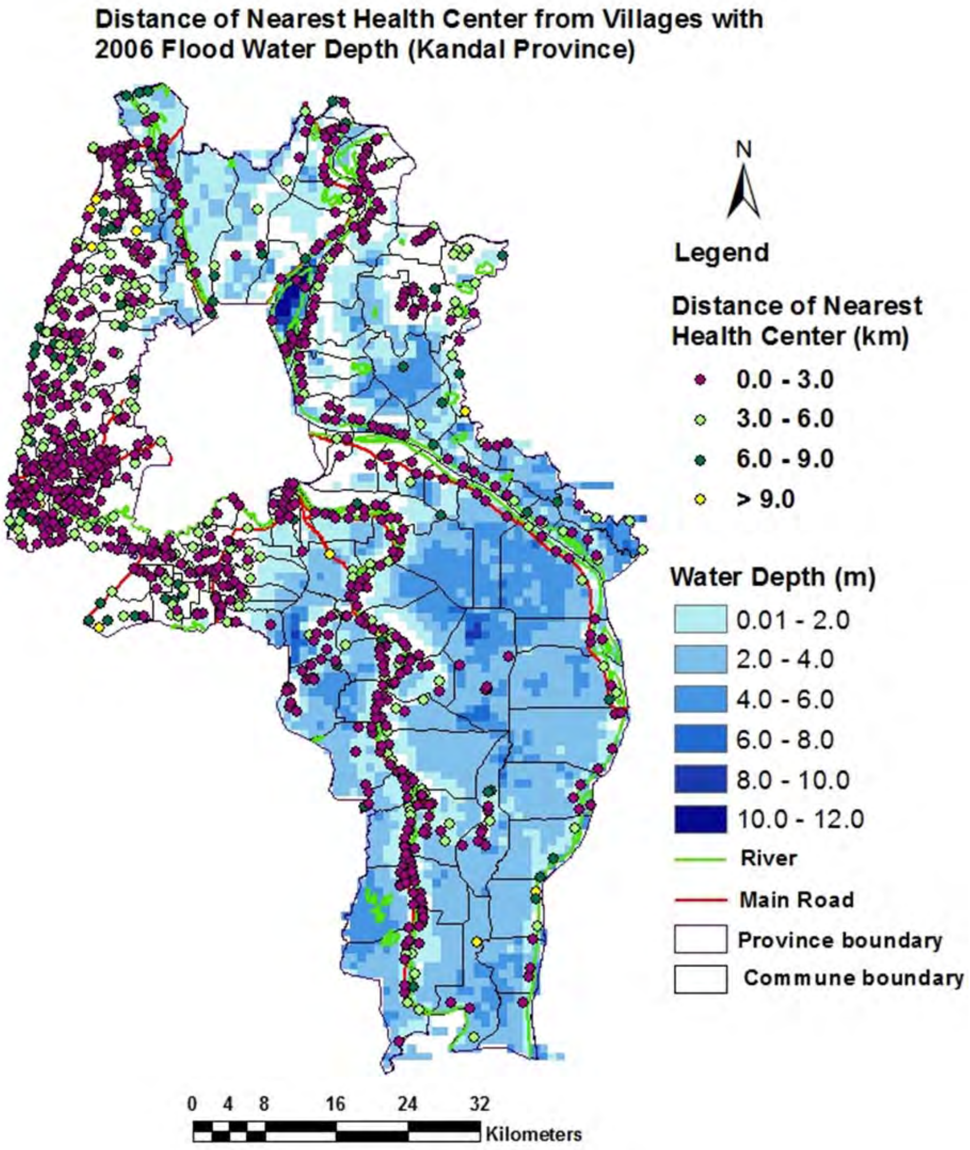


Figure 5.5: Distance of Nearest Health Center from Village Center in Kandal Province (commune level map)

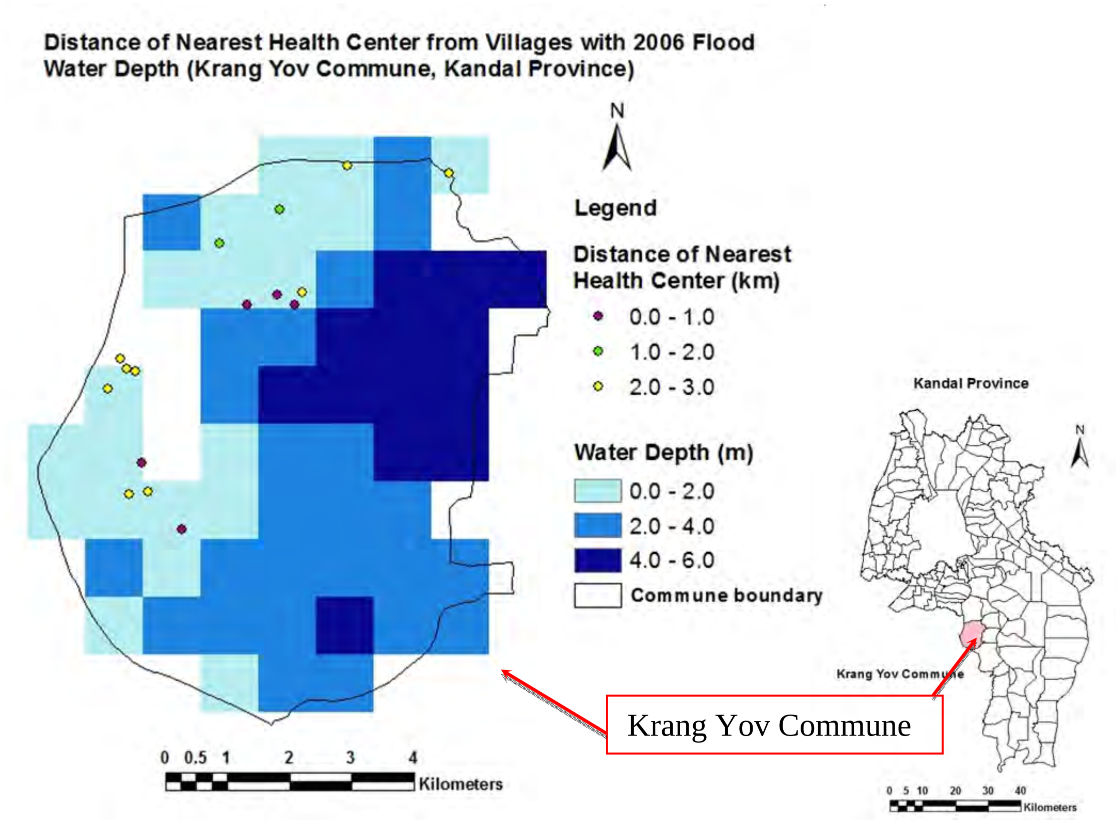


Figure 5.6: Distance of Nearest Health Center from Village Center in Krang Yov Commune, Kandal Province

The floods also effect on education system in the flooding area. It might be difficult to go to school for students as well as teachers in the area where flood depth is high. Also, flood inundation may occur in the school area and inside the class room during the flooding period, where student cannot take classes for several days. Figure 5.7 shows the location of center of the villages in Kandal province and average distance of nearest school from village. Figure 5.8 shows the location of center of the villages and average distance of nearest school from villages in Krang Yov commune of Kandal province. The nearest school from most of the village center is located within less than 1 km distance. Normally, if flood water depth is greater than 0.5 m, it might be difficult to go to school in flood prone area. Also the schools can be used for evacuation shelter during the flood event. If the distance of school from the village is far, the people living in the area have to prepare for the flood.

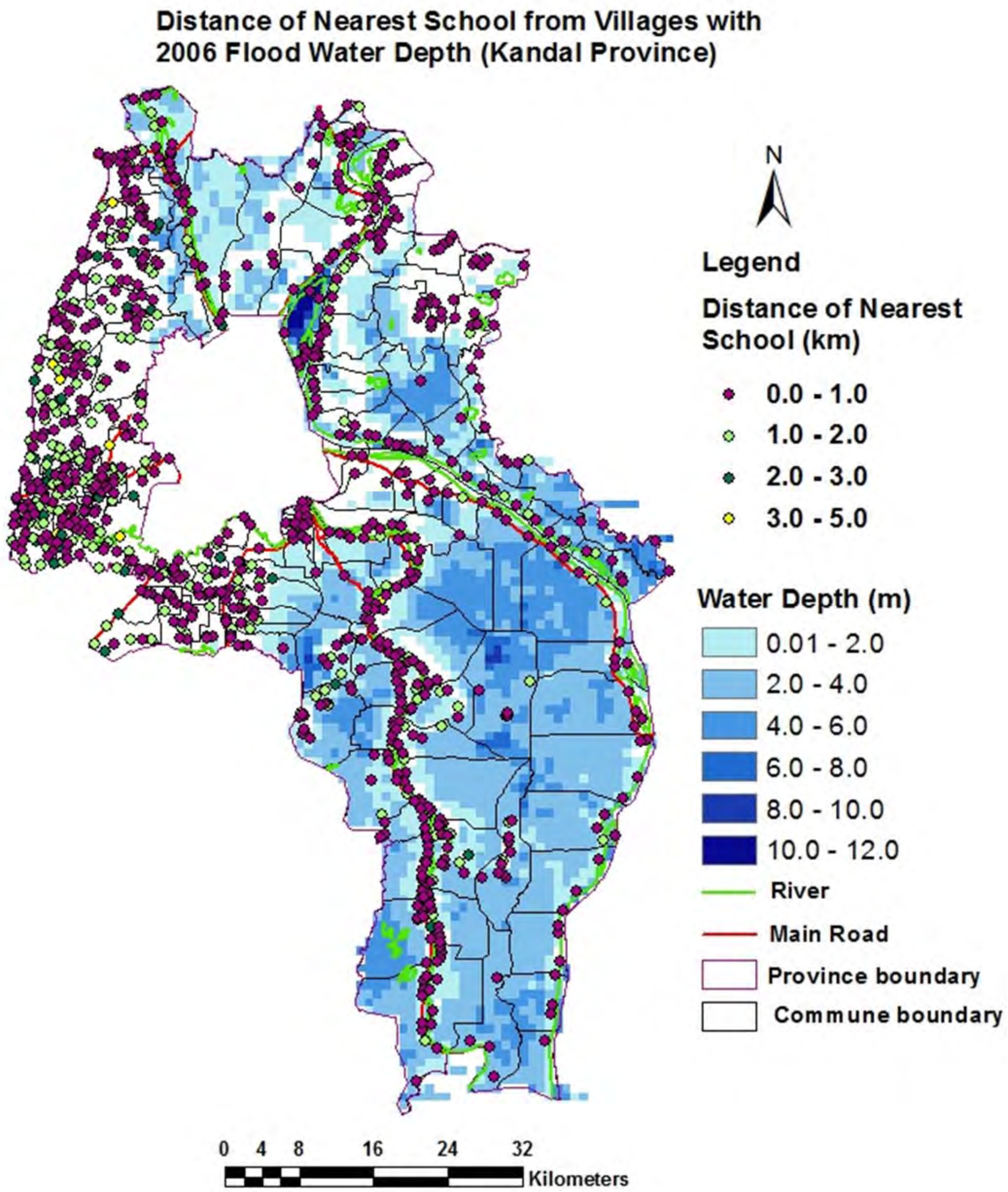


Figure 5.7: Distance of Nearest School from Village Center in Kandal Province (commune level map)

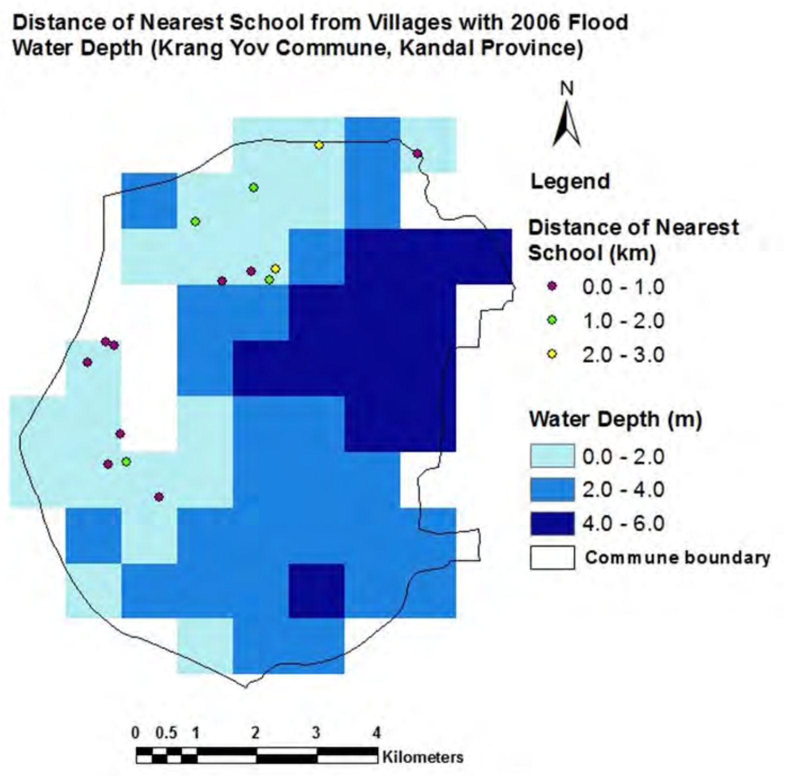


Figure 5.8: Distance of Nearest School from Village Center in Krang Yov Commune, Kandal Province

The developed flood inundation map with social information such as distance of nearest health center and school as shown in Figures 5.5 and 5.7 are also very useful for community awareness raising, evacuation system and community based flood management system as well as implementation of flood prevention works. It will be also useful for training purpose to understand the flood situation and evacuation route. Figure 5.9 shows the flooding area greater than 0.5 m water depth. In the figure, the white color area inside the inundation area is either water depth less than 0.5 m or non-flooded area. Figure 5.10 shows the flooding area greater than 1 m water depth. In this figure also, the white color area inside the inundation area is either water depth less than 1 m or non-flooded area. Such information of flooding area less than 0.5 m and 1.0 m water depth and non-flooded area can be useful for delineate evacuation route and rescue purpose. Normally, the flooding area less than 0.5 m water depth can be useful for evacuation purpose. However, there is also possibility to use evacuation route in flooding area less than 1.0 m water depth for adult people.

The agricultural crops also can be damaged during the floods and the damages of agricultural mainly depend on flood water depth and the duration, for example damages will be higher with high flood level and longer duration. Also the house damages and other property damages will be higher when high flood occurs. The detail estimation of agricultural and house damages in Lower Mekong Basin will be discussed in next sections.

The developed flood inundation maps with social information of some other provinces of Cambodia are presented in Appendix 4. These maps are very useful for local community and community leader to take an action during flood events and also to understand their

hazard situation for awareness raising. These maps can be also useful for the decision makers and policy makers for the development of community based flood management systems, and designing and implementation of countermeasures to cope the flood events.

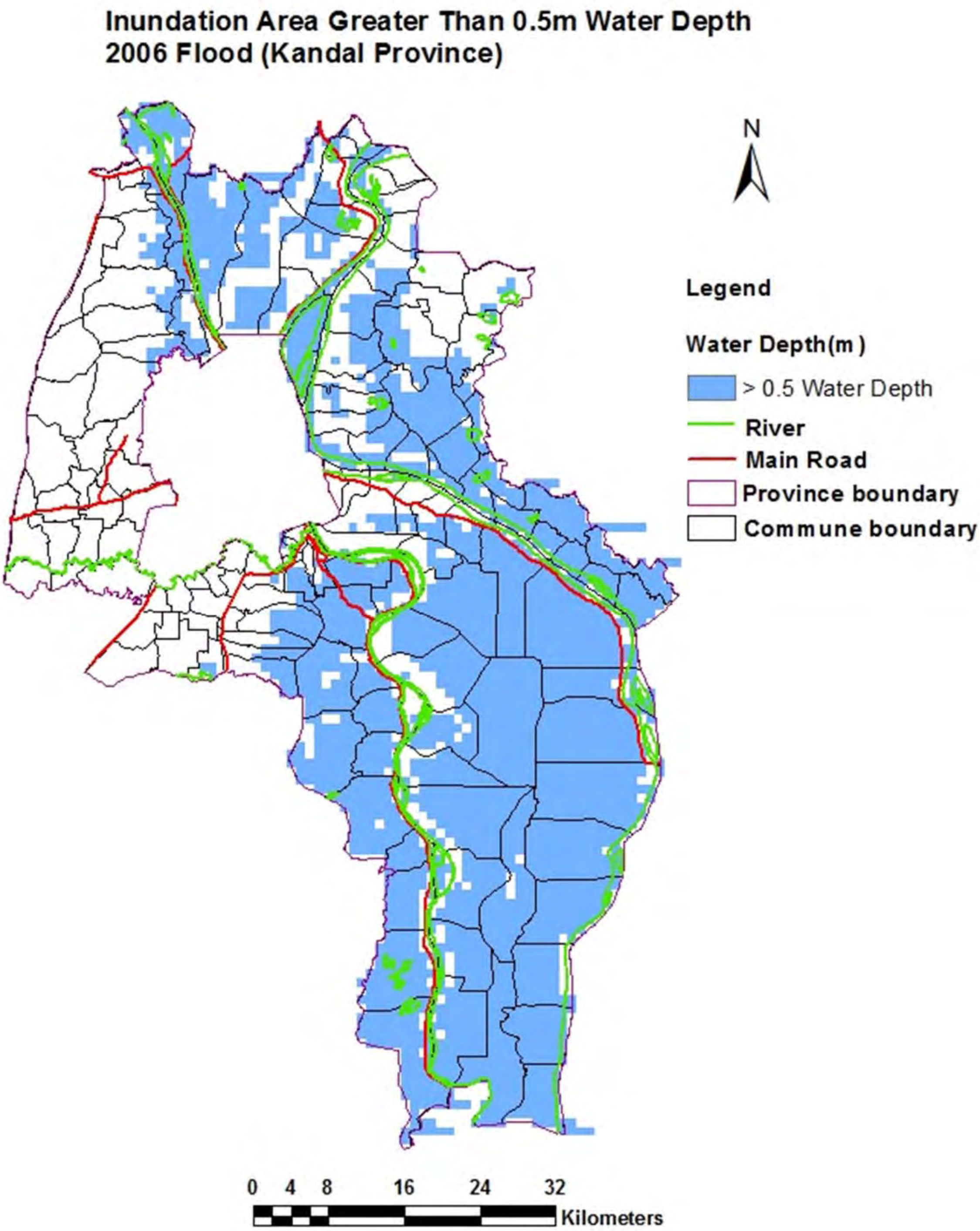


Figure 5.9: Flood Inundation Area Greater than 0.5 m Water Depth (commune level map)

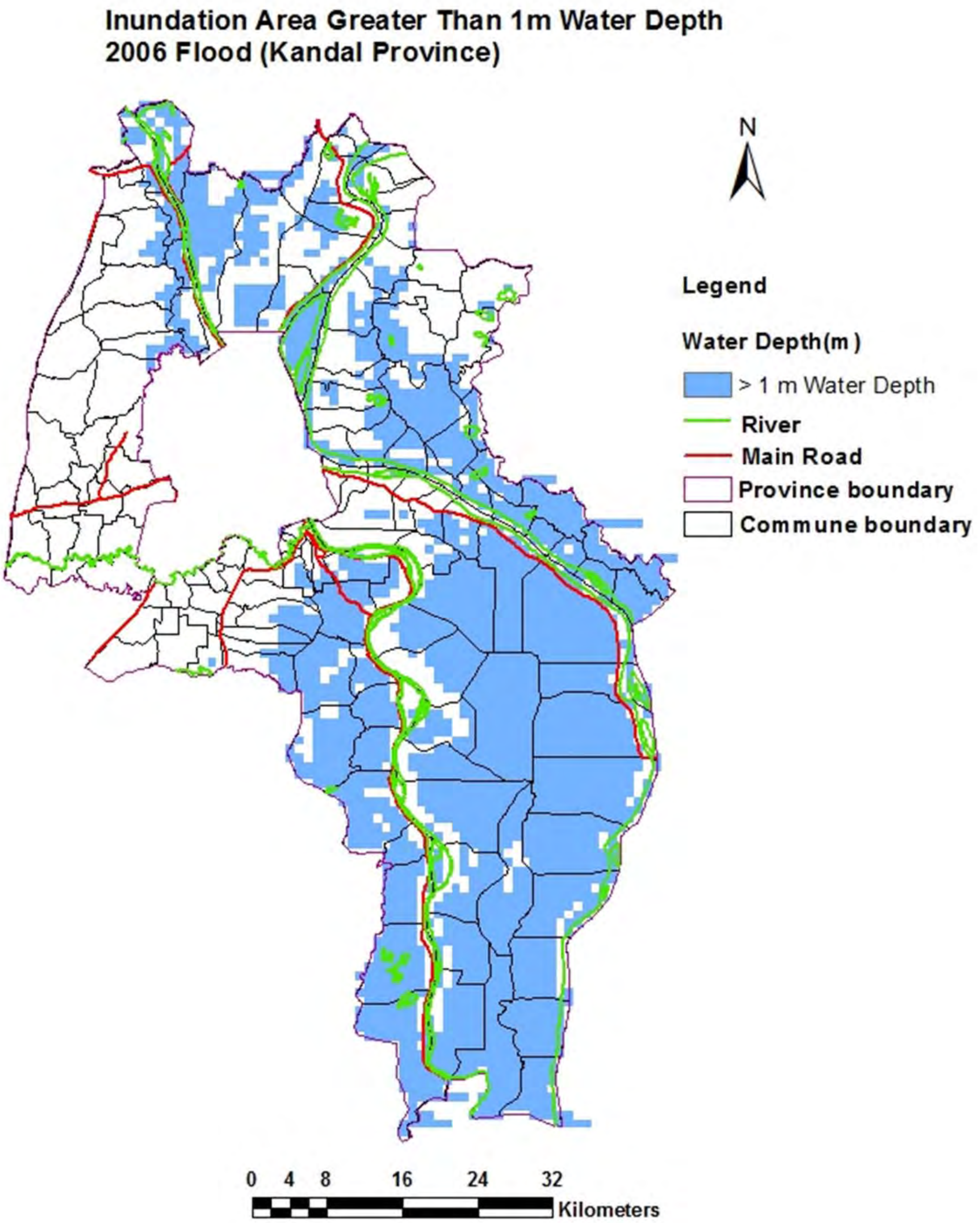


Figure 5.10: Flood Inundation Area Greater than 1 m Water Depth (commune level map)

5.2. Agricultural damages and FVI for agricultural damages

The agricultural damage in the flood inundation area depends on the flow depth and flood duration. Based on Taniguchi (2009), it was adopted the assumption that the farmers start cultivation when accumulated rainfall becomes 500 mm. The cultivation period of wet season rice is 90 days. In Cambodia, if flood water depth does not reach 0.5 m during the damageable period of 90 days following plantation, floodwater depth does not cause to damage wet season rice. If the water depth exceeds 1.5 m, the percentage of damages

becomes constant. The agricultural land use data made by MPWT and JICA in 2003 was used in order to consider cultivated land in Cambodia.

Figure 5.11 shows the distribution of agricultural damages in LMB of Cambodian floodplain in case of flood in 2000. The results are based on grid calculation. In agricultural damages it was considered wet season rice as it is main cultivation in Cambodia. The 2000 flood represents extreme flood in Cambodia based on 1991 to 2007 flood observation. The greatest damages occurred during this flood. The distribution of agricultural damages in case of flood in 2006 is shown in Figure 5.12. The 2006 flood represents the average year flood they often experience such floods in Cambodia. In average year flood case also, people living in Cambodian floodplain experienced some agricultural damages. In Figure 5.11 and Figure 5.12, we can clearly see that agricultural damages in middle and downstream area of flood plain are higher compared to upstream area. In both cases, the amount of potential agricultural damages ranges from 17 US$ to 33,035 US$. The maximum agricultural damages (i.e. 33,035 US$) occurred when 100% damage occurs in the grid calculation. The average agricultural damages in case of 2000 flood and 2006 flood are found to be about 20,560 US$ and 21,786 US$, respectively. There is not so big difference between the average values of agricultural damages in the cases of 2000 Flood and 2006 Flood.

Figure 5.13 shows the Flood Vulnerability Indices for Average Flood (FVI-AF) of potential agricultural damages in LMB of Cambodian floodplain in case of average year flood, i.e 2006 Flood. The FVI-AF is defined from low to very high vulnerable area based on normalization value ranges from 0 to 1. The normalized value ranges 0 – 0.25, 0.25 – 0.5, 0.5 to 0.75 and 0.75 to 1 respectively defined as low, medium, high and very high vulnerable. In the Figure 5.13, the blue color area is low vulnerable and red color area is very high vulnerable. In average year flood also, people living in the area often faced agricultural damages. Based on the FVI-AF map they can decide which area should be cultivated or not in order to reduce the damages.

The Flood Vulnerability Indices for Extreme Flood (FVI-EF) are shown in Figure 5.14. The figure shows the identification of agricultural damages gap area between average year flood (2006 Flood) and extreme flood (2000 Flood). In red color area of the figure, agricultural damages are very higher in extreme flood than average flood. In the blue color area of the figure, agricultural damages are higher in average year flood than extreme flood case. In average year also agricultural damages can be higher than extreme flood case, because the agricultural damages mainly depended on maximum flood water depth during the growing period of wet season rice. The agricultural damage is caused by significant inundation during growing period which is determined with accumulated rainfall of that area. In order to calculate agricultural damages it was assumed that the farmers start cultivation when accumulated rainfall becomes 500 mm and the cultivation period of wet season rice is 90 days. During the period of 90 days after starting cultivation, damages occur if flood water depth reaches over 0.5 m. Thus, if flood water depth in case of 2006 flood is higher than in case of 2000 flood during the 90 days growing period of wet season rice, agricultural damages in 2006 flood can be higher than in 2000 flood. Figure 5.15 (a) shows the accumulated rainfall and water level in years 2000 and 2006 at Kampong Cham station. The Kampong Cham station lies inside blue color area of Figure 5.14. The detail location of stations is shown in Figure 4.7. The rainfall in 2000 is higher than 2006. So, the accumulated rainfall to reach 500mm threshold rainfall of cultivation in 2000 leads earlier than 2006 in this area. They harvest wet season rice early before arriving accumulated flood. In year 2006, accumulated rainfall to reach 500 mm threshold rainfall is delayed than 2000 and the cultivated wet season rice is affected by accumulated

peak flood. The figure shows that maximum water level in 2000 during the cultivation period (growing period) of 2000 is lower than the maximum water level in 2006 during the cultivation period of 2006. Thus, in the blue color area of Figure 5.14, agricultural damages are higher in 2006 than in 2000.

Figure 5.15 (b) shows the accumulated rainfall and water level in years 2000 and 2006 at Neak Loeang station, Prey Veng (the location is shown in Figure 4.7). This station lies in the area where agricultural damages in 2006 are lower than in 2000 (yellow color area of Figure 5.14). This figure shows that maximum water level in 2000 during the cultivation period of 2000 is higher than in maximum water level in 2006 during the cultivation period of 2006. Thus, the damages in 2006 are lower than in 2000.

The average flood brings not so big agricultural damages but extreme flood brings big agricultural damages. The map of agricultural damages gap area between average year flood and extreme flood is very useful to identify the area where damages occur during extreme flood. In average year flood also they experienced some agricultural damages. But they have to prepare also for extreme flood case. By using this map local community, decision makers and policy makers can recognized the agricultural damages area during extreme flood as well as during average year flood.

The commune level maps of agricultural damages and FVIs of agricultural damages in case of Kandal province are shown in Figures 5.16 to 5.19. Similar maps of Prey Veng and Takeo provinces are shown in Appendix 4.

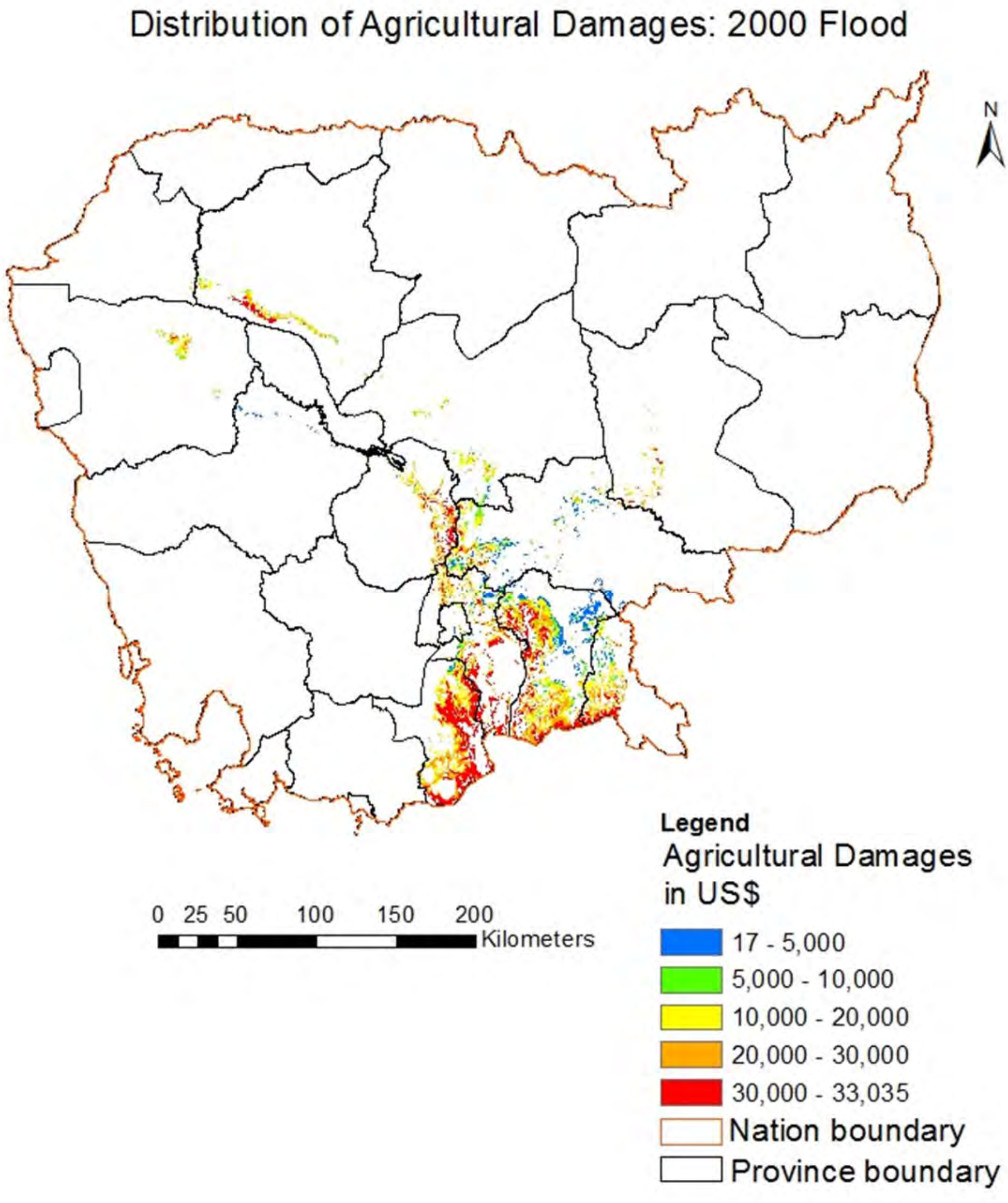


Figure 5.11: Distribution of Agricultural Damages in 2000 Flood

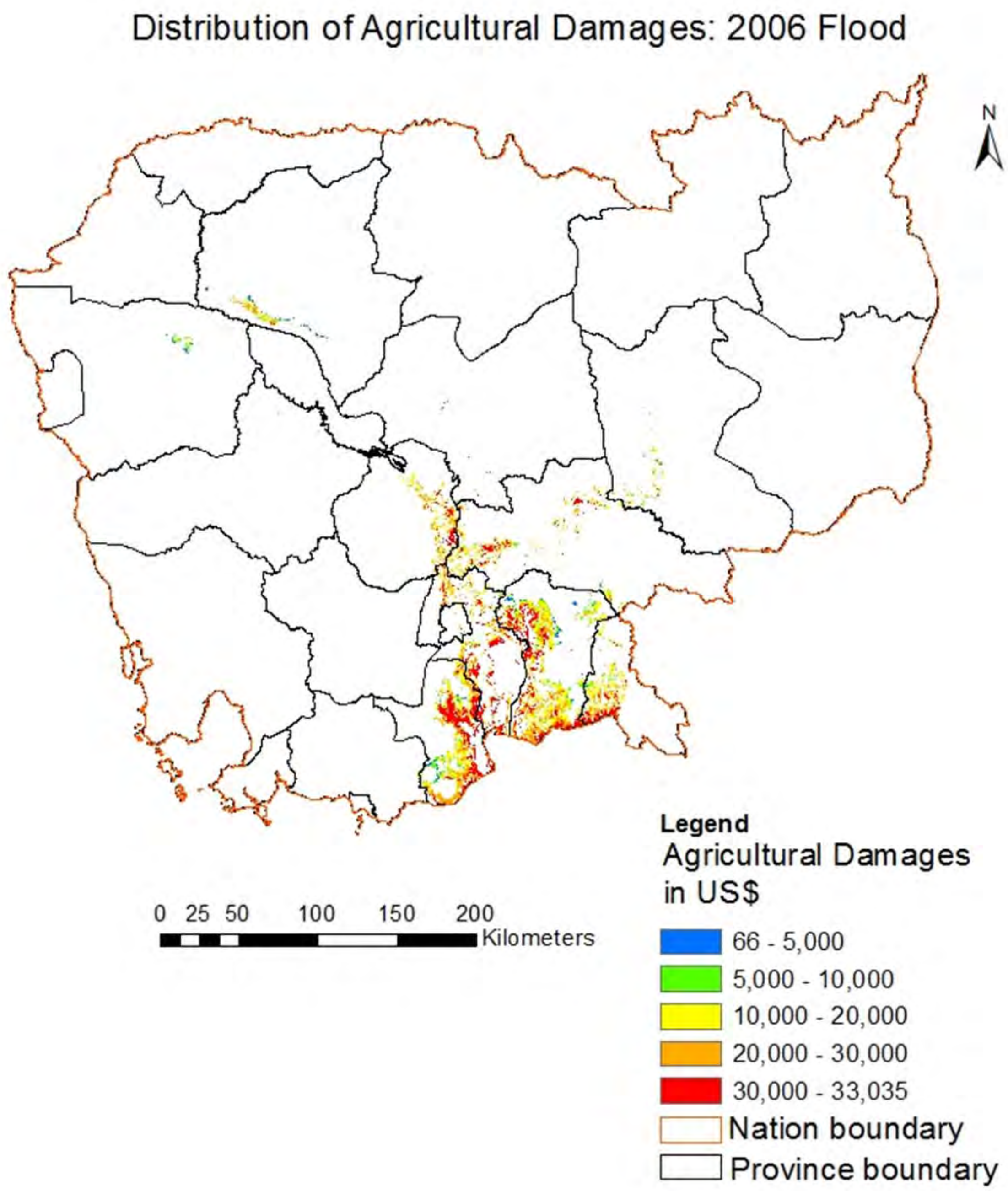


Figure 5.12: Distribution of Agricultural Damages in 2006 Flood

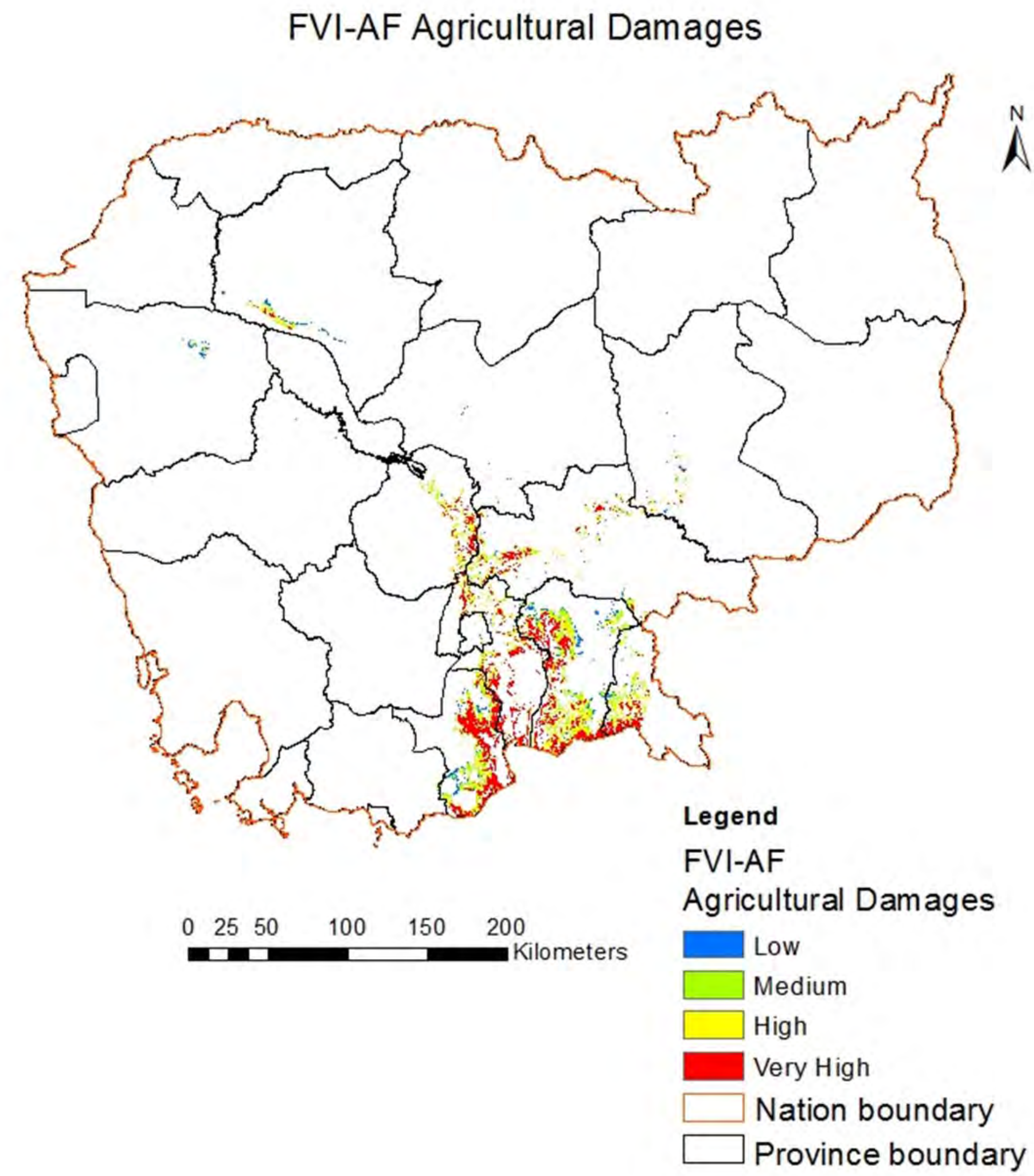


Figure 5.13: Flood Vulnerability Indices of Agricultural Damages for Average Flood (2006 flood)

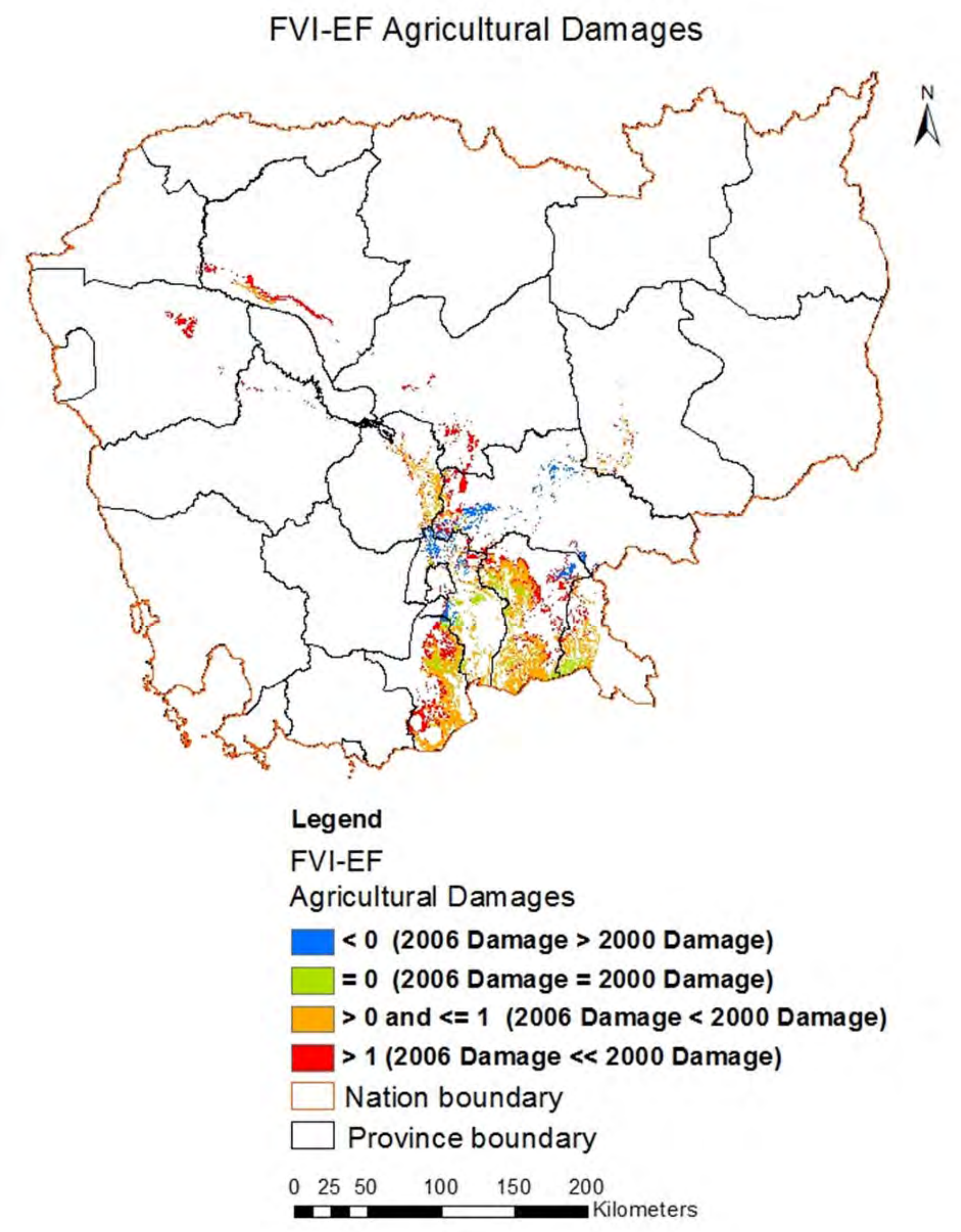
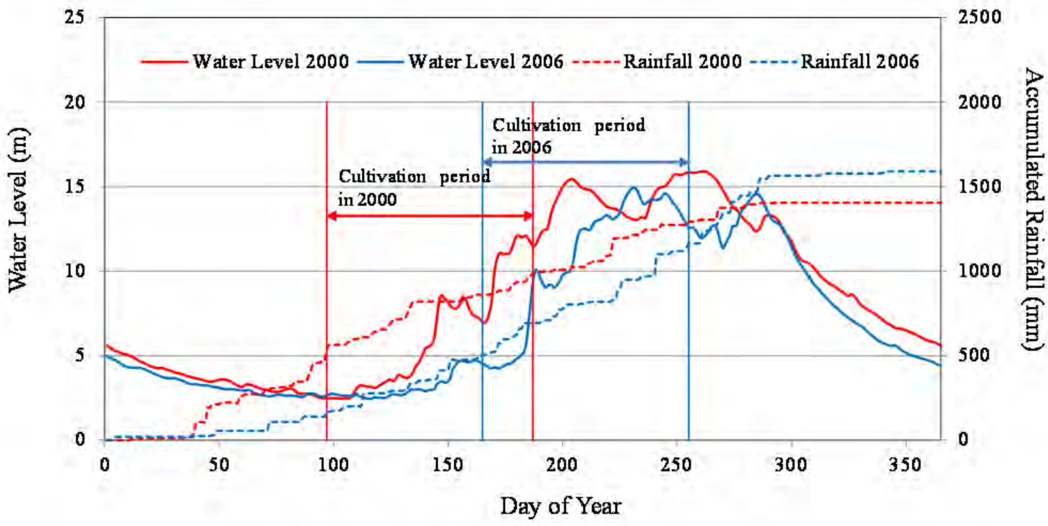
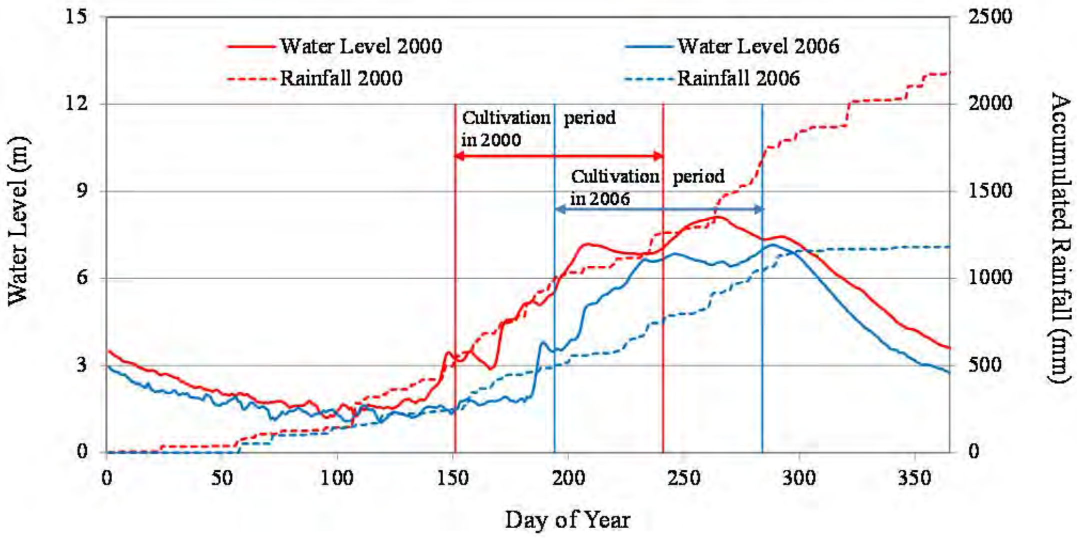


Figure 5.14: Flood Vulnerability Indices of Agricultural Damages for Extreme Flood



(a) Accumulated Rainfall and Water Level in Years 2000 and 2006 at Kampong Cham Station



(b) Accumulated Rainfall and Water Level in Years 2000 and 2006 at Neak Loeang, Prey Veng

Figure 5.15: Accumulated Rainfall and Water Level at Kampong Cham and Neak Loeang, Prey Veng (location of stations are shown in Figure 4.7)

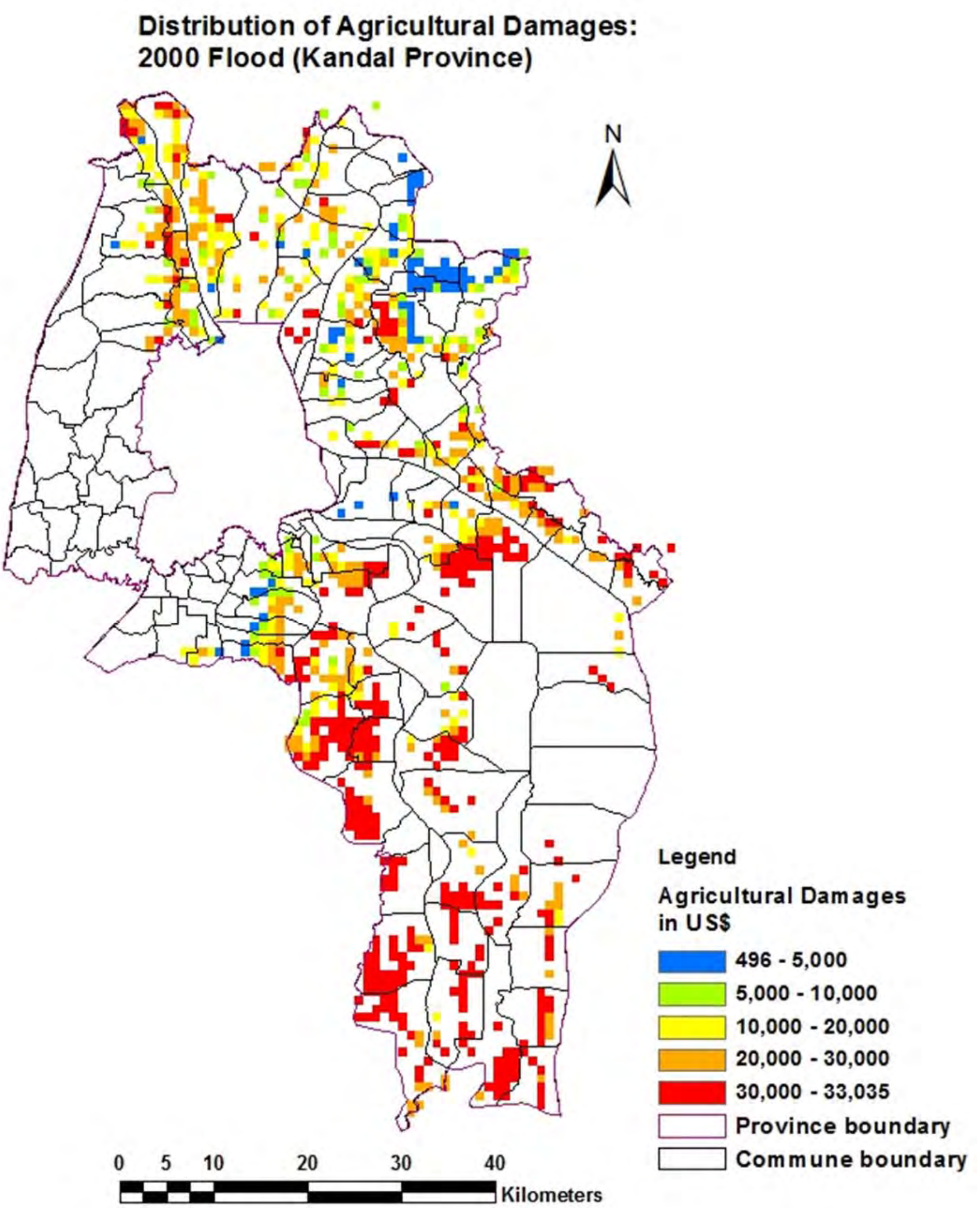


Figure 5.16: Distribution of Agricultural Damages in Case of Kandal Province (2000 Flood)

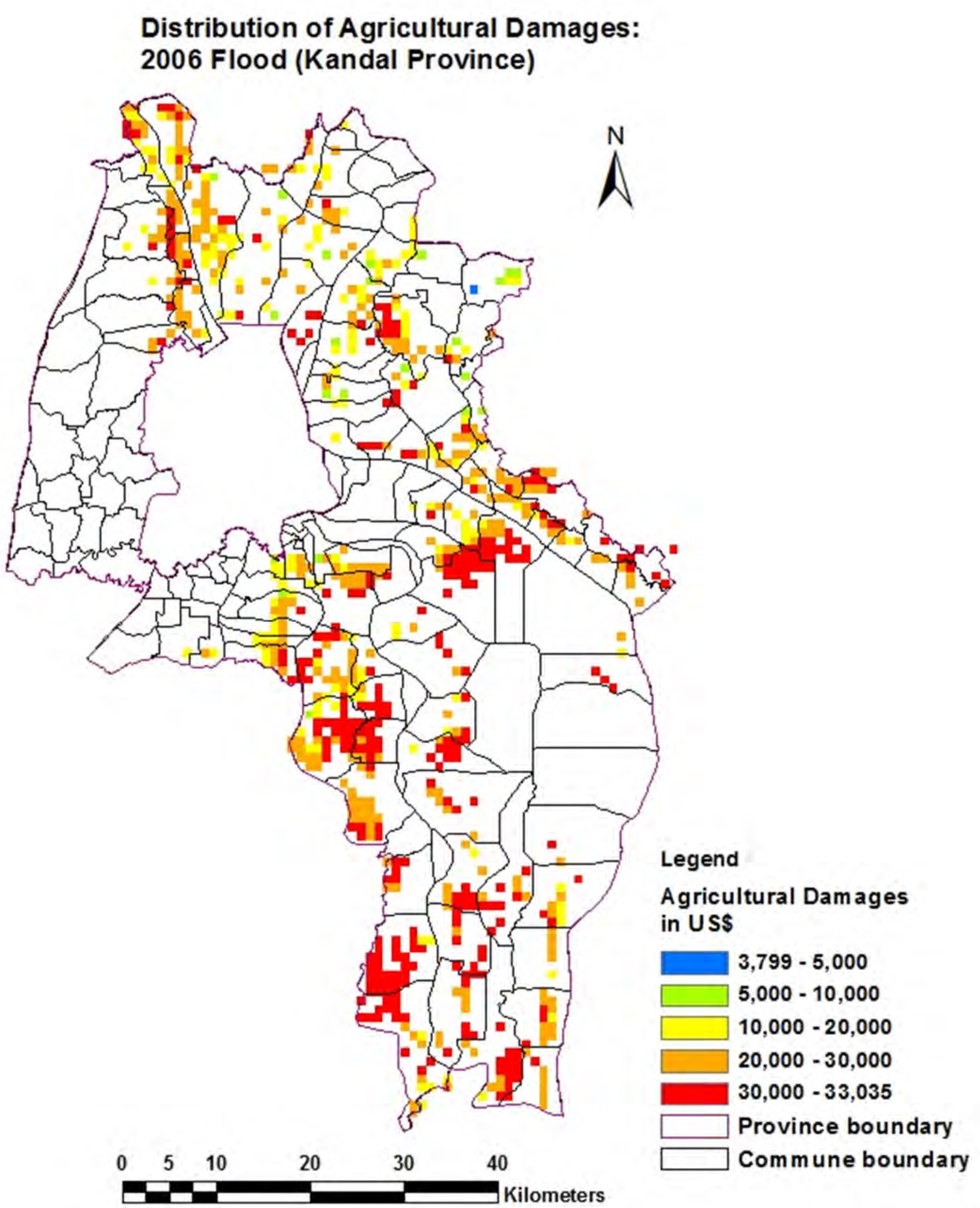


Figure 5.17: Distribution of Agricultural Damages in Case of Kandal Province (2006 Flood)

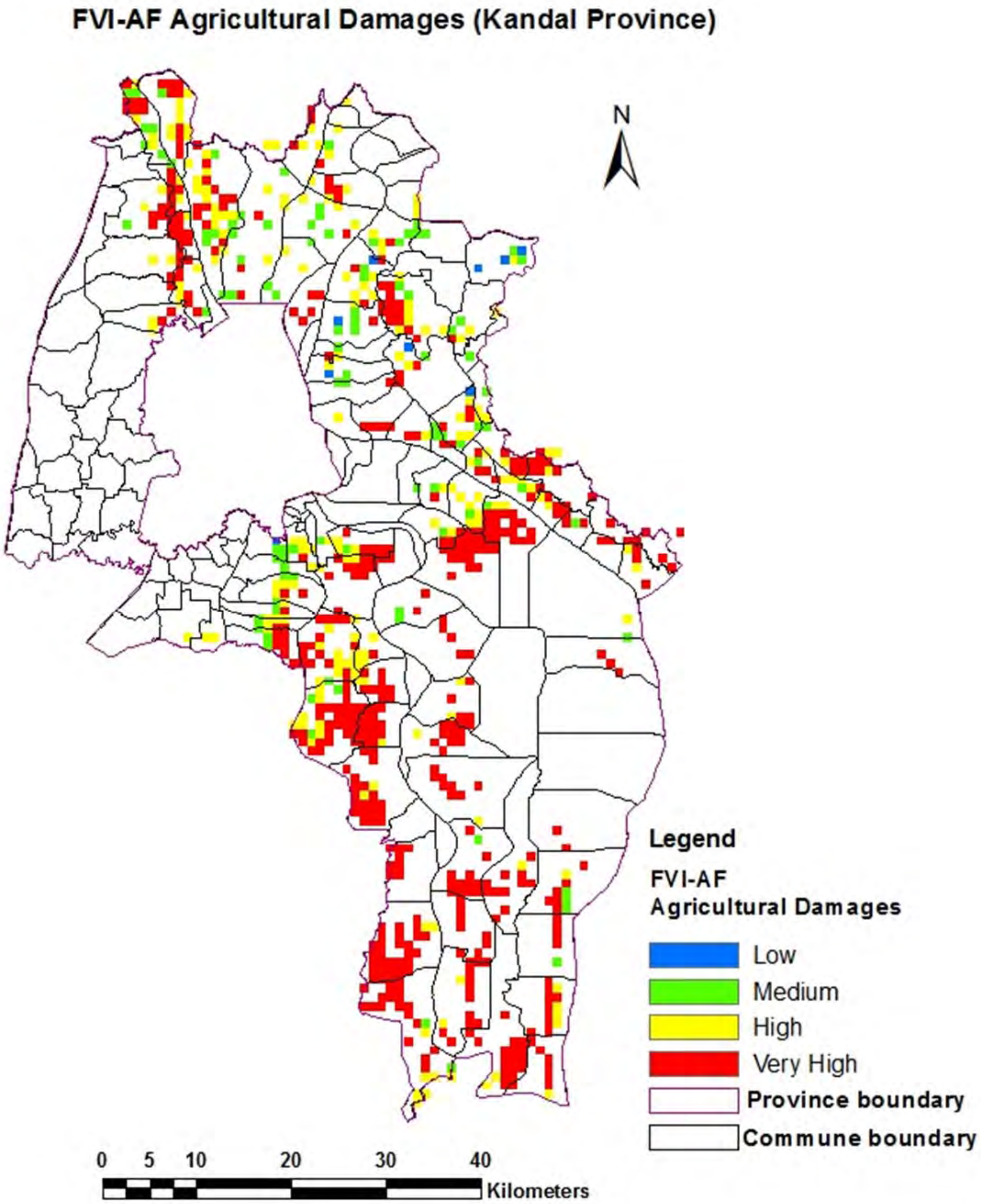


Figure 5.18: Commune Level FVI-AF Map for Agricultural Damages of Kandal Province

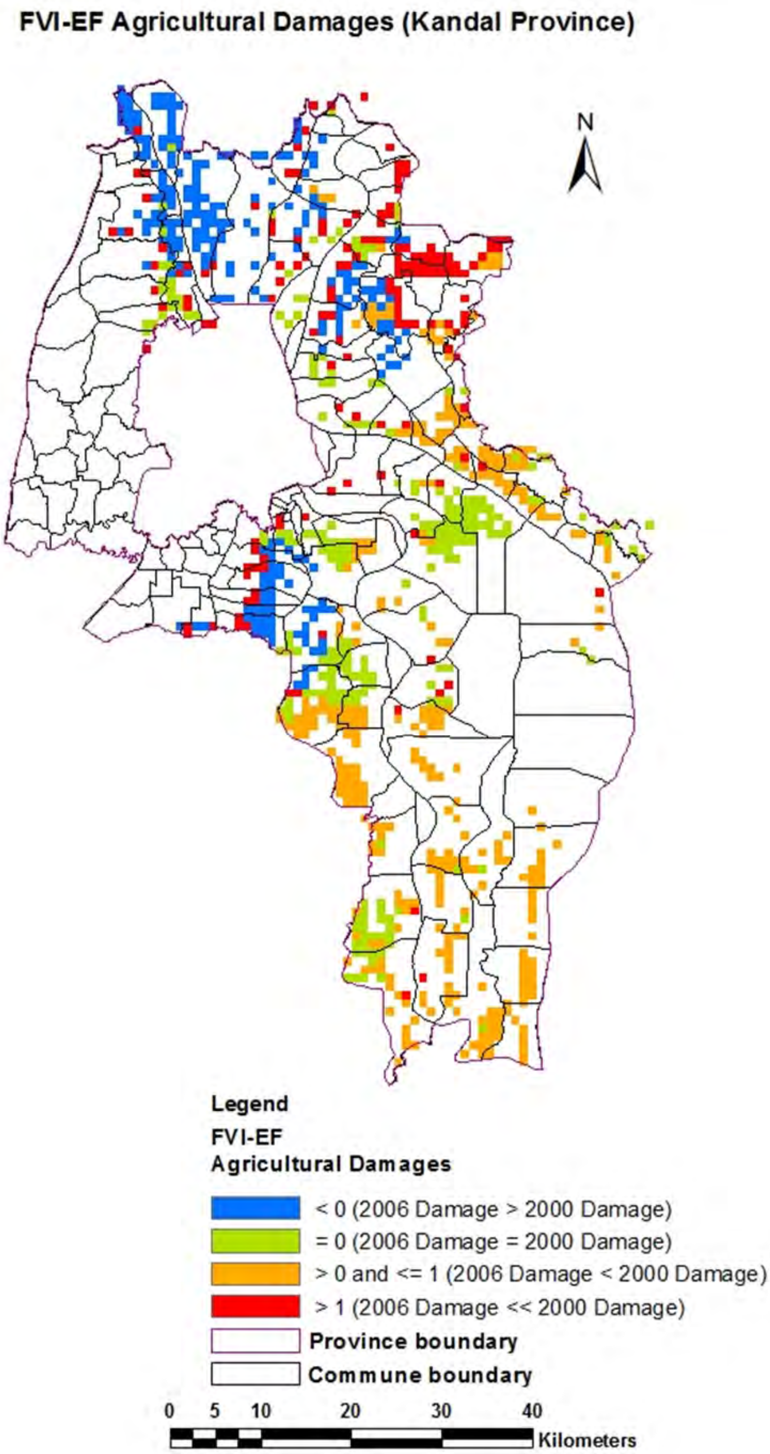


Figure 5.19: Commune Level FVI-EF Map for Agricultural Damages of Kandal Province

5.3. House Damages and FVI for House Damages

The results of grid calculation for house damages conducted according to IHGM method based on flood water depth are presented in Figure 5.20 for 2000 flood and Figure 5.21 for 2006 flood. All 30 seconds grids with more than 2000 persons were removed in order to consider only rural zone and only Cambodia is considered.

The amount of potential house damages in 2000 flood ranges up to 108,541 US$. However, in case of 2006 flood, the amount of potential house damages ranges up to 75, 150 US$. The average house damages in case of 2000 flood and 2006 flood were found to be about 2,951 US$ and 2,107 US$, respectively. The difference in house damage between extreme flood (2000 flood) and average flood (2006 flood) is very significant. The house damages are calculated only for water level higher than average flood level (2006 flood level).

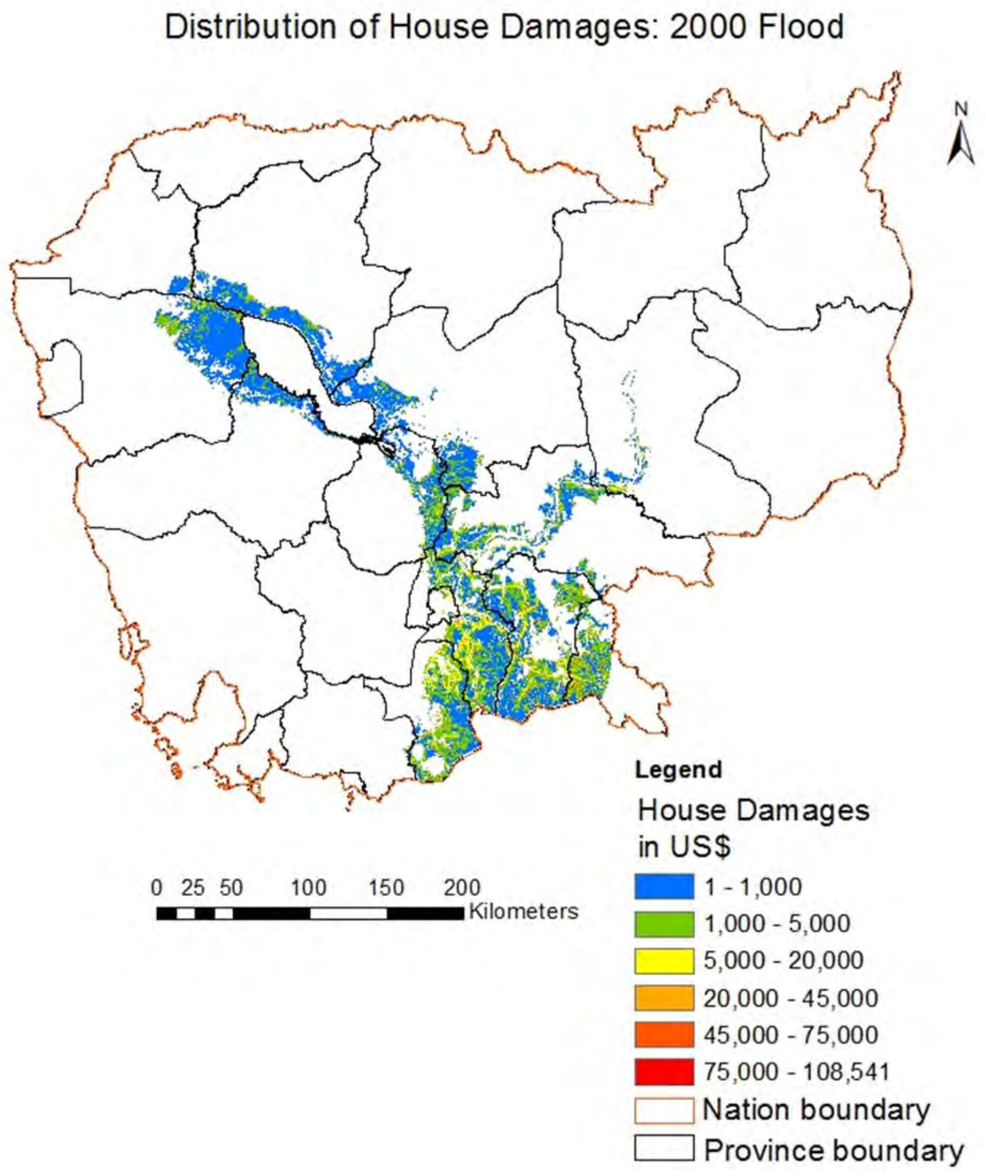


Figure 5.20: Distribution of House Damages in LMB of Cambodian Floodplain in 2000 Flood

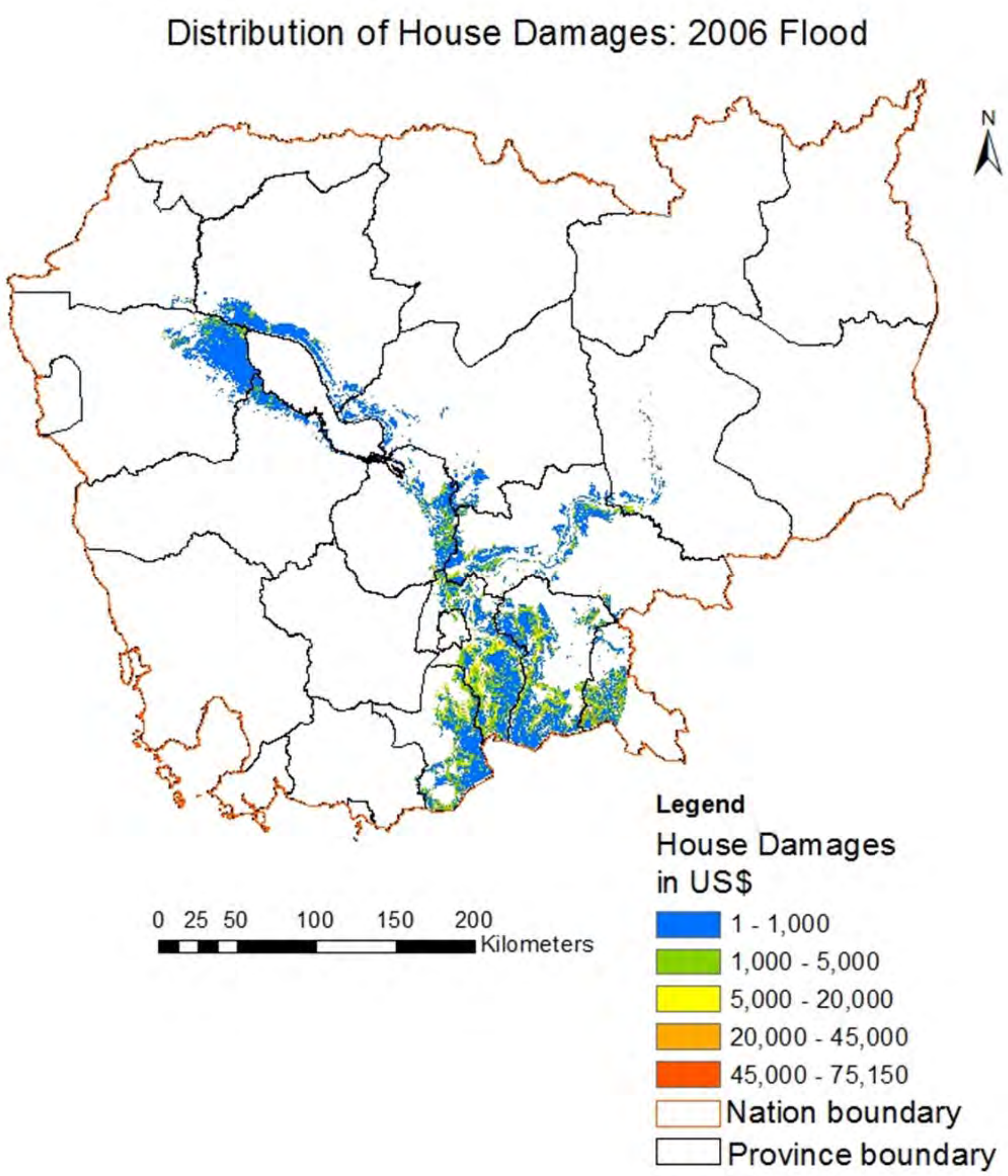


Figure 5.21: Distribution of House Damages in LMB of Cambodian Floodplain in 2006 Flood

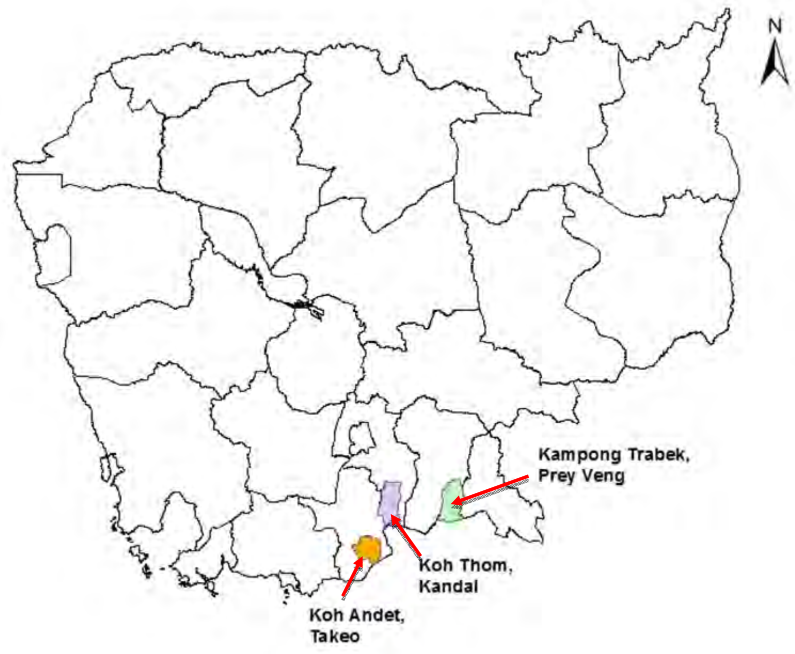


Figure 5.22: Location Map of Three Districts Koh Andet in Takeo, Koh Thom in Kandal and Kampong Trabek in Prey Veng

Table 5.1: Validation of Calculated House Damages with Statistical Data (2006 Flood)

	Koh Andet-Takeo	**Koh Thom-Kandal**	**Kampong Trabek-Prey Veng**
House damages from calculation (US$)	826,585	1,404,623	1,016,493
House damages of statistical data by up-scaling FMMP 2008 survey (US$)	508,000	1,817,632	100,238
Population based on LANDSCAN data	61,375	178,998	116,000
Population based on district statistics	51,000	151,000	125,000

For the validation of house damage calculation, the estimated results of three districts Koh Andet in Takeo province, Koh Thom in Kandal province and Kampong Trabek in Prey Veng province were checked with statistical data of house damages based on FMMP (2010) (Figure 5.22). Table 5.1 shows the comparison between calculated house damages with house damages based on statistical data for 2006 flood. In case of Koh Andet of Takeo and Koh Thom district of Kandal, there are not so big variations in the results between estimated and statistical house damages. However, in case of Kampong Trabek district of prey Veng, there is some variation in the results which may be due to some variation of population between LANDSCAN population data and statistical population data. Because in this study we used LANDSCAN population data for the house value calculation. Also, the statistical data of house damages is based on household survey area

coverage less than 1% of whole district. However, the overall results of house damages calculation are reasonable with statistical data.

Figure 5.23 shows the FVI for average flood of house damages in LMB of Cambodian floodplain. The FVI-AF is prepared for average flood, i.e. in case of 2006 flood. The FVI-AF of house damages is also defined from low to very high vulnerable areas based on normalization value ranges from 0 to 1. The normalized value ranges 0 – 0.25, 0.25 – 0.5, 0.5 to 0.75 and 0.75 to 1 respectively defined as low, medium, high and very high vulnerable for house damages. In the Figure 5.23, the blue color area is low vulnerable and red color area is very high vulnerable. From the figure, it is clear that most of the houses are located in low or medium vulnerable area. Because they often face average flood and the newly constructed house are concentrated in higher elevation area (higher than average flood level). There are also some houses located in high and very high vulnerable area. The people living in high and very high vulnerable area have to do preparedness for flood. In average year flood also, people living in the area often faced house damages. Based on the FVI map they can decide which area should be prepared for flood and also they can decide location for new house construction.

Figure 5.24 shows the flood vulnerability indices for extreme flood of house damages to identify the gap area between average flood (2006 Flood) and extreme flood (2000 Flood). During the average flood, they experienced some house damages. However in extreme flood, they experienced big house damages in the area. The map of house damages gap area between average year flood and extreme flood is very useful to identify the area where house damages occur during extreme flood. In average year flood also they experienced some house damages. But they have to prepare also for extreme flood case. By using this map local community, decision makers and policy makers can recognized the houses damages area during extreme flood as well as during average year flood.

The commune level maps of house damages and FVI of house damages in case of Kandal province are shown in Figures 5.25 to 5.28. Similar maps of Prey Veng and Takeo provinces are shown in Appendix 4.

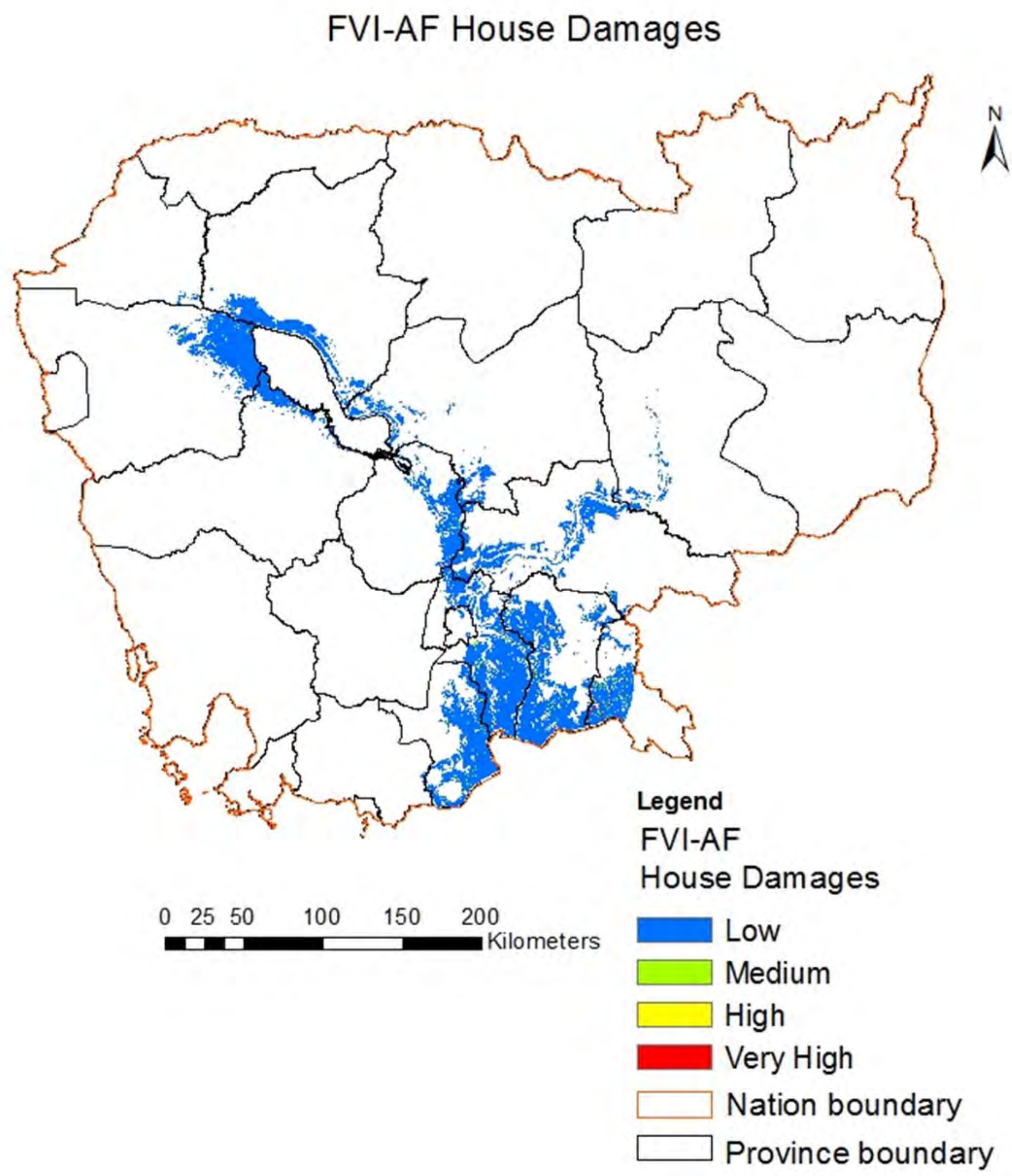


Figure 5.23: Flood Vulnerability Indices of House Damages for Average Flood (2006 flood)

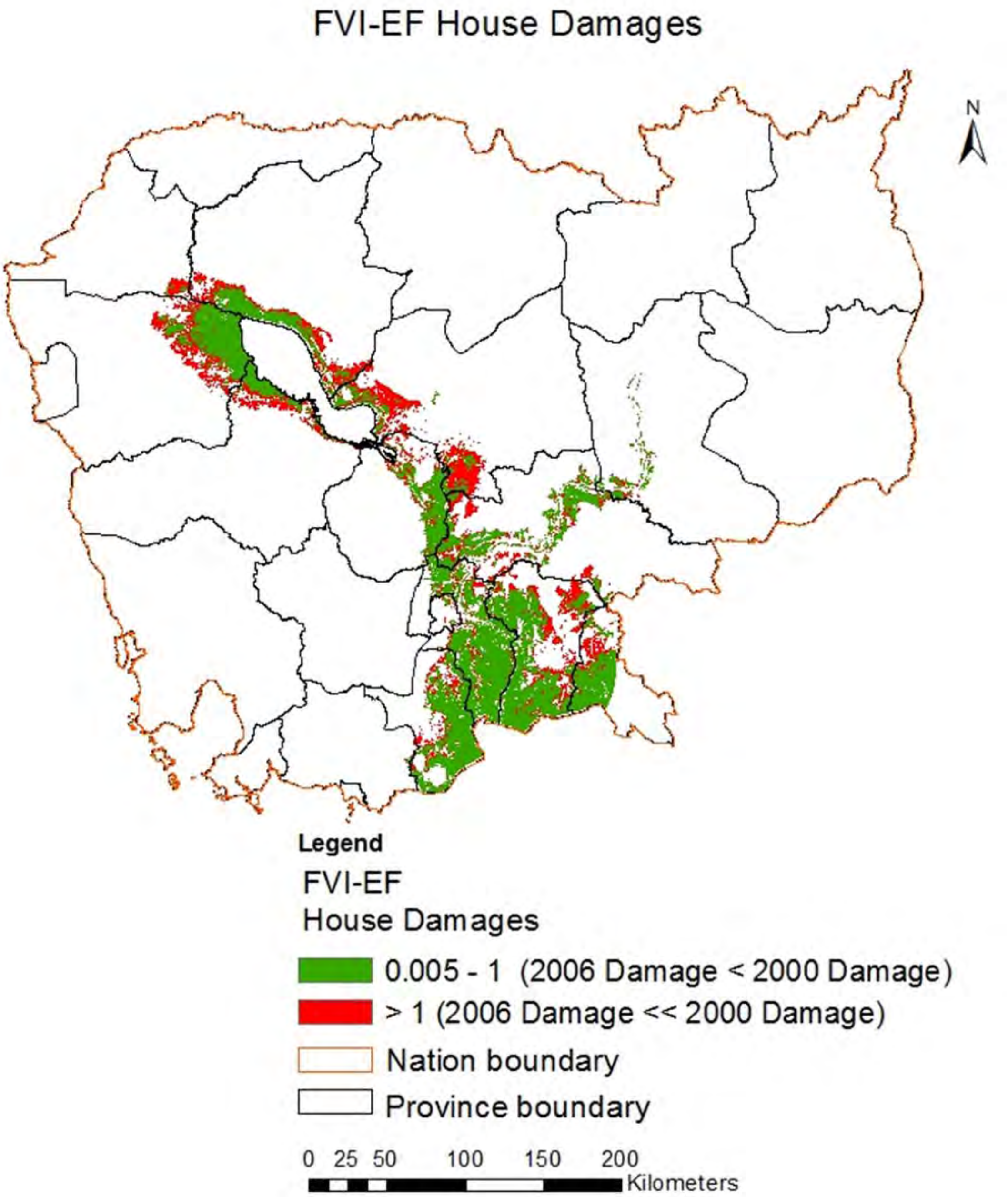


Figure 5.24: Flood Vulnerability Indices of House Damages for Extreme Flood

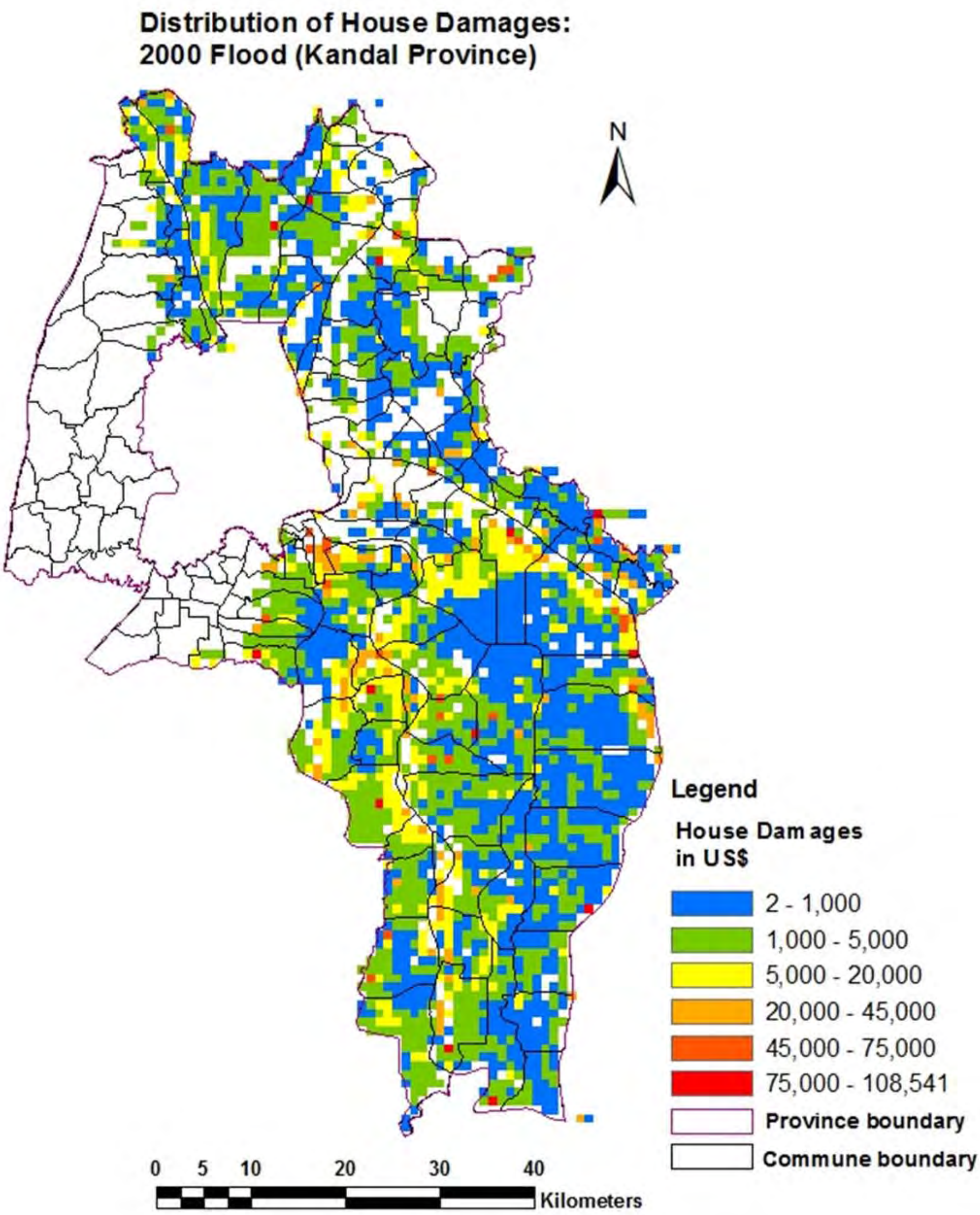


Figure 5.25: Distribution of House Damages in Case of Kandal Province (2000 Flood)

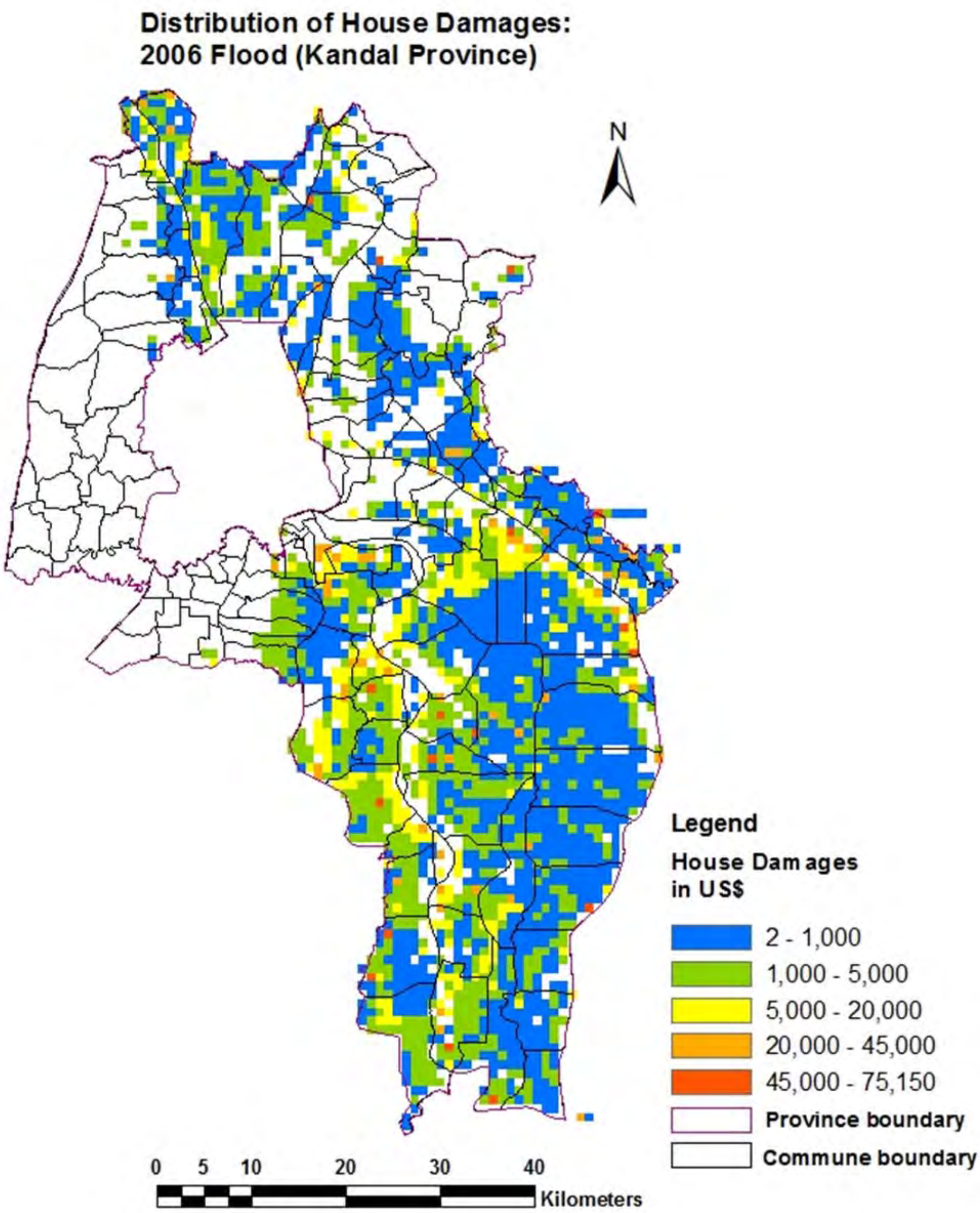


Figure 5.26: Distribution of House Damages in Case of Kandal Province (2006 Flood)

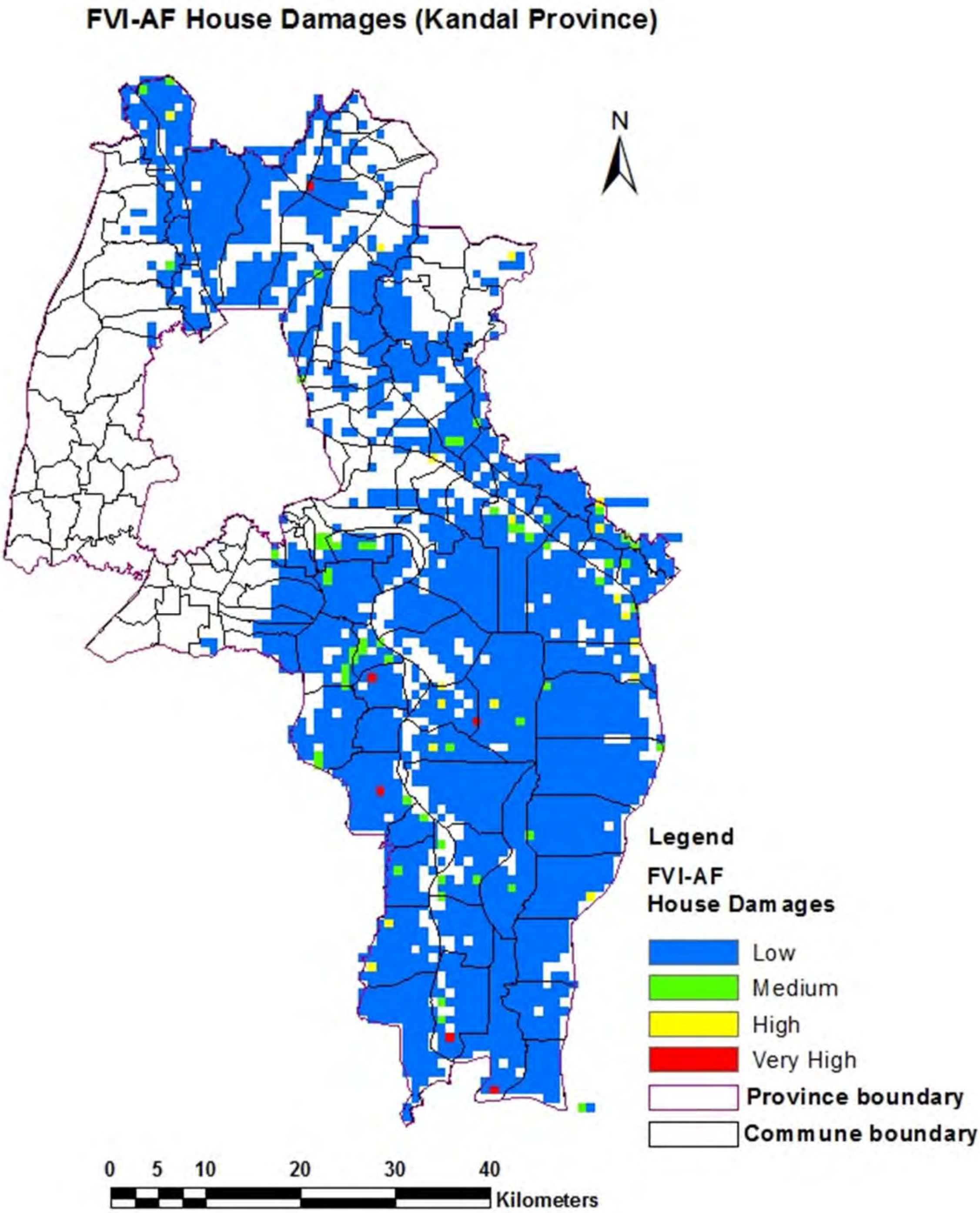


Figure 5.27: Commune Level FVI-AF Map for House Damages of Kandal Province

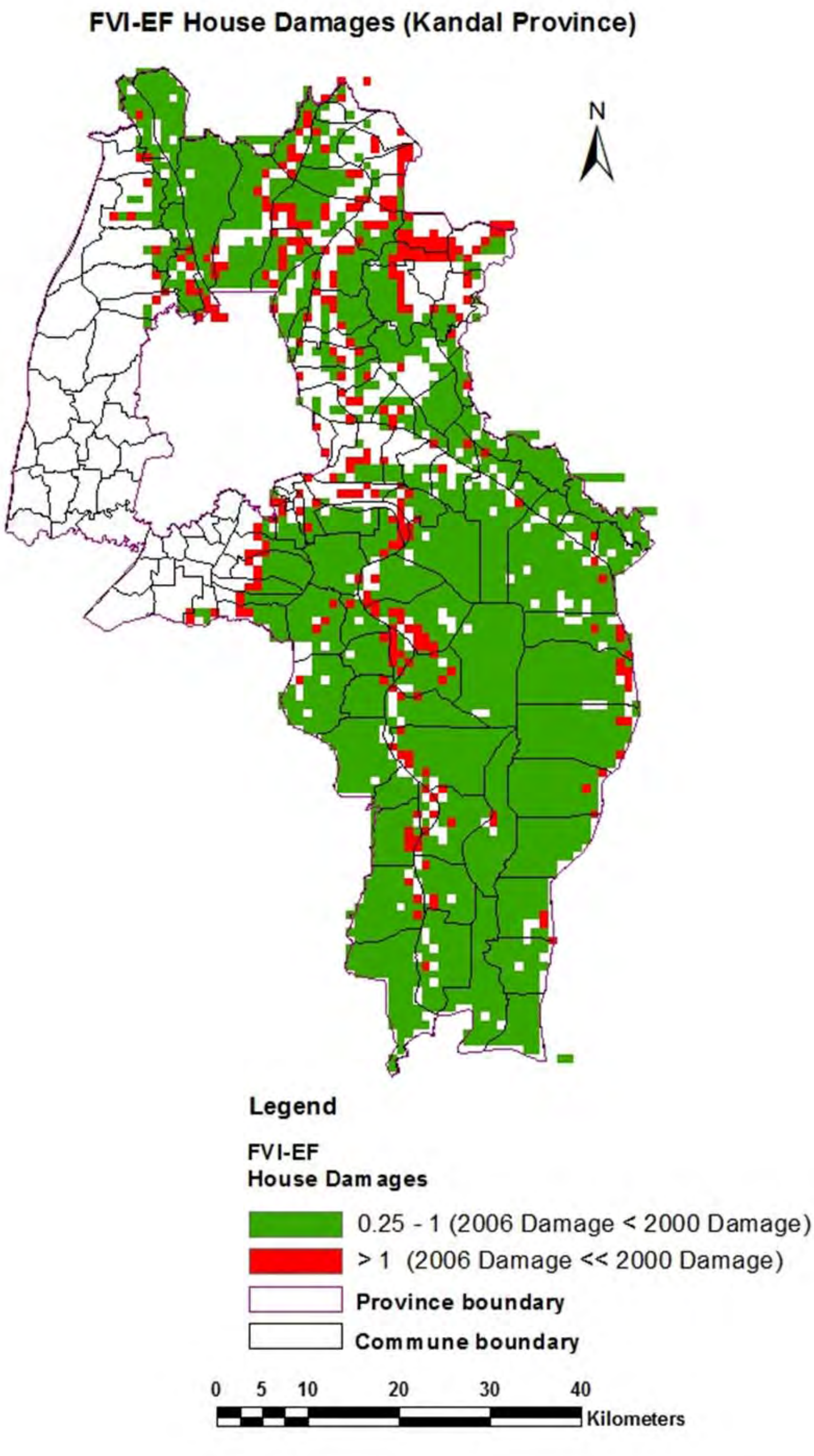


Figure 5.28: Commune Level FVI-EF Map for House Damages of Kandal Province

5.4. Weighted Total Damages and FVI for Total Damages

The weighed total damages were calculated by giving different weight for agricultural damages and house damages. The weightage of agricultural damages was given based on Engel's coefficient. The calculated results of distribution of weighted total damages in extreme flood (2000 Flood) and in average flood (2006 Flood) are shown in Figure 5.29 and Figure 5.30, respectively. Figure 5.31 shows the FVI for average flood of total damages considering both agricultural and house damages. The normalized value ranges 0 – 0.25, 0.25 – 0.5, 0.5 to 0.75 and 0.75 to 1 respectively defined as low, medium, high and very high vulnerable area. In the figure, the blue color area is low vulnerable and red color area is very high vulnerable. The people living in high vulnerable and very high vulnerable area have to do preparedness for agricultural and houses damages caused by flood in the area.

Figure 5.32 shows the FVI-EF of total damages to identify the gap area between average year flood and extreme flood. The average year flood brings not so big damages but extreme flood brings big damages. By using map of identification of damages gap area, local people, decision makers, developers and policy makers can recognized the most serious area in extreme flood. So they can do preparedness for extreme flood. In the middle stream part (blue color area), total damages in average flood (2006 Flood) is greater than extreme flood (2000 Flood) case, because agricultural damages in this part is higher in average flood than extreme flood. In this area serious damages may occur due to flood. Also in yellow color area of the map, the serious damages may occur during average flood almost same as in extreme flood. So, the preparedness for flood in these areas is necessary.

The commune level maps of house damages and FVI of house damages in case of Kandal province are shown in Figures 5.33 to 5.36. Similar maps of Prey Veng and Takeo provinces are shown in Appendix 4.

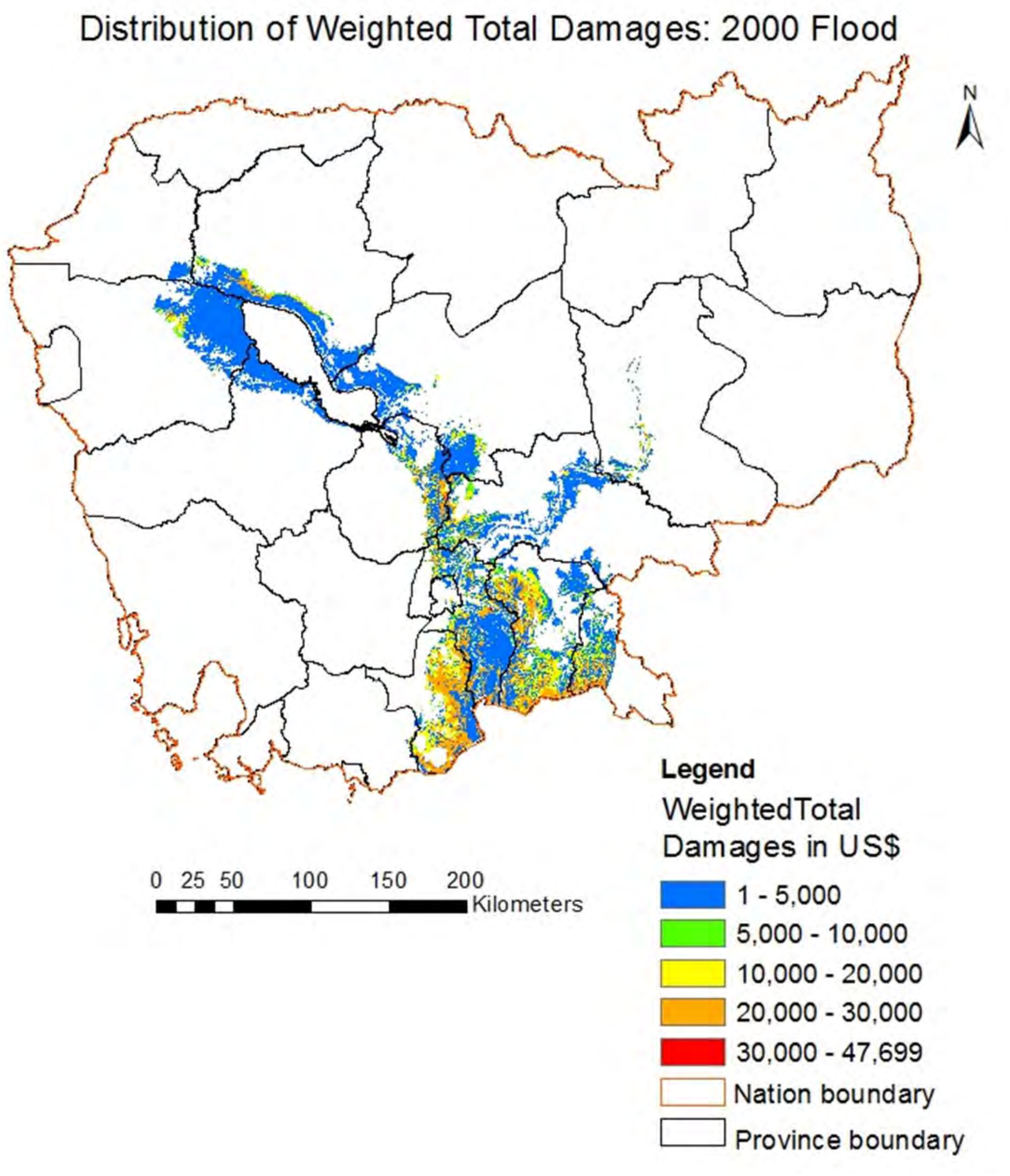


Figure 5.29: Distribution of Weighted Total Damages in LMB of Cambodian Floodplain in 2000 Flood

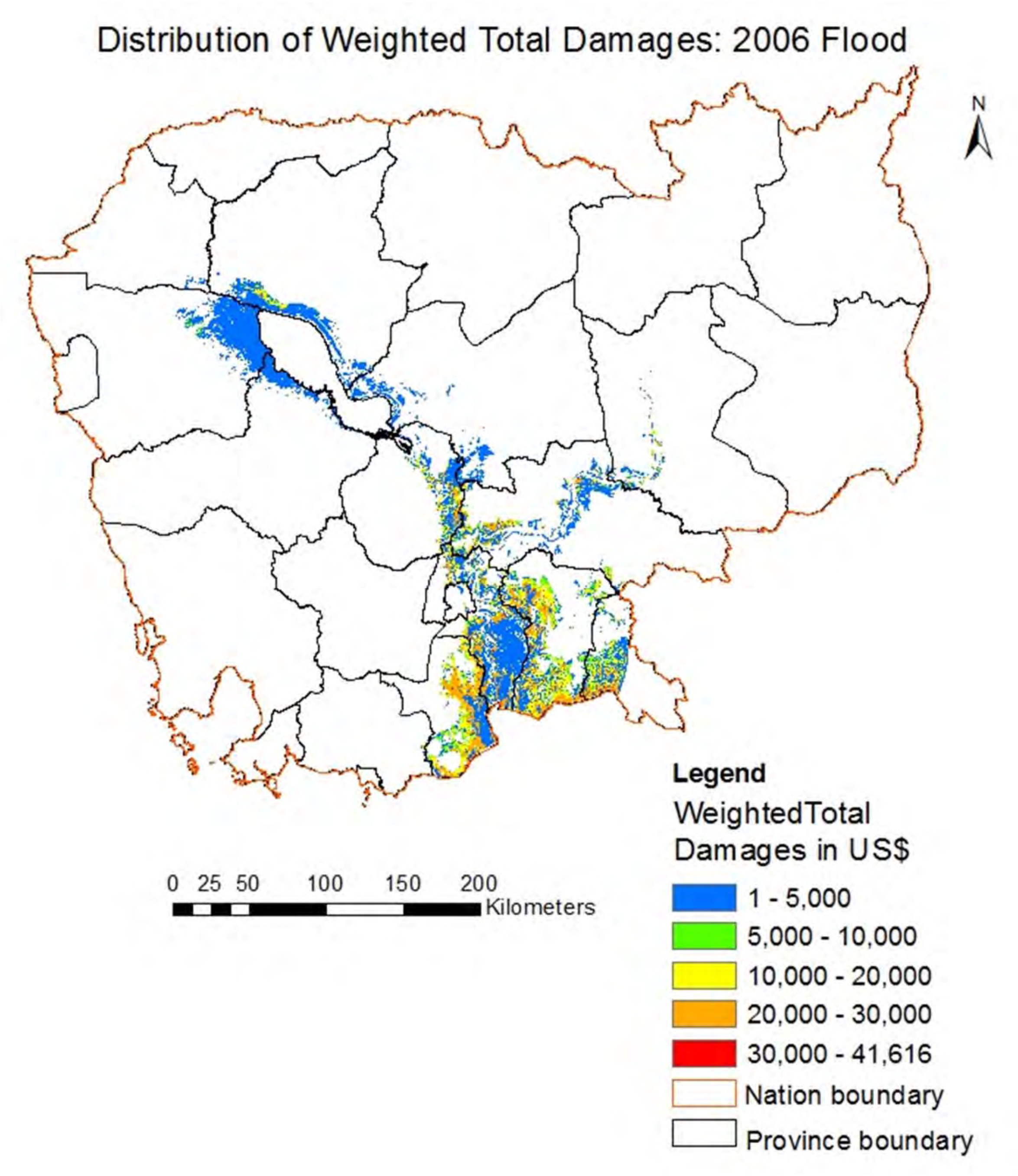


Figure 5.30: Distribution of Weighted Total Damages in LMB of Cambodian Floodplain in 2006 Flood

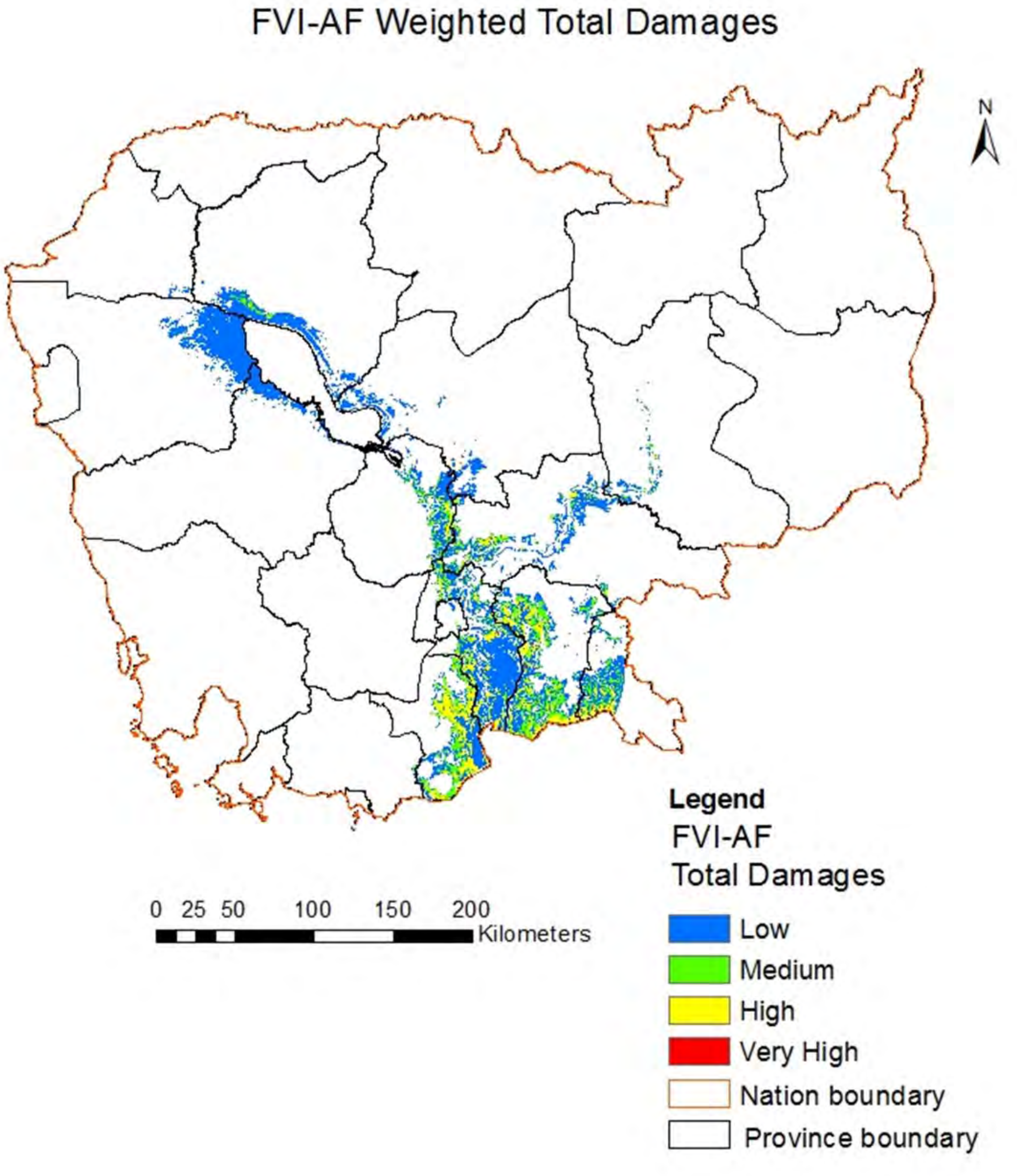


Figure 5.31: Flood Vulnerability Indices of Total Damages for Average Flood (2006 flood)

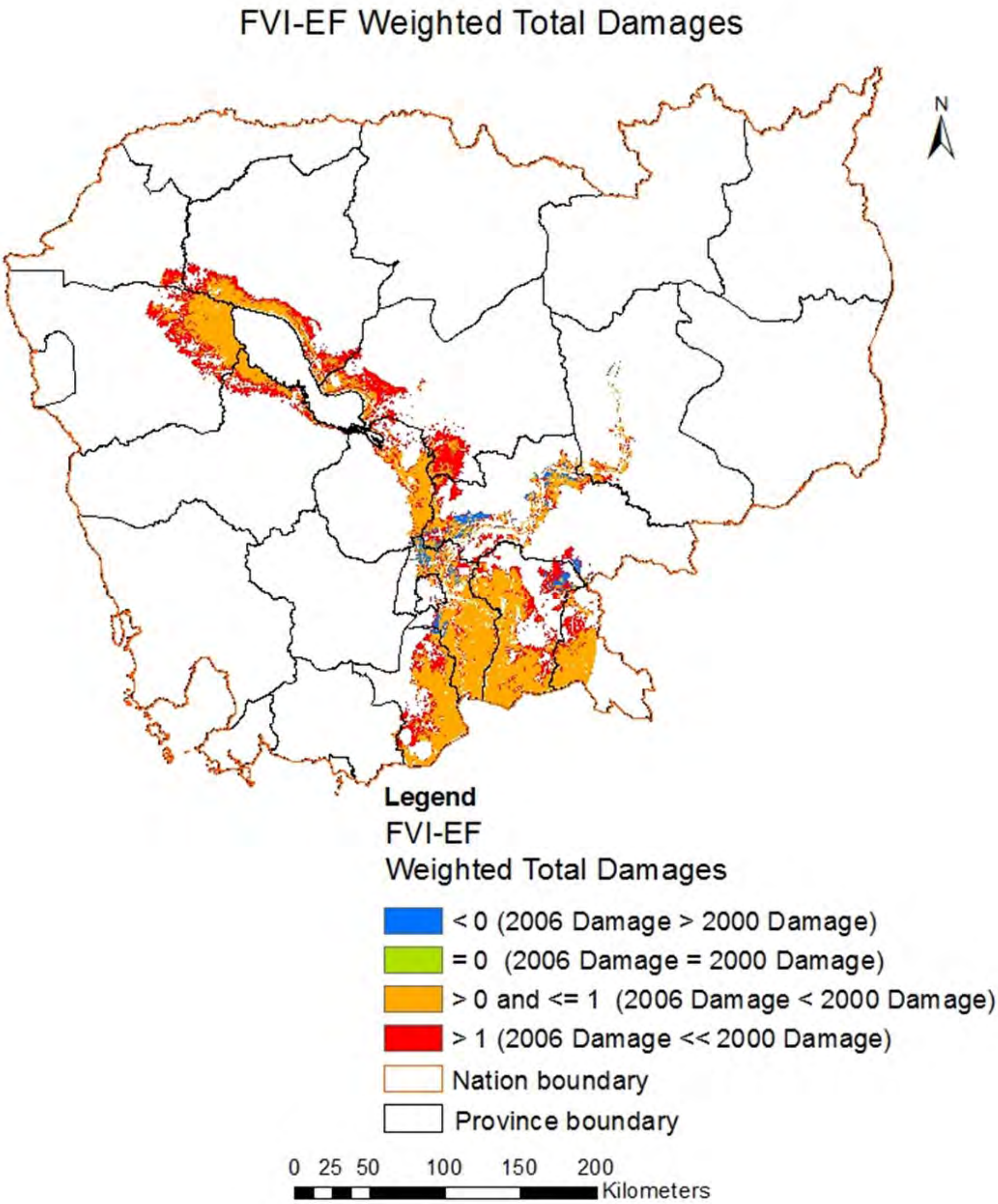


Figure 5.32: Flood Vulnerability Indices of Total Damages for Extreme Flood

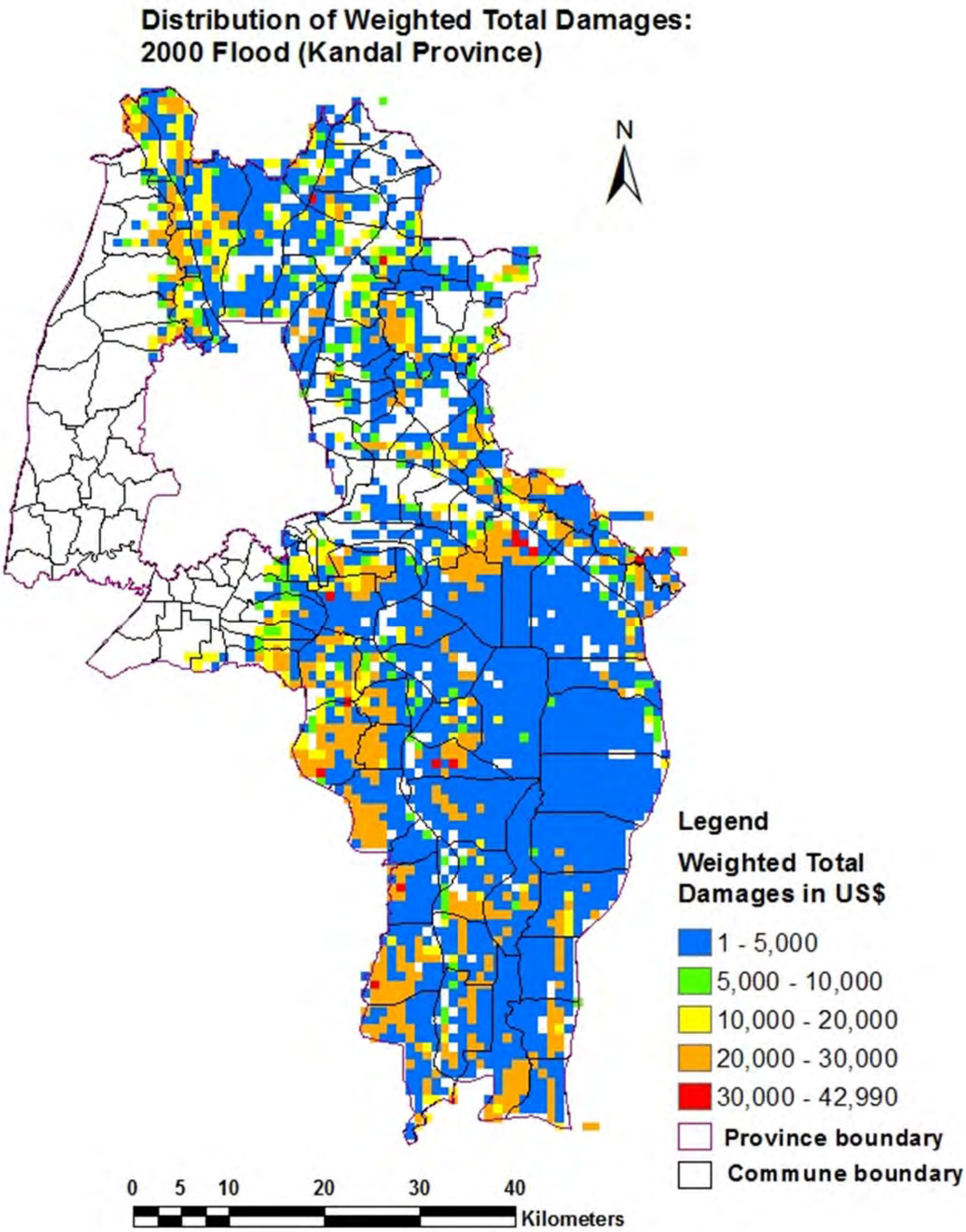


Figure 5.33: Distribution of Total Damages in Case of Kandal Province (2000 Flood)

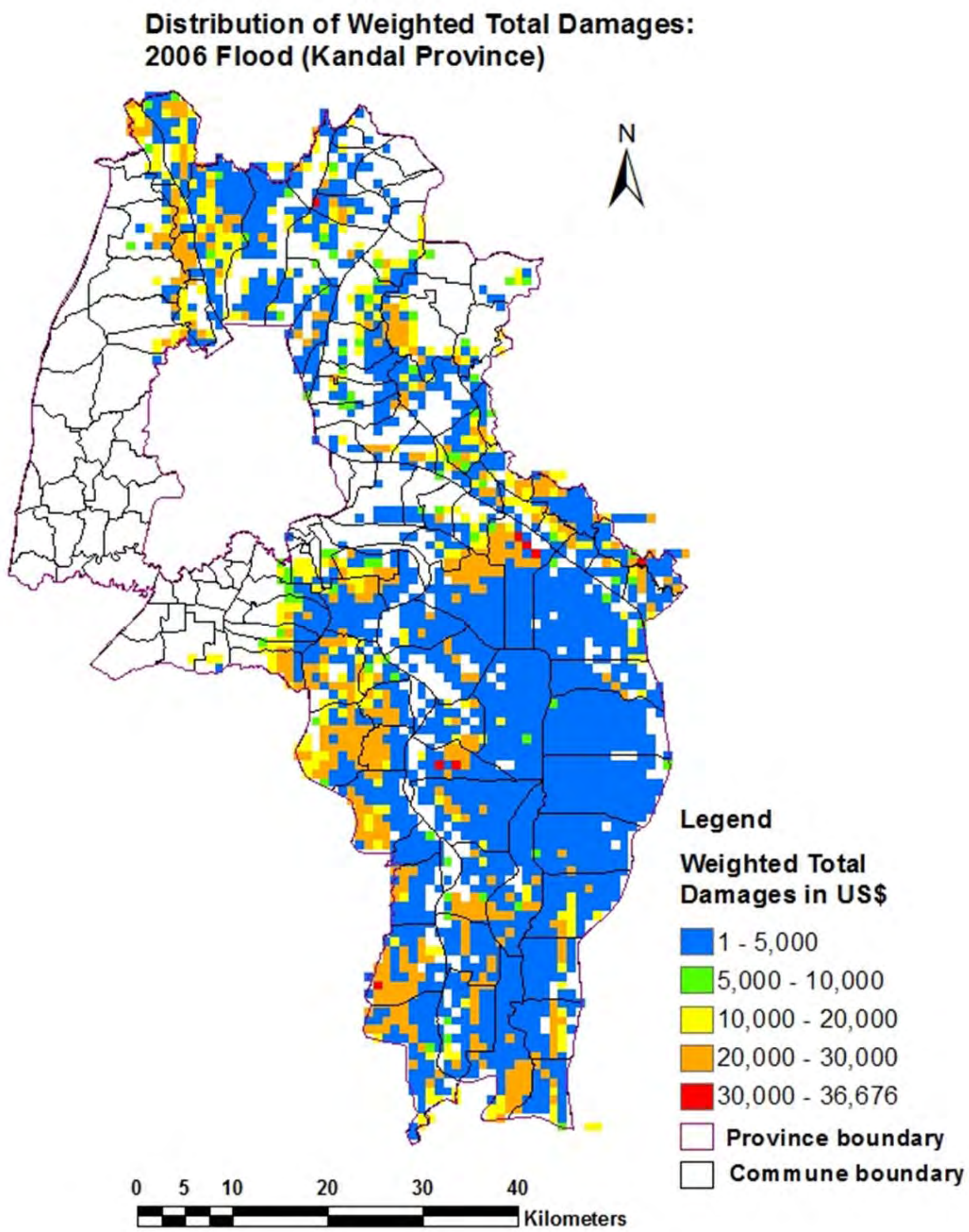


Figure 5.34: Distribution of Total Damages in Case of Kandal Province (2006 Flood)

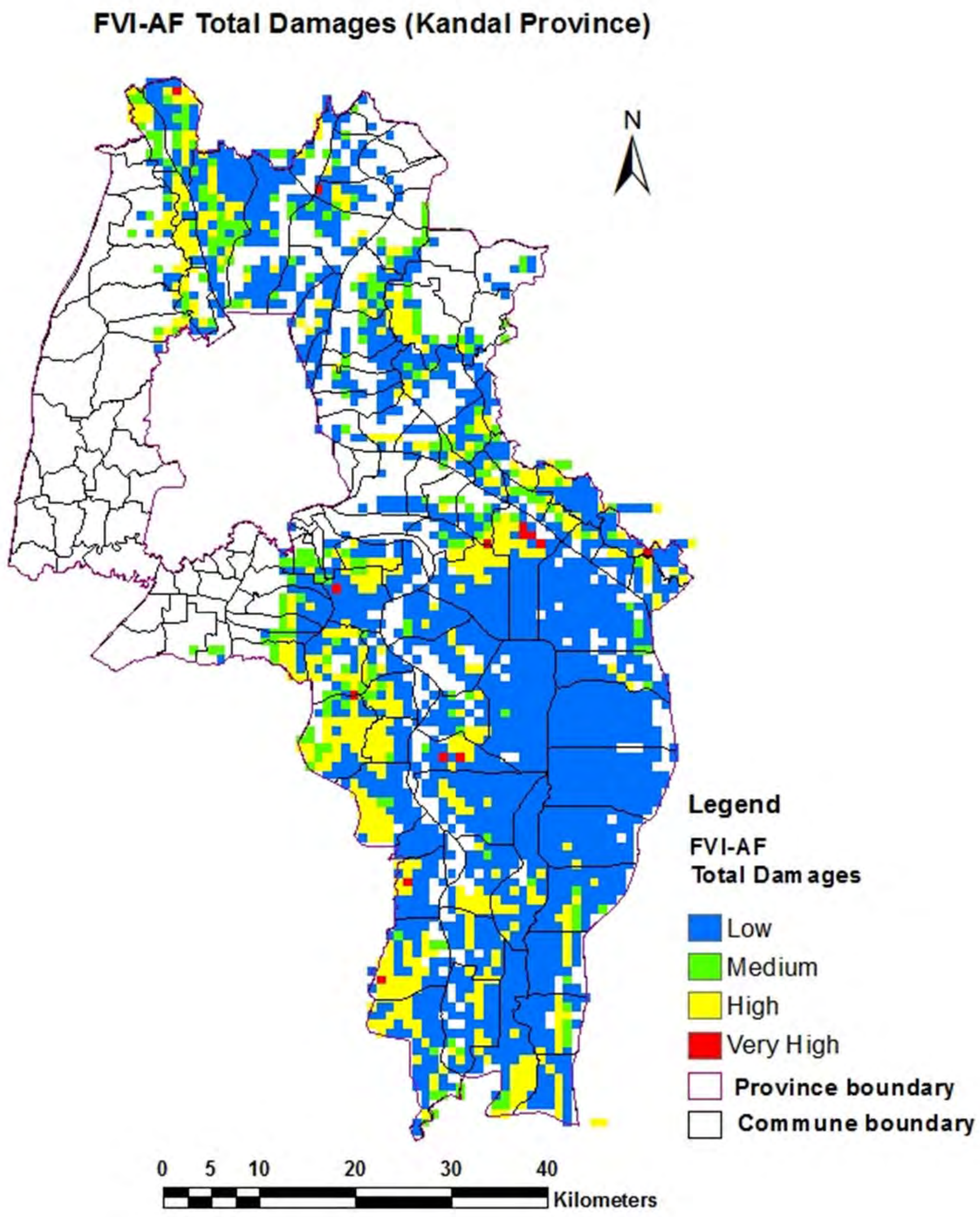


Figure 5.35: Commune Level FVI-AF Map for Total Damages of Kandal Province

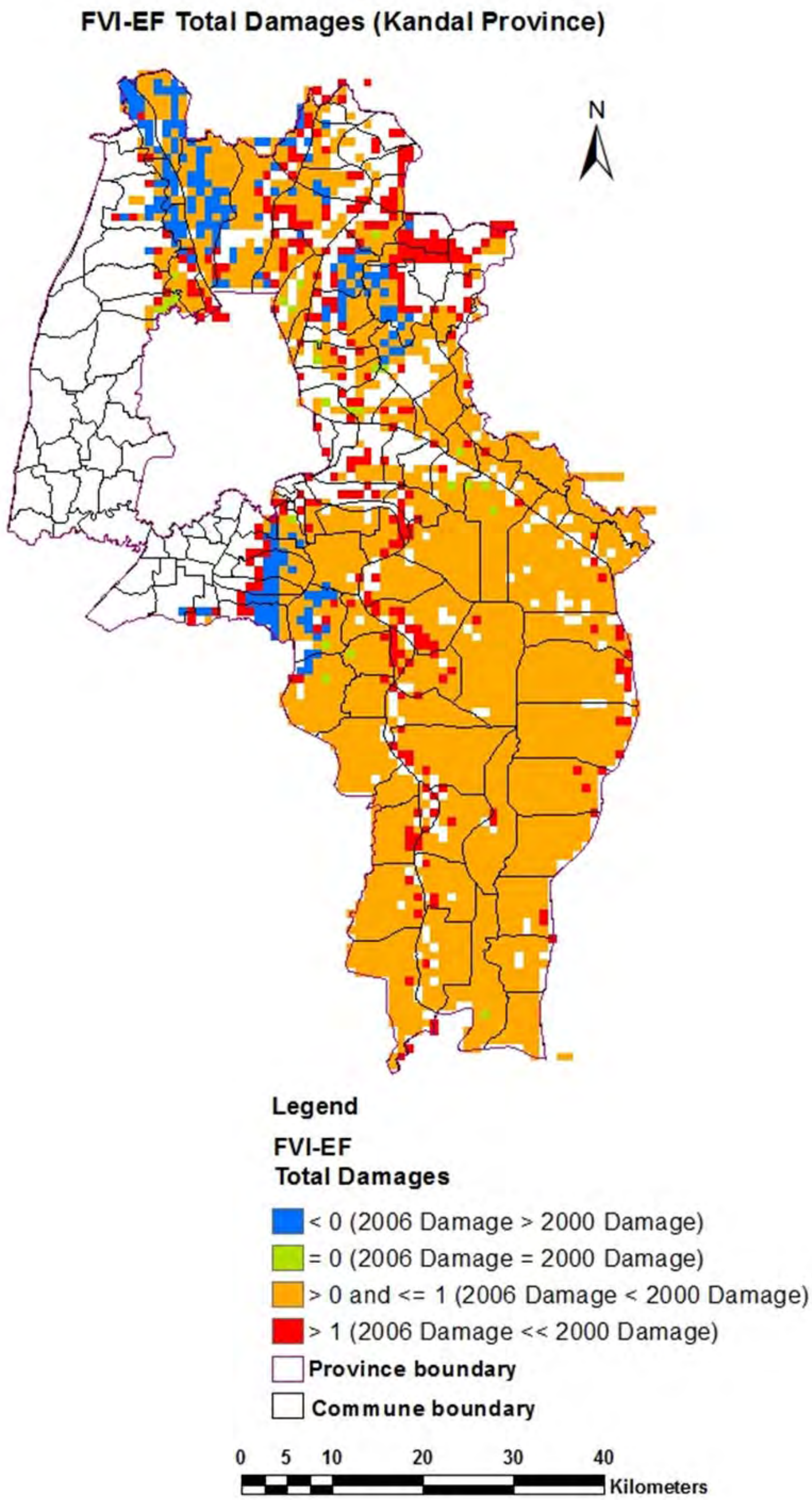


Figure 5.36: Commune Level FVI-EF Map for Total Damages of Kandal Province

5.5 Analysis of population distribution and agricultural land use

Micro-topography (undulation of the ground) reduces damage of flood. Mono-topographical area will be totally affected when extreme events come. If the area is rich in topography, even small deference, risk from floods can be limited. Spatial diversity (undulation of the ground) means availability of various land uses. Temporal diversity means there are differences from yearly average (rainfall, water level data etc.) and leads to risk. Risk occurs when deviation from yearly average pattern becomes un-adaptable for people (flooded are too high, too small, too early, too long especially when it happens in paddy period). The undulation of topography can be described based in distribution of Standard Deviation (SD) of the flood water depth.

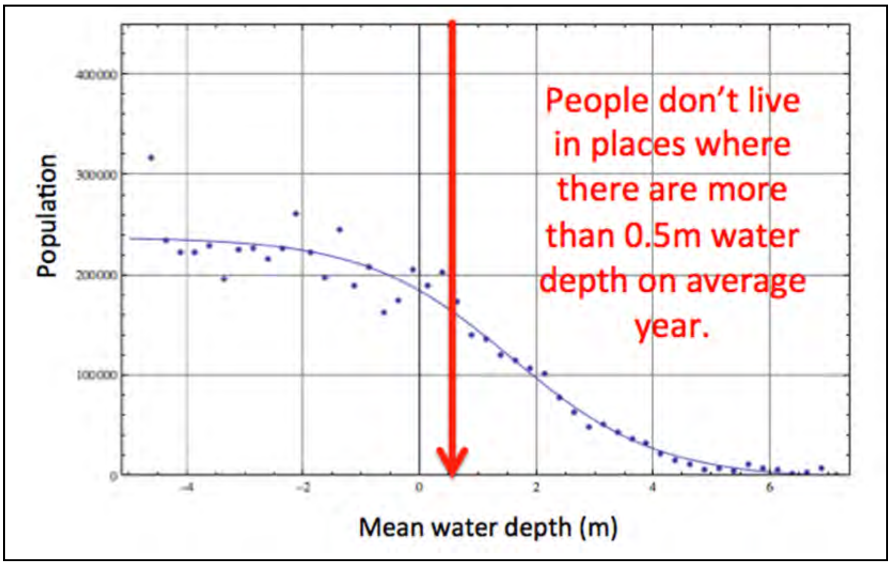


Figure 5.37: Population Distribution According to Maximum Flood Water Depth

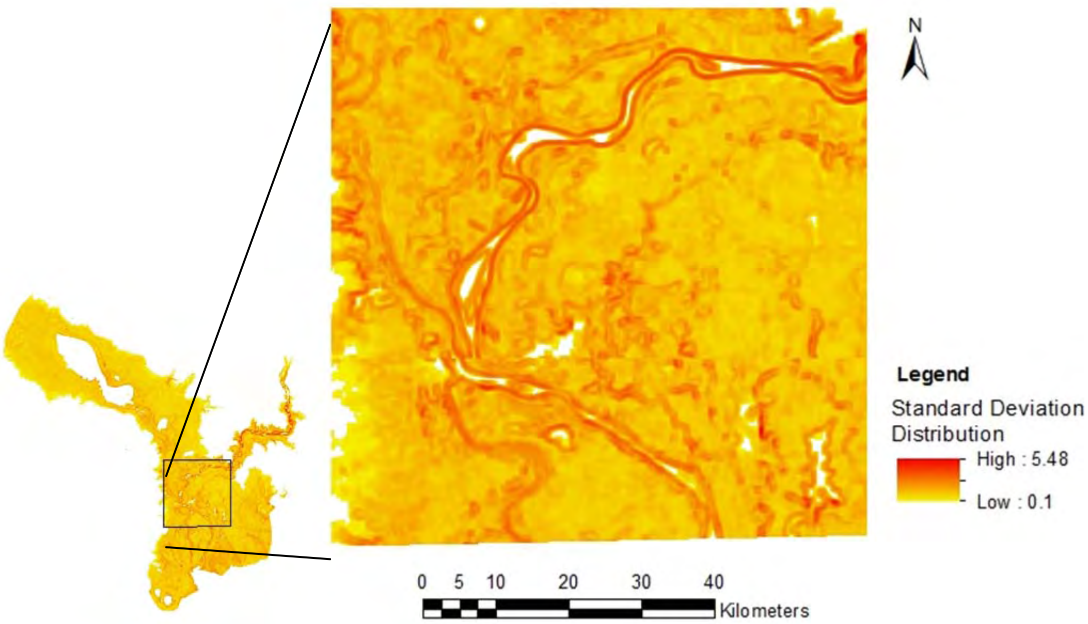


Figure 5.38: Distribution of Standard Deviation of Average of Maximum Flood Water Depth of Years 1991 to 2007

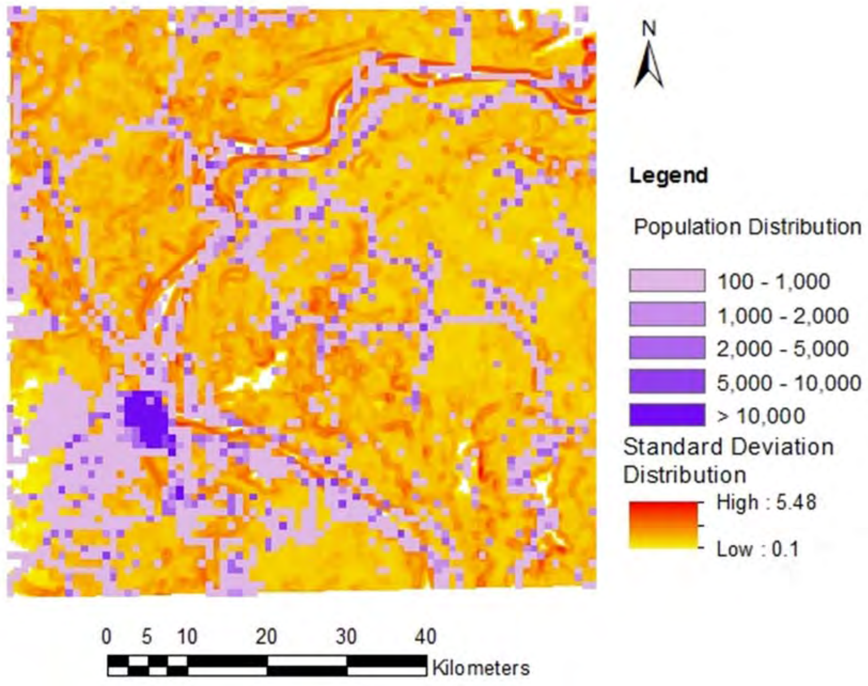


Figure 5.39: Population Distribution with Standard Deviation

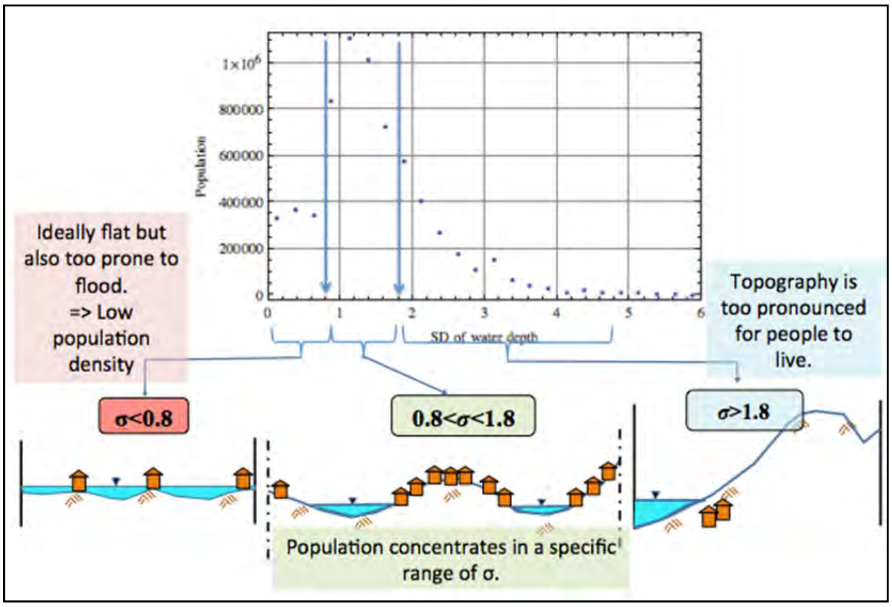


Figure 5.40: Maximum Flood Water Depth Standard Deviation and Population Distribution

The backbone of ICHARM vulnerability assessment is flood water depth. Hence, a analysis of population distribution as well as agricultural land use according to flood water depth was also conducted. Indeed, LANDSCAN population density data at 30 seconds mesh and 30 seconds averaged maximum flood water depth as well as standard deviation of flood water depth up-scaled from 3 seconds to 30-seconds calculated by ICHARM Hydro-Geo method were considered for this analysis.

Intuitively, we know that the population distribution will be accordingly to the annual flood water depth patterns. From our statistical analysis, first it was made clear that the population in Cambodian floodplains concentrates in location where the annual maximum flood water depth is lower than 0.5 m (Figure 5.37).

As flood water depths were calculated for 3 seconds mesh, while up scaling their value to 30 seconds mesh, and in order to take in account the variability of water depth in the 3 second cells during the up scaling process, the Standard Deviation (SD), was also up scaled. Figure 5.38 shows the distribution of SD calculated from average of maximum flood water depth of years 1991 to 2007. Figure 5.39 shows the population distribution with SD. As flood water depth is calculated as the difference between flood level and elevation, a high SD accounts for a cell with high variation in elevation, i.e. a topographically marked cell (Figure 5.40, SD or **σ** >1.8) and on the other hand, a cell with a small SD (Figure 5.40, SD or **σ** <0.8) accounts for a cell with low variation in elevation or a flat cell. It was then found that population concentrates in a specific range of SD (Figure 5.40, 0.8<SD or **σ** <1.8). Figure 5.41 shows the agricultural land use with distribution of SD. An agricultural land is not concentrated in the area where SD is too high and too low. Indeed, if SD is too low, or if the cell is too flat, it makes it conveniently flat to build housing or for agriculture, however, it makes it very sensitive to flood event, as flood water will disperse without natural topographical barrier. On the other hand, if the cell is too topographically marked, proportion flat enough for housing or agriculture becomes limited. Therefore, in between cells are then a good compromise with ideally flat portion and enough topographical barriers to limit flood water dispersion during flood events. In conclusion, SD of flood water depth can explain and indeed constrains where people live in the Cambodian flood plain.

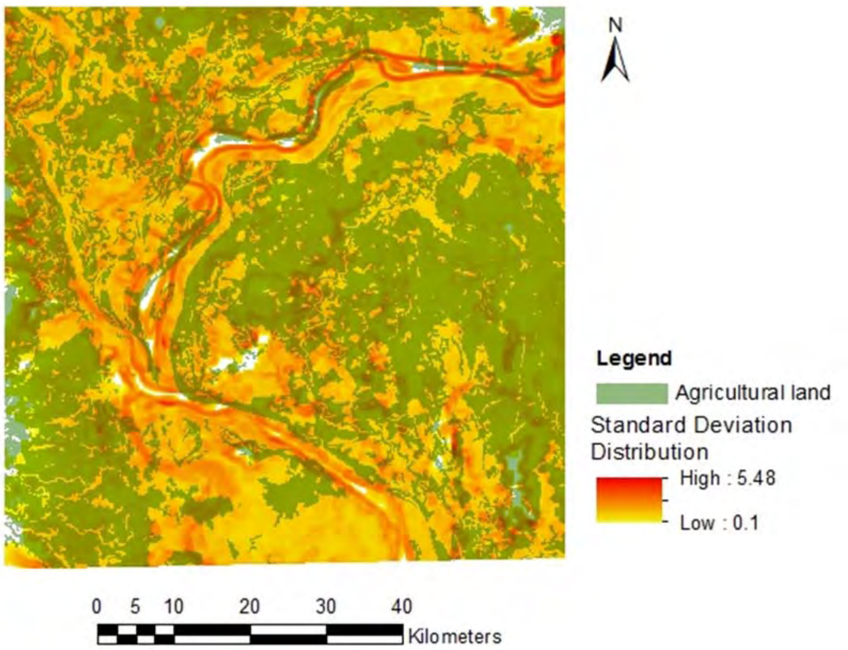


Figure 5.41: Agricultural land use with SD distribution

6. Utilization of Flood Vulnerability Indices

Populations living in Cambodian flood plain are vulnerable to flood disasters. These disasters are occurring with increased frequency as a consequence of socio-economic development and land-use development and also due to climate change. The floods can cause serious damages of property as well as loss of life. Thus, there is a necessary to identify the vulnerable of flooding in flood prone areas to support decisions in flood management for local community people, community leaders, decision makers, developers and policy makers.

The FVI identifies area which easy to be affected by flood. The results of FVI guide well preparedness for flood in agricultural as well as house and assets. The FVI can be used by local community people, community leaders, decision makers, developers and policy makers. It is useful to identify and develop preparedness plans to deal with floods and flooding. It will help to improve local decision-making processes by selecting preventive measures to reduce vulnerability at local and commune levels. The use of flood vulnerability indices can produce helpful understanding into vulnerability and capacities for using it in planning and implementing projects. Also the FVI makes it possible for decision makers, developer and policy makers to identify the priority area for implementation of disaster-related projects.

In this study we developed two kinds of flood vulnerability indices. First one is flood vulnerability indices for average flood and second one is flood vulnerability indices for extreme flood. We developed FVIs for LMB of Cambodian flood plain. By using FVI-AF, local people can recognize their highly vulnerable area. Thus, they can make preparedness for high vulnerable or very high vulnerable area. By utilizing FVI-AF, we can easily find the information of vulnerable area and we can easily identify where preparedness is needed. In average flood also, they experienced some damages of agricultural and houses in Cambodian floodplain. But when extreme flood occurs, the big damages occur in the area. It means serious preparedness for extreme flood is needed in such area. By utilizing FVI-EF to identify gap area between average flood damages and extreme flood damages, we can recognize the area where serious preparedness for extreme flood is needed.

7. Conclusions and Future Recommendations

7.1. Conclusions

Flood in the Mekong River basin has this particularity to be either good or bad. Indeed, floods have provided benefits to cultivation in Cambodian Plain bringing water and nutrients but once flood level reaches a threshold, flood becomes bad flood and brings damages. Therefore, in terms of development in this area, it is essential to identify clearly the benefits and damages both brought by floods. Hence ICHARM developed ICHARM Hydro-Geo Method, using Satellite Topographical Data as a complement to limited hydrological data sets in the river basin in order to identify flood vulnerable area in Cambodian floodplain. ICHARM technology makes it possible by its hydro-meteorological analysis in combination with careful analysis from past important surveys done by FMMP and others.

Thus, flood vulnerability has been defined as the amount of potential damages in this project. With this specific definition, it made it possible to quantitatively assess flood vulnerability for Cambodian floodplain. Indeed, vulnerability was defined as the combination of damages occurring to income and damages occurring to assets. In case of Cambodian floodplain, the major source of income affected by flood had been identified as wet season rice and the major assets as residential assets. Therefore, flood vulnerability was calculated as the combination of wet season rice damages and residential damages. After calculating maximum average year flood water depth through ICHARM Hydro-Geo method, agricultural and house damages were calculated. It was found that in the Cambodian floodplain, almost all the territory is subject to both house and wet season rice damages during an average year. The agricultural damages depend on flood water depth and its duration as well as accumulated rainfall in the area. The house damages mainly depend on maximum water depth. The distribution of house value and damage ratio were computed based on 2008 household survey for 2006 flood of FMMP project. For the validation of house damage calculation, the estimated results of three districts Koh Andet in Takeo province, Koh Thom in Kandal province and Kampong Trabek in Prey Veng province were checked with statistical data of house damages. If house and assets of a household damage, the same amount of house damage or greater than amount of house damage is necessary for rehabilitation of house and assets damages.

The FVI means identification of area which easy to be affected by flood. It has been developed for average flood and has been identified by normalizing the calculated grid value of damages. The average water depth of flood in 2006 is almost same as average water depth of 17 years period (1991-2007) and flood in 2000 is maximum flood in the period. So the flood in 2006 is considered as average flood and flood in 2000 is considered as extreme flood. To normalize the calculated grid value of damages, the calculated value in each grid is divided by maximum value of calculated damages. The FVI is defined from low to very high vulnerable area based on normalization value ranges from 0 to 1. The normalized value ranges 0 – 0.25, 0.25 – 0.5, 0.5 to 0.75 and 0.75 to 1 respectively defined as low, medium, high and very high vulnerable. In the high and very high vulnerable area, well preparedness is necessary for flood in agricultural as well as houses and assets. The FVIs have been prepared for agricultural damages, house damages and total damages.

In this study, we also identified the damages gap area between average flood and extreme flood. Some damages occur during average flood in LMB of Cambodia. However, big

damages occur during extreme flood in the area. So, serious preparedness for extreme flood is needed in such area. By utilizing the map of gap area i.e. FVI-EF, local people can make preparedness for extreme flood. The maps of FVI and identification of damages gap areas can be also utilized for planning flood disaster risk reduction projects in flood prone area and then it would be also useful to estimate cost for flood disaster risk reduction project.

The people living in flood prone area of Cambodian flood plain often faced average flood. So to avoid flooding, they construct high flood houses and also they construct the houses at higher elevated area than average flood level. Also they concentrate their reconstruction activities in such area where elevation is higher than average flood level. In Cambodian flood plains, most of the houses are built on stilts to avoid flooding. The poor people living in the area cannot construct permanent houses and they construct temporary houses.

The flood vulnerability indices will help design a standard flood preparedness procedure into local community management system in LMB. The results of FVI-AF and FVI-EF are useful for local people to recognize their vulnerable area for preparedness of flood. Also it can be used for awareness raising in local community. The final results of this report are quite useful information to all activities in relation to flood disaster management in community level. The output results are very much useful for decision makers, planners, and local government to establish the policies required for reducing the vulnerability. The results can support for following potential investments:

- All infrastructures and development related to Mekong River and Cambodian Floodplain will affect from flood phenomena. So this result can be used for infrastructures and other development activities in the area.
- The results and developed maps in this work are also very much useful for the future development in Lower Mekong Area as well.
- For guidance building code.
- The results can also help to design a standard flood preparedness procedure to assure a positive spiral installed into community management system in LMB.
- The output results can be also used for awareness raise to local community and for training and building capacity at community level.
- Other possibilities can expand more from this result for sound development of Lower Mekong Area.

7.2. Future Recommendations

In IHGM method, the flood water depth was calculated as the difference between flood level and elevation. Therefore, a preliminary condition to apply ICHARM method is to have enough available hydro-meteorological data (rainfall data from a sufficient number of rain gauges and river water level data from a sufficient number of river monitoring stations). There are still discussions on accuracy of this method. However, as first step ICHARM tried to grasp outline even though still uncertainty. In order to achieve effective flood risk forecasting for poorly gauged sub-basins in the lower Mekong after rough feasibility study, Integrated Flood Analysis System (IFAS) or Block-wise Top (BTOP) models is not feasible to apply in LMB area due to very flat and big area in this plain. So, in the case of poorly gauged river basin, flood level can still be calculated through other hydrological model such as Rainfall Runoff Inundation (RRI) model using satellite based

rainfall estimates such as GSMaP[1] or 3B42RT[2]. Application of RRI model can be more precise reproduction of inundation area (Sayama et al., 2012).

The final output results of this report are useful for community based disaster management by forming a community flood defense committee. In order to form a community flood defense committee, in some villages it is difficult to form a new committee. So, we recommend using existing committee or group for community flood defense committee.

In this study, we have developed flood vulnerability indices in LMB. So, further action is necessary to utilize the developed results of flood vulnerability indices to community people, decision makers, policy makers and developers. For this propose, formulation of working group is necessary to develop framework for the utilization of developed flood vulnerability indices in LMB and also on creation of results as preparedness kits to community people or community leaders for disaster management. In more specific further action is necessary to prepare guidebook for effective utilization of developed flood vulnerability indices as a tool to community people, community leaders, decision makers, policy makers and developers for disaster management and to prepare the preparedness kits for community people or community leaders.

It is also recommended to expand the study area to Vietnam and Lao PDR. This study area is affected by major river flood. However small river affected by flash flood also should be considered in the future.

[1] GSMaP (Global Satellite Mapping of Precipitation) product. “The GSMaP project was promoted for a study "Production of a high-precision, high-resolution global precipitation map using satellite data," sponsored by Core Research for Evolutional Science and Technology (CREST) of the Japan Science and Technology Agency (JST) during 2002-2007. Since 2007, GSMaP project activities are promoted by the JAXA Precipitation Measuring Mission (PMM) Science Team. “http://sharaku.eorc.jaxa.jp/GSMaP_crest/index.html

[2] This data set contains Satellite NASA GSFC/3B42RT data. http://data.eol.ucar.edu/codiac/dss/id=82.008

Acknowledgement

This final report of Lower Mekong Basin Component is prepared under in-country project support program of Asian Development Bank, Technical Assistance for Supporting Investments in Water-Related Disaster Management (TA7276). We, International Centre for Water Hazard and Risk Management (ICHARM), Public Works Research Institute (PWRI), Japan, would like to express our gratitude to Mr. Katsuhito Miyake, Senior Disaster Risk Management Specialist, the World Bank and Mr. Kimio Takeya, Visiting Senior Advisor, Japan International Cooperation Agency for their kind support to prepare initial implementation plan of Lower Mekong Basin Component and for their suggestions when they have been assigned to ICHARM and ADB respectively.

We would also like to express our thankful to Prof. Shigeko Haruyama, Professor, Department of Environmental Conservation Studies, Mie University, for her suggestions to analyze flood and floodplain characteristics in Lower Mekong basin areas of Cambodia. We would also like to thank Dr. Takao Masumoto, Chief Researcher, Water Resources Engineering and Hydrology and Water Resources Management, National Agriculture and Food Research Organization, for his suggestions to access agricultural damages due to flood in Cambodian floodplain.

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Appendix 1: ICHARM Hydro-Geo Method

General Background

A methodology described in this study is to identify flood vulnerability area considering the micro-topographical effect in communities of the Lower Mekong Basin (LMB) in Cambodian floodplain. The methodology makes it possible to be assessed, although roughly, in a large area of the basin using off-site information such as Digital Elevation Model (DEM) and satellite observations. Figure A1.1 shows the variation of ground level. The effect of mixed topography and land use in selected area is important as the multiple income sources in an individual farmer or village save the total loss of production and make their livelihood resilient. Even in a small area, there may be variations of land elevation and different cultivation patterns. Such mixture would work as a resilience to flood variation for farmers.

The inundation level changes with the distance from the river center in each river segment. It may be negligible in case of high floods over natural levees but significant in lower stages of flooding, advancing as well as retreating, with the delay in inflow or outflow through small ditches. Such relation among micro-topographical condition of the land, normal flood pattern and normal rice cultivation exercises are identified and reflected in the FVI.

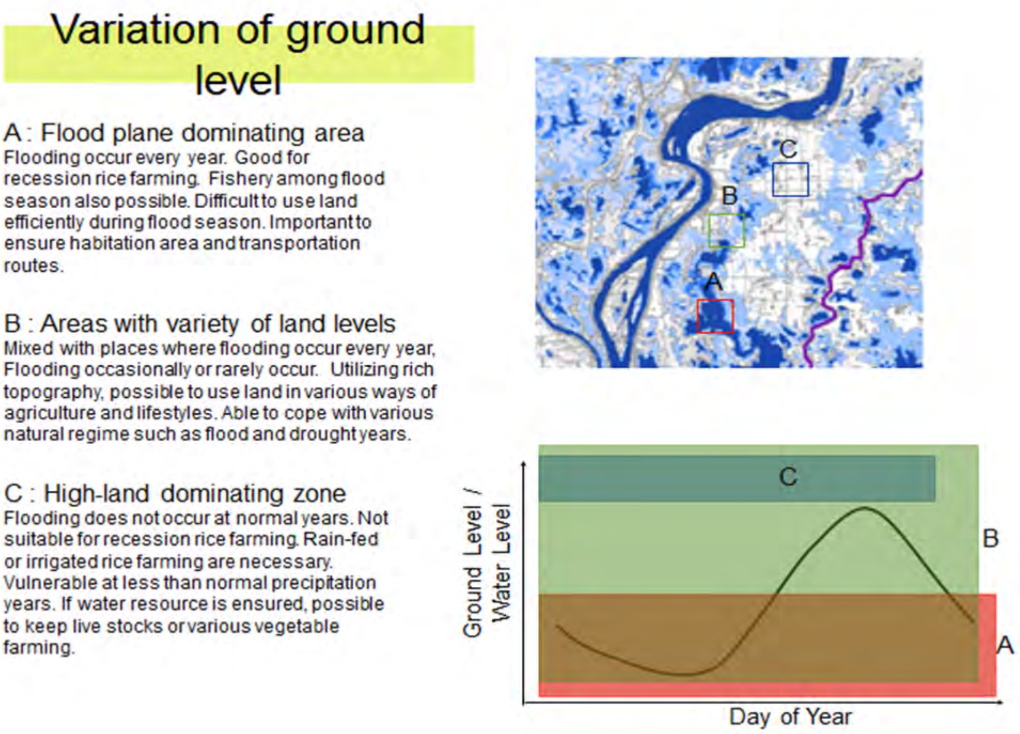

Figure A1.1: Variation of Ground Level

ICHARM Hydro-Geo Method: General Process

a. Identify floods and other natural hydro-climatic phenomena

- Choose Cambodian floodplain as model area.
- Use water-level data sets in monitoring stations in Mekong River.

Figure A1.2: Cambodian Floodplain and Inundation

Figure A1.2 shows the Cambodian floodplain and inundation.

b. Identify micro-topographical conditions

- Base data: The Shuttle Radar Topography Mission (SRTM)) data with horizontal resolution of 3"*3" and vertical resolution of 1m.
- SRTM obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth (Figure A1.3). SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during an 11-day mission in February of 2000. The elevation data of the Universal Transverse Mercator (UTM) datasets are referenced to the WGS84 EGM96 geoid, and horizontally geo-referenced to the WGS-84 ellipsoid using a UTM projection. (NASA, http://www2.jpl.nasa.gov/srtm/)

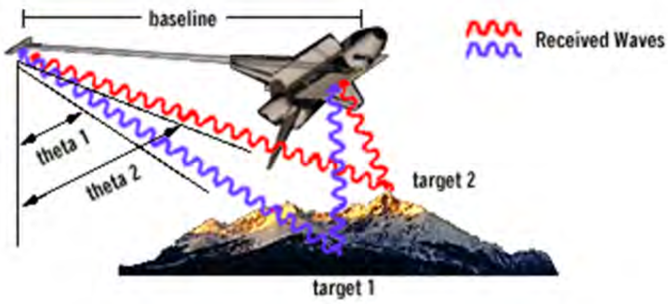

Figure A1.3: Differential Distance Gives Topography (NASA, 2011)
http://www2.jpl.nasa.gov/srtm/instrumentinterfmore.html

c. Assess the agricultural exercises according to given patterns of floods and hydro-climatic phenomena and identify deviation stresses and dominating risks for each agricultural pattern.

- The dominating rice cultivation styles are wet season rice farming (accounting for app. 80% of the total yield), and dry season recession rice farming (accounting for app. 20% of the total yield) in the area. However for dry season rice farming, farming risk is not very notable as people can expect planting and growing dry season rice according to flood receding pattern. The risk in farming is much more for wet season rice farming. Therefore we focus on wet season rice farming in the example to follow.
- For wet season rice farming, we consider following two risk factors as serious conditions to lead losses in rice production.

(1) Failure in rice planting

- When precipitation is too small and soil condition is premature to start rice planting and then if flood comes, farmers will fail in rice planting. We adopt the assumption that cumulative rainfall threshold for rice planting is 500mm. It is simulated by rainfall and flood inundation level in chronological manner.

(2) Damage to rice harvesting

- If water level rises and exceeds standing water level (e.g. 50cm) of rice before harvest timing (e.g. 3 months after planting), rice harvesting will be damaged to some extent. This number of days with harmful inundation level could be used as potential physical factor for rice harvesting.

d. Develop a FVI to account the impact of deviation stress over any specified area

- By combining two factors under c, agricultural damage is defined.

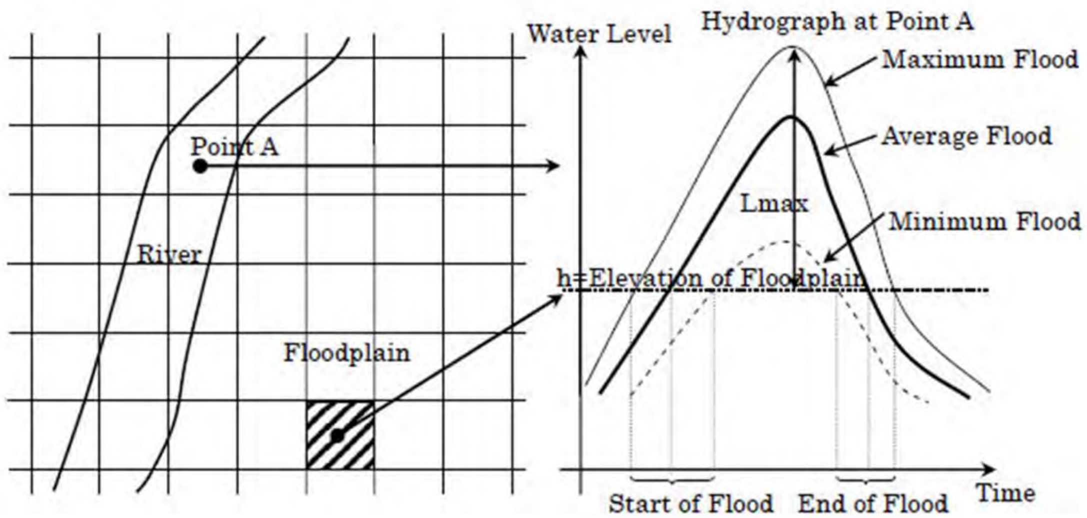

Figure A1.4: Image of Cells and Elevation of Inundation in the Selected Area

e. House damage calculation

- House damage is calculated based on household survey data (Detail will be described in Appendix 3.

Figure A1.4: shows the image of cells and elevation of inundation in the selected area.

ICHARM Methodology: Detail Process

1) Preparation

- ➢ Daily flood hydrographs
  - at Kampong Cham, Phnom Penh and Neak Luong
  - from 1990- 2009 (20 years), especially for year 2000 (high flood) to be used as the potential flood area.
- ➢ Rainfall data and cumulative rainfall curves (500mm from the end part of dry season which makes suitable soil condition for rice planting)
  - at all available points and apply the rainfall pattern
  - from 1991 to 2010 on daily basis
  - calculate the date of cumulative rainfall of 500mm

- Topographical maps
  - SRTM3 (elevation data: 3”*3” resolution)
  - Detail DEMs of Lovea Em, Peam Ro and Leul Dek prepared by FMMP C5 of FMMP project, MRC
  - Other precision maps whatever available
- Excerpts of useful findings of previous MRC projects, especially on FMMP C2 and C5 such as:
  - Inundation depth/duration and production loss (US$) relation
  - River stage and flood mark relation

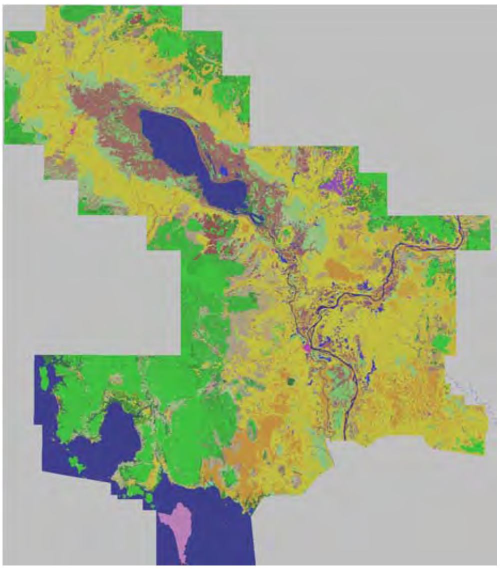

Figure A1.5 Detail Land Use Map

2) Basin geographical and topographical classification
   - Classify the target area (Cambodian floodplain) into urban, mountain/hill slope (flash flood areas) and floodplain (Urban and rural).
     - Use of already available land use maps with geo-referenced form is one of good means for such classification, to identify water-body and urban areas.

   - Classify the floodplain into river segments and bands of area (or stripes) roughly vertical to the main stream of the Mekong. Within the same segment inundation occurrence is controlled by the river stage of the main stream of the Mekong that belongs to the river segment.

3) Procedure of identifying micro-topographical effects on flood patterns
   - Select a cell.
   - Identify the elevation of the cell (Z).
   - Identify the river segment where this cell belongs.
   - Identify the hydrographs (of the high flood year, the normal flood year and the dry season) at the river segment where the cell belongs.
   - Cut the hydrographs by the elevation of the cell. This will make inundation curve for the cell for selected year.

- Identify data-rich rain gauge stations that represent selected area.
- Divide basin in multiple areas, each of which will represent rainfall data of the cells included in each area.
- Make the data set table in the following manner.
- Calculation:
  - Find date of cumulative rainfall reach 500mm (CR_0)
  - Find date of start of inundation
  - Calculate number of days between A and B
  - Find inundation depth during 90 days after A
  - Compare D and standing water level (e.g. 0.5m)
- Assess risk for failure in rice planting by C, and risk of crop damage by E.

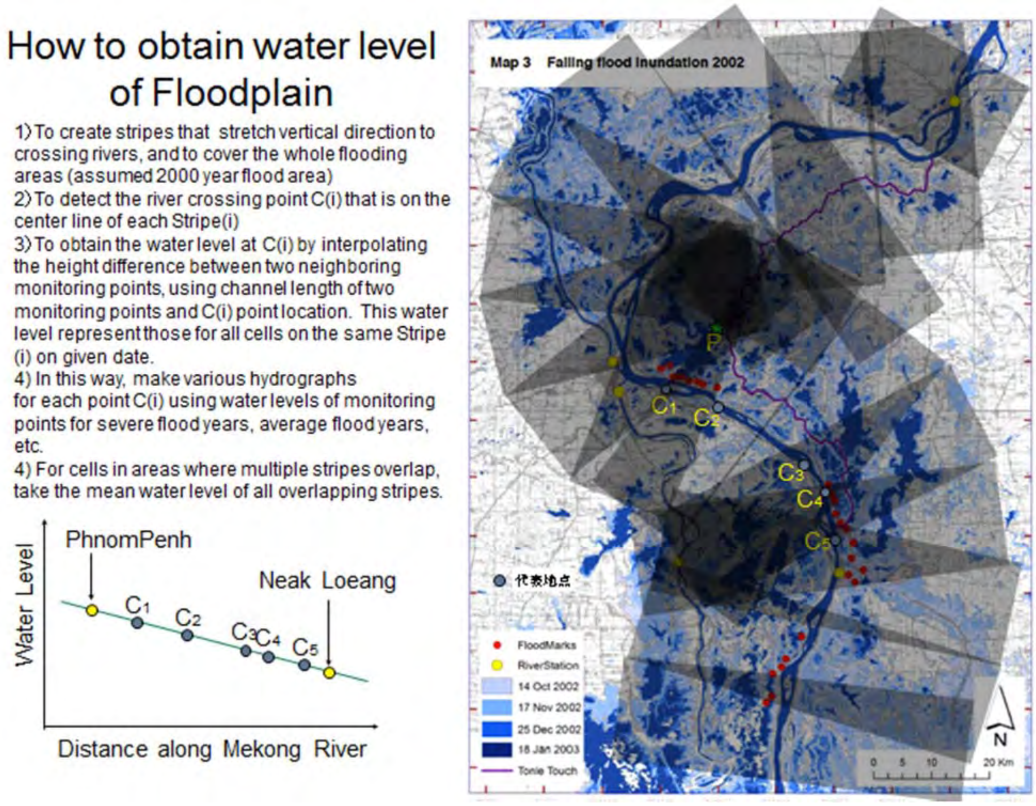

Figure A1.6: Description of Water Level Calculation in Floodplain

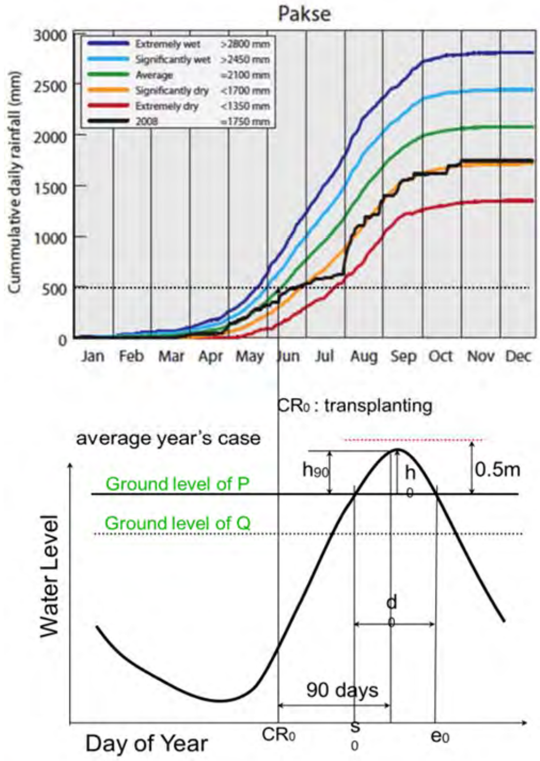

Figure A1.7: Image of Calculation Process

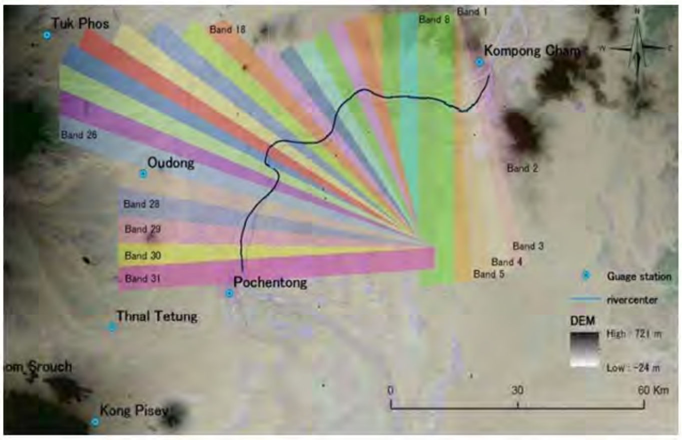

Figure A1.8: Division of Floodplain by Bands

ICHARM Trial at Model Area

- DEM data and division of floodplain by bands:

The trial calculation was set for the area between Kampong Cham and Phnom Penh, which extends about 168km*130km. The area was covered by 31 bands as shown in Figure A1.8, each of which is about 5km wide (Figure A1.8). Totally there are 1867*1449 (2,705,283) cells and each cell has its own elevation. SRTM3 was used for the ground elevation data for this area.

- Flood hydrographs to apply for each band

We obtained water stage data (hydrographs) at Kampong Cham (Figure A1.9) and Phnom Penh. The data was used for interpolating hydrographs in the middle areas. Hydrographs were created for each of 31 bands by interpolation of monitoring water levels for the same dates, in proportion to the location between monitoring stations (Figure A1.10).

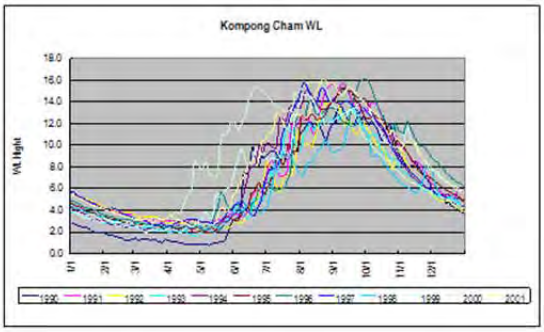

Figure A1.9: Hydrographs at Kampong Cham

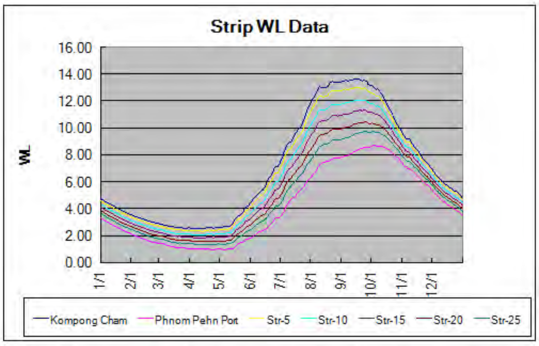

Figure A1.10: Flood Hydrographs to Apply for Each Band

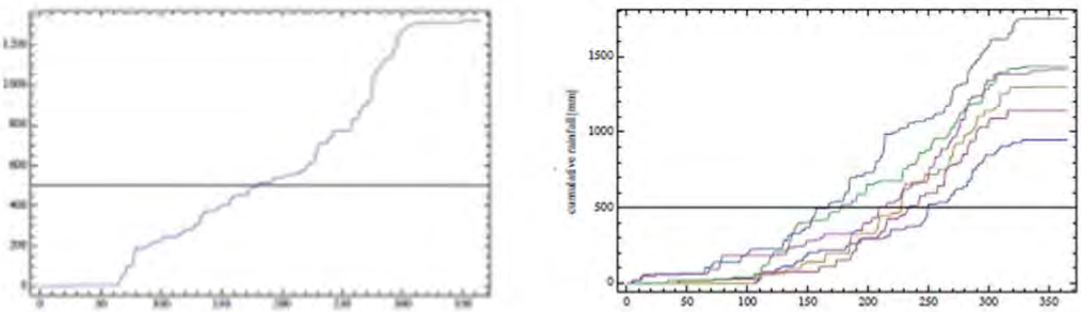

Figure A1.11: Cumulative Rainfall at Kampong Cham (left) and Oudong (right)

- For the areas covered by overlapping bands, the interpolated hydrographs at middle of the overlapping bands were adopted.
- Rainfall data: within and nearby model area, there are several rainfall monitoring stations such as Kampong Cham, Oudong and Pochentong. Through simple analysis it was found that the average cumulative rainfall and that of 2001 are similar. For the

trial simulation we used rainfall dataset monitored at Oudong and Kampong Cham (Figure A1.11).

- Calculation results:

The Figure A1.12 shows calculated maximum inundation depth of inundation (below 0m, 0 to 7m, and over 14m).

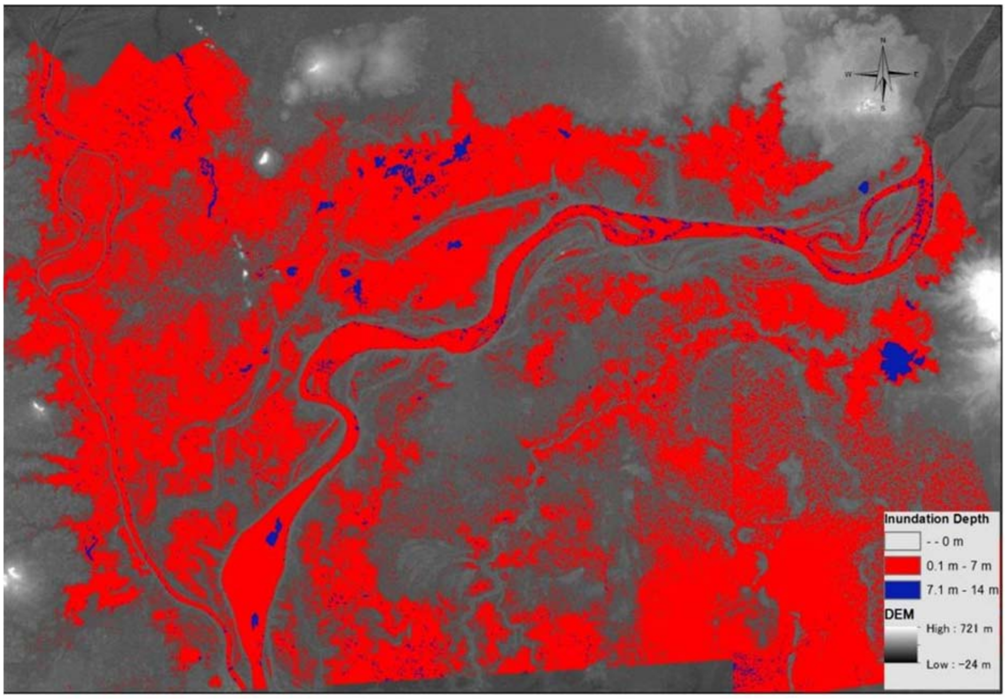

Figure A1.12: Distribution of Maximum Inundation Depth

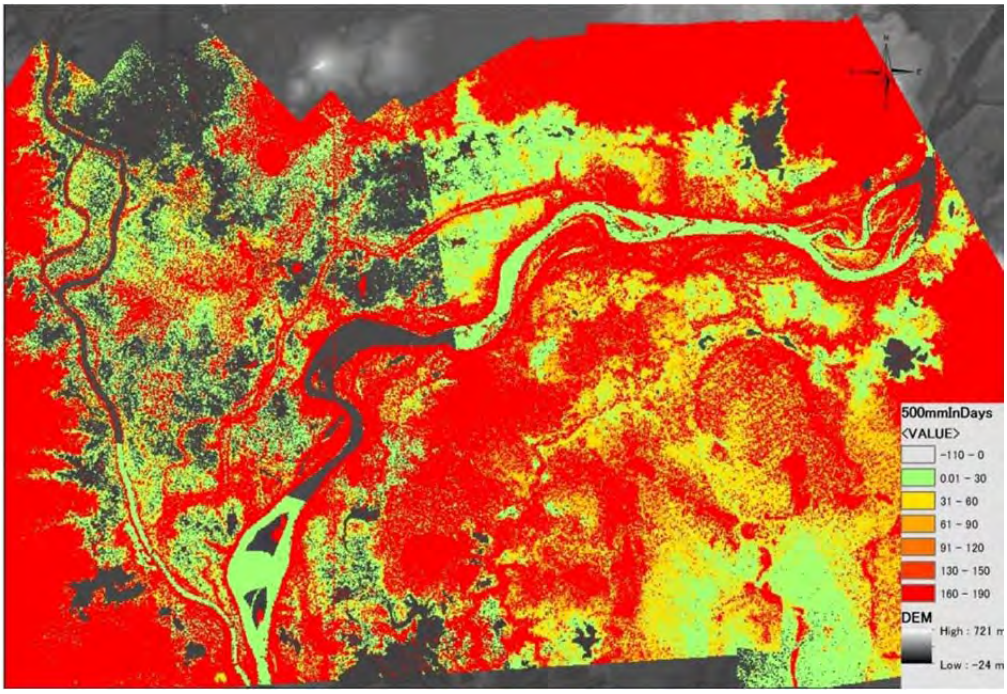

Figure A1.13: Average Number of Inundation Days in a Year

The Figure A1.13 shows the same area with calculated inundation occurrence days (every 30 days range). The Figure A1.14 shows representative cutting figure of ground level and inundation depth, when we cut the area with arbitral lines. The Figure A1.15 shows the number of days with inundation depth > 0.5m, during 90 days after cumulative rainfall reached 500mm. In this figure the gray scale area shows low risk area for rice planting (0 day of inundation level > 0.5m) while dark blue area shows high risk area or permanent water body. The Figure A1.16 shows the example representation of cross section of Figure A1.15 (in this case cut with East-West line at 410th cell from the North).

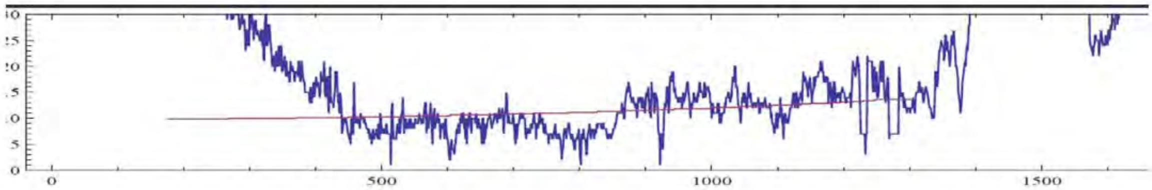

Figure A1.14: Ground Level and Inundation Depth

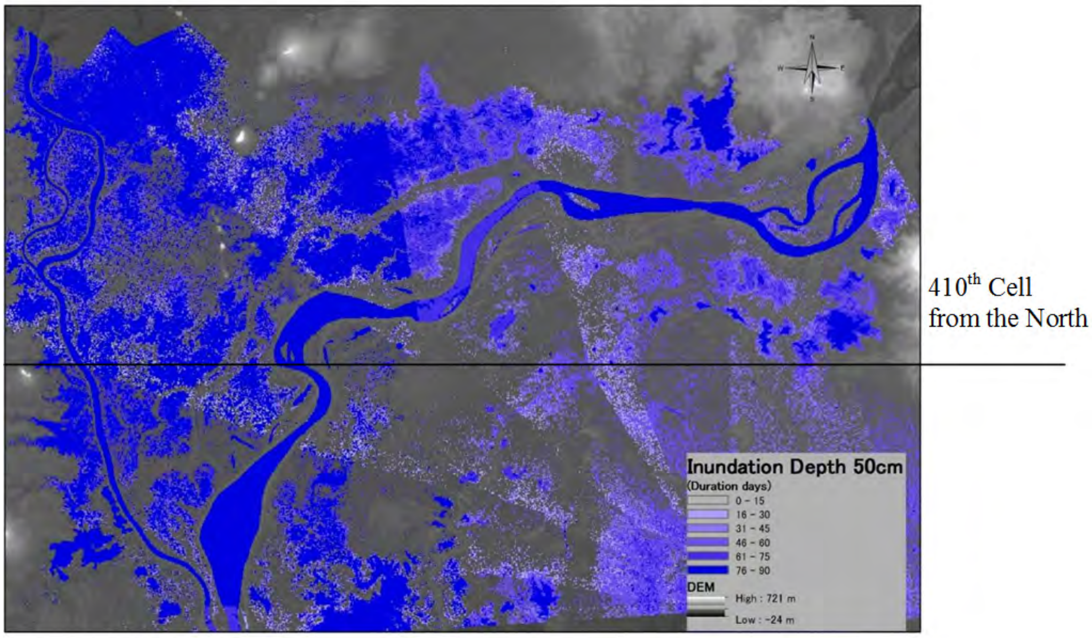

Figure A1.15: Number of Days Cumulative Rainfall Reached 500 mm and 90 Days after that Date with Inundation Depth > 0.5 m

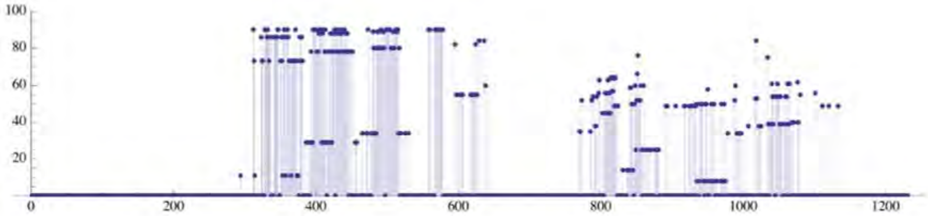

Figure A1.16: Representative Cross Section of Figure A1.15

Appendix 2: Household Questionnaire Survey

The survey sample was designed as at least 90 households and business in each three selected districts Koh Andet in Takeo province, Koh Thom in Kandal province and Kampong Trabek in Prey Veng province (FMMP, 2010). The damages to households in the 2006 flood was asked and potential damages to the house under the survey investigated by asking the questions how much the flood damage to house would be if a flood water depth higher than 2006 flood by 0.5m, 1.0m, 1.5m and 2.0m. The following questionnaire survey format was used by 2008 survey for 2006 flood for FMMP project.

HOUSEHOLD FLOOD DAMAGES QUESTIONNAIRE

Flood reference year: 2006

Interviewer: **Date:**
Starting time:
Finished time:

1. SURVEY LOCATION AND SAMPLING CRITERIA				
1.1 Interview number *(in each location use consecutive numbers, e.g., 1, 2, 3, 4, etc.)*			1.1	
1.2 Name of province	1.2			
1.3 Name of district	1.3			
1.4 Name of sub-district / commune (as / if relevant)	1.4			
1.5 Name of village	1.5			
1.6 House / unit number(s) (as / if relevant)	1.6			
1.7 GPS coordinates	1.7-a	x		
	1.7-b	y		
	1.7-c	Ground height:		
1.8 Sampling criteria		Residential structure type 1- Permanent 2- Semi-Permanent 3- Temporary	1.8-a	
		Main household economic activity 1- Agriculture 2- Non-agriculture (e.g., business, Government employment, etc.)	1.8-b	
		Poverty: Local officials designate this household as 1- Non-poor 2- Poor or very poor	1.8-c	
1.9 Was respondent living in this household in 2006? ***N.B.** If response is "no", change respondent to other person within household.*		1- Yes 2- No	1.9	
2. HOUSEHOLD DATA				
2.1 What is the sex and ethnicity of the <u>household head</u>? *Please make sure this information is about the household head.*		Sex: 1- Male 2- Female	2.1-a	
		Ethnicity: 1- 2- 3- 4- 5- 6-	2.1-b	

<table>
<tr><td rowspan="2">2.2 What is the number of people who <u>normally live in this household</u>?</td><td></td><td rowspan="2"></td><td>a) Male</td><td>2.2-a</td><td></td></tr>
<tr><td></td><td>b) Female</td><td>2.2-b</td><td></td></tr>
<tr><td rowspan="3">2.3 What is the average household cash income from <u>all sources</u>?

Currency =</td><td></td><td colspan="2">Dry season, average monthly</td><td>2.3-a</td><td></td></tr>
<tr><td></td><td colspan="2">Flood season, average monthly</td><td>2.3-b</td><td></td></tr>
<tr><td></td><td colspan="2">Annual, average total</td><td>2.3-c</td><td></td></tr>
<tr><td rowspan="2">2.4 What percentage of your total agricultural production (crops, animals, etc.)
□ Does your household consume?
□ Do you sell for cash income?</td><td></td><td colspan="2">% consumed by household</td><td>2.4-a</td><td></td></tr>
<tr><td></td><td colspan="2">% sold for cash income</td><td>2.4-b</td><td></td></tr>
<tr><td rowspan="5">2.5 What is major profession?</td><td rowspan="5"></td><td colspan="2">Farmer</td><td>2.5-a</td><td></td></tr>
<tr><td colspan="2">Fishing</td><td>2.5-b</td><td></td></tr>
<tr><td colspan="2">Vender</td><td>2.5-c</td><td></td></tr>
<tr><td colspan="2">Manufacture</td><td>2.5-d</td><td></td></tr>
<tr><td colspan="2">Factory Worker</td><td>2.5-e</td><td></td></tr>
</table>

3. <u>2006</u> FLOOD EVENTS – HOW HOUSEHOLD IS AFFECTED				
This section asks the household to provide basic information about how the flood waters affected them in 2006. If there was only one "flood event", only complete the first section. If flood waters affected the household more than once in 2006, complete the appropriate number of "flood events".				
Flood event # 1				
3.1 When did the flood event occur (or start)?		1- June 2- July 3- August 4- September 5- October	3.1	
3.2 How long did the flood event last?		Number of <u>days</u>	3.2	
3.3 What were the maximum depths of flood waters: Near your house / in the house yard?		Depth in meters (m)	3.3-a	
Inside your house?		Depth in meters (m)	3.3-b	
On your agricultural land?		Depth in meters (m)	3.3-c	
Flood event #2				
3.4 When did the flood event occur (or start)?		1- June 2- July 3- August 4- September 5- October	3.4	
3.5 How long did the flood event last?		Number of <u>days</u>	3.5	
3.6 What were the maximum depths of flood waters: Near your house / in the house yard?		Depth in meters (m)	3.6-a	
Inside your house?		Depth in meters (m)	3.6-b	
On your agricultural land?		Depth in meters (m)	3.6-c	
Flood event #3				
		1- June		

4. RESIDENTIAL Losses Due to Flooding in 2006			
Residential Assets			
4.1 Total area of main house structure	m^2	4.1	
4.2 Total estimated value of main house structure	Currency =	4.2	
2006 Flood Damage			
4.3 In 2006, did you experience damage or losses to your residential property due to flooding? ***Note**: If response is "no", go to Question 4.9.*	1- Yes 2- No	4.3	
If "yes", please complete the following section about losses / damages to residential structures and assets that occurred during 2006. The respondent should be asked to first provide some background information about residential assets and then, to the best of his/her ability provide information about the costs of different kinds of losses and damages to buildings, equipment, vehicles, inventory, etc. If possible, the respondent should consult any records that would document these costs.			
Value of flood losses / damages : all flood damages during 2006			
4.4 Damage to house structure	Currency =	4.4	
4.5 Damage to other structures, e.g., separate toilet, kitchen		4.5	
4.6 Damage to house furnishings		4.6	
4.7 Damage to major appliances / durable goods, e.g., TV, refrigerator, etc.		4.7	
4.8 Damage to vehicles, e.g., car, motorbike, boats		4.8	
What would be the value of flood losses / damages if the flood had been higher? ***Note**: This following section is to be answered by all surveyed households.*			
4.9 What was total estimate of losses / damages = sum of 4.4 through 4.8 ***Note**: If no flood damages in 2006, the response to Question 4.9 = 0.*		4.9	
4.10 If the flood was 0.5 m higher – what would be total losses / damages?		4.10	
4.11 If the flood was 1.0 m higher – what would be total losses / damages?		4.11	
4.12 If the flood was 1.5 m higher – what would be total losses / damages?		4.12	
4.13 If the flood was 2.0 m higher – what would be total losses / damages?		4.13	
Other Information on Residential Losses / Damages			

Appendix 3: Details of House Damage Estimation

General Methodology

The few inevitable approximations to be considered in the house damage calculation are as follows:

- o How does the water depth at the unit scale considered (e.g. mesh size for remote sensing data, inundation model data, and political unit scale) translate as the water depth at the household scale?
- o Can the water depth be considered as homogeneous at the calculation unit scale?
- o In other words, can the house distribution be considered as homogeneous at the calculation unit scale? (Usually there are more houses in places less subject to flood)
- o How representative are the socio-economical characteristics of the surveyed households for greater political units such as provinces or even at national level?
- o How to use population density data from one scale to a smaller scale? How to distribute the population into a smaller scale? For example, for LANDSCAN data, population density at 30 seconds is available; therefore, how the 30 seconds cell/grid population density data can be utilized to understand the distribution of the housing at smaller scale or at bigger scale?

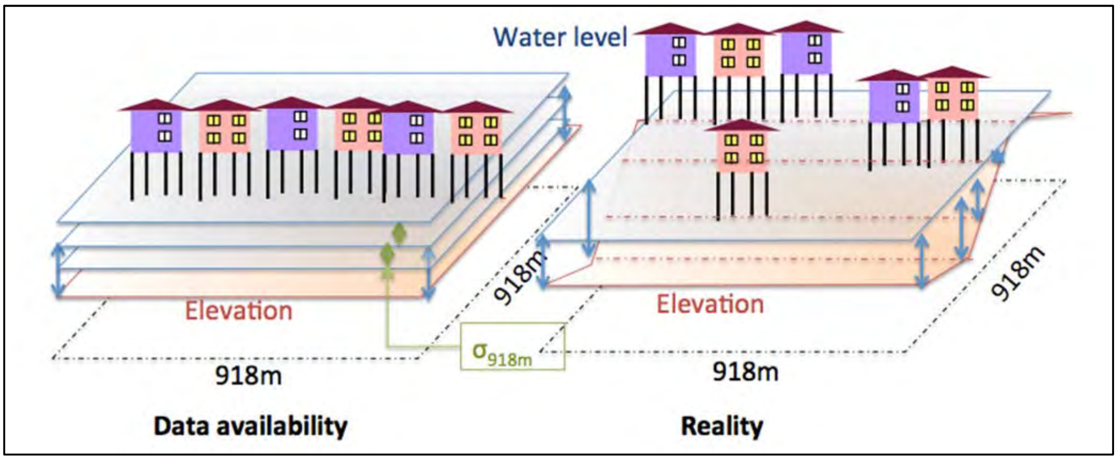

Figure A3.1: House Distributions According to Micro-Topography (e.g. considering upscale from 3 seconds to 30 seconds grid)

Figure A3.1 shows the house distributions according to micro-topography. The spatial unit considered for house damages calculation was set to 30 seconds. Therefore, this method consists in calculating house damages as a function of average year maximum flood water depth (h). Moreover, damage curves are usually differentiated according to socio-economic factors. They can either be a relationship between damage ratio and water depth or damage (currency) and water depth. The general house damage equation for cell k is described as follows:

$$HD_k = N_k \cdot \int_{h_i=h_k}^{\infty} f(h_i)\ dh_i \cdot \left\{ \sum_{j=1}^{n} s_j . DamageCurve(h_i, So_j) + \sum_{j=1}^{n} (1 - s_j). DamageCurve(h_i, 1 - So_j) \right\}$$

where,

N_k: total number of houses in cell k
h_i : water depth at i
f(x): probability density function for houses distribution according to x(h)
s_j: proportion of the houses according to socio-economic factor So_j
DamageCurve(h_i, So_j): unit damage at h_i for houses according to socio-economic factor So_j.

Data Availability for Residential (House) Damages Calculation

Residential damages' assessment was based on FMMP household survey of 2008 concerning 2006 flood used in FMMP C2 component project (FMMP, 2010). The survey was conducted in 262 villages among 7 communes in 3 districts in 3 provinces.

Figure A3.2: Max Water Depths Measured from Inside the House or from the Yard

The specific data considered from FFMP household survey:

- Max water depth in the yard (m) (refer to Figure A3.2)
- Max water depth in the house (m) (refer to Figure A3.2)
- The total amount of assets damaged and equals to the sum of damages to the house, to structures, to furniture, to goods, to vehicles.
- Potential damages if water depth had been more than 0.5m, 1.0m, 1.5m,

2.0m than 2006 flood depth (Figure A3.3).

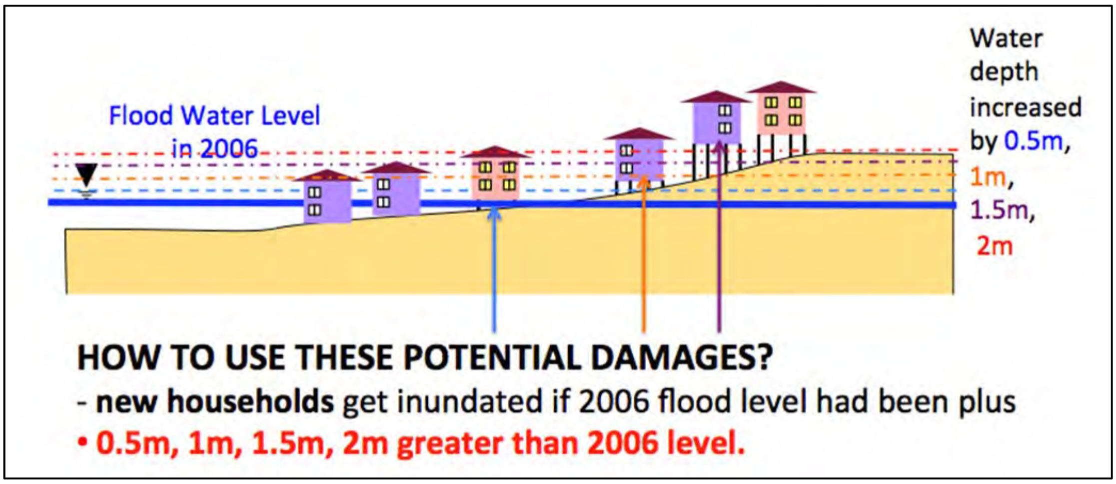

Figure A3.3: Potential Damages if Water Depth Was 0.5 m, 1.0 m, 1.5 m or 2.0 m Higher than in 2006

The outputs of this household survey are:

- The average number of people constituting one household
- A damage curve linking residential damages and maximum water depth in the yard (actual damages and depth following 2006 flood and potential damages estimations).
- The distribution of the houses/house value according to water depth.

Box A2.1 General assumptions for residential damages estimations

Assumptions box:

- Household is the unit considered. And one household lives per house i.e. one house equal to one household.
- Water depth is calculated as the difference between the actual flood level minus the elevation is considered as the water depth in the yard of the household.
- Houses number and house value distributions according to water depth, indeed they are more expensive houses where water depth is low in an average year.

Calculation of House Damages for 30 seconds Mesh on Cambodian Floodplain

For each 30 second mesh in the province of Prey Veng, Kandal and Takeo, residential damages were calculated with the following approximations in addition to the assumptions from Box A2.1 for the general model:

One unique damage curve without differentiation according to socio-economic factors:

- Because of the limitations of the dataset, it was decided that differentiating

damage curves according to socio-economic factors was not adequate. For example while considering house type, one of the categories was missing in the households surveyed; there was no sample of permanent houses. Thus, differentiating damage curves according to housing type (temporary, semi-permanent, permanent) as usually done in the literature (Meyer & Messner, 2005) was not appropriated.

- The damage curve utilized was calculated by integrating both actual damages estimated after 2006 flood, being the average year flood level, and potential damages estimates in case 2006 flood had been 0.5m, 1.0m, 1.5m and 2.0m greater. While aggregating both actual damages and potential damages, it is important to consider how much damage occurred as a consequence of relative variation of water depth (in this survey every 0.5m) and not think in terms of absolute water depth.
- In particular, for a house, which has not been flooded in 2006 but would have been if water depth in 2006 had been 0.5m greater, the damages that would have occurred are the result of a 0.5m water depth and not 2006 water depth+0.5m (Table A3.1, total damages resulting from water depth under 0.5m are the sum of the damages in the green frames). Then, if we want to calculate ***Damage ratio*** relative to water depth under 0.5m, the Total House Value (Table A3.1, total house value subject to water depth under 0.5m is the sum of the house values in the blue frames) is the ratio weighted by the number of observation for each category of damages:
- $N_{2006Loss}$, the number of households which suffered damages in 2006, $N_{+0.50}$, the number of households which would have suffered damages in 2006 if water depth had been 0.50 m higher than in 2006, $N_{+1.00}$, the number of households which would have suffered damages in 2006 if water depth had been 1.0 m higher than in 2006, $N_{+1.50}$, the number of households which would have suffered damages in 2006 if water depth had been 1.50 m higher than in 2006 and $N_{+2.00}$, the number of households which would have suffered damages in 2006 if water depth had been 2.0 m higher than in 2006; and damage ratio is described as follows.

$$DamageRatio = \frac{N_{2006Loss} * 2006Loss + N_{+0.50} * Damages_{+0.50} + \dots + N_{+2.00} * Damages_{+2.00}}{(N_{2006Loss} + N_{+0.50} + N_{+1.00} + N_{+1.50} + N_{+2.00}) * Total\ HV_{+0.50}}$$

(Figure A3.4, the red frame corresponds to the damage ratio value for water depth under 0.5m.)

- By repeating the same procedure, it was possible to calculate the damage ratio corresponding to water depths between 0.50m and 1.0m (Table A3.1 and Figure A3.4 orange frames), damage ratio corresponding to water depths between 1.0m and 1.5m (Table A3.1 and Figure A3.4 purple frames etc).

Table A3.1: Compilation of Data on House Value (HV), Damages Estimates After 2006 Floods (2006 Loss), and Potential Damages if 2006 Flood Had Been 0.5, 1.0, 1.5 or 2.0 m Higher than in 2006

	HV	2006Loss	+0.50	+1.00	+1.50	+2.00
-2.25	1.45×10^{7}	0	0.	0.	0.	0.
-1.75	1.72×10^{7}	0	0.	0.	0.	1.2×10^{6}
-1.25	1.01×10^{8}	0	0.	0.	7.15×10^{6}	9.15×10^{6}
-0.75	1.755×10^{8}	0	0.	1.05×10^{7}	2.64×10^{7}	4.18×10^{7}
-0.25	7.7×10^{7}	0	7.1×10^{6}	1.16×10^{7}	1.55×10^{7}	1.86×10^{7}
0.25	2.4405×10^{8}	4.551×10^{6}	7.558×10^{6}	1.8925×10^{7}	3.8938×10^{7}	7.68×10^{7}
0.75	3.3046×10^{8}	8.445×10^{6}	2.1076×10^{7}	3.7735×10^{7}	7.1282×10^{7}	1.0934×10^{8}
1.25	1.835×10^{8}	6.022×10^{6}	1.472×10^{7}	2.63×10^{7}	4.9775×10^{7}	6.9665×10^{7}
1.75	7.24×10^{7}	7.391×10^{6}	1.045×10^{7}	1.235×10^{7}	2.68×10^{7}	4.11×10^{7}
2.25	3.99×10^{7}	1.336×10^{6}	1.913×10^{6}	2.333×10^{6}	8.186×10^{6}	9.706×10^{6}
2.75	6.54×10^{7}	8.596×10^{6}	1.315×10^{7}	1.615×10^{7}	2.48×10^{7}	4.48×10^{7}
3.25	1.2578×10^{8}	1.0322×10^{7}	1.945×10^{7}	2.777×10^{7}	5.311×10^{7}	6.137×10^{7}
3.75	$9.\times10^{6}$	550000.	1.5×10^{6}	1.5×10^{6}	$5.\times10^{6}$	5.5×10^{6}
4.25	$9.\times10^{6}$	912000.	1.25×10^{6}	2.65×10^{6}	3.8×10^{6}	5.8×10^{6}
4.75	0	0	0	0	0	0
5.25	0	0	0	0	0	0
5.75	0	0	0	0	0	0
6.25	0	0	0	0	0	0
6.75	0	0	0	0	0	0
7.25	0	0	0	0	0	0
7.75	0	0	0	0	0	0
8.25	1.625×10^{7}	400000.	600000.	600000.	$1.\times10^{6}$	$1.\times10^{6}$

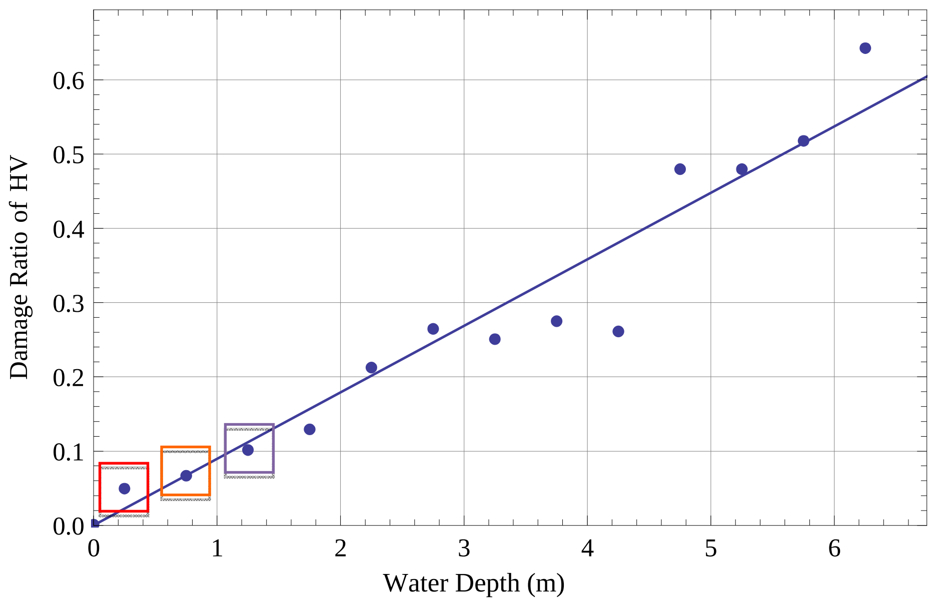

Figure A3.4: Damage Curves Calculated from Actual Damages after 2006 Flood and Potential Damages that Would Have Occurred if 2006 Water Depth Had Been 0.5 m, 1.0 m, 1.5 m and 2.0 m Higher

Gamma distribution for house value distribution according to water depth for all provinces:

- It was assumed that population distribution in all cell in Cambodian floodplain

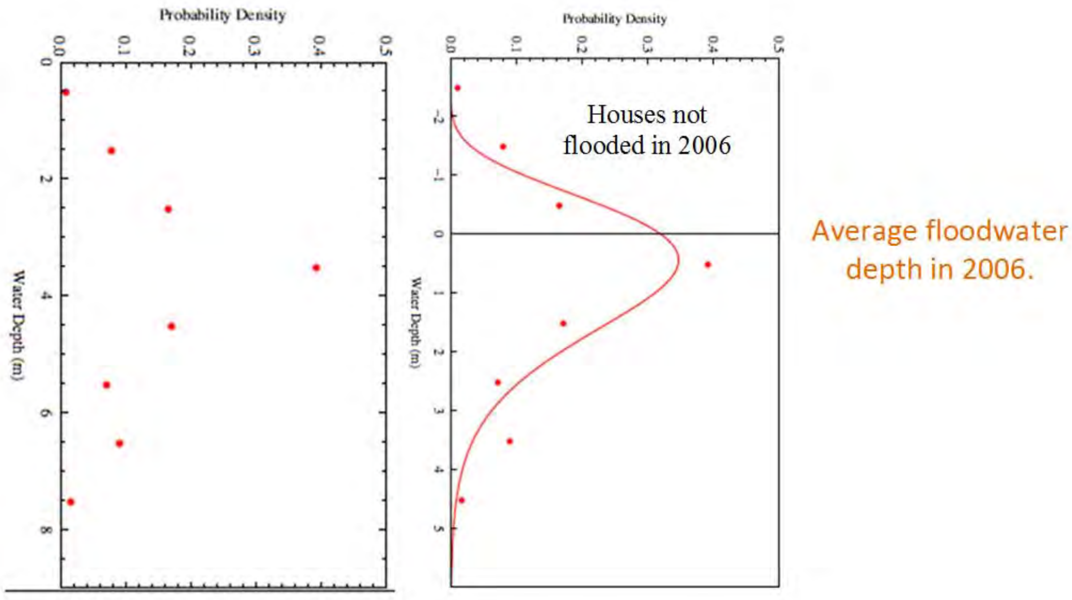

Figure A3.5: House Value Distribution According to Water Depth in the Yard and 2006 Flood

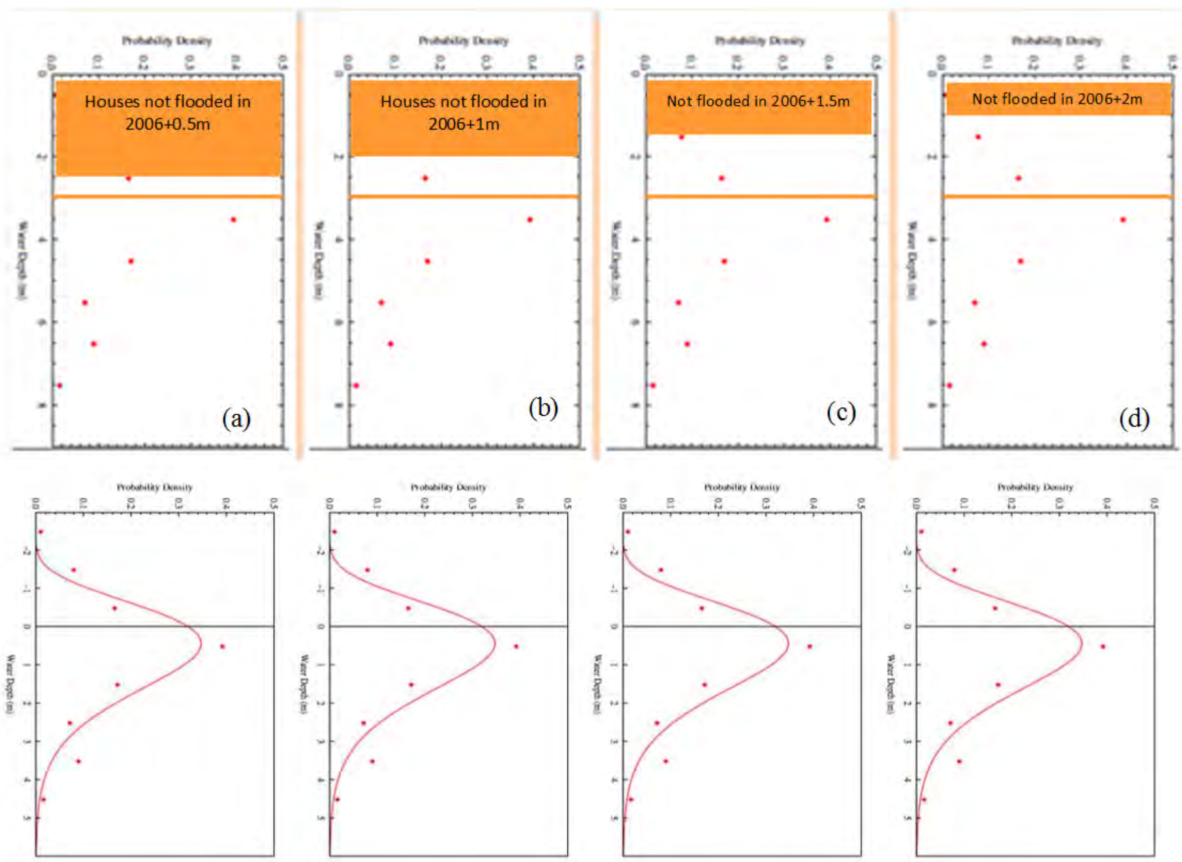

Figure A3.6: House Value Distributions According to Potential Water Depth in the Yard (in orange line is the average flood water depth in 2006 or in an average year) if Water Depth Had Been 0.5 m (a), 1.0 m (b), 1.5 m (c) and 2.0 m(d) Higher than in 2006.

will fit a gamma distribution.

- First, Figure A3.5 shows the inundated houses' values distribution according to floodwater depth for 2006 flood. The red dots show the aggregated inundated houses values per 0.5m water depths.
- Second, as it was asked to each household surveyed what would be the estimated damages if flood water depth had been 0.5m, 1.0m, 1.5m and 2.0m higher than in 2006, it was possible to also distribute inundated houses values per additional 0.5 water depths (Figure A3.6).
- Third, it was possible to fit a <u>gamma distribution</u> to the distribution of inundated house values according to water depth measured in the yard (Figure A3.6, Figure A3.7).

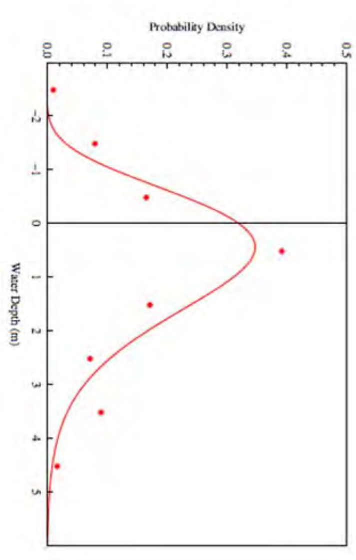

Figure A3.7 Gamma distributions fitted to house value distribution according to water depth

- There is a need to approximate house value distribution for every cell/grid of the Cambodian floodplain. And population distribution is not homogeneous over the whole province, i.e. not only at the calculation scale unit; there are some unit cells with more people and some with less. Therefore, the distribution of the houses present in those cells might be different from the one adjusted to the surveyed house distribution data. Moreover, the number of houses in the considered spatial unit is influenced by house value distribution. But this approximation of considering a unique house distribution function per water depth should be counterbalanced by the heterogeneity in the total number of houses distribution.
- In order to account for those heterogeneities, as water depth data from 3 seconds (100cells) are up-scaled to 30 seconds both the mean of the 100 water depths at 3 seconds (h) and the standard deviation (σ), resulting are calculated during the up scaling process.
- Then, by exploiting Gamma distribution property; i.e. the relationship between the distribution parameters (α, β) and the mean and standard deviation, (refer to

Box A2.2, Figure A3.8), a specific Gamma distribution was fitted for each 30 seconds cell for house value distribution.

Box A2.2 Properties of gamma distributions

Gamma distribution property:

- The Gamma distributions considered here are the 2-parameter continuous probability distributions. It has a shape parameter α and an inverse scale parameter β, called a rate parameter.
- The probability density function can be parameterized in terms of this shape parameter α and this rate parameter β:

$$g(x;\alpha,\beta) = \beta^{\alpha}\frac{1}{\Gamma(\alpha)}x^{\alpha-1}e^{-\beta x} \text{ for } x \geq 0 \text{ and } \alpha,\beta > 0$$

- The Gamma distribution also presents the following properties:

$$\bar{h} = \alpha.\beta \text{ and } \quad \sigma^2 = \alpha.\beta^2$$

$$\Leftrightarrow$$

$$\alpha = \left(\frac{\bar{h}}{\sigma}\right)^2 \text{ and } \beta = \frac{\sigma^2}{\bar{h}}$$

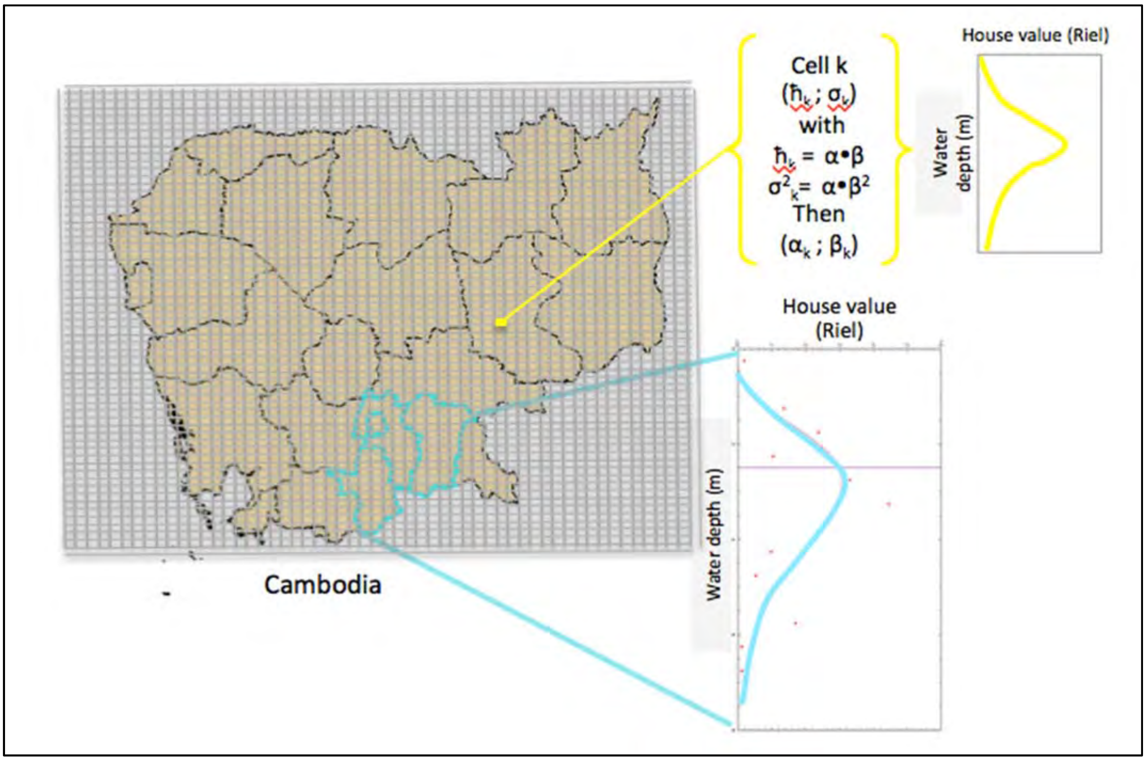

Figure A3.8: Rationales behind Fitting a House Value Distribution for Each Grid of 30seconds in the Cambodian Floodplain from House Value Distribution for the Three Provinces Surveyed in 2008

- The residential damage, HD_k equation for 30 seconds mesh cell k is calculated.

The residential damage equation for cell k for the whole Cambodian floodplain is described as follows:

$$HD_k = N_k \cdot HV \int_{h_i=h_k}^{\infty} \left(g(x,\alpha,\beta) \cdot DamageRatio(h_i)\right) \cdot dh_i$$

where,

N_k: total number of inhabitant in cell k
HV: average house value per inhabitant (US$/person)
h_i : water depth at i
g(x, α, β): gamma distribution probability density function for houses value distribution according to x(h)
Damage Ratio (h_i,): unit damage at h_i

The used house value per person is US$ 245 which was determined based on household survey data for 2006 flood from FMMP project for FMMP (2010). People living in Cambodian floodplain often experienced average flood. So, they construct elevated houses by using stilts which floor height of houses is higher than average flood level or they constructed at higher elevation than average flood level to avoid flood damages. Thus, house damages are calculated only for water level higher than average flood level.

Appendix 4: Maps of Some Provinces in Commune Level

Water Depth and Social Information

Prey Veng Province:

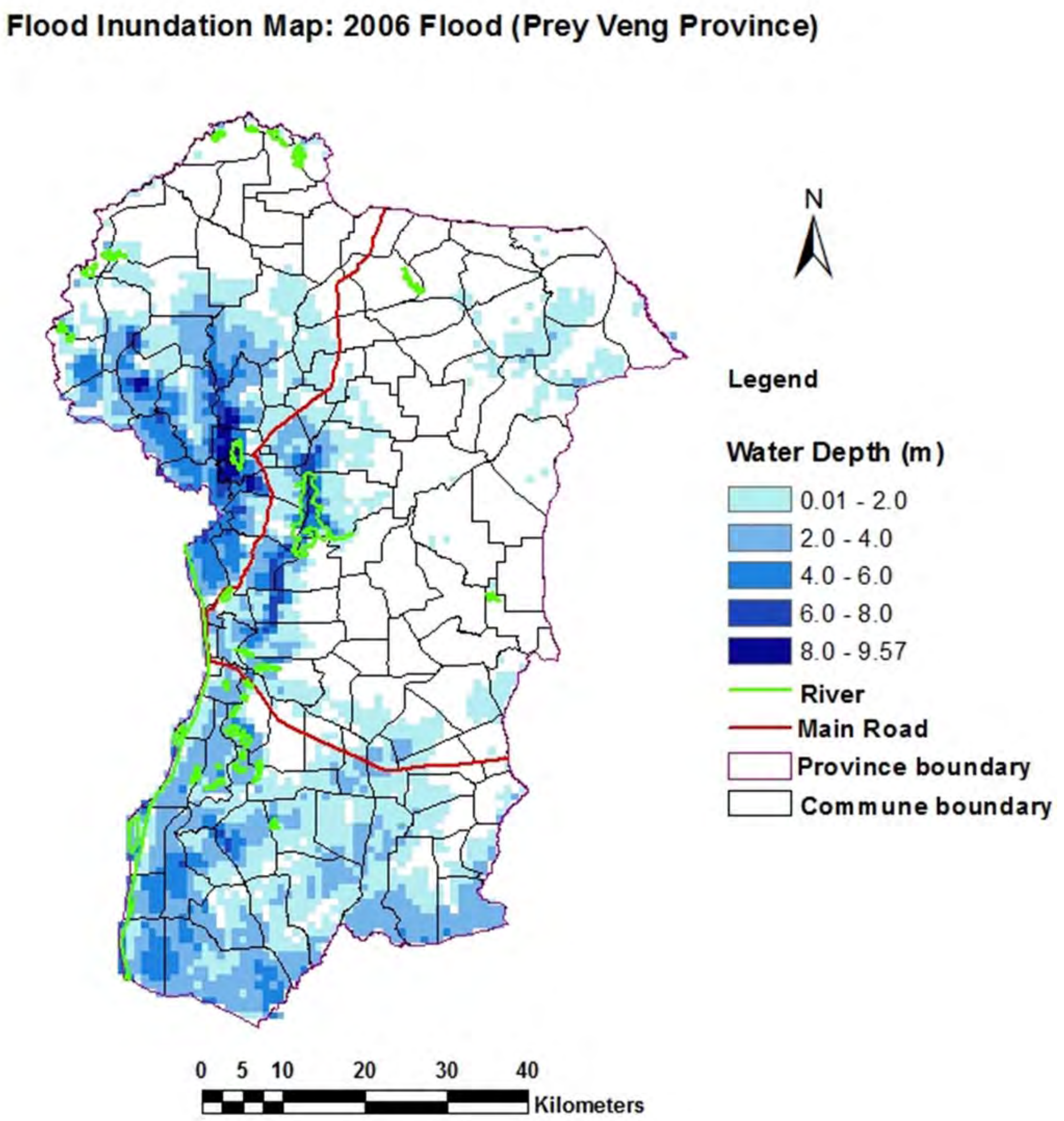

Figure A4.1: Flood Inundation Map of Prey Veng Province for 2006 flood (commune level map)

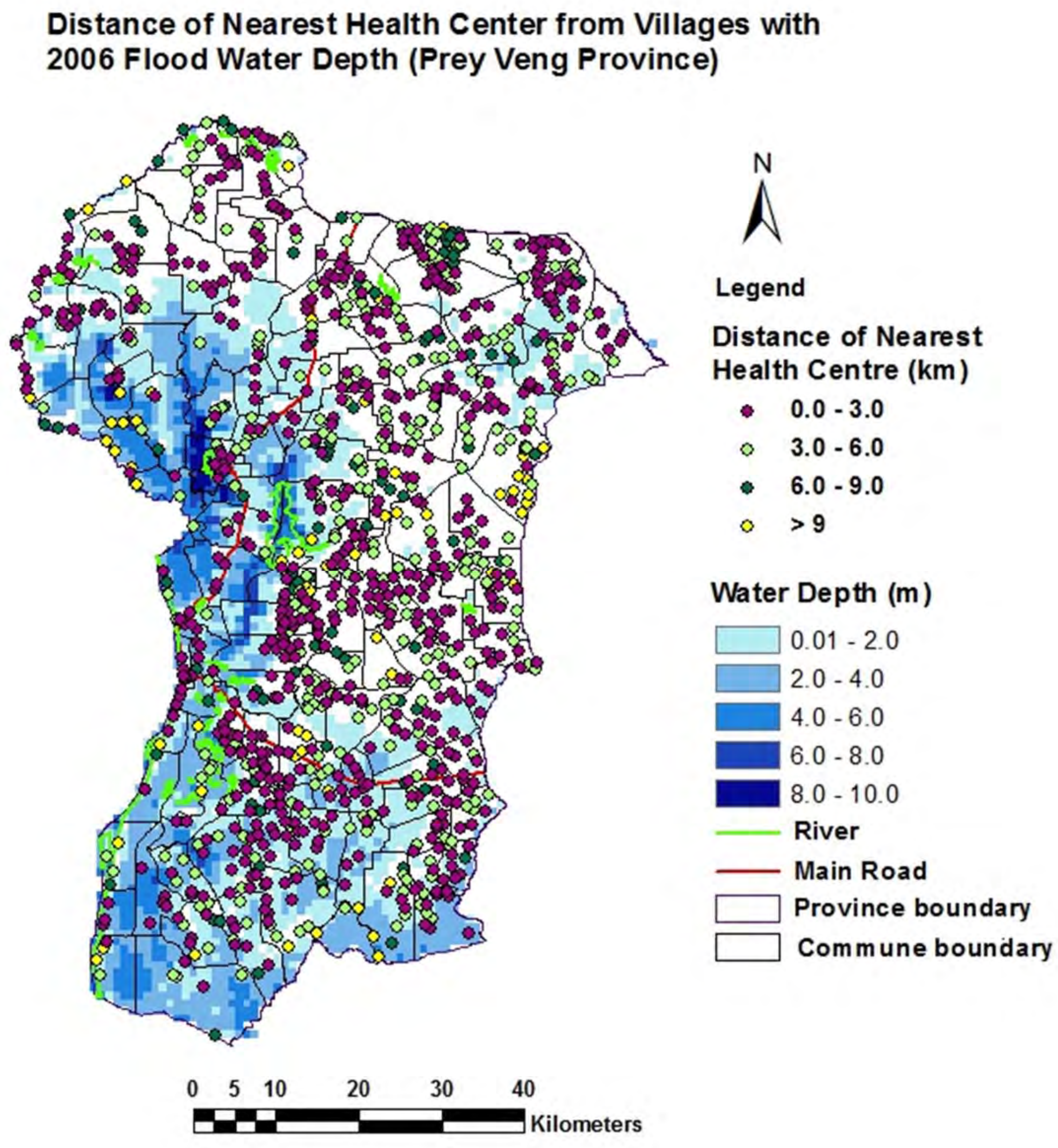

Figure A4.2: Village Center and Distance of Nearest Health Center from Villages in Prey Veng Province (commune level map)

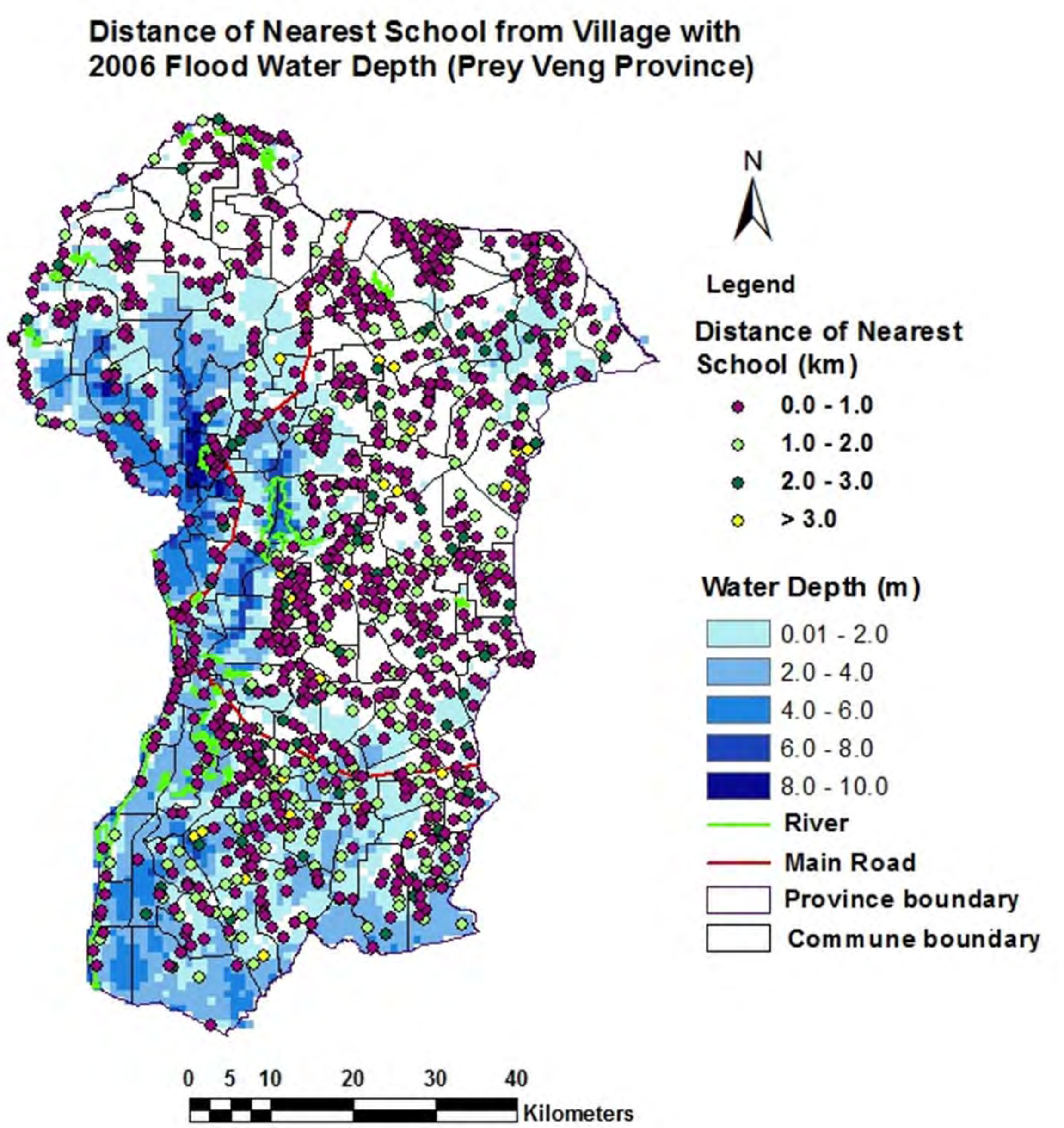

Figure A4.3: Village Center and Distance of Nearest School from Villages in Prey Veng province (commune level map)

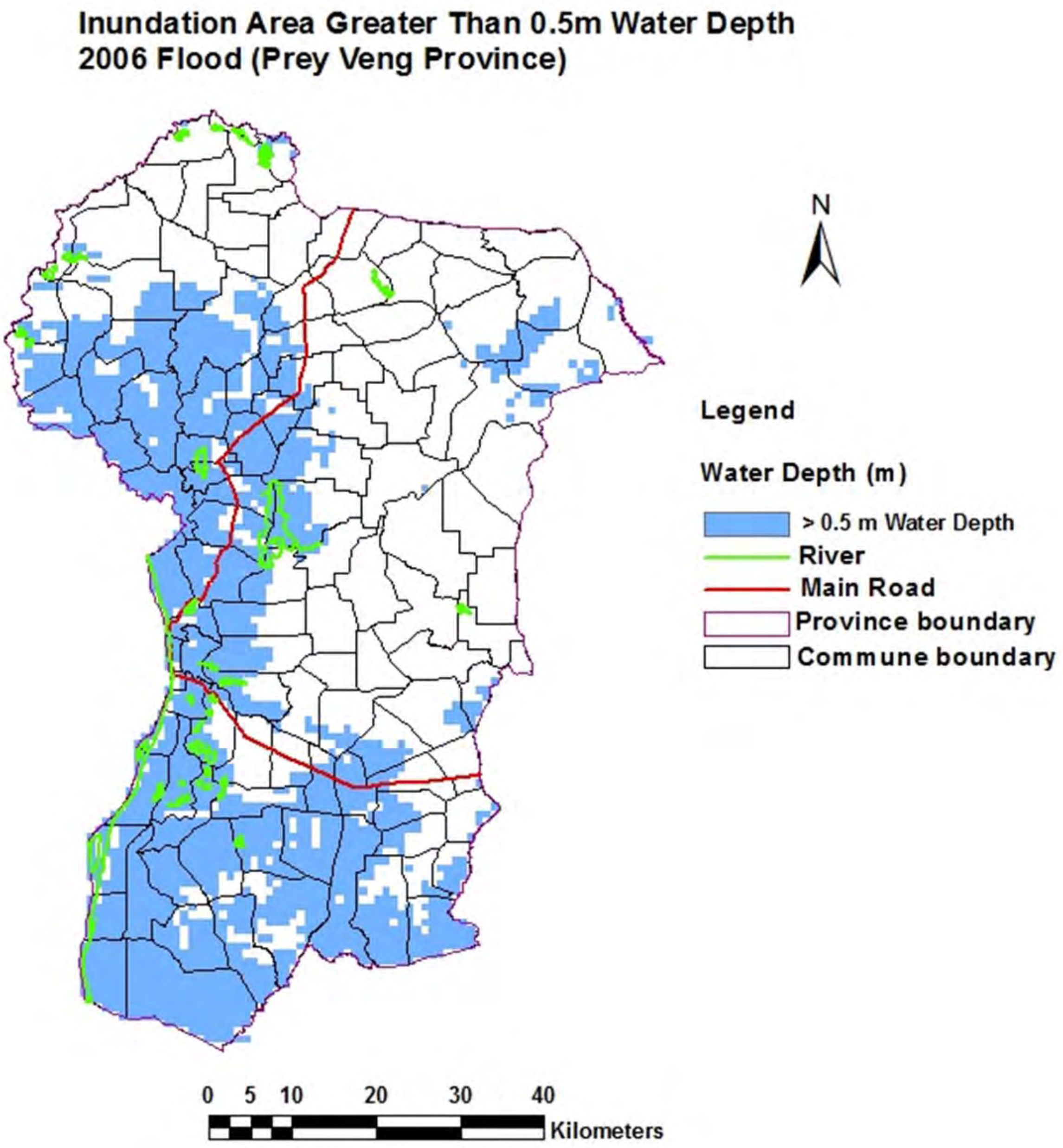

Figure A4.4: Flood Inundation Area Greater than 0.5 m Water Depth in Prey Veng province (commune level map)

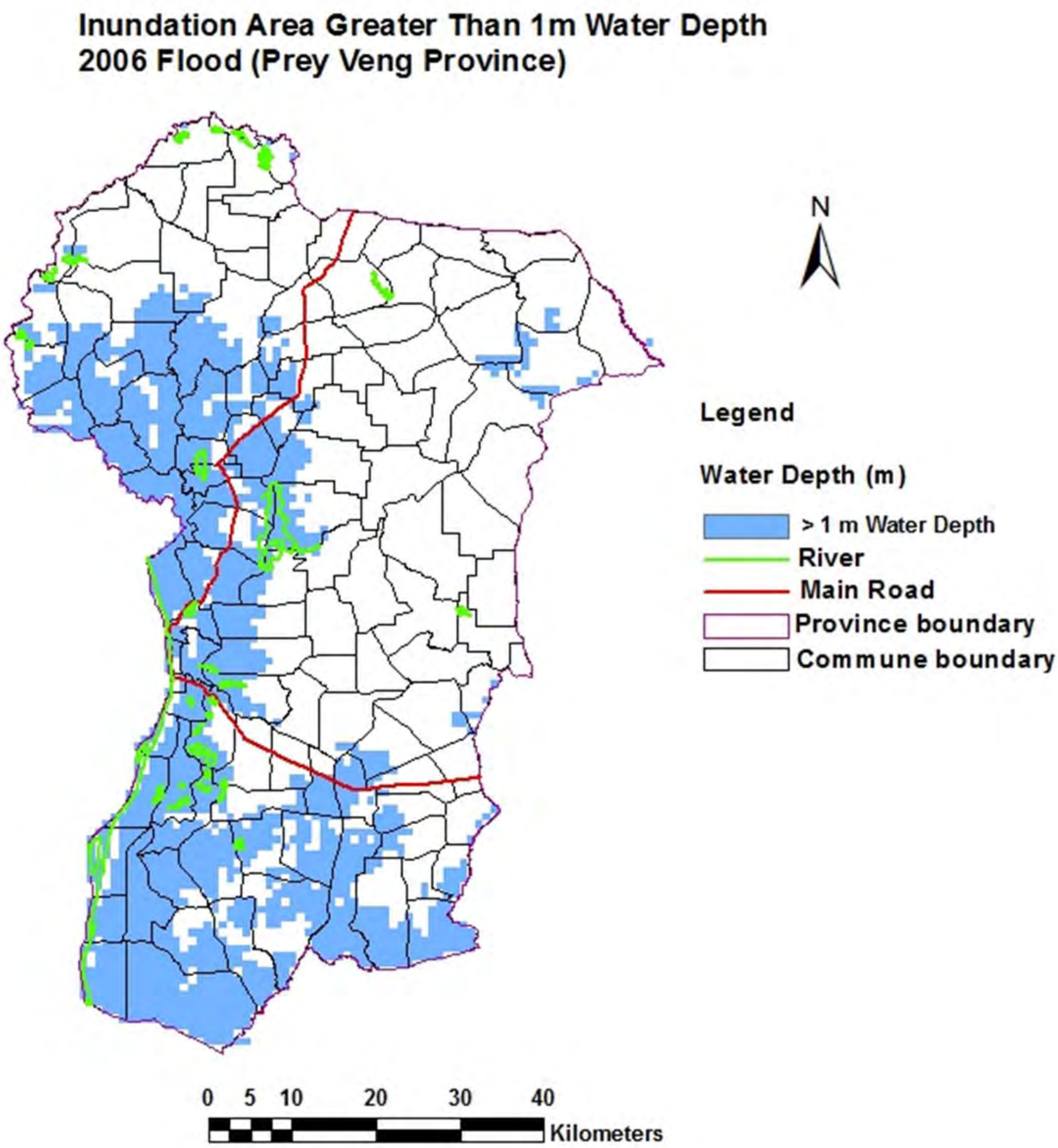

Figure A4.5: Flood Inundation Area Greater than 1.0 m Water Depth in Prey Veng province (commune level map)

Takeo Province:

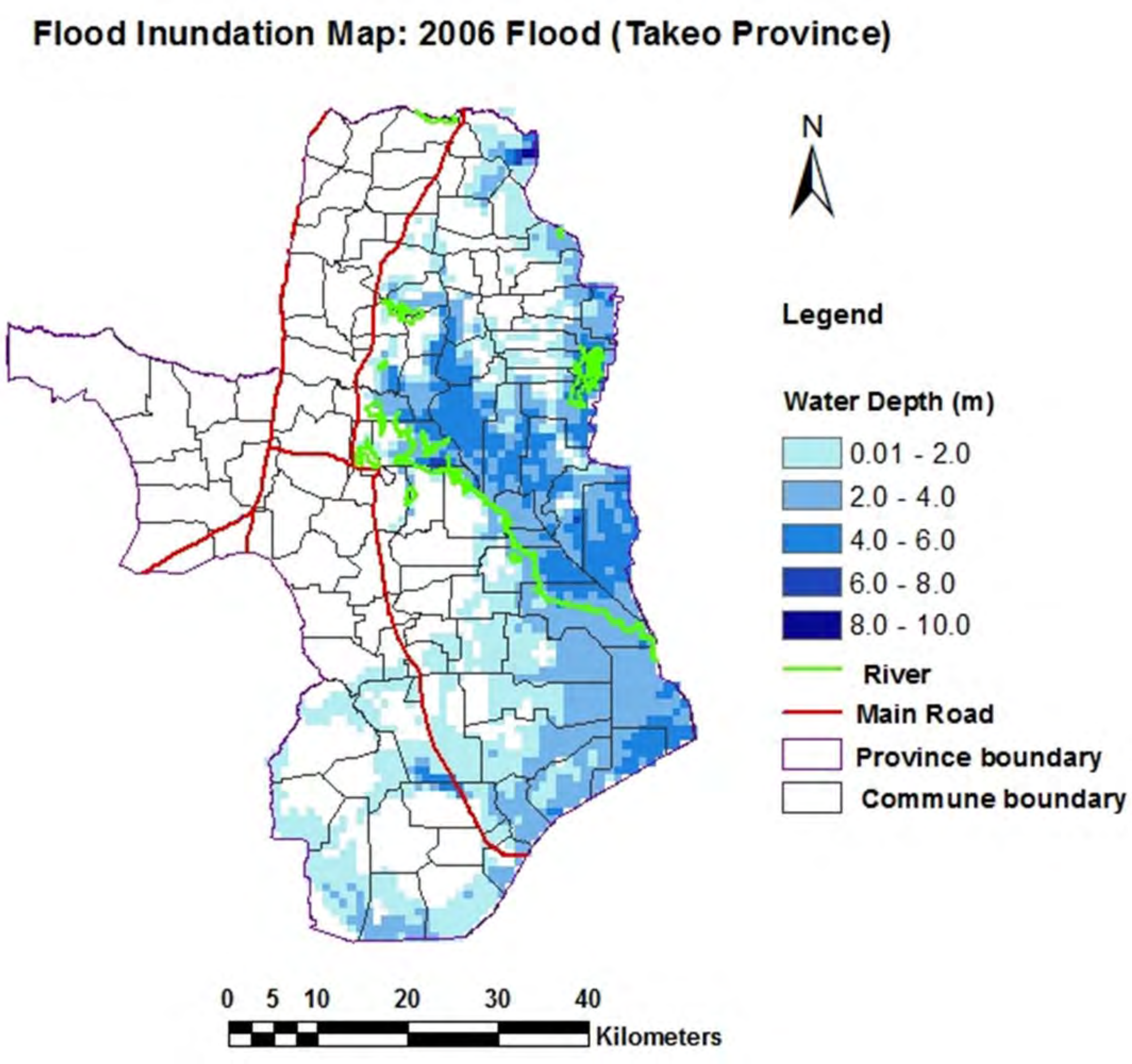

Figure A4.6: Flood Inundation Map of Takeo Province for 2006 flood (commune level map)

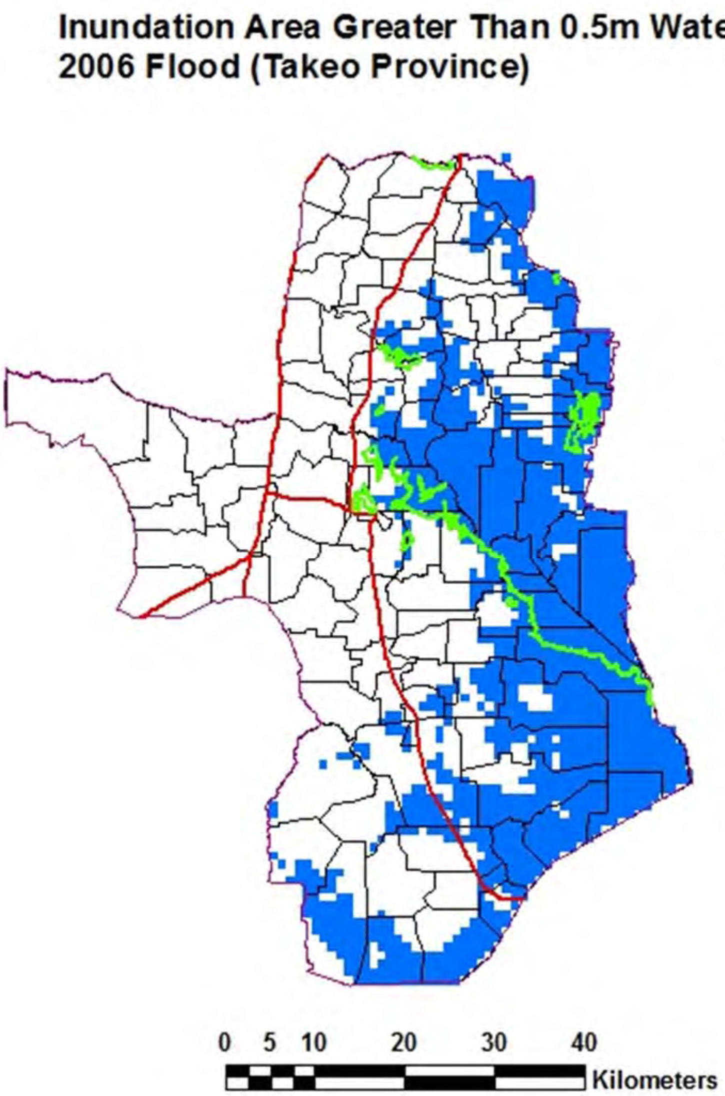

Figure A4.7: Flood Inundation Area Greater than 0.5 m Water Depth in Takeo Province (commune level map)

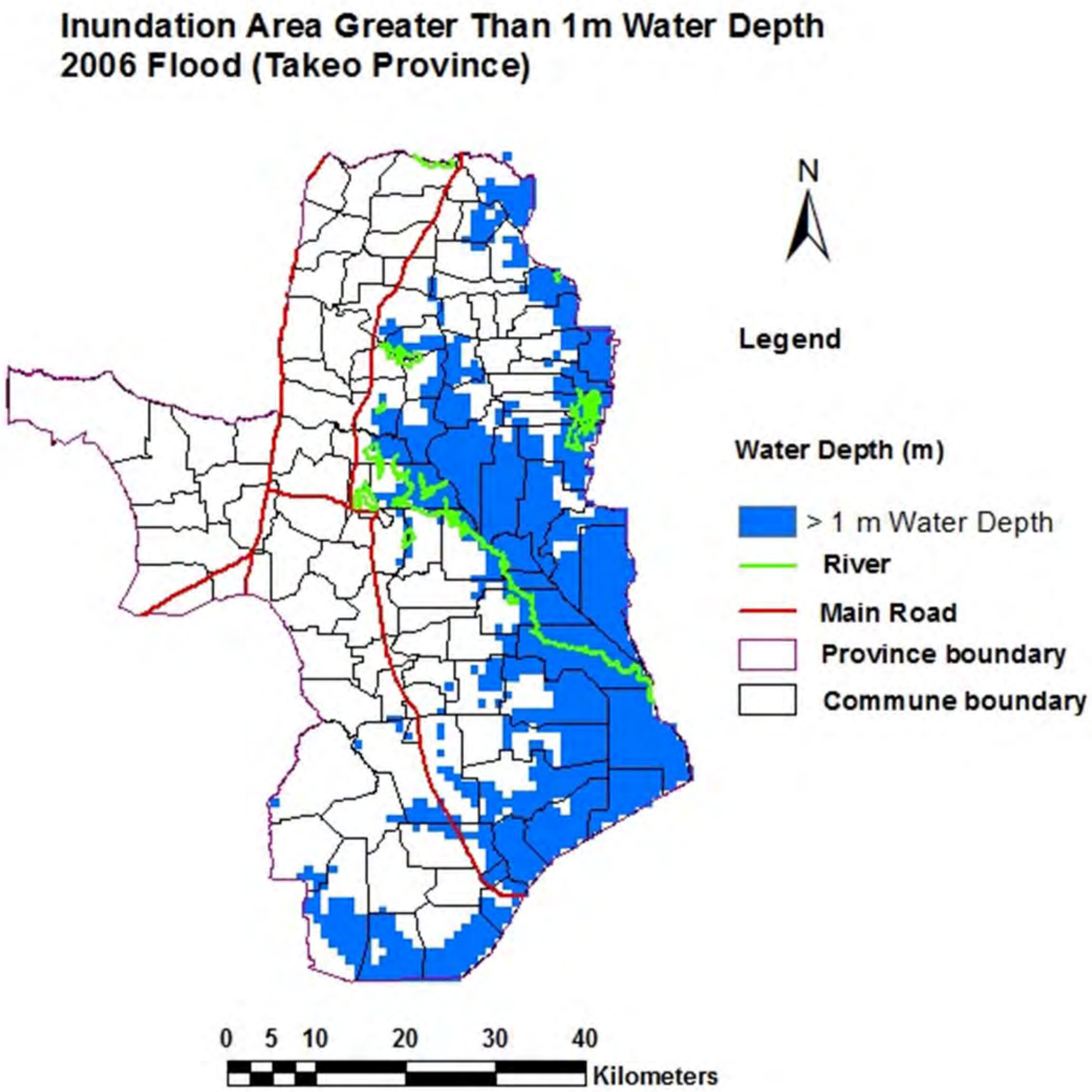

Figure A4.8: Flood Inundation Area Greater than 1.0 m Water Depth in Takeo Province (commune level map)

Agricultural Damages and FVI of Agricultural Damages: *Prey Veng Province*

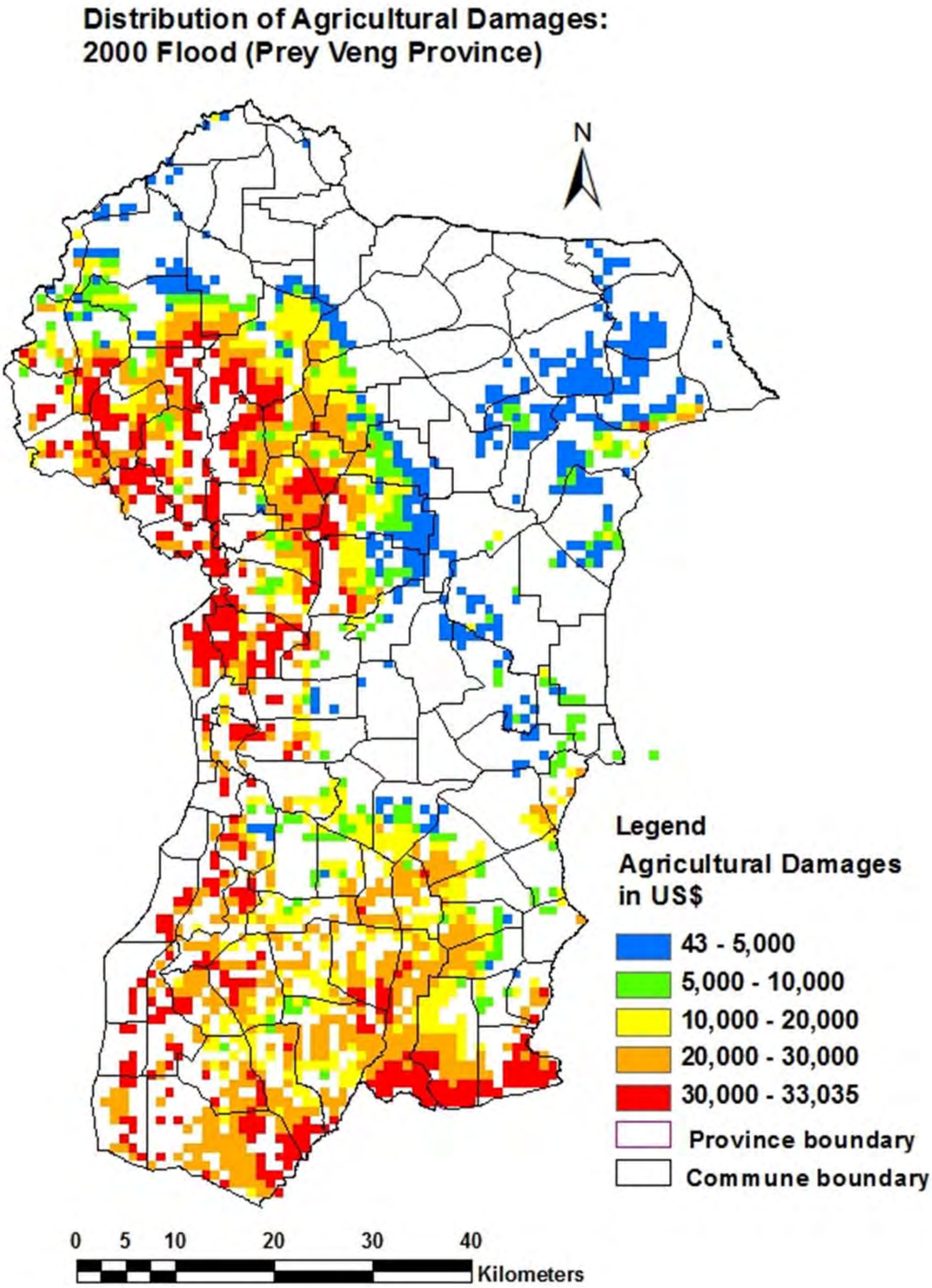

Figure A4.9: Distribution of Agricultural Damages in Prey Veng Province in 2000 Flood

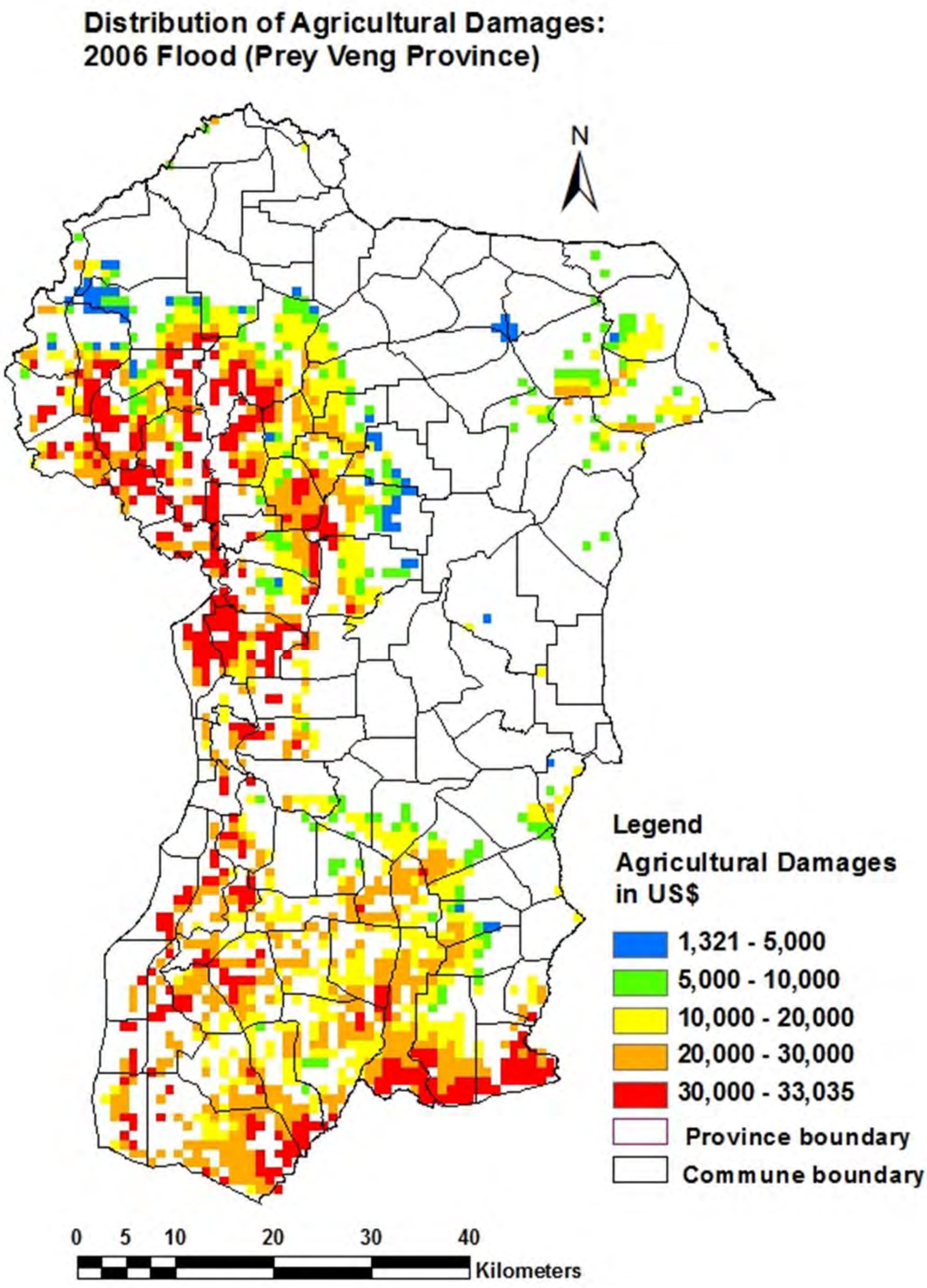

Figure A4.10: Distribution of Agricultural Damages in Prey Veng Province in 2006 Flood

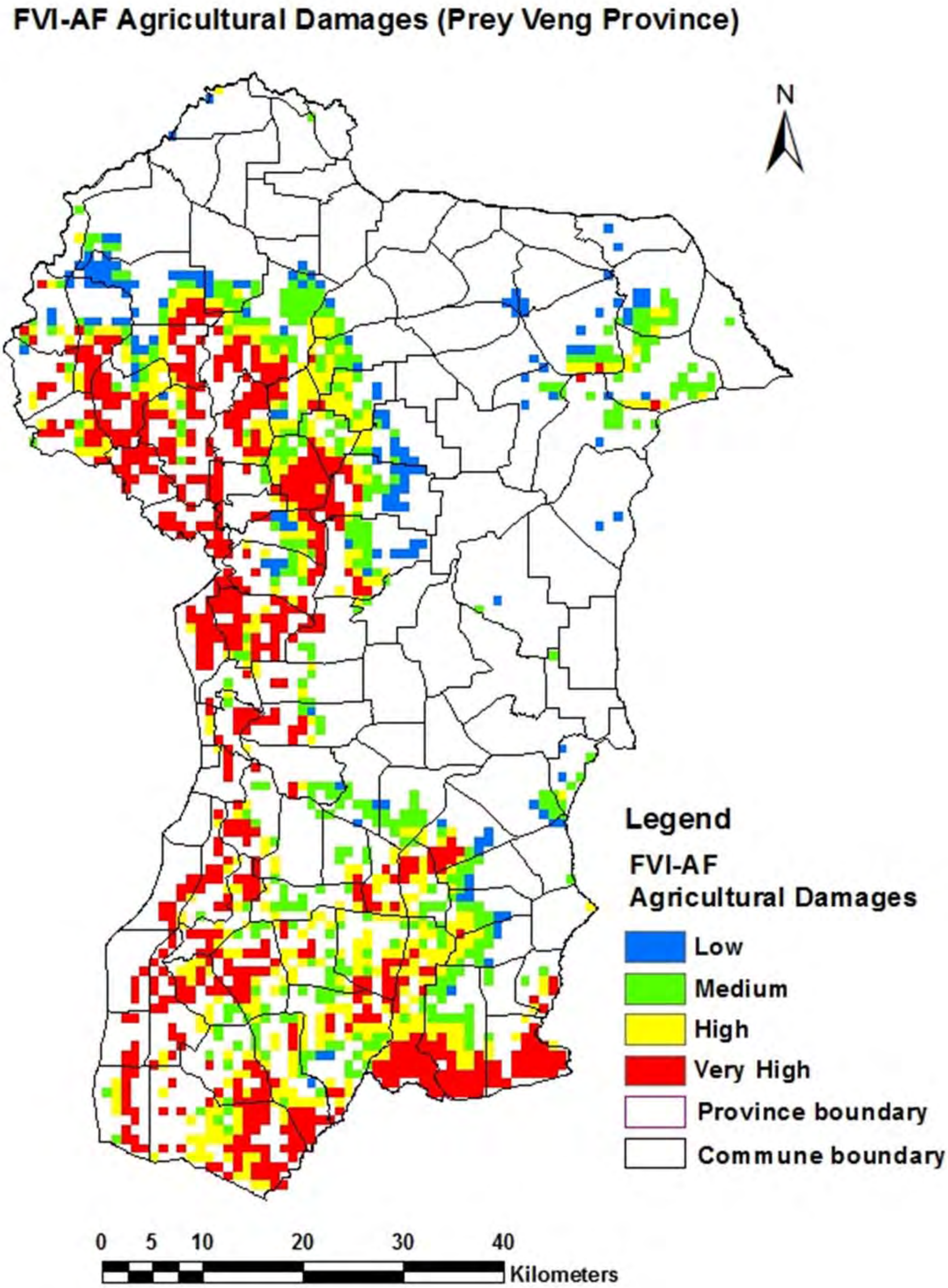

Figure A4.11: FVI-AF for Agricultural Damages in Prey Veng Province

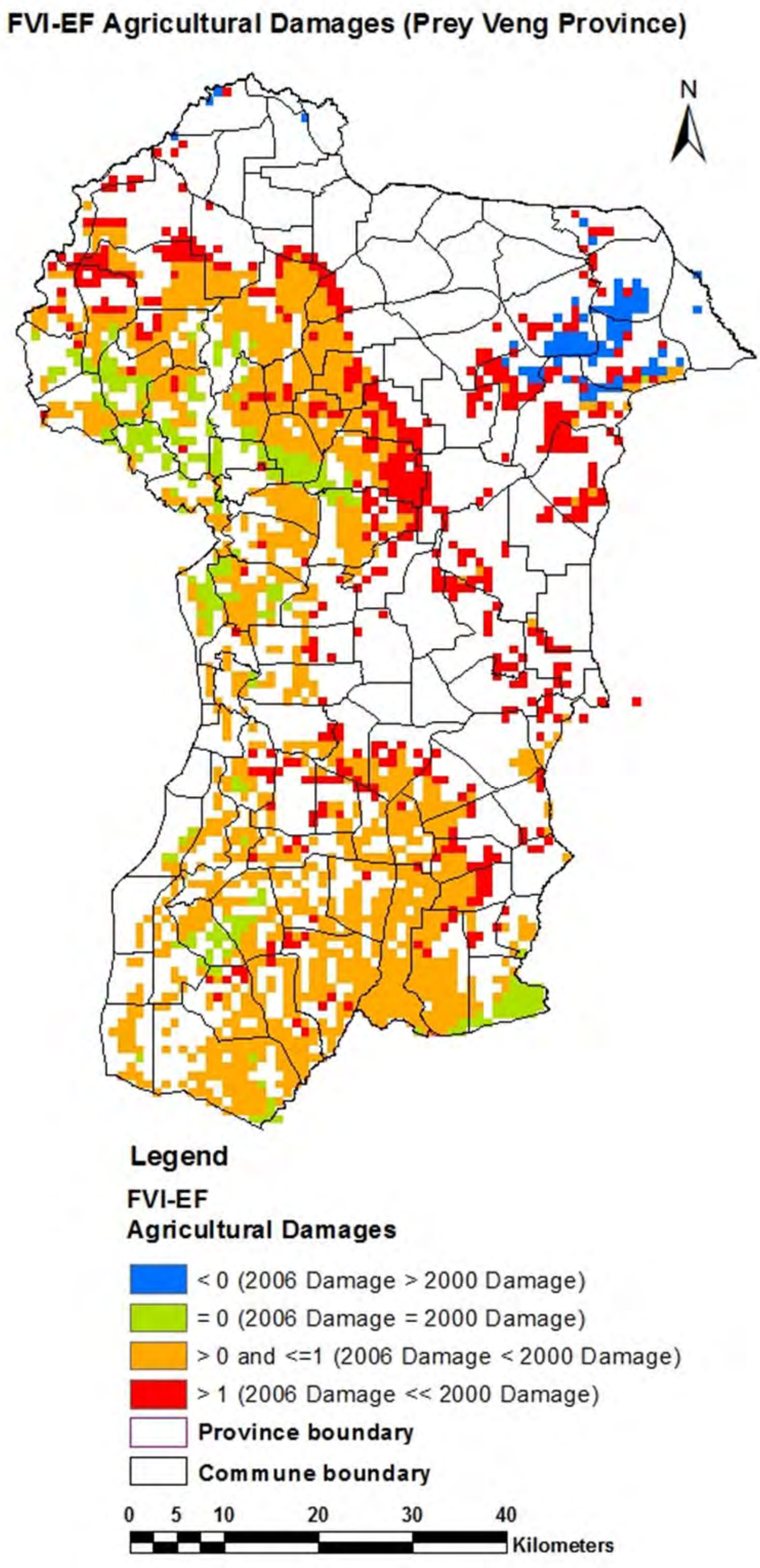

Figure A4.12: FVI-EF for Agricultural Damages in Prey Veng Province

House damages and FVI of house damages: *Prey Veng Province*

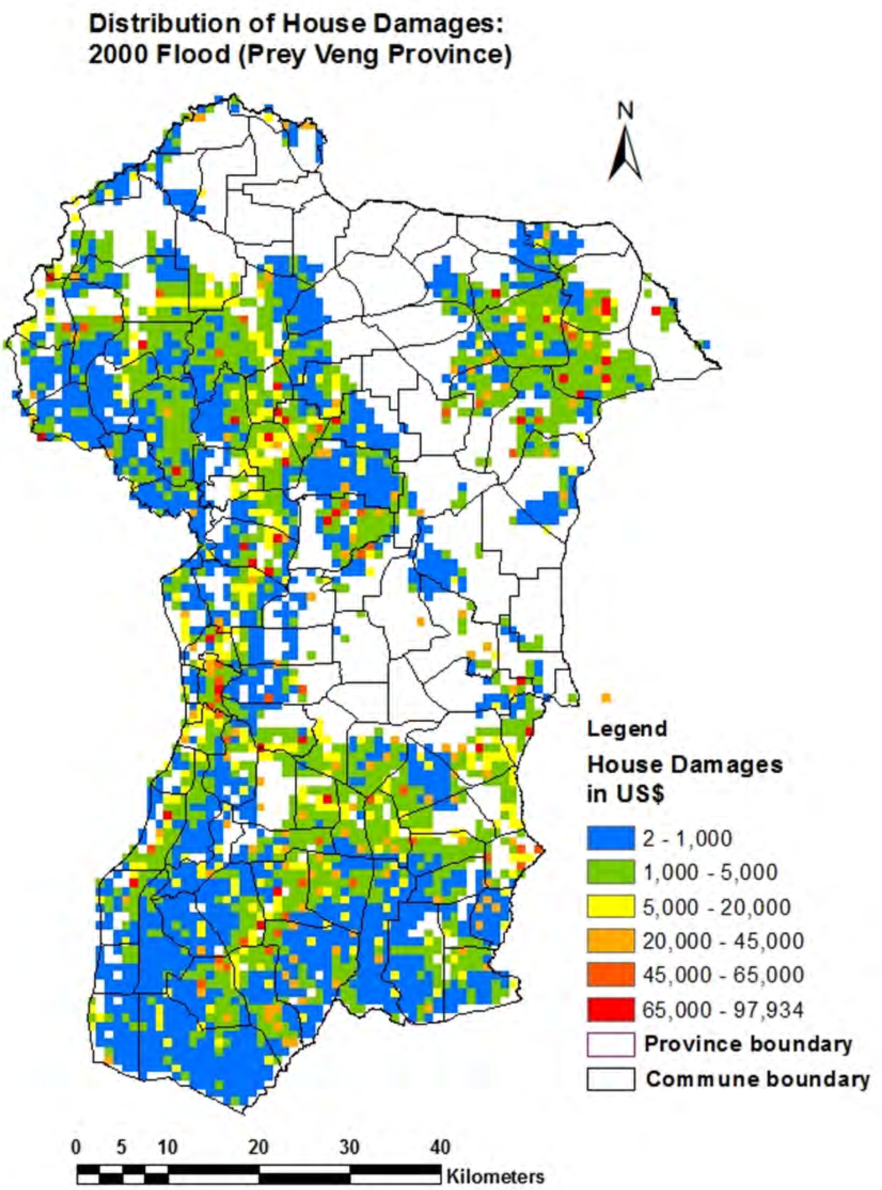

Figure A4.13: Distribution of House Damages in Prey Veng Province in 2000 Flood

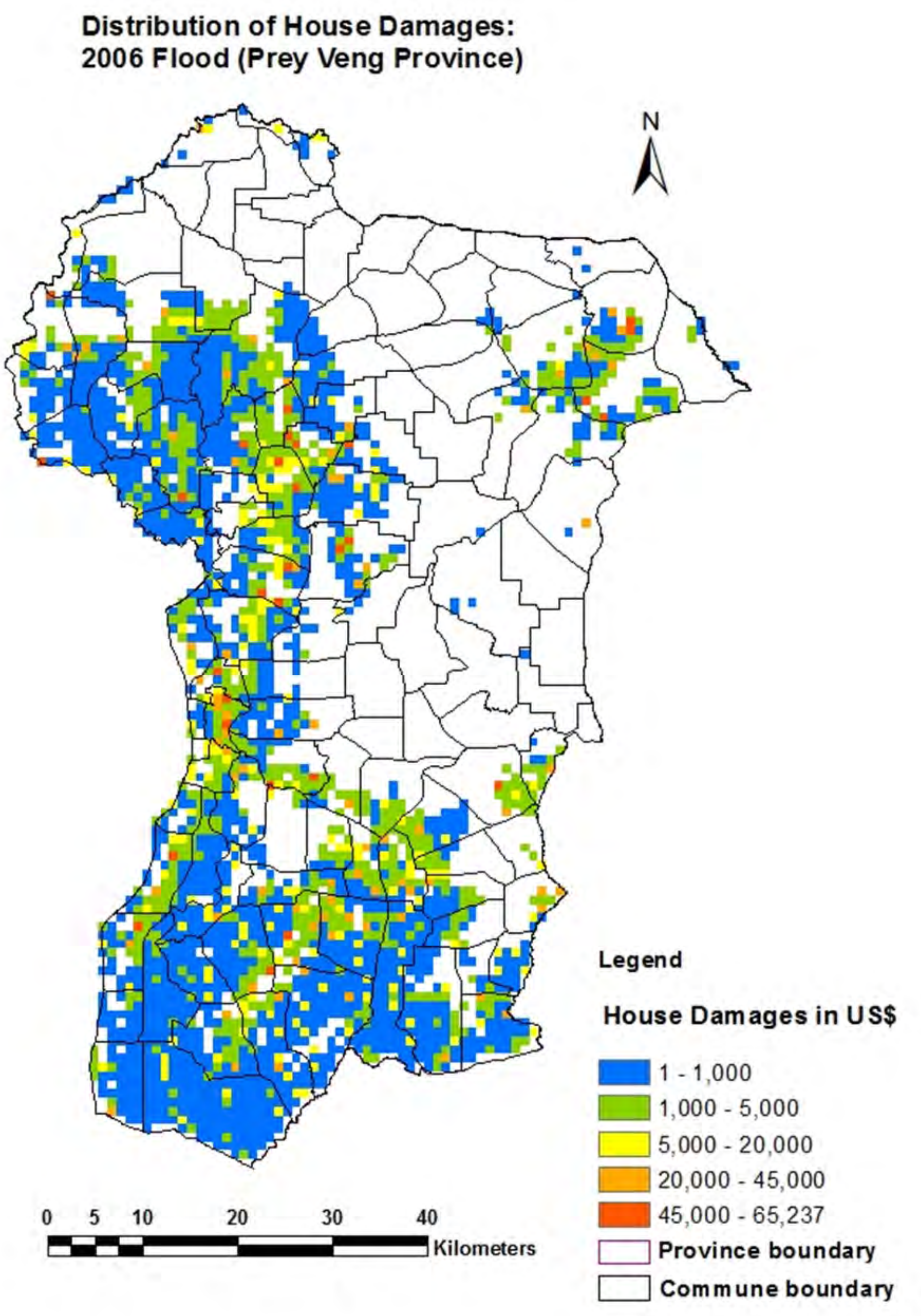

Figure A4.14: Distribution of House Damages in Prey Veng Province in 2006 Flood

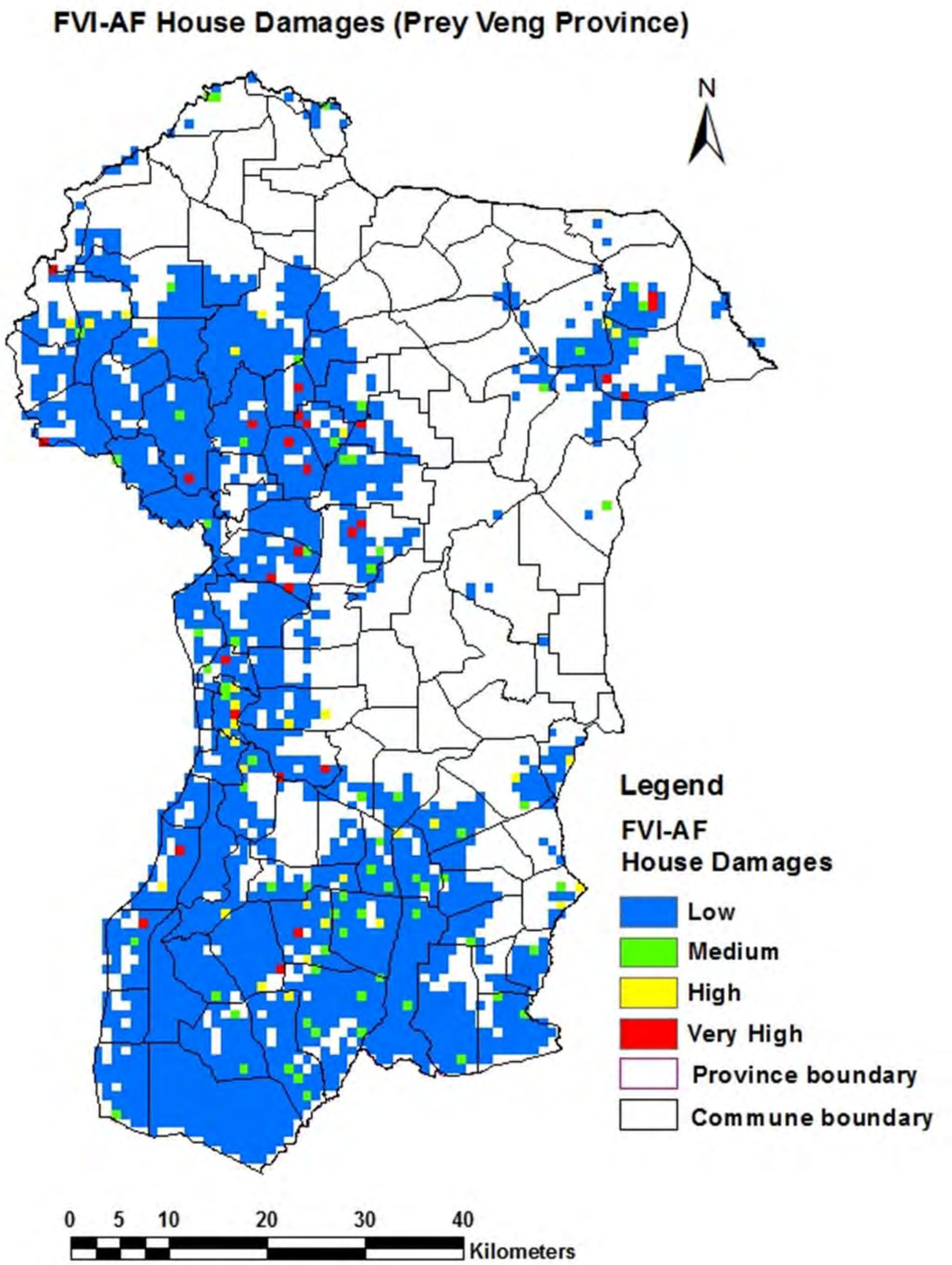

Figure A4.15: FVI-AF for House Damages in Prey Veng Province

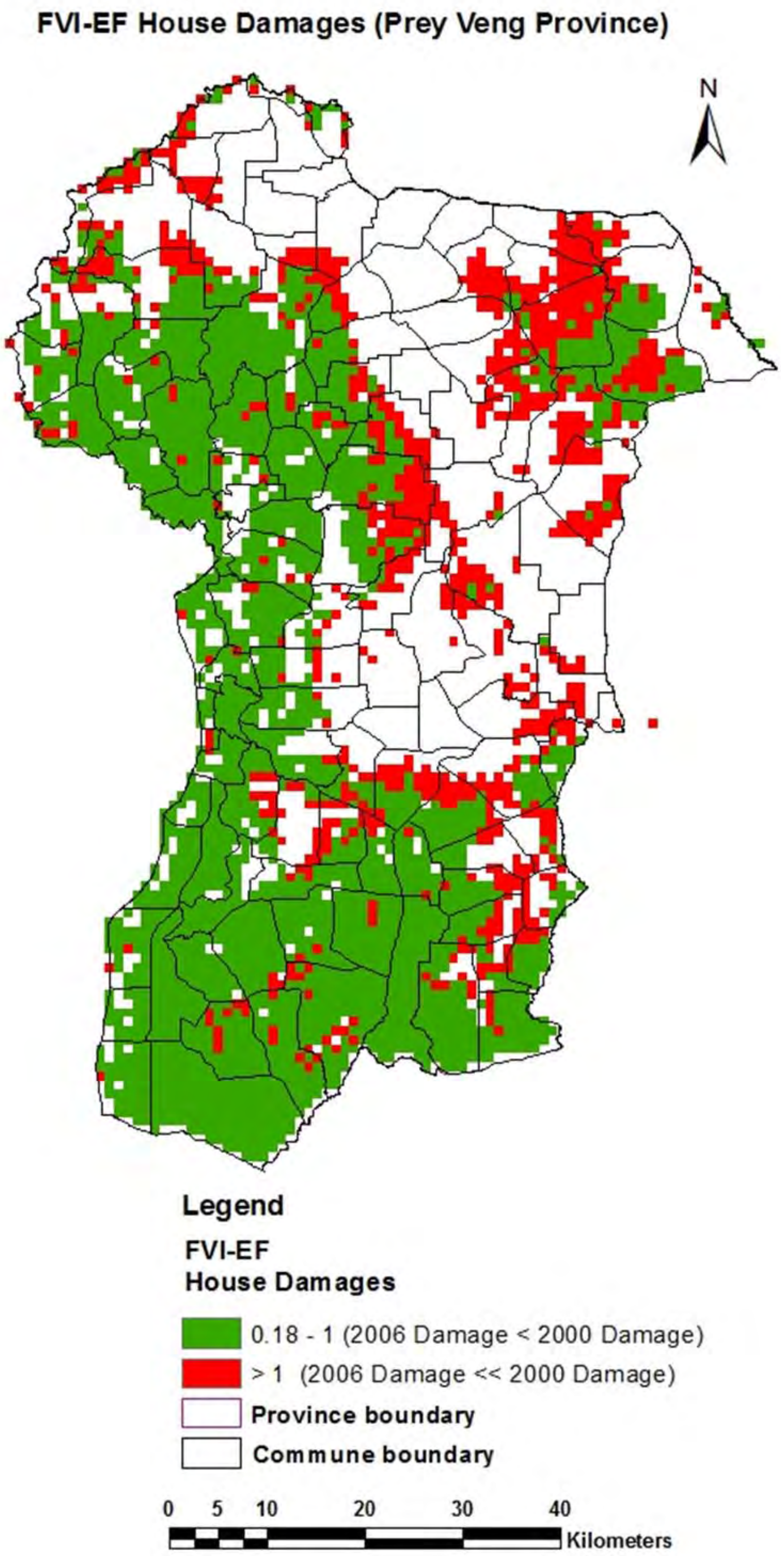

Figure A4.16: FVI-EF for House Damages in Prey Veng Province

Total Damages and FVI of Total Damages: *Prey Veng Province*

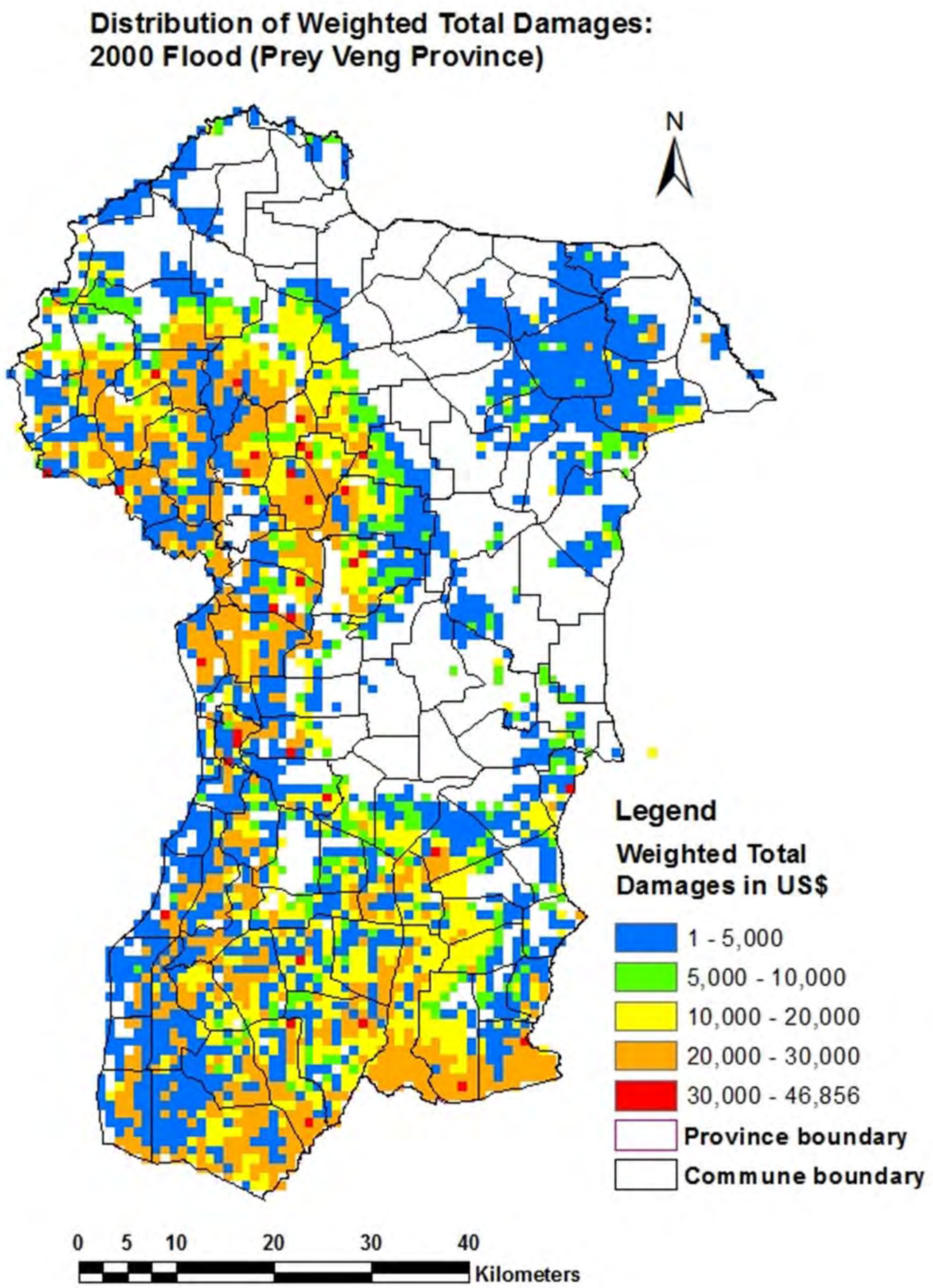

Figure A4.17: Distribution of Total Damages in Prey Veng Province in 2000 Flood

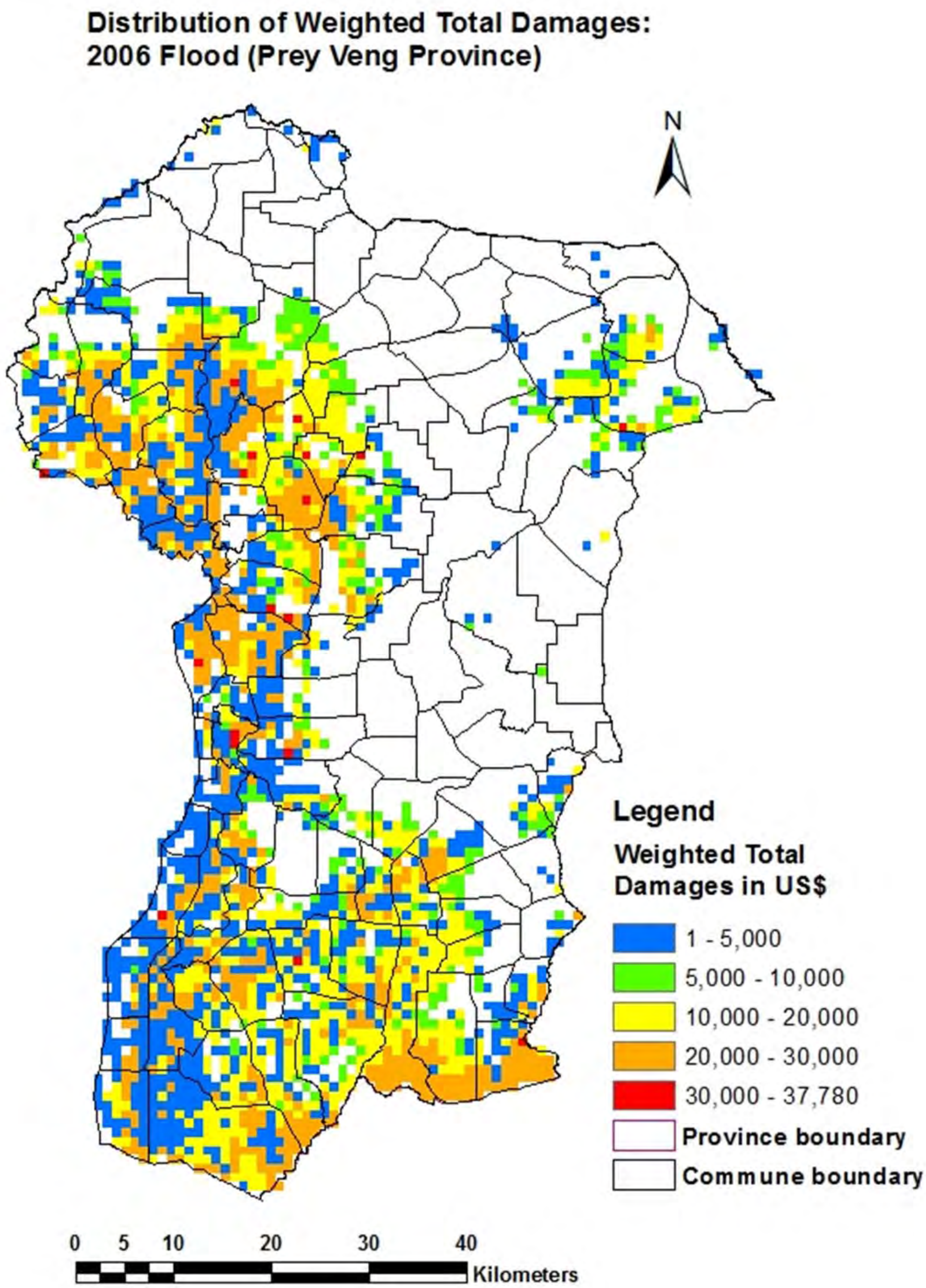

Figure A4.18: Distribution of Total Damages in Prey Veng Province in 2006 Flood

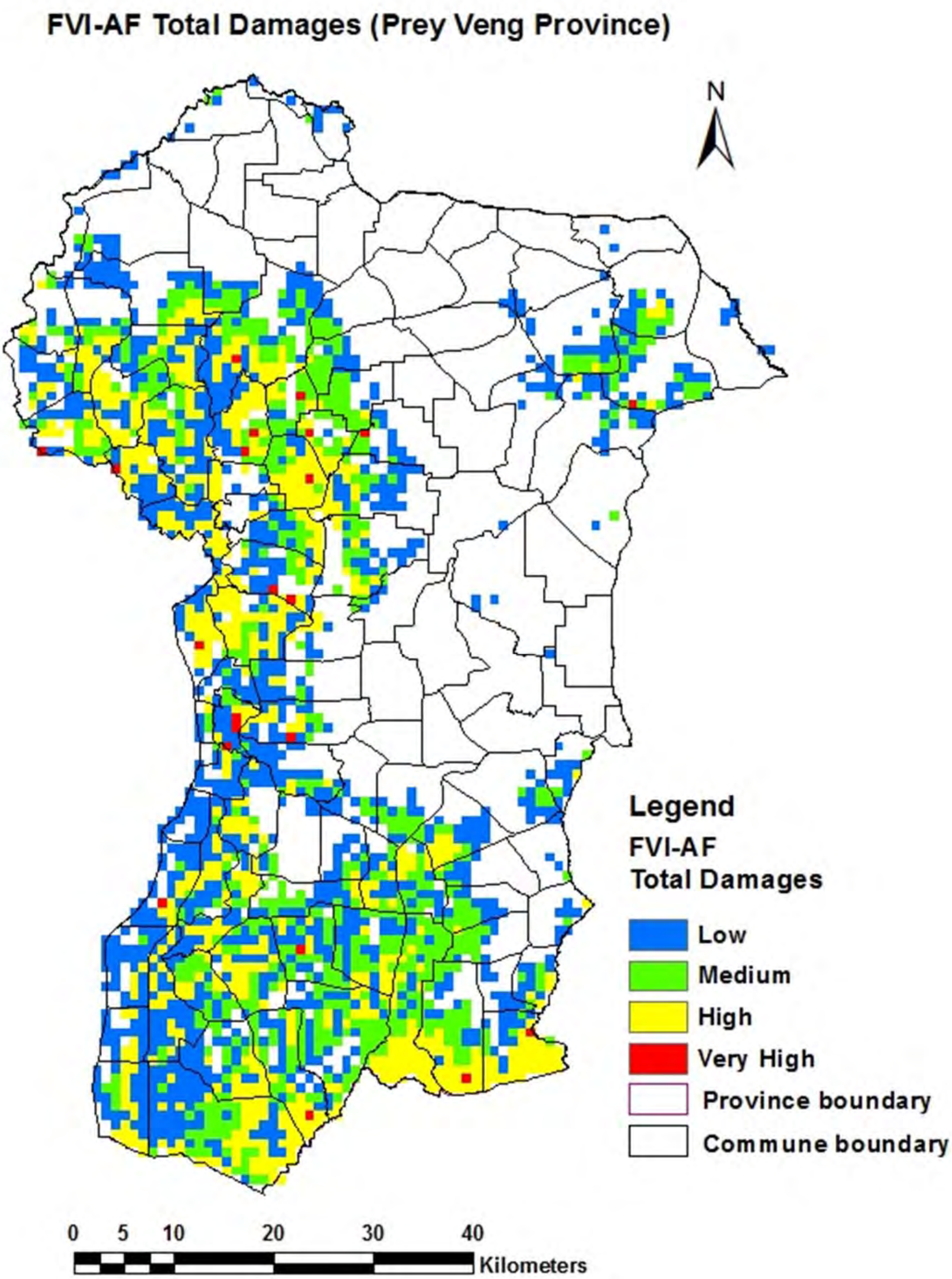

Figure A4.19: FVI-AF for Total Damages in Prey Veng Province

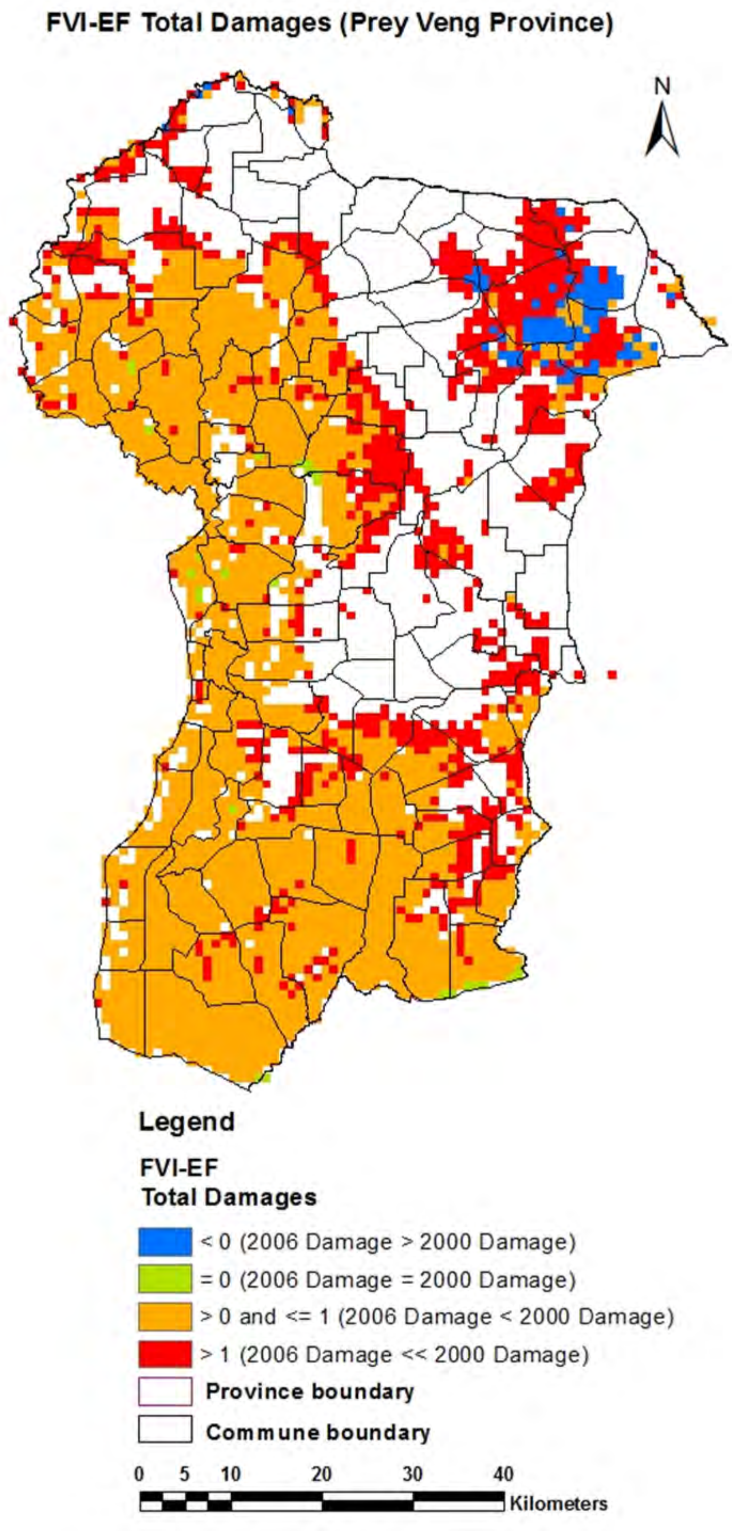

Figure A4.20: FVI-EF for Total Damages in Prey Veng Province

Agricultural Damages and FVI of Agricultural Damages: *Takeo Province*

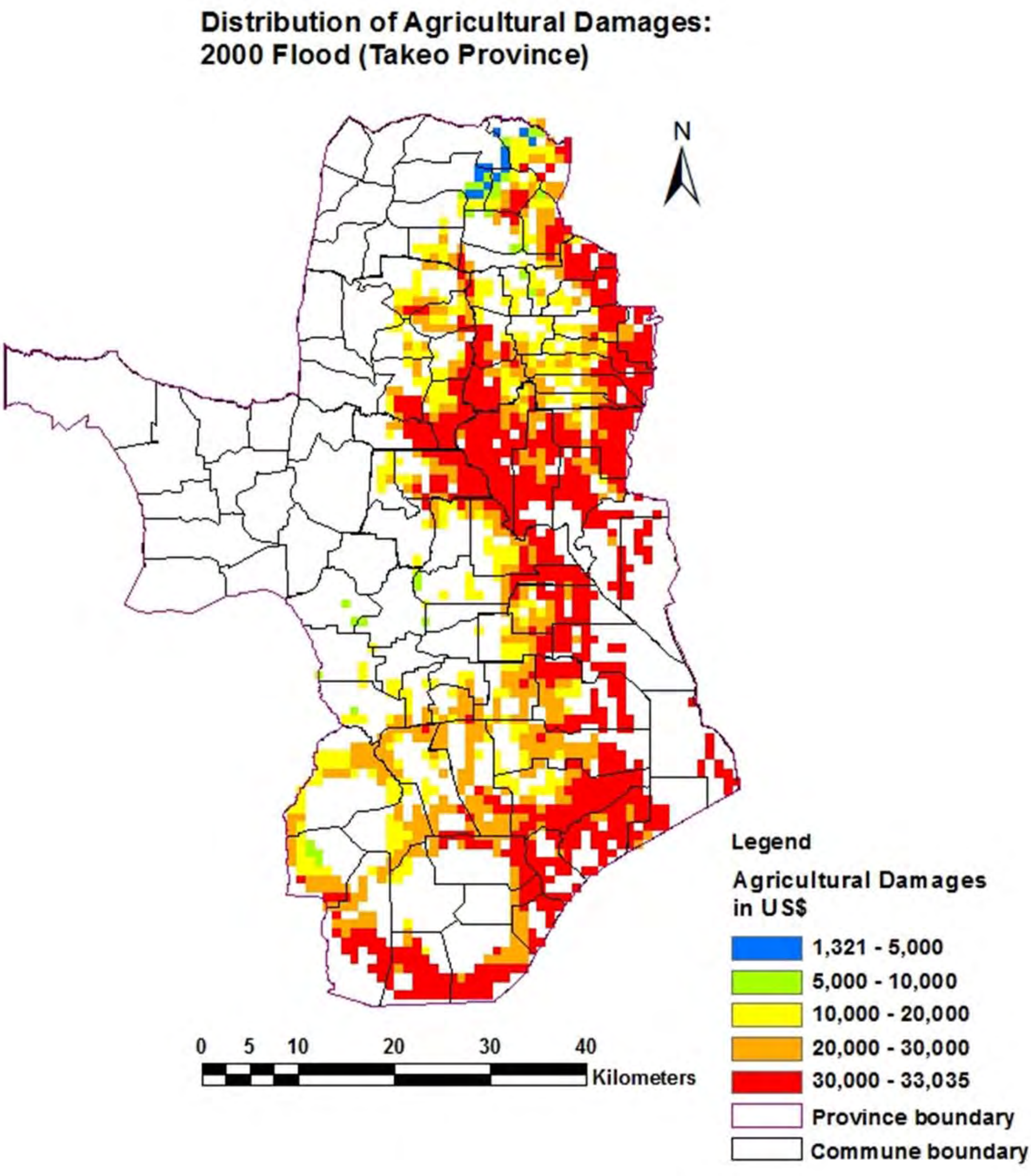

Figure A4.21: Distribution of Agricultural Damages in Takeo Province in 2000 Flood

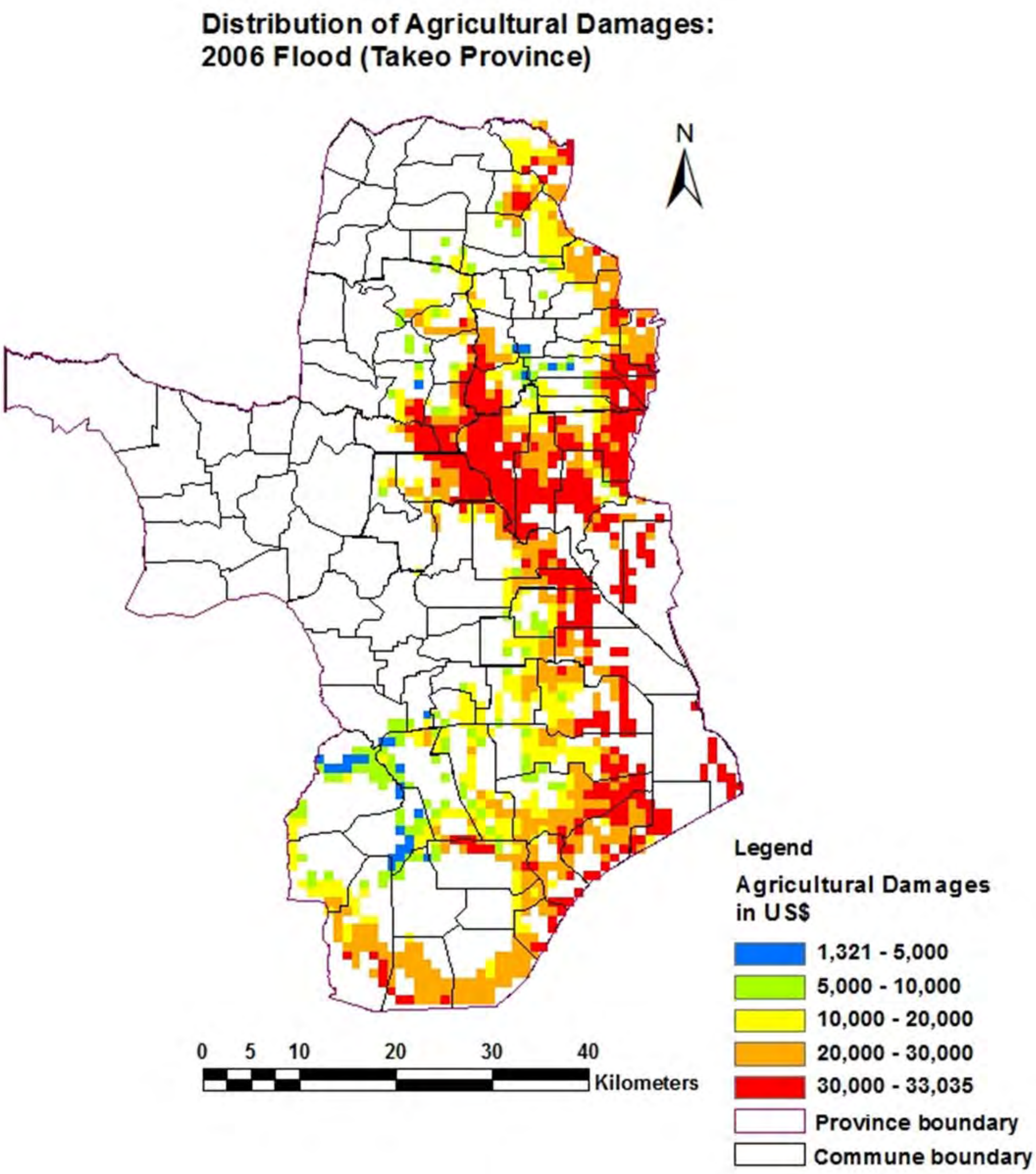

Figure A4.22: Distribution of Agricultural Damages in Takeo Province in 2006 Flood

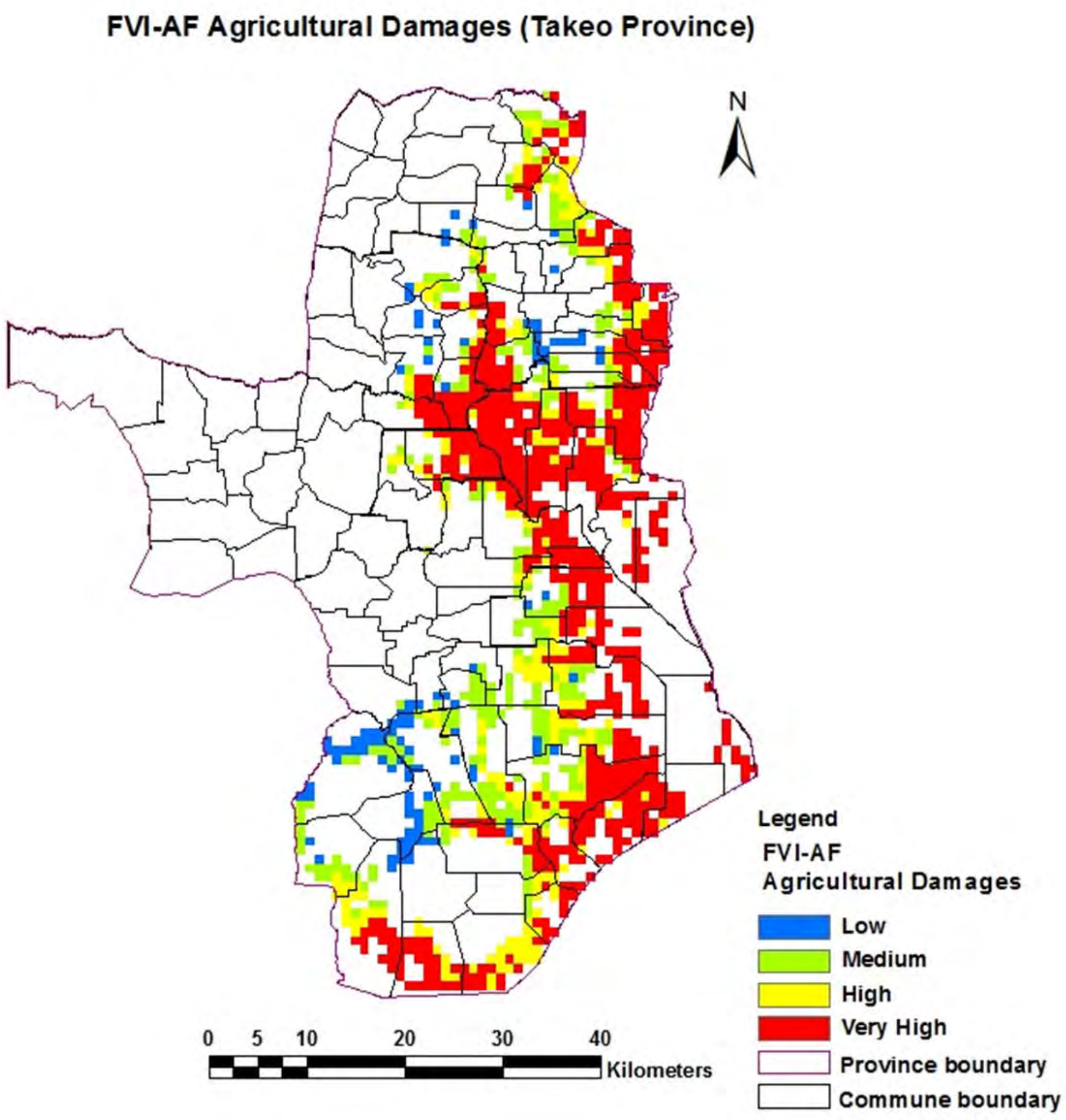

Figure A4.23: FVI-AF for Agricultural Damages in Takeo Province

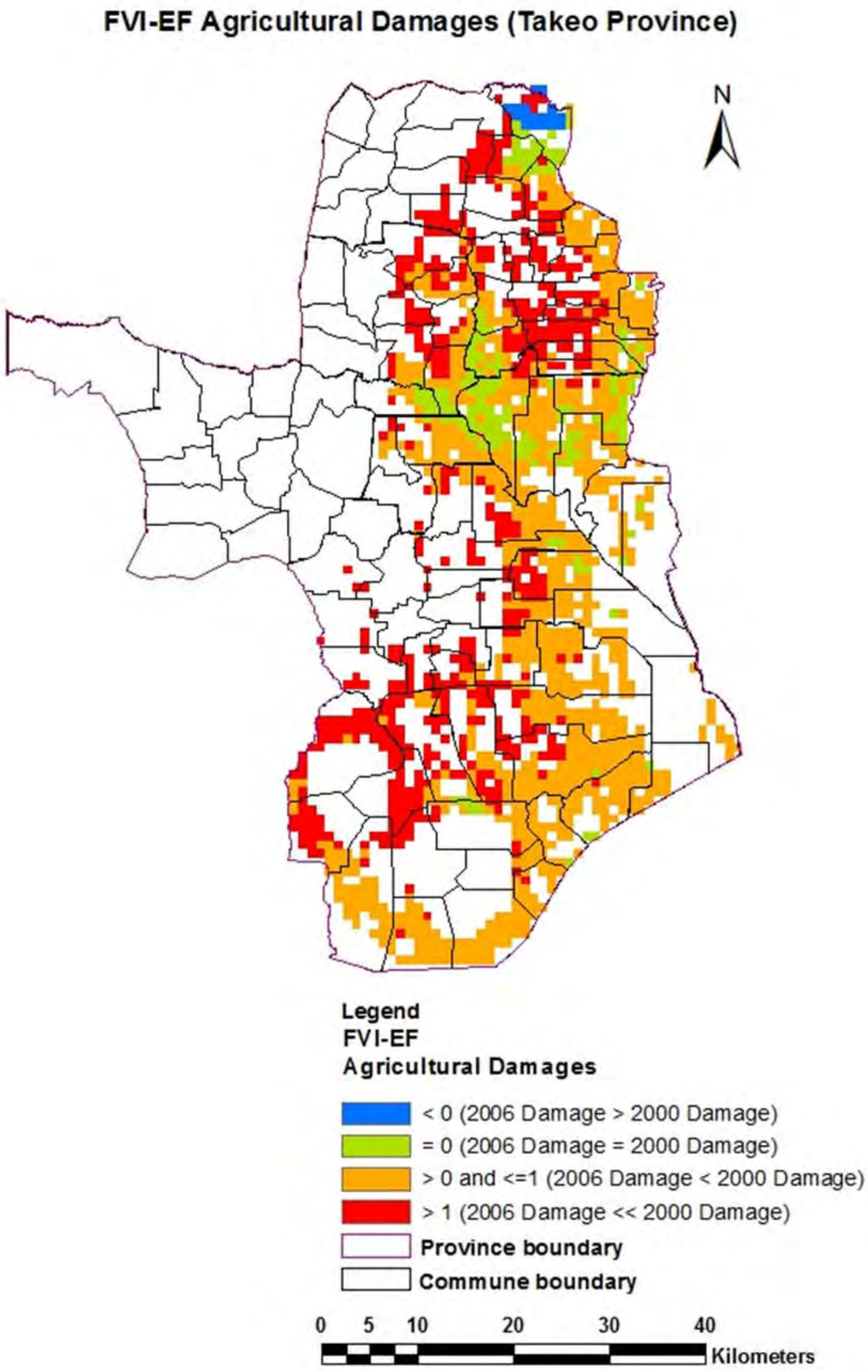

Figure A4.24: FVI-EF for Agricultural Damages in Takeo Province

House Damages and FVI of House Damages: *Takeo Province*

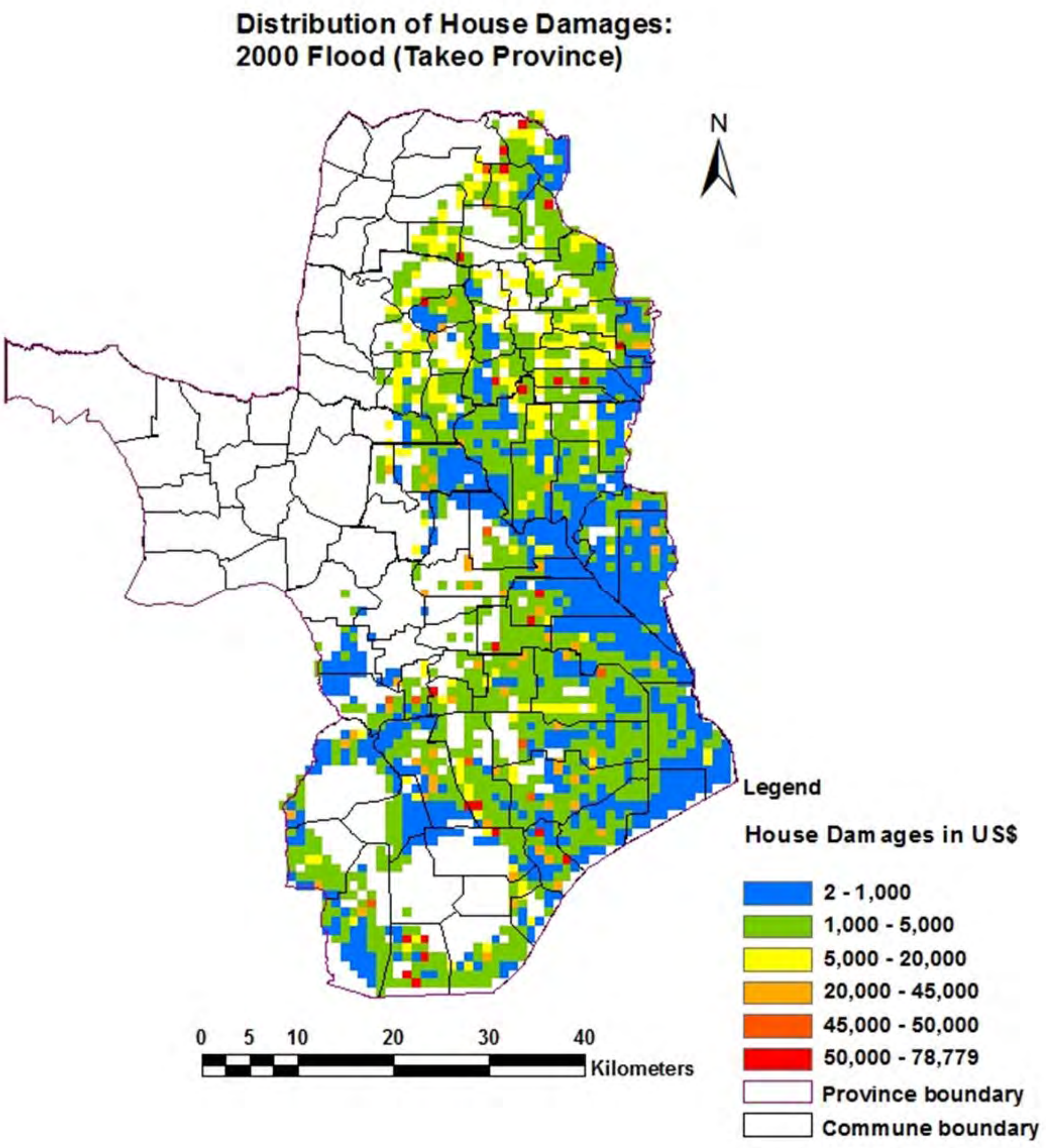

Figure A4.25: Distribution of House Damages in Takeo Province in 2000 Flood

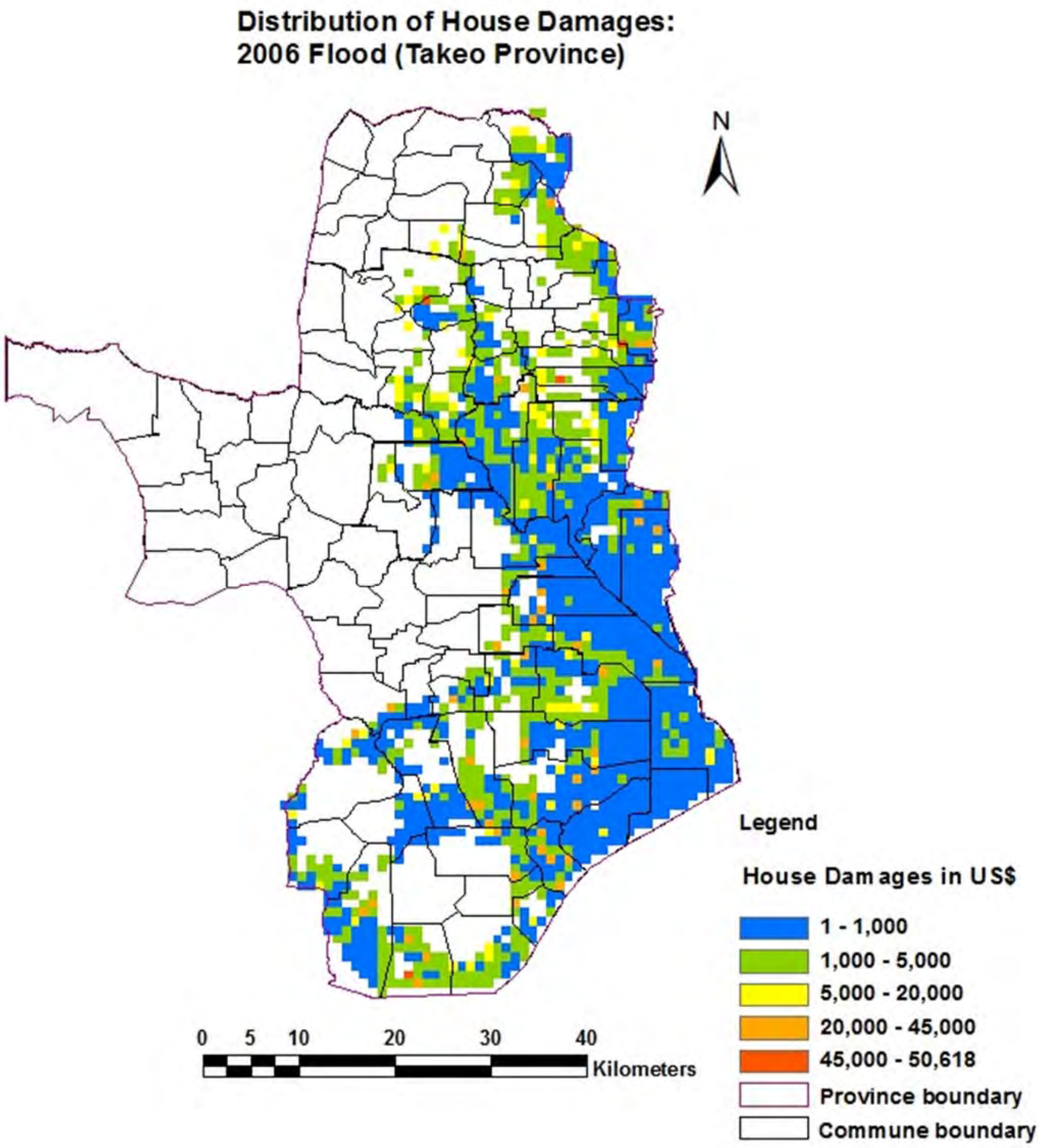

Figure A4.26: Distribution of House Damages in Takeo Province in 2006 Flood

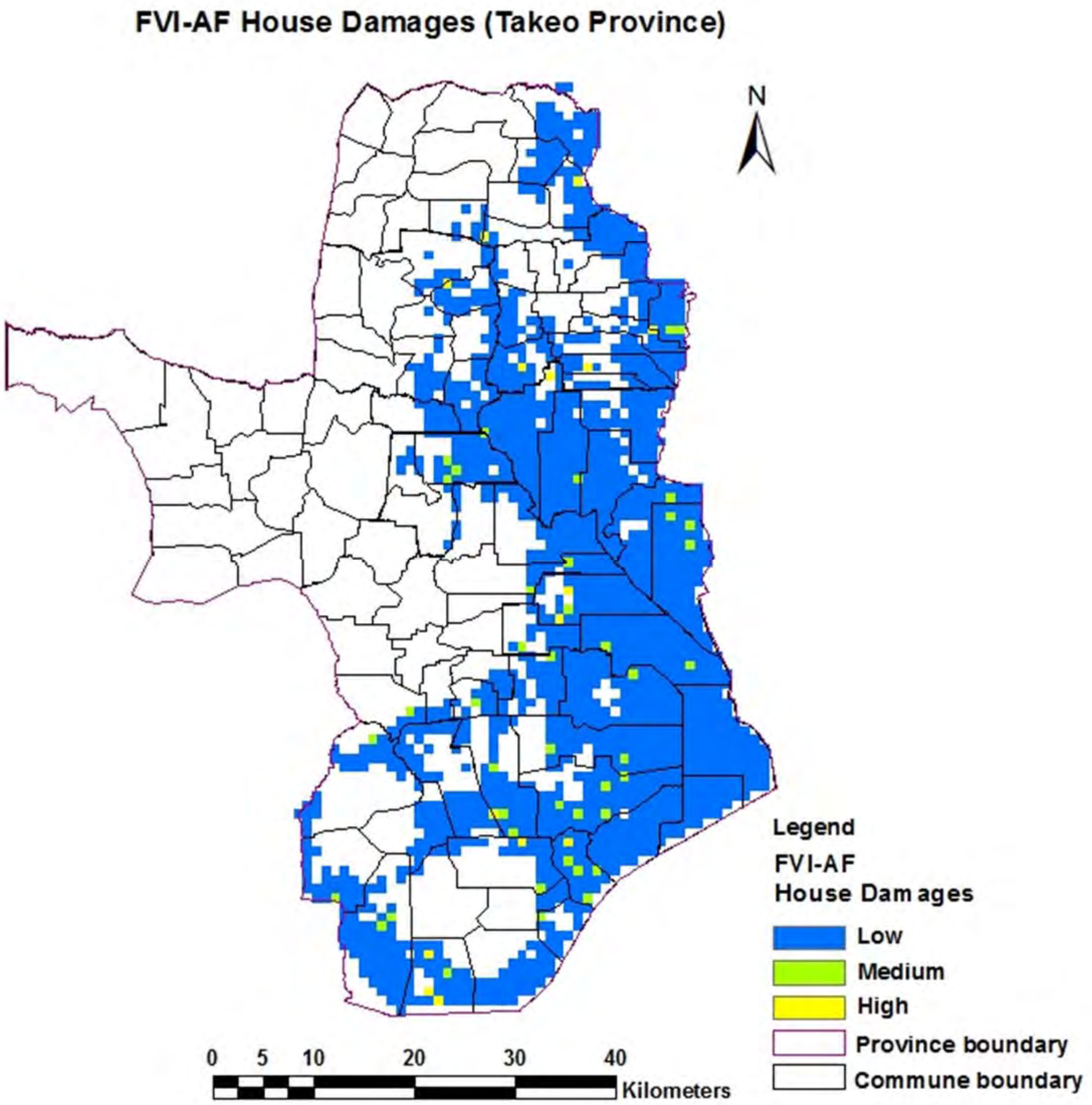

Figure A4.27: FVI-AF for House Damages in Takeo Province

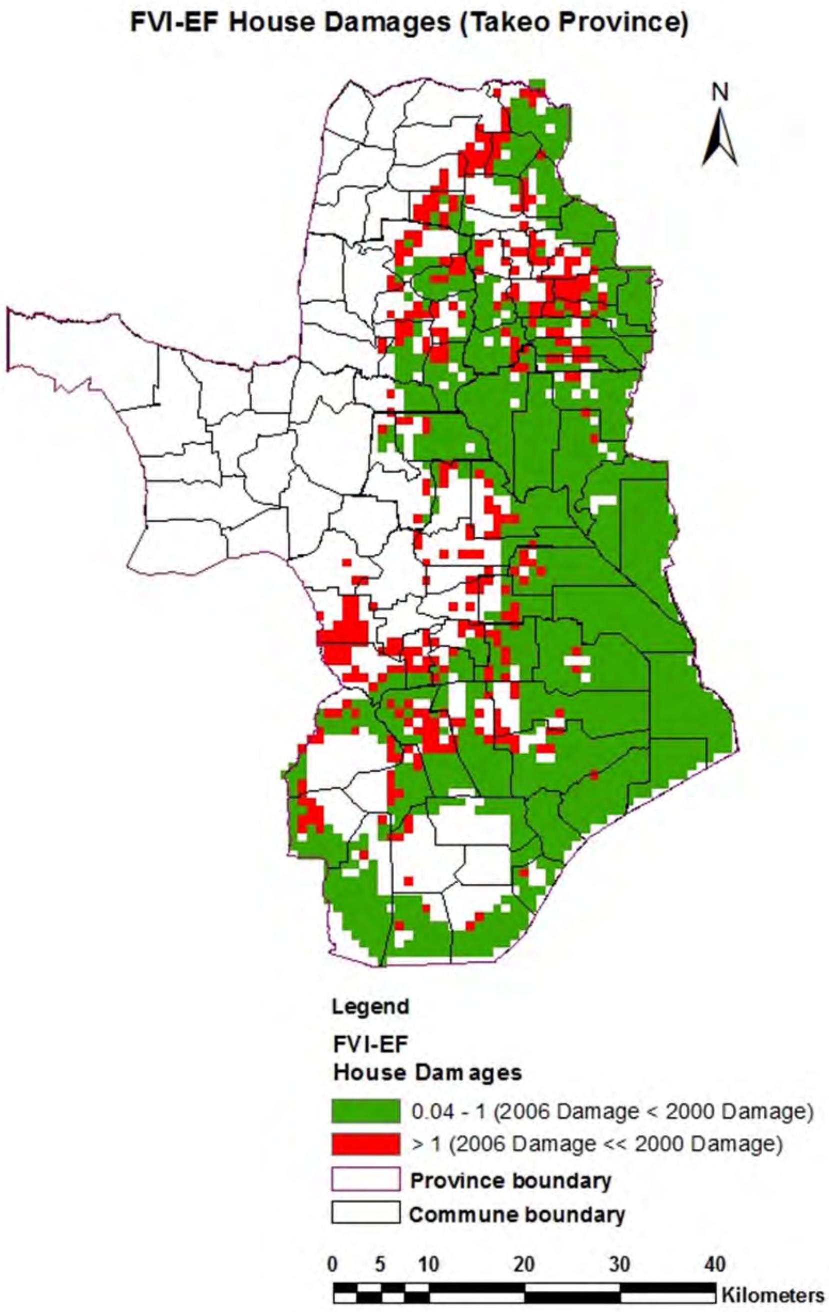

Figure A4.28: FVI-EF for House Damages in Takeo Province

Total Damages and FVI of Total Damages: *Takeo Province*

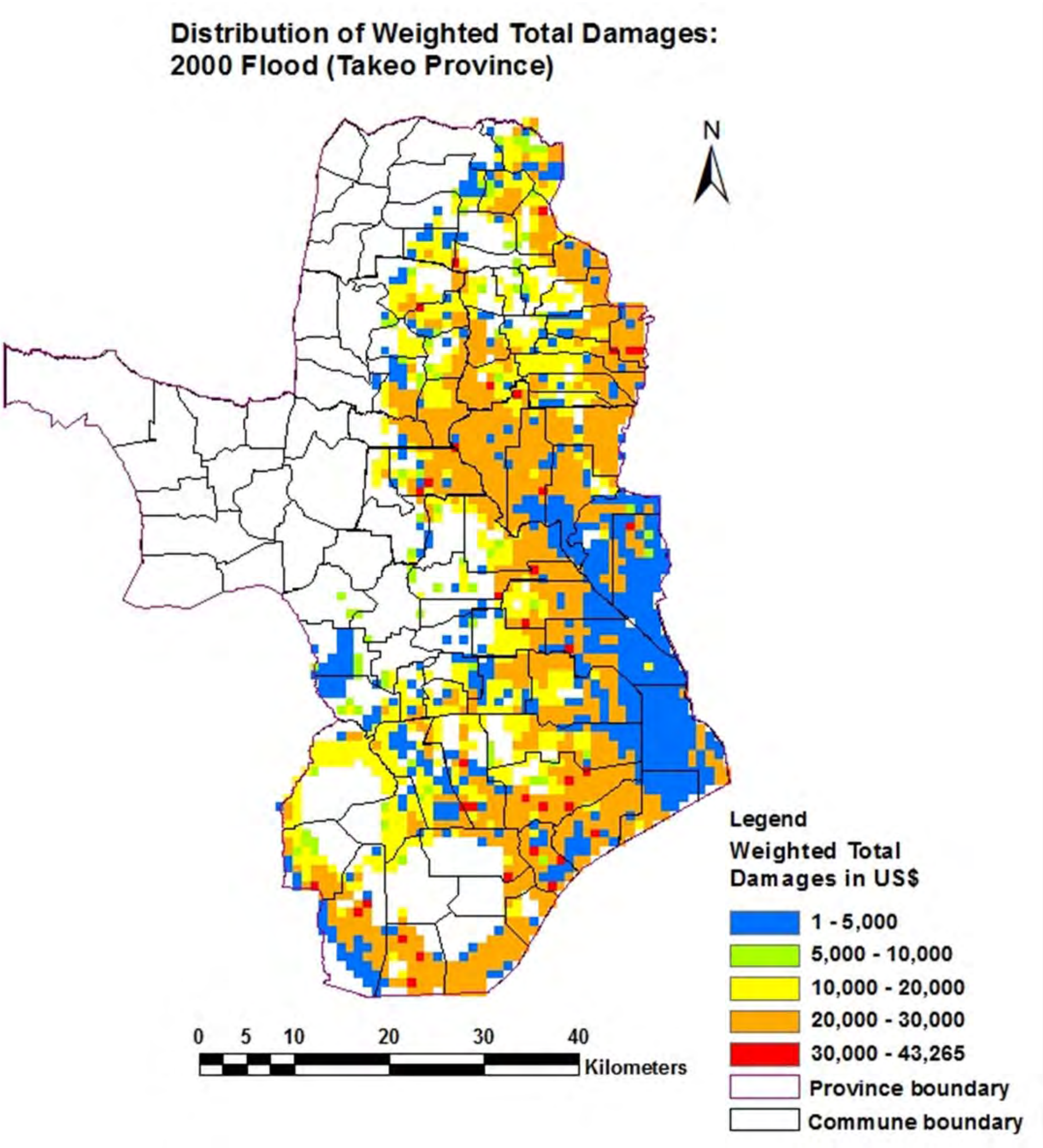

Figure A4.29: Distribution of Total Damages in Takeo Province in 2000 Flood

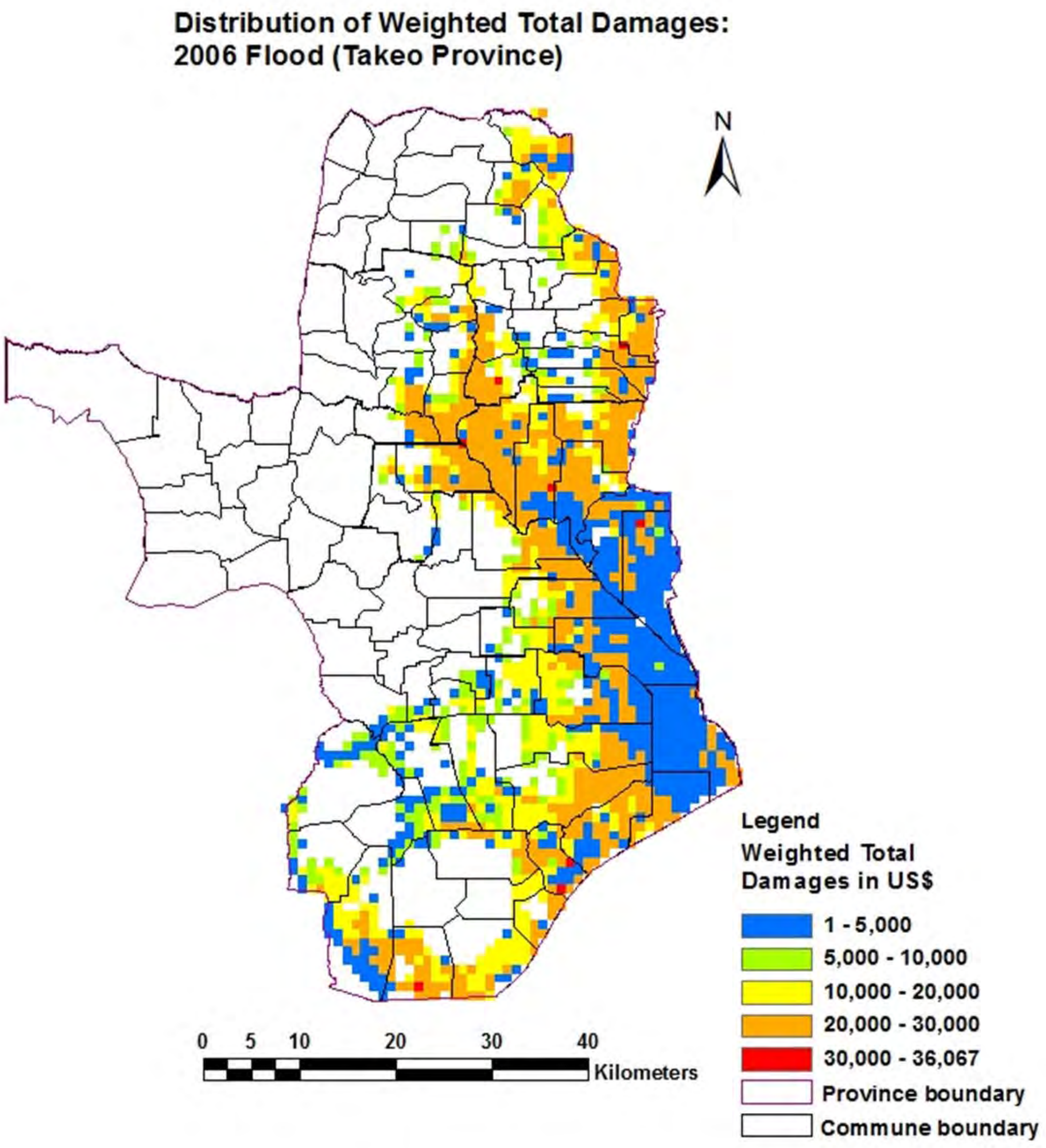

Figure A4.30: Distribution of Total Damages in Takeo Province in 2006 Flood

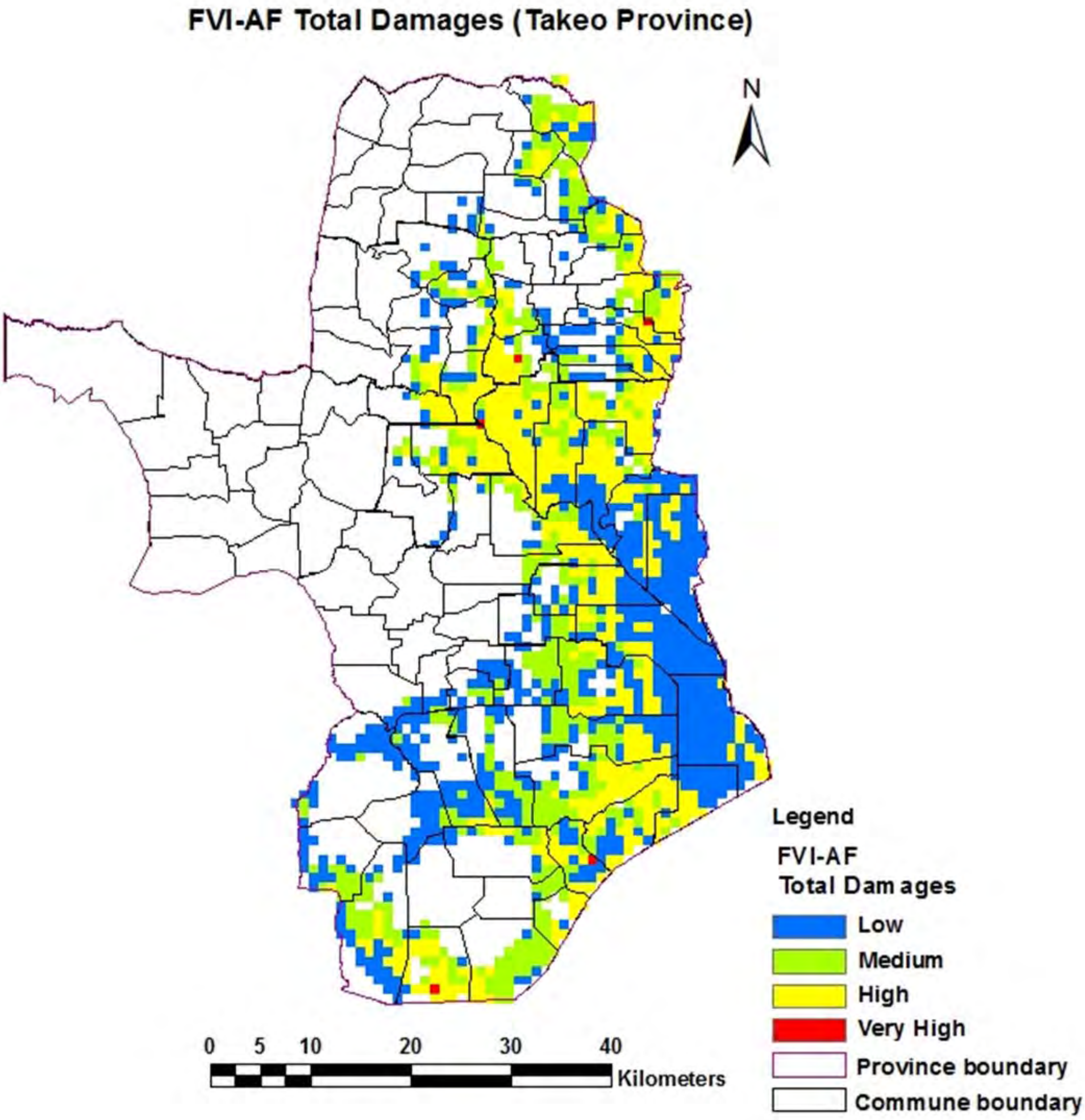

Figure A4.30: FVI-AF for Total Damages in Takeo Province

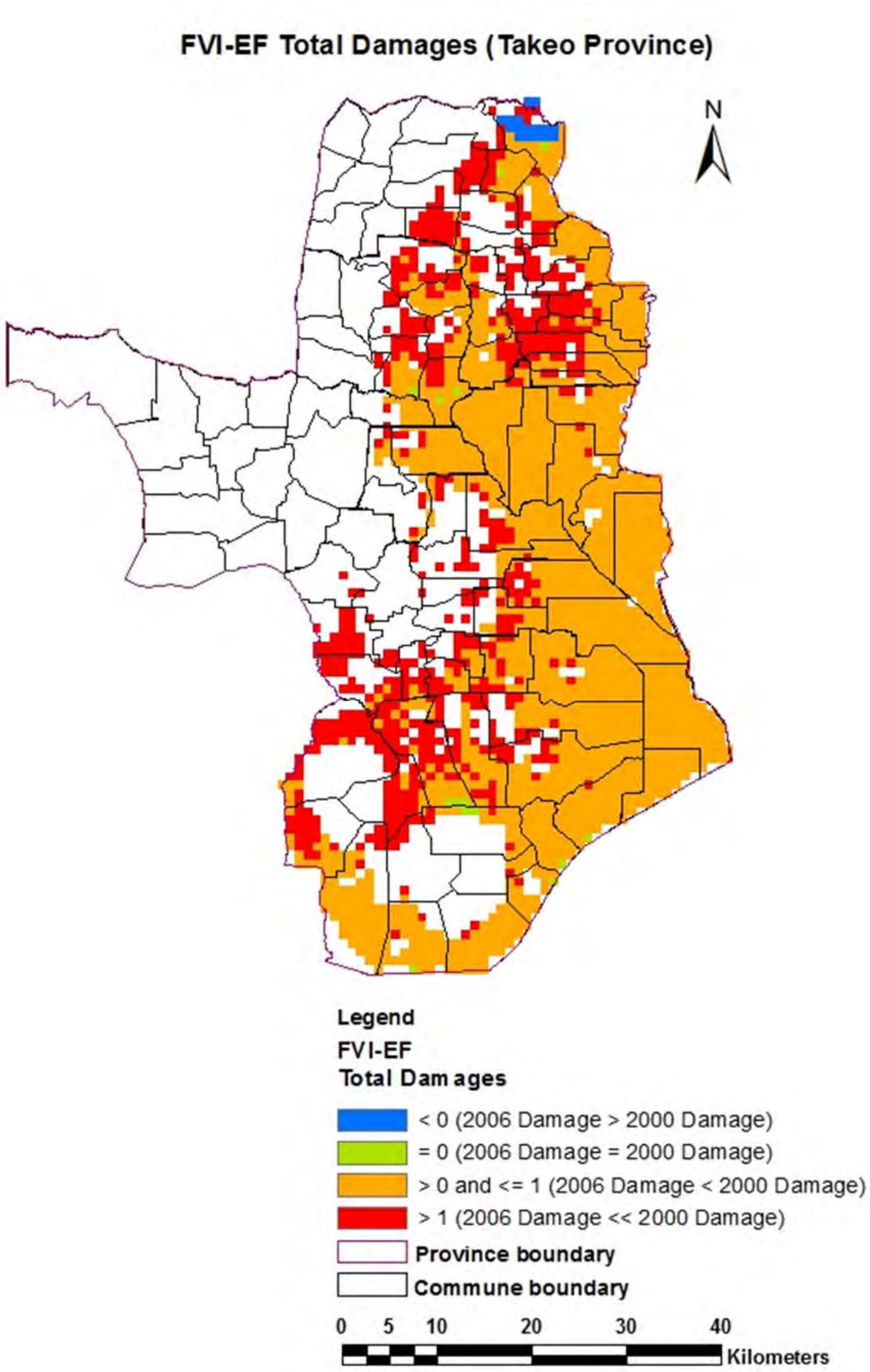

Figure A4.31: FVI-EF for Total Damages in Takeo Province

Asian Development Bank

Technical Assistance
for
Supporting Investments in Water-Related Disaster Management
(TA7276)

Final Report
(Volume 5)
Philippines Component

March 2013

International Centre for Water Hazard and Risk Management
under the auspices of UNESCO (ICHARM)

Public Works Research Institute (PWRI)

Structure of Reports

(TA 7276 for Supporting Investments in Water-Related Disaster Management)

The reports of TA 7276 for Supporting Investments in Water-Related Disaster Management are divided into following volumes:

Volume 1: Main Volume

(i) Development of Index for Water-Related Disaster Risk Management
(ii) Organization of regional knowledge sharing workshops, exchange visit program and capacity development trainings, etc.

Volume 2: Bangladesh Component

(i) Technical support for improvement of current early warning system
(ii) Capacity building of engineers and managers

Volume 3: Indonesia Component

(i) Satellite-based flood alert system
(ii) Capacity building on local disaster management
(iii) Implementation of community based flood disaster risk management

Volume 4: Lower Mekong Basin Component

(i) Supporting Mekong River Commission Secretariat in developing flood vulnerability indices

Volume 5: Philippines Component

(i) Applying Integrated Flood Analysis System (IFAS) to the river basins
(ii) Identifying causes of historical floods
(iii) Training on utilization of IFAS as supplementary information of the existing flood monitoring systems

List of Authors of TA 7276 Final Reports

Overall	Toshio Okazumi, Shigenobu Hibino
Volume 1: Main Volume	Badri Shrestha, Lee Sangeun, Youngjoo Kwak
Volume 2: Bangladesh Component	Badri Shrestha, Mamoru Miyamoto
Volume 3: Indonesia Component	Seishi Nabesaka, Dinar Istiyanto
Volume 4: Lower Mekong Basin Component	Badri Shrestha, Ai Sugiura, Shigenobu Tanaka, Youngjoo Kwak
Volume 5: Philippines Component	Mamoru Miyamoto, Seishi Nabesaka

Asian Development Bank

Technical Assistance
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Final Report

(Volume 5)

Philippines Component

March 2013

International Centre for Water Hazard and Risk Management
under the auspices of UNESCO (ICHARM)

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List of Acronyms and Abbreviations

ADB	Asian Development Bank
ASCII	American Standard Code for Information Interchange
BDCC	Barangay Disaster Coordinating Council
CDCC	City Disaster Coordinating Council
CDRRMO	City Disaster Risk Reduction Management Office
CREST	Core Research for Evolutional Science and Technology
CSV	Comma-Separated Values
DEM	Digital Elevation Model
DCC	Disaster Coordinating Council
DHI	Danish Hydraulic Institute
DOST	Department of Science and Technology
DPWH	Department of Public Works and Highways
ESRI	Environmental Systems Research Institute, Inc.
FA	Flood Advisory
FB	Flood Bulletin
FFWC	Flood Forecasting Warning Center
FFWS	Flood Forecasting and Warning System
FFWSDO	Flood Forecasting and Warning System for Dam Operation
GDP	Gross Domestic Product
GIS	Geographical Information System
GSMaP	Global Satellite Mapping of Precipitation
ICHARM	International Centre for Water Hazard and Risk Management
ICT	Information and Communication Technology
IFAS	Integrated Flood Analysis System
IWRM	Integrated Water Resources Management
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency
JST	Japan Science and Technology Agency
LGU	Local Government Unit
MOC	Main Operation Center
MWR	Micro Wave Radiometer
MWWSS	Metropolitan Water Works and Sewerage System
NASA	National Aeronautics and Space Administration
NIA	National Irrigation Administration
NOAA	National Oceanic and Atmospheric Administration

NPC	National Power Corporation
OCD	Office of Civil Defense
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PDCC	Provincial Disaster Coordinating Council
PDRRMO	Provincial Disaster Risk Reduction Management Office
PRBFFWC	Pampanga River Basin Flood Forecasting and Warning Center
PSWDO	Provincial Social Welfare and Development Office
PWRI	Public Works Research Institute
RDCC	Regional Disaster Coordinating Council
RRI	Rainfall-Runoff Inundation
SBT	Space-Based Technology
TA	Technical Assistance
WMO	World Meteorological Organization

Summary

In the Philippines where has been hit by severe floods frequently, the basin-wide flood monitoring and warning systems are being installed sequentially. The objective of this project is to support the PAGASA in applying IFAS in the Pampanga and Cagayan River basins. In the Pampanga River basin, IFAS was applied to identify causes of historical floods in the basin by incorporating satellite-based and ground observed data. In the Cagayan River basin, IFAS was applied mainly to identify causes of historical floods in the middle reaches.

In addition, another objective is to organize training programs for developing capacity of staffs of PAGASA through training programs. The training programs had been conducted to staff of PAGASA headquarters and regional offices, optimizing their human and technical resources and experience: (a) training on identifying causes of historical floods by incorporating satellite-based and ground observation data, (b) training on understanding the mechanism of floods in the Cagayan and Pampanga River basins, and (c) training on utilizing IFAS in practical work as a supplementary information for the existing flood monitoring system. Staffs of selected government organizations were also invited to the programs.

The fundamental flood analyses and IFAS applications in the Pampanga and Cagayan River basin were conducted by ICHARM in order to identify the causes of past floods and contribute to forecast future floods. According to results, flood characteristics and applicability of IFAS in the Pampanga and Cagayan River basin were clarified, particularly recent floods.

The training programs for flood risk management, “Capacity Development for Effective Flood Management in River Basin of the Philippines”, had been organized on 26-28 September in Metro Manila and on 2-4 October in Tuguegarao City, Philippines for the purpose of capacity development. As the result, the training program was successful in having reached consensus among managers and practitioners of all stakeholders on flood risk management in the Pampanga and Cagayan River basins on the causes and measures for flood risk management in these river basins. Advantage and weakness of IFAS and its effectiveness as supplementary information for the existing flood monitoring system were well recognized.

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1. Introduction

1.1. Back ground

Asian Development Bank (ADB) and International Centre for Water Hazard and Risk Management (ICHARM), Public Works Research Institute (PWRI) started collaborating on implementation of Technical Assistance (TA) and training/workshops in Water-Related Disaster Management. The TA for Supporting Investments in Water-Related Disaster Management (TA7276REG) has been implementing since 2009 to help prepare and implement flood management investment projects through knowledge and capacity development services that will reduce vulnerability to water-related disasters with in-country and regional assistance. The TA7276REG has two components: i) project support and ii) program quality support. The first phase of TA7276REG started since 13th November 2009 until 30th June 2012. The project support has been provided to Bangladesh, Indonesia and to the Mekong River Commission Secretariat in its 1st phase. More countries participated in the regional cooperation activities under the program quality support component through knowledge sharing workshops and capacity building trainings.

The second phase of TA7276REG started from June 2012 to March 2013. In the 2nd phase of TA7276REG, project support was provided to the Philippines.

In the Philippines, the project support was provided to support the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) to develop their capacity through training programs by applying Integrated Flood Analysis System (IFAS) in the Pampanga and Cagayan River basins.

1.2. Objectives of the Philippines component

The main objectives of the project support of 2nd phase of TA7276REG in the Philippines are as follows.

(i) To support the PAGASA by applying IFAS in the Pampanga and Cagayan River basins. In the Pampanga River basin, IFAS will be applied to identify causes of historical floods in the basin by incorporating satellite-based and ground observed data. In the Cagayan River basin, IFAS will be applied mainly to identify causes of historical floods in the middle reaches including Tuguegarao City by incorporating satellite-based rainfall data in the southeastern upstream and ground observed hydrological data in the southwestern upstream.

(ii) To develop the capacity of staffs of PAGASA through training programs. The training programs were conducted to staff of PAGASA headquarters and regional offices including San Fernando and Tuguegarao, optimizing their human and technical resources and experience: (a) training on identifying causes of historical floods by incorporating satellite-based and ground observation data, (b) training on understanding the mechanism of floods in the Cagayan and Pampanga

River basins, and (c) training on utilizing IFAS in practical work as a supplementary information for the existing flood monitoring system. Staff of selected government organizations will also be invited to the programs.

2. Present Flood Situation in the Philippines

2.1. Observation network for flood early warning in the Philippines

In the Philippines is suffering from severe floods frequently, the basin-wide flood monitoring and warning systems are being installed sequentially. At present the Pasig-Marikina River basin, the Pampanga River basin, the Agno River basin, the Bicol River basin and the Cagayan River basin are covered by PAGASA’s hydrological monitoring system for the purpose of flood forecasting and flood early warning. Each river basin has several gauging stations of rainfall and water level as shown in Figure 2-1. Hydrological data observed at each station is delivered to sub-center on near real-time through the system. Furthermore, not only point data such as ground-gauge stations, but also spatial information such as meteorological radar is available in several river basins.

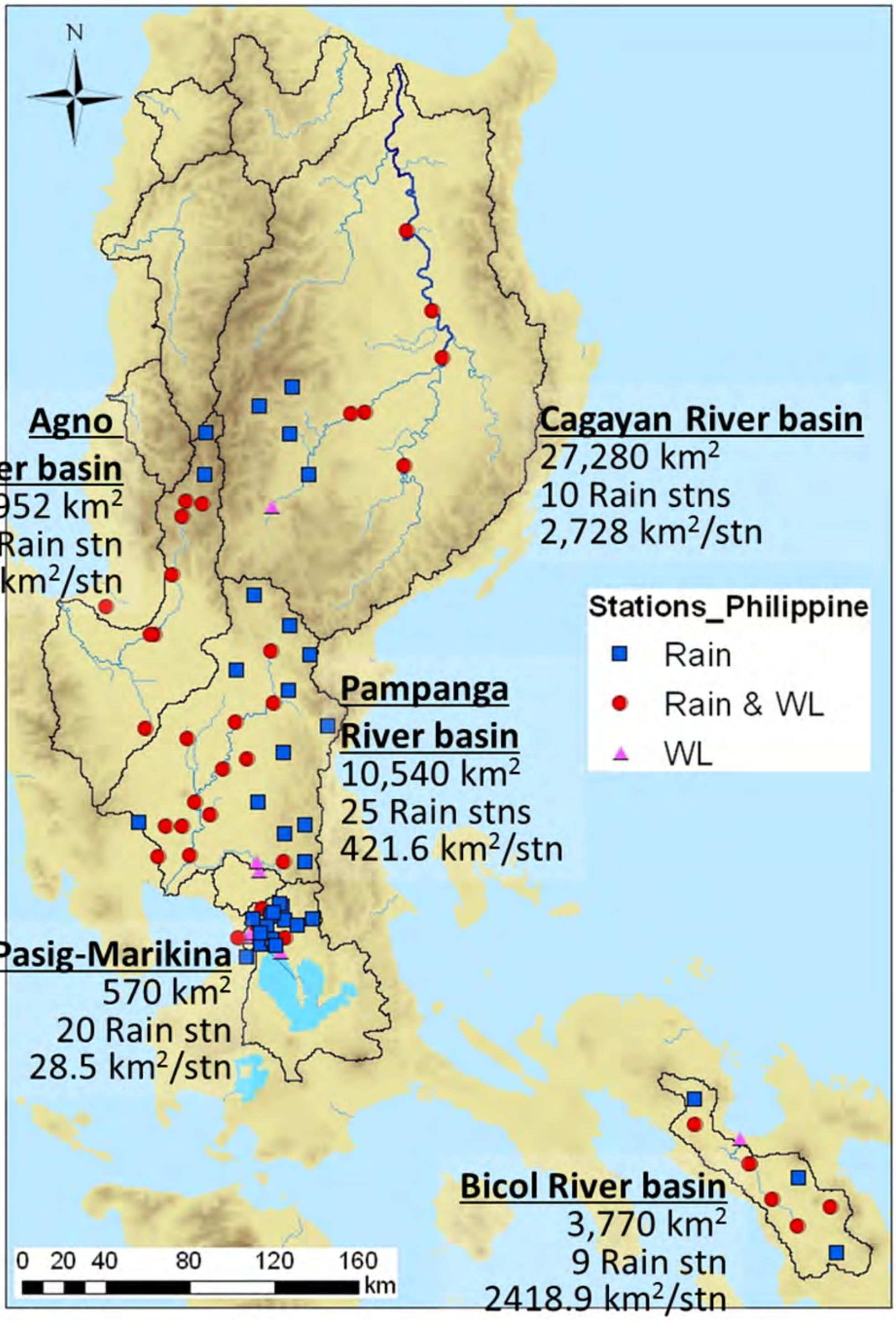


Figure 2-1 Monitoring network of gauging stations in Philippines by PAGASA

2.2. Present flood management in the Pampanga River basin

2.2.1. Descriptions of river basin and hydrological observation system by ground-gauge

The Pampanga River basin is the 4th largest basin in Philippines and covers 10,454km^2 (includes the

allied basin of Guagua River). The basin extends over the southern slopes of the Caraballo Mountains, the western slopes of the Sierra Madre range and the major portions of the Central Plain of Luzon. It encompasses the provinces of Nueva Ecija; part of Bulacan, Tarlac and Quezon; and almost whole of Pampanga. The total length of the main river, the Pampanga River, is about 260km. The basin is drained through the Pampanga River and via the Labangan Channel into the Manila Bay. The main river is supported by several tributaries, the principal ones of which are the Penaranda and the Coronel-Santor Rivers on the eastern side of the basin and the Rio Chico River from the northwest side. The Angat River joins the Pampanga River at Calumpit in Bulacan via the Bagbag River. The Labangan channel, on the other hand, acts as a cut-off channel for the Angat River into Manila Bay. Somewhere between the middle and lower portion of the basin stands Mount Arayat, about 1,026 meters in elevation. Adjacent to Mount Arayat, across the Pampanga River, just on the eastern side is the Candaba swamp, covering an area of some 250 km^2. Absorbing most of the flood flows coming from the eastern sections of the basin and the overflowing of the Pampanga River via the Cabiao Floodway. This area is submerged during the rainy season but is relatively dry during summer. At the lower sections of the basin, where the Pampanga delta lies, the Pampanga River system divide into relatively small branches, crisscrossed with fishponds to form a network of sluggish, tidal flats and canals, which eventually find their way to Manila Bay. The main river has a relatively low-gradient channel particularly at the middle and lower sections. The basin experiences, on an average, at least one flooding in a year. The dry season generally occurs from December to May, and wet the rest of the year. The wettest months are from July to September. The frequency of tropical cyclone passage over the basin is about 5 in 3 years.

The map of the Pampanga River basin is shown in Figure 2-2. The Pampanga River basin has 18 rainfall ground-gauge stations and 11 water level stations as a telemetric system. The observation type and location of gauging stations are shown in Table 2-1. Table 2-2 shows the altitude of staff gauge at the major stations. The values surrounded by red flame don’t mean the altitude of benchmark but the absolute elevation of staff gauge. As Figure 2-3 shows layout of the Arayat station as an example, this elevation is also same to the elevation of water level observation equipment. Also, assessment levels of cross-section at major stations are shown as the local height in Table 2-3. Each assessment level is defined by flow area of cross-section; the Alert level is 40 percent, the Alarm level is 60 percent, and the Critical level is 100 percent of whole flow area of cross-section.

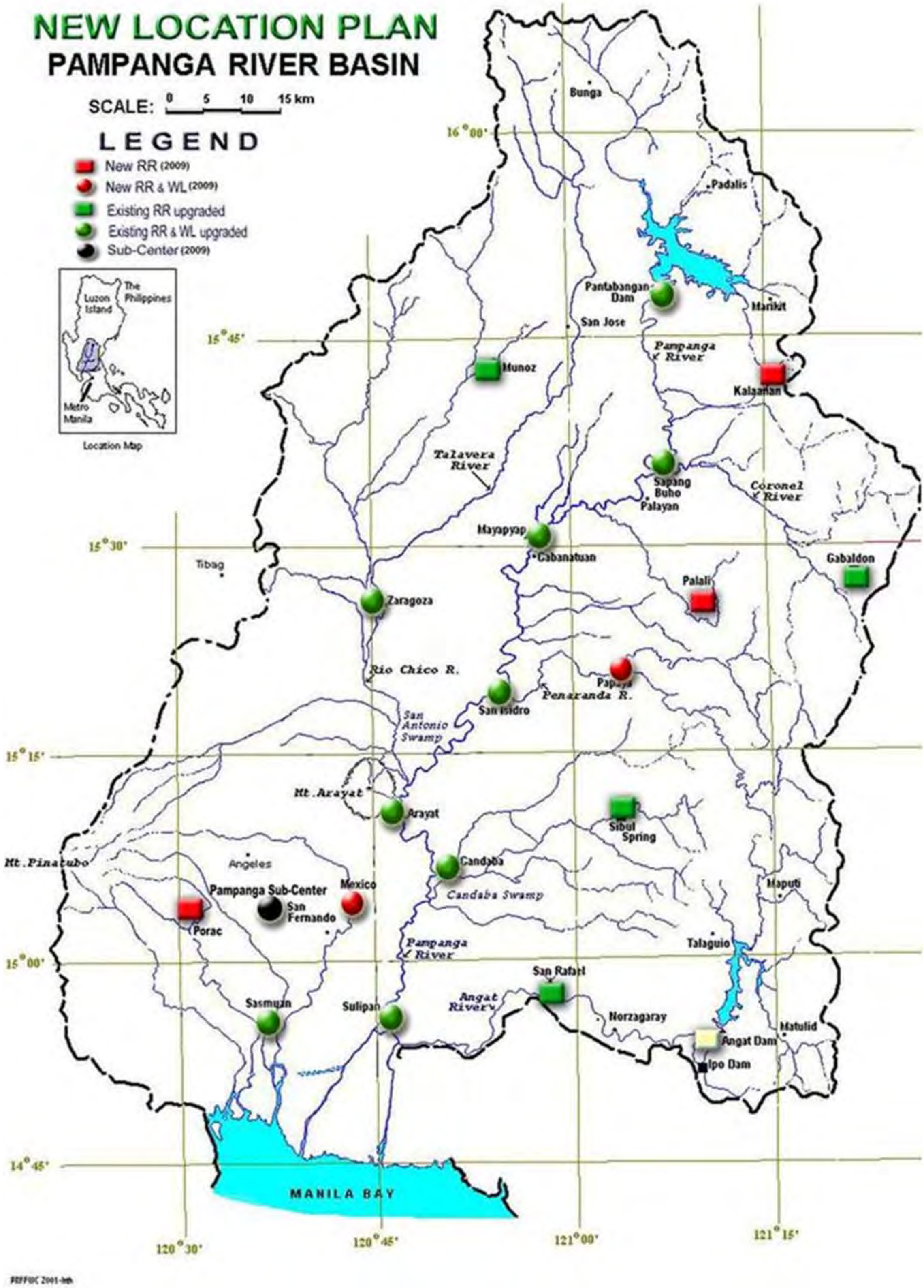


Figure 2-2 Pampanga River basin map and ground-gauge stations

Table 2-1 Observation type and location of gauging stations

No.	Station name	Station type	Latitude	Longitude	Estimated BM elevation (m)
1	SUB-CENTER	Office	15.06620	120.65800	28
2	MUÑOZ	rainfall	15.73806	120.96083	80 (estimated)
3	SAPANG BUHO	combined	15.59417	121.11917	61.5
4	MAYAPYAP	combined	15.51444	120.95556	36.4
5	GABALDON	rainfall	15.49861	121.35556	558 (estimated)
6	ZARAGOZA	combined	15.44333	120.75083	21 (estimated)
7	SAN ISIDRO	combined	15.31361	120.90250	19.8
8	ARAYAT	combined	15.16833	120.78222	9 (estimated)
9	CANDABA	combined	15.11556	120.85028	2.5
10	SIBUL SPRING	rainfall	15.16778	121.05750	55 (estimated)
11	SASMUAN	combined	14.93722	120.62306	2 (estimated)
12	SULIPAN	combined	14.93944	120.75861	3.1
13	PENARANDA	combined	15.35389	121.00556	
14	MEXICO	combined	15.06808	120.73075	10 (estimated)
15	CALAANAN	rainfall	15.64831	121.18586	80 (estimated)
16	PALALI	rainfall	15.38056	121.16139	260 (estimated)
17	PORAC	rainfall	15.08014	120.54542	100 (estimated)
18	PANTABANGAN DAM	combined	15.81833	121.10944	

Table 2-2 Altitude of staff gauge at the major stations

PAMPANGA RIVER BASIN STATIONS (survey as of August 2009)				
Station	River / Swamp	New S.G. Elevation of "0" gage (meters)	Remarks	NOTES
Sapang Buho	Pampanga River	50.212	ok	
Mayapyap	Pampanga River	25.697	ok as of Nov. 4, 2009; 1750	DPWH "0" gage = 23.779
Zaragoza	Rio Chico River	10.213	tel. rdg. + 10.213 to get equivalent MSL elev	Tel. Rdg. +10.213
Peñaranda (new)	Peñaranda River	18.296	ok as of Nov. 5, 2009; 0828	base on TBM of 30.0m @ bridge approach U/S LB
San Isidro	Pampanga River	9.585	ok as of Nov. 5, 2009; 0959	
Arayat	Pampanga River	0.077	ok	
Sulipan	Pampanga cut-off channel	-0.062 (old)	ok as of Nov. 4, 2009; 0756	-0.062 m.
Mexico (new)	Abacan	5.933	ok as of Nov. 5, 2009; 1325	base on TBM of 10m @top of stn wall below stn house
Sasmuan	Pasac-Guagua	-1.417	ok	
Candaba	Candaba Swamp	-0.157 (old)	ok as of Nov. 5, 2009; 1209	new stn SG referred to old one
Apalit-NLEX Bridge	Pampanga River	"0"	ok	based on DPWH S.G. near the site

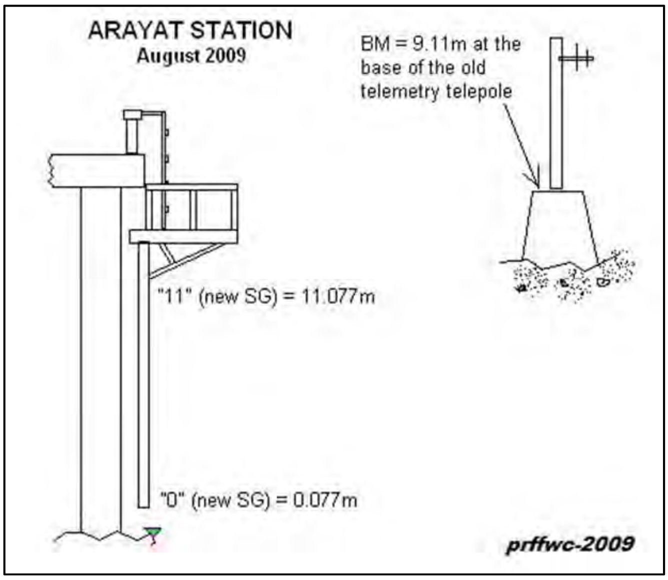


Figure 2-3 Description of the Arayat gauging station

Table 2-3 Assessment levels of major stations (local height)

Station	Alert	Alarm	Critical
SAPANG BUHO	3.70	4.50	6.50
MAYAPYAP	3.00	3.50	4.50
SAN ISIDRO	3.20	4.50	6.00
ZARAGOZA	11.00	12.50	14.50
ARAYAT	5.00	6.00	8.50
SULIPAN	3.60	4.20	5.00
CANDABA	3.0	4.50	5.00

2.2.2. Field visit in the Pampanga River basin

ICHARM researchers in charge of Philippine country component and Dr. Osti from ADB conducted field surveys of the Pampanga and the Cagayan River basin with support from PAGASA from 26th to 29th May 2012. The main purpose of the visit is to investigate the current situation of the Pampanga and Cagayan River basins, existing rainfall stations, water level stations and dam conditions, and current situation of Flood Forecasting and Warning System (FFWS). The purpose of visit is also to discuss and check on availability of necessary data for IFAS application in the river basins.

In the Pampanga River basin, they visited the Pampanga River Basin Flood Forecasting and Warning Center (PRBFFWC), the Sulipan station, the Arayat station and Mexico stations. Photo 2-1 shows the scene of field visit at PRBFFWC, the Sulipan station, the Arayat station and the Mexico station. The PRBFFWC, PAGASA sub-center of Pampanga, which is located at San Fernando City, is responsible for management of rainfall and water level data observation, and also responsible for

flood forecasting based on real-time monitoring. Therefore, observed hydrological data is delivered to PRBFFWC in real-time through the repeater stations and stored in database of PRBFFWC. This delivered data is also imported in existing flood forecasting model of PAGASA. Next, Photo 2-2 shows the rainfall and water level gauges at the visited stations, the Sulipan, the Arayat and Mexico. The Sulipan station and the Arayat station are located beside the main stream of the Pampanga River. However, the Mexico station is located beside the Guagua River which lies southwest part of target river basin. These three stations have telemetered rainfall equipment and pressure type water level gauge. The sensors of water level observation equipment at gauging stations except the Sulipan are put at the downstream side of bridge pier. At the Sulipan station, it was also found that there is a tidal effect.

The Guagua River which is included in the management of the Pampanga River basin was also visited in this field survey, because the devastating disaster was occurred in Guagua-Bacolor area caused by the eruption of Mount Pinatubo in 1991. The eruption affected not only the regional but also the national economy, which recorded a negative growth rate in national GDP. Photo 2-3 shows the old church which was buried by eight meters due to lahar eruption within 4-5 years after the lahar eruption in 1991. The doors shown in the photograph were originally the windows of second floor before sediment deposition. Currently there is no possibility of lahar eruption, which was already stabilized. The structural countermeasures such as Mega Dikes in both sides of lahar flows and big spurs were constructed to protect cities. The height of Mega Dikes is more than 12 m higher. Currently there are no more sensors for lahar forecasting in the area because it is already become stable. The huge amount of lahar sediments were deposited at almost all inside area of the Mega Dikes. There are many sediment mining sites inside the dikes that might be used for construction purpose.

The major findings of field visit are as follows;

- The Pampanga River basin has two major flood characteristics, costal floods due to tidal effects, and riverine flood due to heavy rainfall.
- River bed fluctuation such as erosion and sedimentation causes significant change of flow capacity of main channel.
- At the Arayat station, the impact from backwater due to tidal effect is less significant.
- Although the cross-section measurements have been conducted several times, the rating curves haven’t been created at any stations due to lack of discharge measurements.
- Japan International Cooperation Agency (JICA) has been supporting about flood management in the Pampanga River basin, however it mainly focuses on dam basin-scale area, particularly in the upstream area of the Pampanga River basin.
- PRBFFWC has the well system of data observation and processing functioning.
- PAGASA has the conventional flood forecasting method based on water level correlation

between upstream and downstream.

- MIKE11 developed by Danish Hydraulic Institute (DHI) have been applied to the Pampanga River basin as a flood forecasting model.


Photo 2-1 PRBFFWC


(Sulipan station)


(Arayat station)

(Mexico station)

Photo 2-2 Rainfall and water level gauges at Sulipan, Arayat and Mexico stations

Photo 2-3 Church at the Guagua-Bacolor area where affected by eruption of Mt. Pinatubo

2.2.3. Major flood damages in recent years

In recent years, the Pampanga River basin had been hit by severe flood in 2012, 2011 and 2009. Amounts of damages by floods of 2009 and 2011 are shown in Table 2-4. By the flood on September 2011, 52 casualties are reported within Region 3 area mostly as a result of drowning. Damage houses for the Region totaled 22,393 of which 3,561 were totally damaged. Photo 2-4 shows scene of inundation due to typhoon “Pedring” on Sep. 2011. By the flood on June 2011, there were a total of 6 drowning casualties in Region 3. Damaged houses for the Region totaled about 109, of which 100 being totally damaged. In case of September 2009 flood; the overall casualties for region 3 included 56 dead, 3 injured, and 7 missing. Damaged houses for the Region totaled 882, of which 513 were totally damaged. Figure 2-4 shows flooding map based on past floods. It is found from Figure 2-4 that the Rio Chi River, Candaba area and costal area are flood-prone area. In particular, Candaba area has become a “Flood way” instead of the Pampanga main stream during flooding.

Table 2-4 Damaged population and houses by recent floods (in Region 3)

Causes	Date	Casualties	Affected people	Affected barangays	Affected houses
Typhoon “Pedring” and “Quiel”	Sep. 2011	52	2,124,000	1,722	22,393
Tropical storm “Falcon”	Jun.2011	6	1,404,734	904	109
Typhoon “Ondoy” and “Pepeng”	Sep.2009	56	667,881	439	882

Photo 2-4 Scene of 2011 inundation due to typhoon “Pedring”

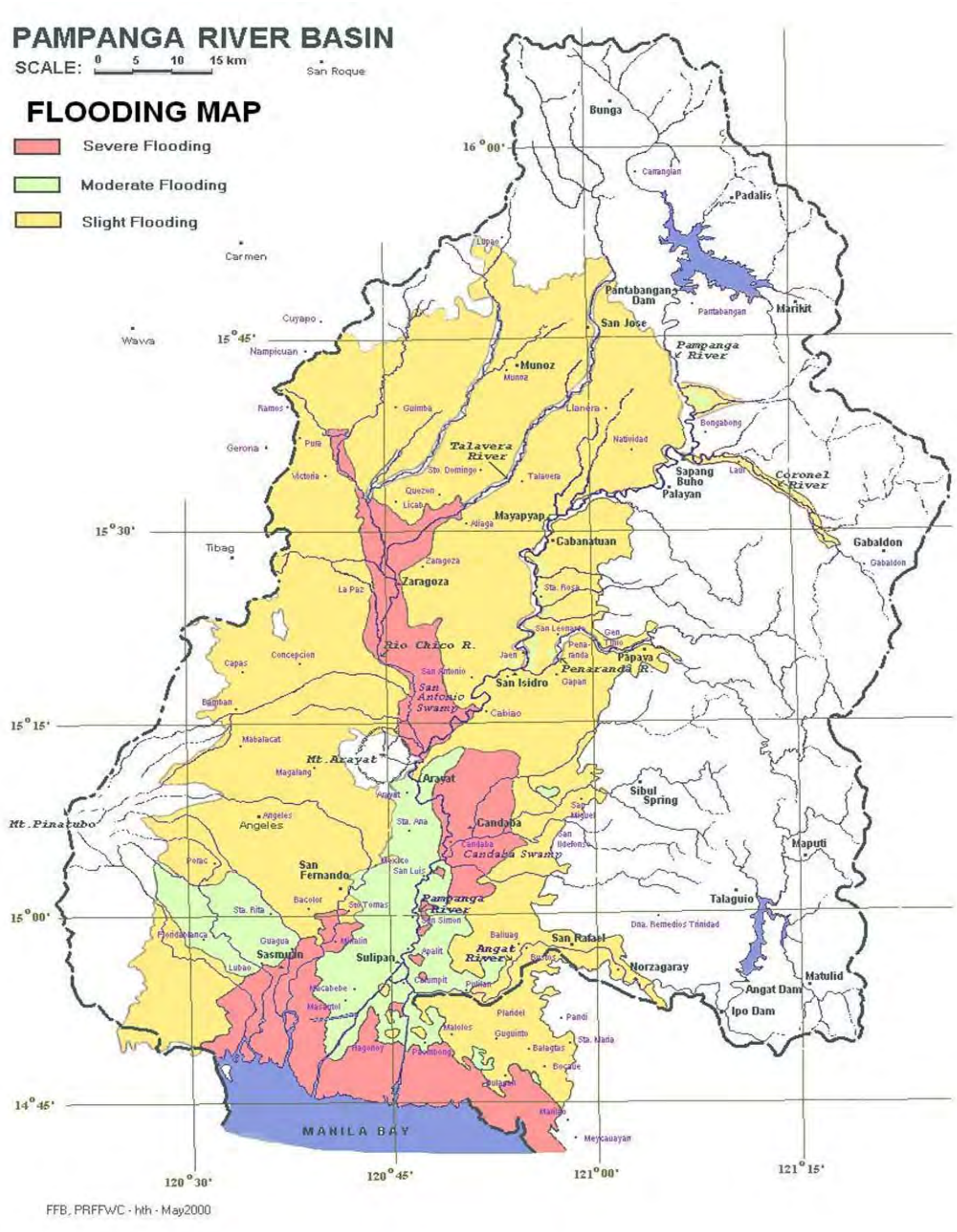


Figure 2-4 Flooding map of past floods in the Pampanga River basin

2.2.4. Cross-section measurements

In 2012, the cross-section measurements were periodically conducted by PAGASA at multiple points shown in Figure 2-5. There are 42 measured points in all, of which 26 are located at main stream of the Pampanga River. Measured cross-section data at the all points is converted to elevation by using

tentative benchmark elevation. However, river bed fluctuation such as erosion and sedimentation is significant in the Pampanga River. Because the shape of cross-section is subject to change due to nature of river bed materials, it can differ substantially before and after flooding. Figure 2-6 shows the long-term change of cross-section shape at the Arayat station. It is found from the lower left figure of Figure 2-6 that the height of river bed got higher by sedimentation before and at time of eruption of Mt. Pinatubo on June 1991. However, it is found from the lower right figure of Figure 2-6 that the height of river bed has become lower by erosion since the eruption of Mt. Pinatubo. Regarding to the cross-section of 2010, heavy deposition at right bank and erosion in central section occurred due to floods.

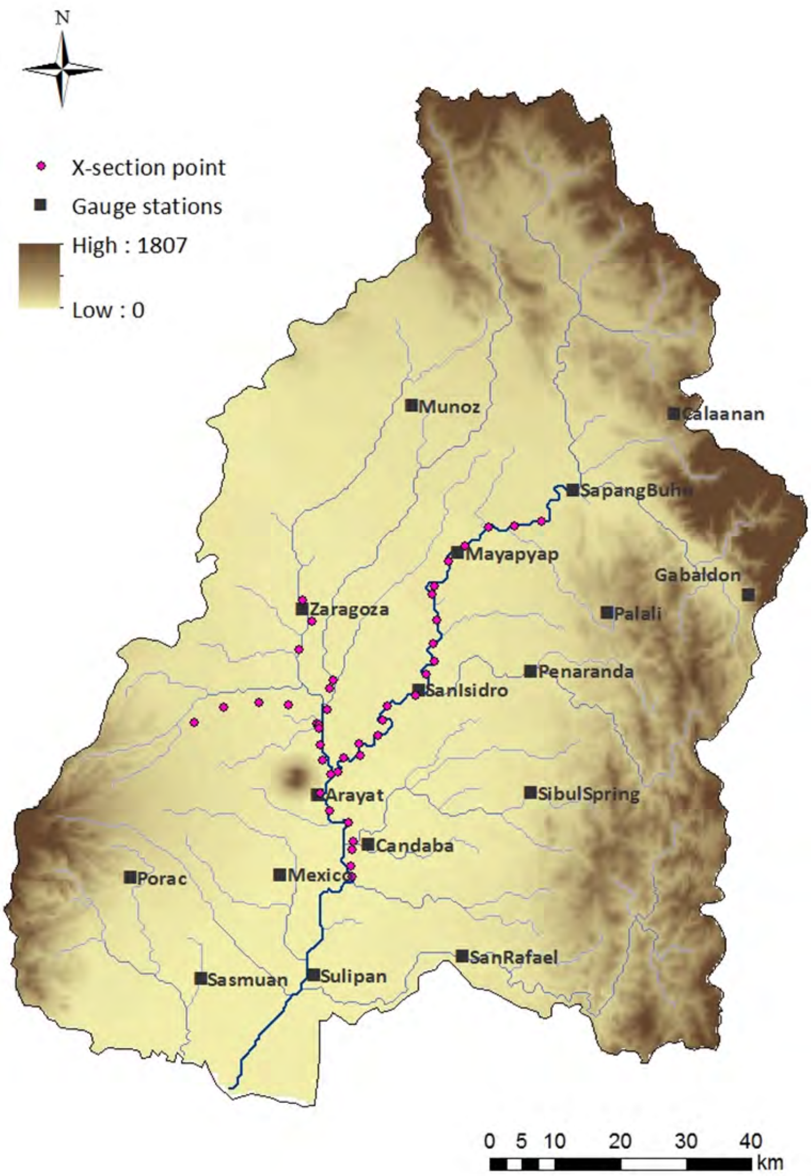


Figure 2-5 Location of cross-section measurement in the Pampanga River basin

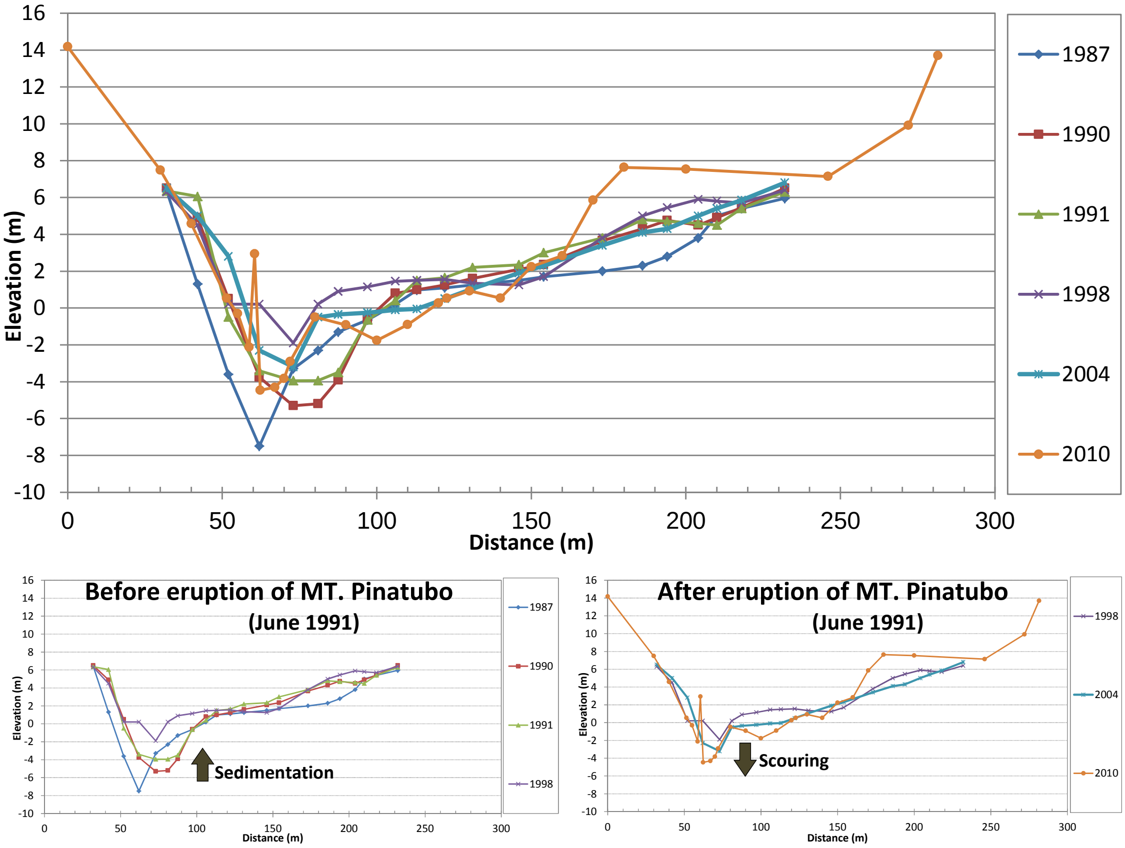


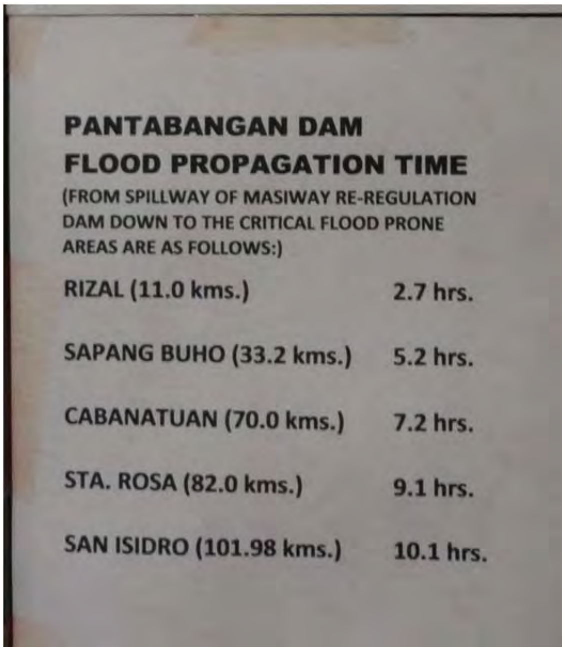
Figure 2-6 Long-term change of cross-section shape at the Arayat station

2.2.5. Existing flood forecasting model in the Pampanga River basin

PAGASA has been applying “water level correlation method” as the existing flood forecasting method during flooding. Water correlation method is based on relationship of water level between upstream and downstream. In PAGASA’s system, this relationship is assumed as a linear correlation; water level at downstream will be calculated by following equation (1).

$$\mathrm{H}_{down} = \mathrm{a}\,\mathrm{H}_{up} + b \qquad (1)$$

Where, H_{down} is water level at downstream (m), H_{up} is water level at upstream (m), a and b are coefficients of correlation. Coefficient “a” and “b” are determined according to correlations of past floods. In this method, flood propagation time from upstream to downstream must be determined as the fixed period. These time differences are also estimated according to flood traveling time of past floods. Photo 2-5 shows estimated flood propagation time from Pantabangan dam and Angat dam to major stations, which are shown at PRBFFWC office. Incidentally, not only water level correlation method but also dam discharge operation refers this flood propagation time.



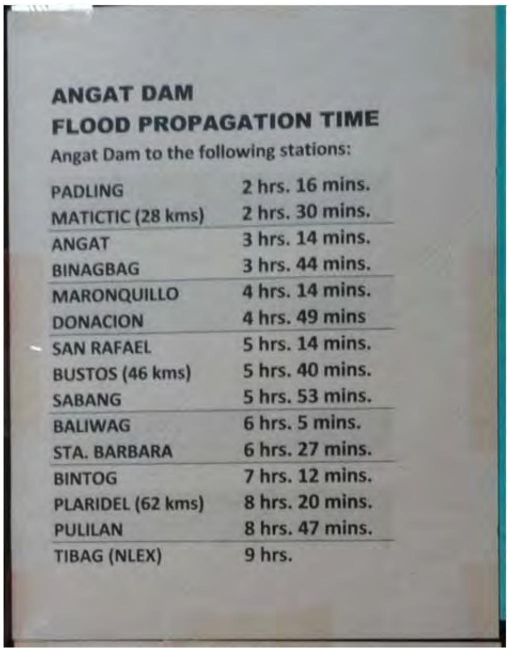


Photo 2-5 Flood propagation time from Pantabangan dam and Angat dam shown at PRBFFWC office

2.3. Present flood management in the Cagayan River basin

2.3.1. Descriptions of river basin and hydrological observation system by ground-gauge

The Cagayan River basin is the largest basin in the Philippines with a drainage area of 27,280 km^2 at its mouth in Aparri. In the Cagayan River Basin, the Philippines government has established 11 rainfall and water level gauging station as shown in Figure 2-7 (out of which 5 are telemetric stations under PAGASA’s management) to facilitate the flood warning along the river mainly to save human lives in the extreme events. The basin encompasses parts of Cagayan, Isabela, Mountain Province, Nueva Vizcaya, Quirino and Quezon Provinces. The basin is roughly elliptical in shape with its major axis oriented in a north-south direction. The Cagayan Valley is relatively flat but mountains with elevations up to 2,000m surround the east, south and west of the drainage basin. The Cagayan River, which is the main drainage channel of the basin, flows in a northerly direction from its head waters in Nueva Vizcaya to its mouth in the Babuyan Channel near Aparri. Its principal tributaries include the Siffu-Malling, Chico, Ilagan and Magat Rivers. The estimated annual discharge is 53,943 million m^3.

The Cagayan River basin is politically subdivided into 29 municipalities, with 820 barangays. Of the 29 municipalities, 3 are first-classed municipalities, 2 are second-classed municipalities, 4 are third-classed municipalities, 14 are fourth-classed municipalities, and 5 are fifth-classed municipalities. Only Sta. Praxedes is a sixth-class municipality. The classification is income-based by the Department of Budget and Management. Cagayan is classified as a first-classed province.

Furthermore, for administration purposes, Cagayan is divided into three congressional districts. The Third District includes the southern municipalities of Amulung, Iguig, Peñablanca, Tuguegarao, Enrile, Solana and Tuao. All other towns west of the Cagayan River comprise the Second Congressional District, except for some parts of Aparri, Camalaniugan, Lal-lo, Alcala, and Amulung, which are found west of the Cagayan River. The rest of the municipalities comprise the First Congressional District, northeast of the Province.

The Magat River is the largest tributary with an estimated annual discharge of 9,808 million m^3. It lies in the southwestern portion of the basin, stretching approximately 150 km from Nueva Vizcaya down to its confluence with Cagayan River about 55 km from the river mouth. Both the Magat and the Chico Rivers have extensive drainage areas which comprise about 1/3 of the whole basin. The Ilagan River originates from the western slopes of the Sierra Madre and drains the eastern central portion of the Cagayan River basin with an estimated annual discharge of 9,455 million m^3. It flows westward and joins the Cagayan River at Ilagan, Isabela, 200 km from the mouth. The Siffu-Malling River lies on the slope of the Central Cordillera ranges flowing almost parallel to the Magat River. Marshes and swamps are found in some parts of its lower reaches. The average annual rainfall is 1,000mm in the northern part and 3,000mm in the southern mountains. Floods caused by this river flow down very slowly because of surface retention over the extensive flood plain, extremely gentle slope, retardation of flood by several gorges and river meander.

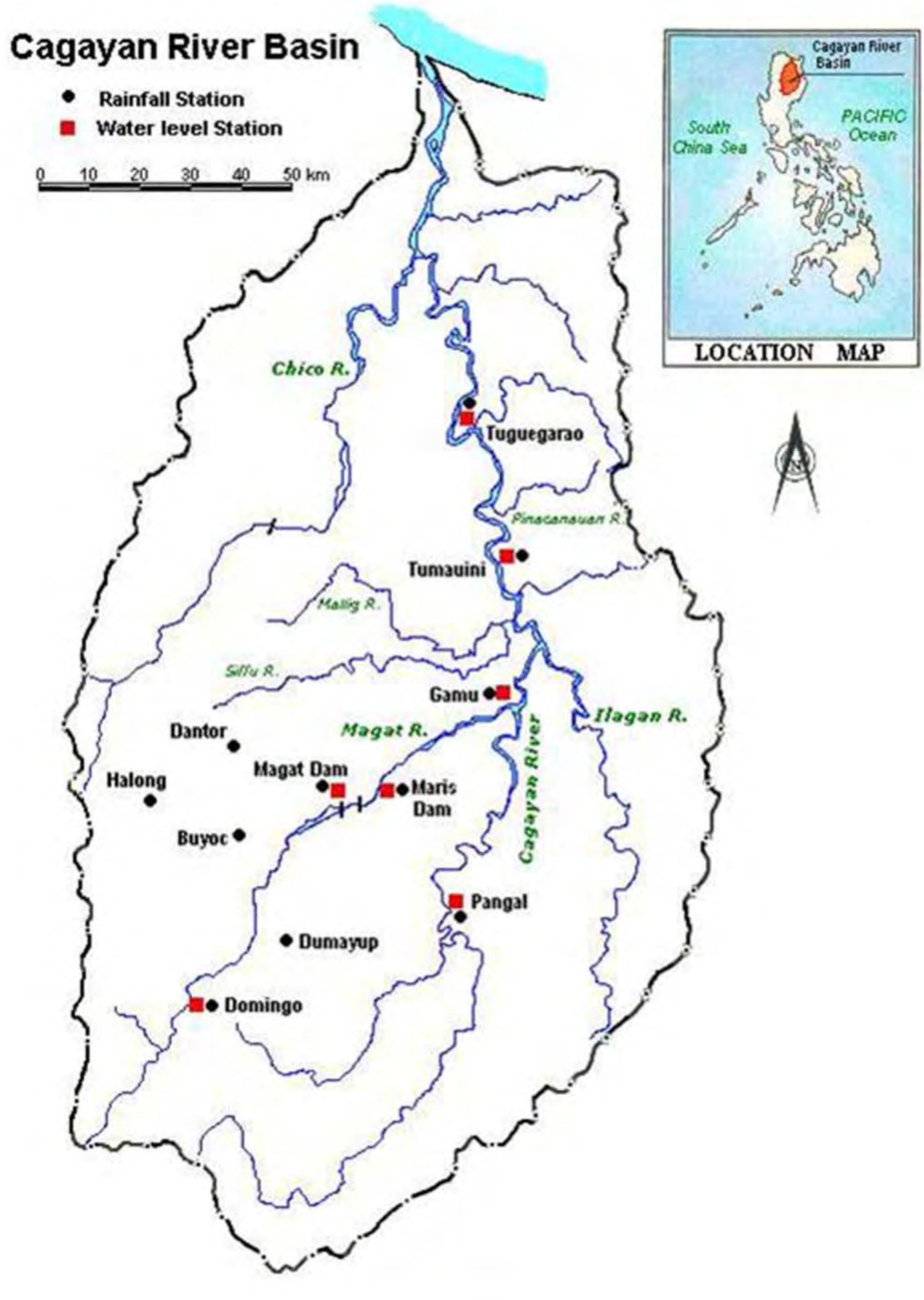


Figure 2-7 Cagayan River basin map and ground-gauge stations

2.3.2. Field visit in the Cagayan River basin

ICHARM members in charge of Philippine country component and Dr. Osti from ADB visited Magat dam, Tuguegarao station and the relevant offices during this field visit. The Magat dam is a multipurpose dam mainly for hydro power generation, irrigation purpose and also for flood control in the river basin. Photo 2-6 shows the photograph of Magat dam and its reservoir. Photo 2-7 shows the installed rainfall and water level station at Tsuguegarao station. It is inferred from the last photograph that bank erosion is significant in this area. Photo 2-8 shows the rainfall and water level monitoring and alert system at PAGASA sub-center, Cagayan Province. Real-time monitoring of rainfall and water level at each station and flood forecasting are conducted in this sub-center.

They also consulted with PAGASA, Office of Civil Defense (OCD) regional offices and Department of Science and Technology (DOST) in Cagayan province on the existing situation of flood forecasting and flood early warning in the Cagayan River basin.

Photo 2-6 The Magat dam and its reservoir

Photo 2-7 Tuguegarao station

Photo 2-8 Rainfall and water level monitoring system at PAGASA sub-center, Cagayan

2.3.3. Major damages by past floods

Flood disasters occur in Cagayan River basin almost every year. Table 2-5 shows the past major disasters related to flood in region 2 defined by OCD. Flood disasters which are mainly caused by typhoons, inflict enormous damages not only on the people but also on agriculture, infrastructure, fisheries and livestock in the Cagayan River basin.

According to past floods, inundation areas are estimated as shown in Figure 2-8. Left-hand figure shows the inundated area of 1973 flood, right-hand figure shows the inundated area of 1998 flood. Inundated area spreads to alluvial plain along the river course.

Table 2-5 Past major disasters related to flood (in Region 2)

YR.	DATE	EVENT	CASUALTIES			ESTIMATED COST OF DAMAGES (IN PESOS)			
			Dead	Injured	Missing	Agriculture	Infrastructure	Fisheries	Livestock
2011	Dec	Monsoon rains	4	Affected population 95,781		Production Cost 157,447	6725000		
						Prevailing farmgate 23,338			
	Dec	Continuous Rains	1	Affected population 17,280					
	Sep	Typhoon "Quiel"	7	12		Production Cost 31,897	505559605.8	30905684.33	
	Sep	Typhoon "Pedring"				Prevailing farmgate 2809986.3			
	Aug	Typhoon "Mina"	Affected population 108,037			Rice 599,888,273 Corn 340,272,753		5110595	
	Jul	Tropical storm"Juaning"	Affected population 86,207			804,316.75	21180000		
2010	Oct	Typhoon "JUAN"	11	147	1	1568835085	475851000	60030402	21996835
	Nov	Flooding	15		2	1074182399	582981000	93056713	
2009	May	Typhoon "EMONG"	7	8		65264543	28605000000	847530	
	May	Typhoon "EMONG"	14	8		29970000	28700000000	931500	
	Jul	Typhoon "JOLINA"				2100000		30660000	
	Sep	Typhoon "ONDOY"	4		1	61530000	94210000000	6330000	
	Oct	Typhoon "PEPENG"	1	7		6570000000	1.7697E+11		
	Oct	Typhoon "RAMIL"				72440000			
	Nov	Northeast Moonsoon	1		3	78730000			
2008	Jul	Typhoon "HELEN"				8493056	11200000	9528790	45000
	Jul	Typhoon "IGME"				3001000			
	Aug	Typhoon "KAREN"	2	3		637661426.7	449875000	69970952	
	Sep	Typhoon "MARCE"				2800000	10200000	3570000	
	Sep	Typhoon "NINA"				26874325.08	48235000	3578591	
	Oct	Typhoon "PABLO"	14		3				
	Nov	Moonsoon Rains	11		3	252593220	155276800	8604807	2920400
2007	Nov	Typhoon "KABAYAN"	9	1		564946343.2	61988266	7730035	575570
	Nov	Typhoon "MINA"	15	6	2	225441623	62400000	13261185.47	
2006	Jan	Moonsoon Rains	6		1	754521866.7	70300000	23167250	4471000
	Aug	Typhoon "HENRY"	5	1	2	23722491	3400000		
	Nov	Typhoon "PAENG"	25	20	3	34463879300	144931600	19458663.95	10769479
2005	Jan	Typhoon "FERIA"				9650550			
	Sep	Typhoon "LABUYO"	4			383199785.8	1261727000	1912950	
	Dec	Moonsoon Rains				1229766554		898890	328000
2004	Jun	Typhoon "IGME"	16	3	1	718002809.7	29655000		
	Aug	Typhoon "MARCE"	1			6472953	30615270		
	Nov	Typhoon "UNDING"/	1		2	163429964	400020	3227010	
	Dec	Typhoon "YOYONG"	27	37	1	1855798755	174831760	55265152	
2003	Jul	Typhoon "HARUROT"	33	117	2	2975550000	321126000	25560000	
2001	Jul	Typhoon "FIERA"	8	6	1	464899752.4	140500000	22063032	
1999	Aug	Typhoon "LUDING"	1			5561223	12000000		
1998	Oct	Typhoon "ILIANG"	23	396	2	1504000000	394900000	4600000	
	Oct	Typhoon "LOLENG"	5	3	3	342905799.3	109955600	3690000	7885350
1997	Oct	Typhoon "NARSING"	16	8		142457023	151375000	10711782	3646470
1996	Jul	Typhoon "GLORING"	5	4		141621000	64042000		
	Aug	Typhoon "LUSING"	1	1		4142000	3850000		
	Sep	Typhoon "MARING"	7	22		10276000	10945000		
	Oct	Tyhoon "SENIANG"	7			139964000	39156000	10410000	
	Oct	Typhoon "WARING"	6	22		10276000	10395000		500000
1995	Aug	Typhoon "GENING"	3	3		167626000	21275000		
	Oct	Typhoon "MAMENG"				299959000	17955000		
	Nov	Typhoon "ROSING"	2			69339950	66567136		
	Nov	Flashfloods	2		11	16523500	4850000		180000
	Dec	Flashfloods	1			235256476.1	78097666	1275237	1675660
1994	Sep	Typhoon "WELING"	10			88263232	38105000	7185000	12055000
1993	Jul	Typhoon "GORING"	32	89		260455025	164820000	2000000	
	Oct	Typhoon "KADIANG"	29	25	6	1101272	81519106		
	Nov	Typhoon "HUSING"	11			96931330	145241666		
1992	Sep	Typhoon "MARING"	2			726819984	56574500	11066259	1329145

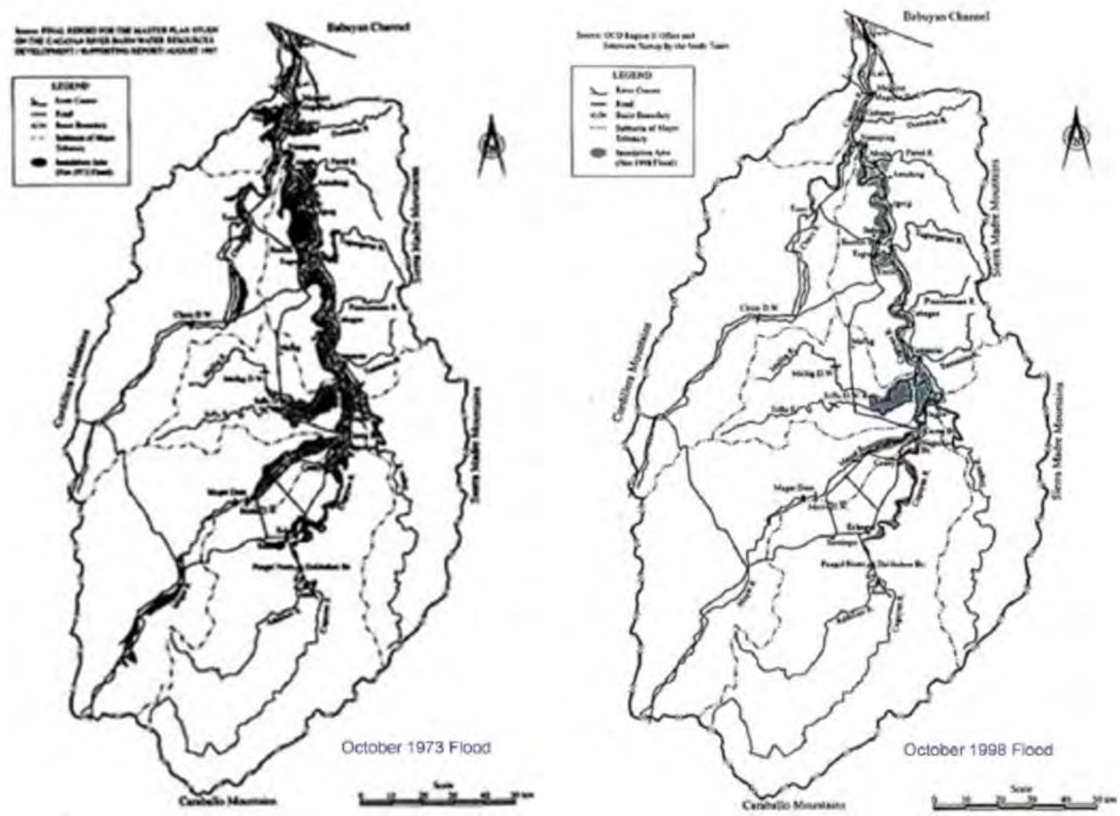


Figure 2-8 Historical inundation area according to past floods

2.3.4. Cross-section and discharge measurements

Cross-section measurements are conducted during the river discharge measurements by a current meter at Gamu station. Discharge measurements by a current meter had been conducted 11 times in all in 2002, 2004, 2010 and 2011 at Gamu station. Photo 2-9 shows the scene of discharge measurement by current meter at Gamu station. Figure 2-9 shows the long-term change of cross-section at Gamu station; bottom figure shows the average of cross-section measured in 2002, 2004 and average of cross-section measured in 2010, 2011. It is found from the comparison of cross-sections that river bed has been lowered due to scouring.


Photo 2-9 Discharge measurement by a current meter at Gamu station on Jan. 2011.

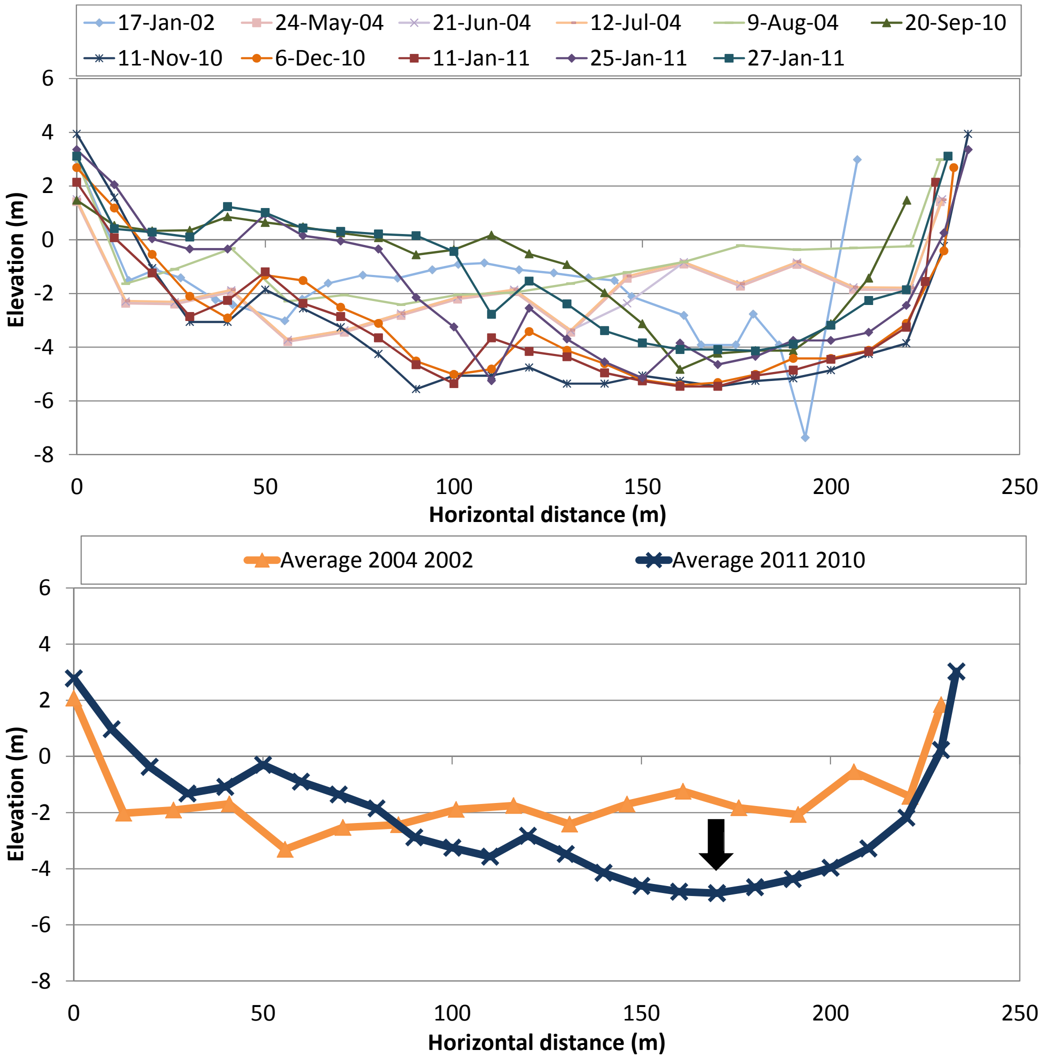


Figure 2-9 Long-term change of cross-section at Gamu station

2.3.5. The Lower Cagayan River Project

In response to the official request of the Republic of the Philippines, the Government of Japan conducted the Feasibility Study of the Flood Control Project for the Lower Cagayan River in the Republic of the Philippines. The Implementing Arrangement of the technical cooperation for the Study was agreed upon between the Department of Public works and Highways (DPWH) and the JICA on December 17th, 1999. In accordance with the Implementing Arrangement, JICA dispatched the “Study Team” to undertake the study in the Philippines.

The study commenced in March 2000 and the field investigations and review of the 1987 MP have been completed except for its implementation schedule. Transfer of technology has been made through on-the-job training, joint meetings with the counterparts and the workshops. The Study was completed in January 2002. The area for the feasibility study is the Lower Cagayan River area. It covers the river course and its riparian area where flow regime of the Cagayan River will be affected by widening of the Magapit Narrows. The whole Cagayan River basin was, however, investigated to formulate an appropriate flood control plan in view of the watershed conservation and the comprehensive river planning. Major Dimensions are as below.

Riverbed Slope:

- River mouth to Magapit Bridge: 1/13,000
- Magapit Bridge to Alcala: 1/8,500
- Alcala to confluence with the Tuguegarao River: 1/9,000
- Tuguegarao River confluence to Cabagan: 1/7,000

Channel Width

- River mouth to Magapit Bridge: 1,000 to 2,000 m
- Magapit Bridge to Alcala: 300 to 1,000 m
- Alcala to Tuguegarao: 500 m - Upstream of Tuguegarao: 600 m

Carrying Capacity

- River mouth to Magapit Bridge: 10,000 to 18,000 m^3/sec
- Magapit Bridge to Alcala: 5,000 to 15,000 m^3/sec
- Alcala to Cabagan: 3,000 to 6,000 m^3/sec

Carrying Capacity of the Lower Chico River

- Confluence to 10 km upstream: 5,000 to 10,000 m^3/sec
- 10 km to 14 km upstream: 2,000 to 4,000 m^3/sec

Carrying Capacity of the Lower Tuguegarao River

- Confluence to 3 km upstream: 3,000 m^3/sec
- 3 km to 9 km upstream: 6,000 m^3/sec
- 9 km to 14 km upstream: 2,000 m^3/sec

2.3.6. Existing flood forecasting model in the Cagayan River basin

In the Cagayan River basin, PAGASA has been using the existing telemetric data for flood forecasting utilizing the gauge to gauge correlation technique with little or no account of rainfall and intermediate tributaries flows as with the Pampanga River basin. This “water level correlation method” is based on equation (1) as above.

There is a scope of applying remote sensing technologies mainly the satellite-based rainfall observation to enhance the flood forecasting, because number of observation stations is less than the minimum requirement recommended by World Meteorological Organization (WMO). Therefore, equally important is to use cutting edge technology mainly advanced numerical hydrological and hydraulic models to forecast the flood in the river basin. Although the reliability of flood forecasting and flood early warning is still under discussion, PAGASA has been trying its best to make real time flood forecasting with available limited numbers of telemetric observations. In order to fill up these gaps, ICHARM intends to help PAGASA apply IFAS in this river basin. IFAS can help develop the confidence level of flood forecaster without replacing and interrupting the existing FFWS.

2.4. Standard operating procedure of flood early warning with relevant organization

2.4.1. Flood forecasting and warning activities during flooding

A Flood Advisory (FA) is hydrological information in general or in its simple form. It is initialized anytime during flood watch period for awareness or preparedness of the flood prone areas within telemetered basin areas, when their rivers and streams are likely to be affected by high stream flow or flooding or flash flooding. A basin general FA is issued also if there is a forecast of significant rainfall based on meteorological/numerical models and other forecasting tools, even if the past rainfall over the basin is nil. The basins Flood Forecasting Warning Center (FFWC) provide the Main Operation Center (MOC), HMD with a copy of the basins’ general FAs. The external dissemination scheme of region general FA is shown in Figure 2-10. Figure 2-11 shows the example of FA issued on September 2011.

Flood Bulletins (FB) are more specific flood information prepared and issued whether or not it is usually being preceded by a basin general FA during flood monitoring. It is initialized anytime and regularly issued by a FFWCs thereafter until being finalized when floodwaters have generally subsided or no significant increases in the present situation is expected further. FB is more near definite and specific as to river level changes, in terms of its rising and falling trends and the possible areas to be affected. FB is issued at 5am and 5pm daily during flood watch operations unless when situations warrants that an intermediate FB needs to be issued at any time between those two issuance stages to cover for unfavorable situations within the basin. The external dissemination scheme of basin and Flood Forecasting and Warning System for Dam Operation (FFWSDO) is shown in Figure 2-12. Figure 2-13 shows the example of FB issued on September 2011.

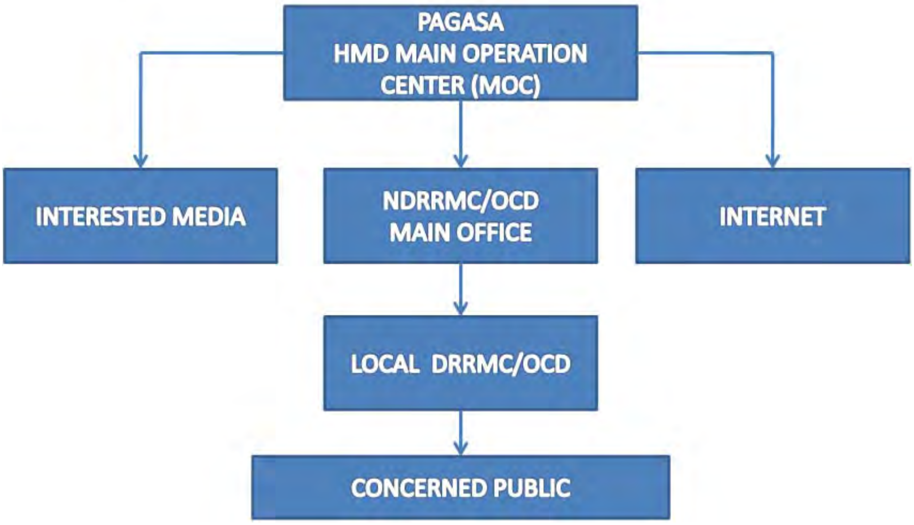


Figure 2-10 External dissemination scheme of region general FA

REPUBLIC OF THE PHILIPPINES
Department of Science and Technology
Philippine Atmospheric, Geophysical and
Astronomical Services Administration (PAGASA)
PAGASA Science Garden, Agham Road, Diliman, Quezon City 1100
Websites: www.pagasa.dost.gov.ph
www.prffwc.webs.com

PAMPANGA RIVER FLOOD FORECASTING & WARNING CENTER
Hydro-Meteorology Division/NCR-PRSD
DOST compound, Bgy. Maimpis, San Fernando, Pampanga 2000

==

GENERAL FLOOD ADVISORY NO. 1
PAMPANGA RIVER BASIN & ALLIED RIVERS

VALID FROM 4:00 PM, 26 SEPTEMBER 2011 TO 5:00 AM TOMORROW UNLESS THERE IS AN INTERVENING ADVISORY OR AN INITIAL BASIN FLOOD BULLETIN TO BE ISSUED.

BASIN RAINFALL AS OF 4:00 PM TODAY

PAST 24-HR OBSERVED RAINFALL (millimeters): 42
FORECAST 12-HR RAINFALL (millimeters): BETWEEN 40 TO 60

WATERCOURSES LIKELY TO BE AFFECTED:
- UPPER MAIN PAMPANGA RIVER
- TRIBUTARY RIO CHICO
- CANDABA SWAMP AREA
- GUAGUA RIVER BASIN AREA - ABACAN. PORAC-GUMAIN. PASAC-GUAGUA, PASIG- POTRERO RIVERS

PUBLIC WARNING:

PEOPLE LIVING NEAR MOUNTAIN SLOPES AND IN LOW-LYING AREAS ADJACENT TO OR ALONG THE ABOVE-MENTIONED RIVERS AND THE LOCAL DISASTER RISK REDUCTION AND MANAGEMENT COUNCILS CONCERNED ARE ADVISED TO BE ALERT FOR POSSIBLE FLASHFLOODS OR RIVER FLOODING AND LANDSLIDES.

Prepared by:

PRFFWC – HTH / RPY / JRD / RFD

Figure 2-11 Example of FA issued on September 2011

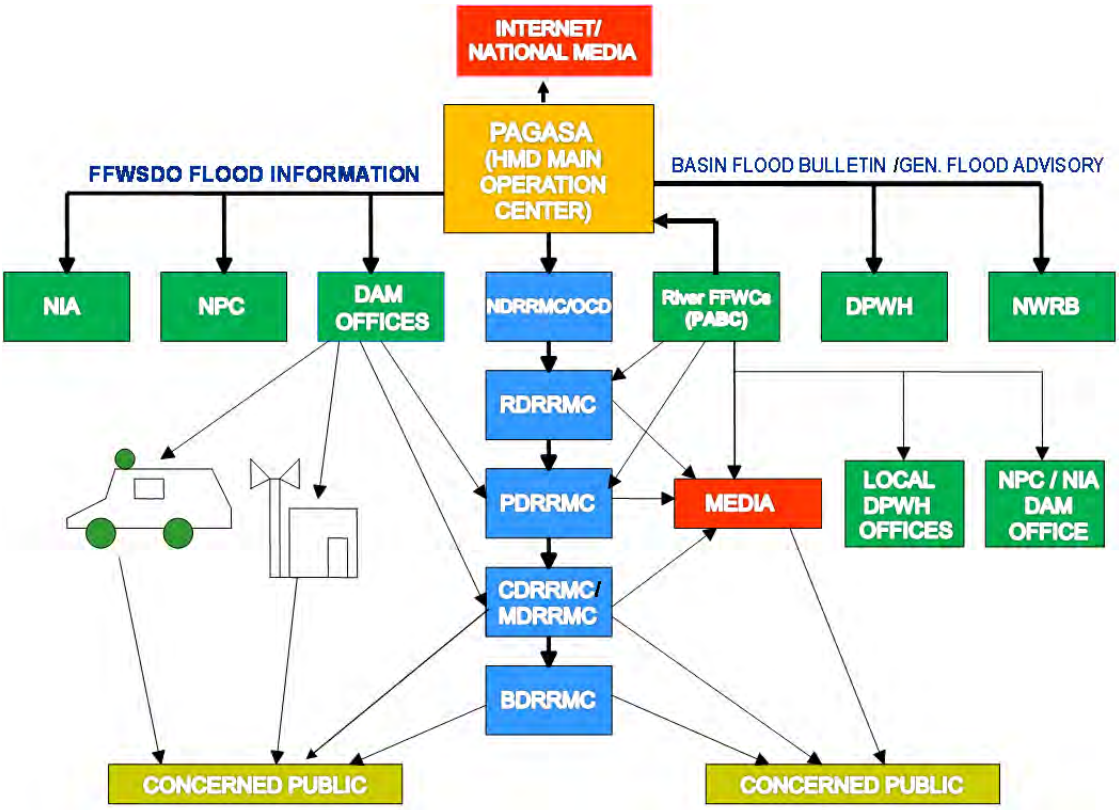


Figure 2-12 External dissemination scheme of basin and FFWSDO flood information

FLOOD BULLETIN NO. 1 – PAMPANGA RIVER BASIN AND ALLIED RIVERS
ISSUED AT: 5:00AM, 27 SEPTEMBER 2011
VALID UNTIL THE NEXT ISSUANCE AT 5:00PM TODAY UNLESS THERE IS AN INTERMEDIATE BULLETIN

BASIN RAINFALL AS OF 4:00 AM TODAY:
PAST 24-HR = 80 MM — FORECAST 24-HR = MORE THAN 80 MM

BASIN EXPECTED RESPONSE:

WATER LEVEL STATION (STN)	RIVER/ SWAMP WATER LEVEL (WL) TREND AT STATION	FLOOD SITUATION MESSAGE	PARTICULAR LOW-LYING AREAS
SAPANG BUHO STN., PAMPANGA RIVER	NOW AT 3.37 M/ SLOW INCREASE TO EXCEED 3.70 M. ALERT WL TODAY	FLOODING IS POSSIBLE BEGINNING TODAY	PALAYAN CITY, NATIVIDAD, LLANERA
MAYAPYAP STN., PAMPANGA RIVER	NOW AT 1.27 M/ SLOW INCREASE TO REACH BELOW 3.0 M. ALERT WL TODAY	FLOODING IS POSSIBLE	CABANATUAN, STA ROSA, SAN LEONARDO
SAN ISIDRO STN., PAMPANGA RIVER	NOW AT 2.99 M/ SLOW INCRESE TO EXCEED 3.20 M ALERT WL TODAY	FLOODING IS POSSIBLE BEGINNING TODAY	SAN ISIDRO, CABIAO
ARAYAT STN., PAMPANGA RIVER	SLOW RISE TO REACH ABOVE 5.00 M. ALERT WL	FLOODING IS POSSIBLE BEGINNING LATE AFTERNOON	CANDABA, SAN LUIS, ARAYAT, SAN SIMON
SULIPAN STN., PAMPANGA RIVER	NOW AT 1.53 M/ SLOW RISE TO CONTINUE	FLOODING IS POSSIBLE BEGINNING TOMORROW MORNING	APALIT, CALUMPIT
ZARAGOZA STN., RIO CHICO RIVER	NOW AT 13.20 M/ SLOW RISE TO REACH 14.50 M. CRITICAL WL BY LATE TONIGHT	FLOODING IS POSSIBLE BEGINNING TONIGHT	SAN ANTONIO, LA PAZ, ZARAGOZA
CANDABA STN., CANDABA SWAMP	NOW AT 3.61 M/ SLOW FILLING-UP TO REACH ABOVE 5.00 M. CRITICAL WL BY LATE TONIGHT	FLOODING IS POSSIBLE BEGINNING TONIGHT	CANDABA, SAN MIGUEL, SAN ILDEFONSO, PULILAN
PEÑARANDA STN., PEÑARANDA RIVER	NOW AT 2.56 M/ SLOW RISE	FLOODING IS POSSIBLE BEGINNING TONIGHT	PEÑARANDA, SAN LEONARDO, GAPAN
SASMUAN STN., GUAGUA RIVER	NOW AT 2.18 M/ SLOW RISE	FLOODING IS POSSIBLE BEGINNING TONIGHT	SASMUAN, LUBAO, GUAGUA
COASTAL FLOODING IN THE LOW-LYING SEASHORE AREAS			HAGONOY, PAOMBONG

THE RESIDENTS AND THE DISASTER RISK REDUCTION AND MANAGEMENT COUNCILS CONCERNED ARE ADVISED TO TAKE THE NECESSARY APPROPRIATE ACTIONS

HTH / RPY / JRD / RFD

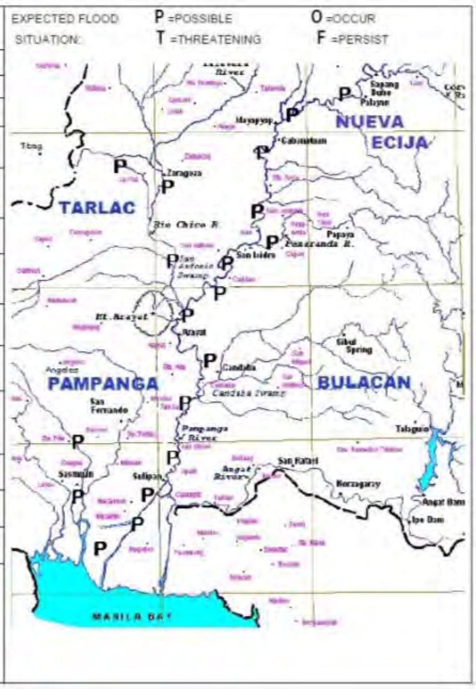


Figure 2-13 Example of FB issued on September 2011

2.4.2. The project of FFWSDO

In April 1983, the FFWSDO project was conceived. The project was meant to prevent occurrences of similar incident such as that one in Angat Dam in the early 70’s which resulted to unprecedented flood heights that caused destruction and deaths downstream of the dam. Implementation of the project was done in stages (Phases I and II). Phase I, for Angat and Pantabangan Dams was completed in July 1986. For Phase II, implementation was fully completed by the onset of the rainy season in 1992. The major components of Phase II are the establishment of the PAGASA Data Information Center, FFWS, FFWS at dam offices, hydrological stations, warning posts, repeater stations and monitoring stations. The project was implemented with the National Power Corporation (NPC) and the National Irrigation Administration (NIA) as cooperating agencies and PAGASA as the lead agency. The FFWSDO aims at the establishment of telemetered flood forecasting warning system that will provide the necessary information for the safe and cost effective operation of the existing five major dams in Luzon and to forewarn the people in the flood plains downstream of these dam sites of the impending release of impounded water through spillways during typhoons.

2.4.3. Present conditions of flood prevention system in Region 2

Disaster Coordinating Council (DCC) prepares damage reports upon occurrence of disasters. Responding to the damage reports, in Region 2, Regional Disaster Coordinating Council (RDCC) 2 prepared the general action plan for typhoons/floods OPLAN BAGYO/LAYOS in May 1998. Cordillera RDCC also prepared Cordillera Regional Disaster Management Plan in 1994. The purposes of the disaster action plans are to implement effective disaster preparedness, mitigation and prevention activities to minimize damage to property and human suffering. In the Cagayan River basin, some joint operation on the disaster management is conducted between RDCC2 and Cordillera RDCC so that an assistance of the RDCC2 is given on the occasion of emergency in the Chico or other river basins.

There are two existing FFWS, one is the Cagayan Flood Forecasting and Warning System operated by PAGASA and the other is Magat Dam Flood Forecasting and Warning System under NIA. The existing evacuation system is operated and maintained by RDCC, Provincial Disaster Coordinating Council (PDCC), City Disaster Coordinating Council (CDCC) and Barangay Disaster Coordinating Council (BDCC). There are 464 designated evacuation centers in Region 2. Major problems are insufficient supply of drinking water and food, and lack of cooking facilities and comfort rooms in the evacuation centers.

3. Fundamental Analysis of Flood Characteristics in the Pampanga and Cagayan River Basin

3.1. Flood analysis in the Pampanga River basin

3.1.1. Topographic conditions

The Pampanga River basin shares topographical features of both mountainous and plain as Figure 3-1 shows. Roughly speaking, east side of river basin is mountainous area, central and southwest side of river basin is plain area. Most of main stream lies on plain area where is lower than 50m altitude. Generally, as riverine flood tends to occur in plain area, almost every area in the Pampanga River basin has the risk of inundation potentially. This aspect from topographic information is corresponding to historical flooding map in the Pampanga River basin shown in Figure 2-4.

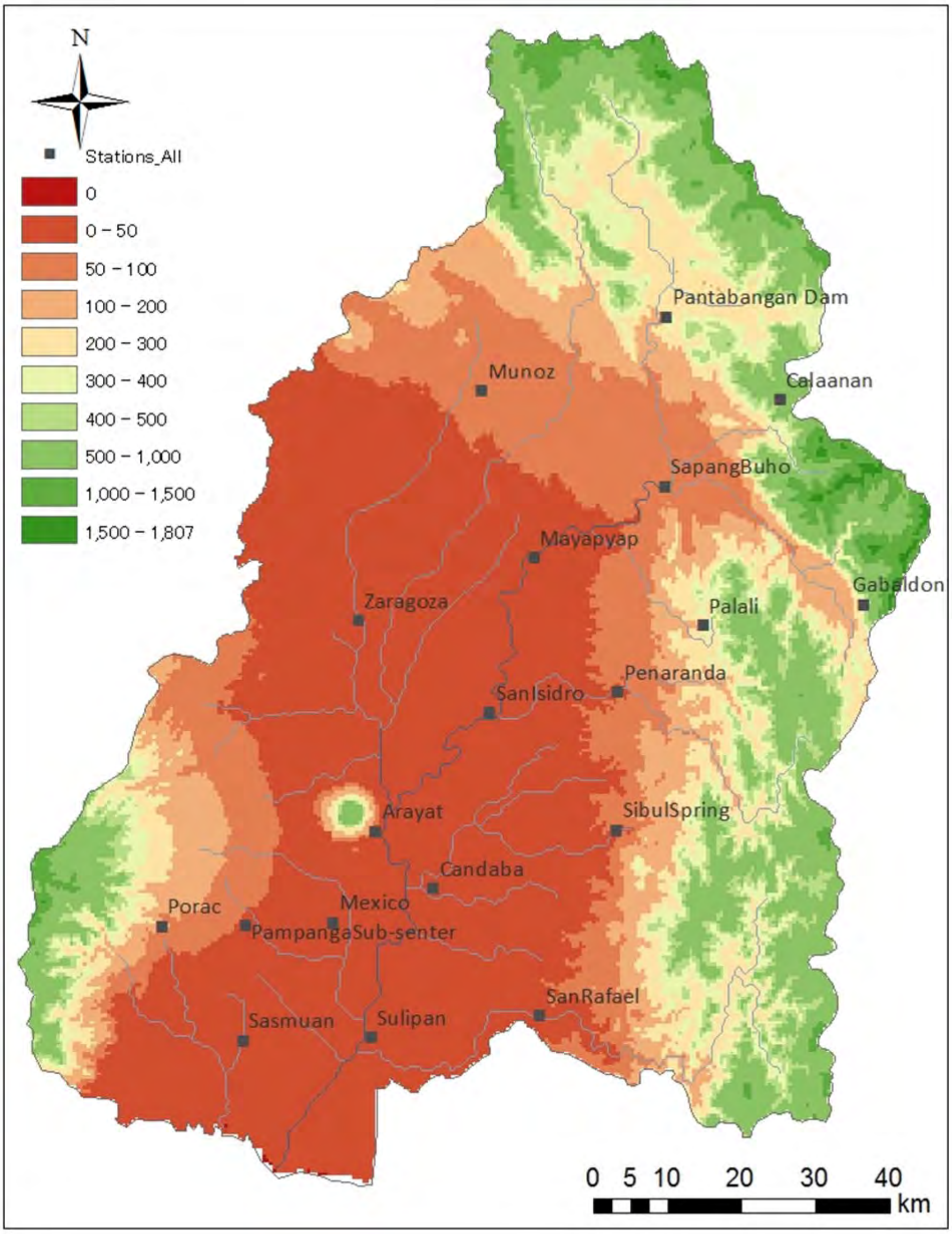


Figure 3-1 Topographic conditions in the Pampanga River basin

3.1.2. Discharge measurements and rating curve

The discharge measurements in the Pampanga River basin have been conducted a number of times at Sapang Buho, Mayapyap, San Isidro and Arayat station in 1990s and recent years (2010 and 2011). In this report, Mayapyap, San Isidro and Arayat are focused because these three stations are covered by cross-section measurement in 2012.

Figure 3-2 shows cross-section, relationship between water level and square root of discharge and

relationship between water level and discharge at the Mayapyap station. Cross-section chart is based on the result of cross-section measurement in 2012 at the nearest point to the Mayapyap. According to Table 2-2, altitude of staff gauge “0” at the Mayapyap station is 25.697m. As there is the liner correlation in the relationship between water level and square root discharge, the following square equation (2) has been employed as the rating curve.

$$Q = a(H + b)^2 \qquad (2)$$

Where, Q is discharge (m^3/s), H is water level (m), a and b are coefficients. Coefficients a and b are calculated by the least-square method. From the lower left figure showing relationship between water level and square root discharge, it is found the significant difference between 1990s and recent (2010 and 2011). The results of recent measurements are lower than the results of 1990s distinctly, which this difference is referable to the effect of scouring during flooding. This difference by scouring leads the different rating curves as the Figure 3-2 (right) shows. The blue line is the rating curve calculated using all measurement results; the red line is the rating curve calculated using only recent results.

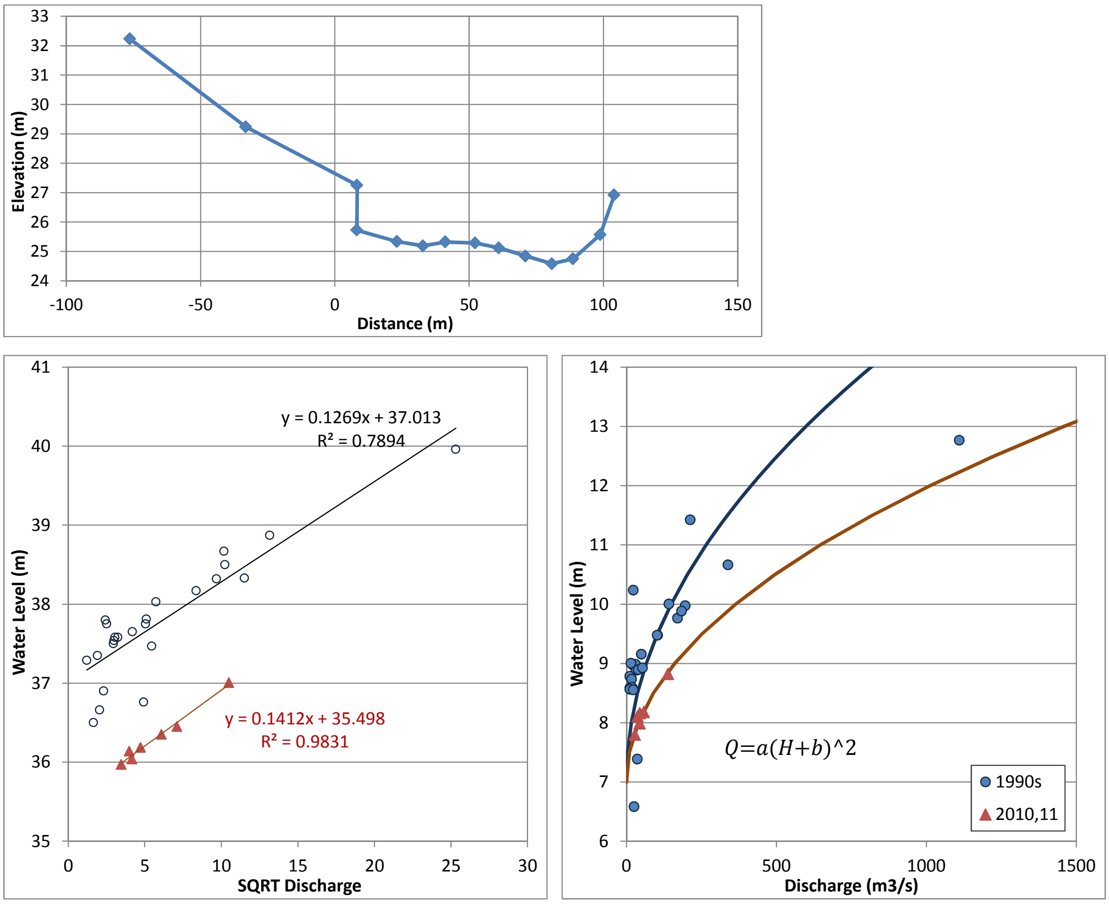


Figure 3-2 Cross-section chart (upper), relationship between water level and square root discharge (left) and relationship between water level and discharge (right) at the Mayapyap station

Figure 3-3 shows cross-section, relationship between water level and square root of discharge and relationship between water level and discharge at the San Isidro station. Since the cross-section measurement in 2012 at the nearest point to the San Isidro is missing, there is no cross-section chart in Figure 3-3. According to Table 2-2, altitude of staff gauge “0” at the San Isidro station is 9.585m. As there is the liner correlation in the relationship between water level and square root discharge, the above square equation (2) has been employed as the rating curve. There is the significant difference between 1990s and recent years (2010, 2011) in the relationship between water level and square root discharge at the San Isidro station as is the case with the Mayapyap. This difference by scouring also leads the different rating curves as the Figure 3-3 (right) shows. These differences of rating curves shown in Figure 3-2 and Figure 3-3 due to change of cross-section shape may make a critical impact on the estimation of river discharge and flood forecasting at the time of flooding.

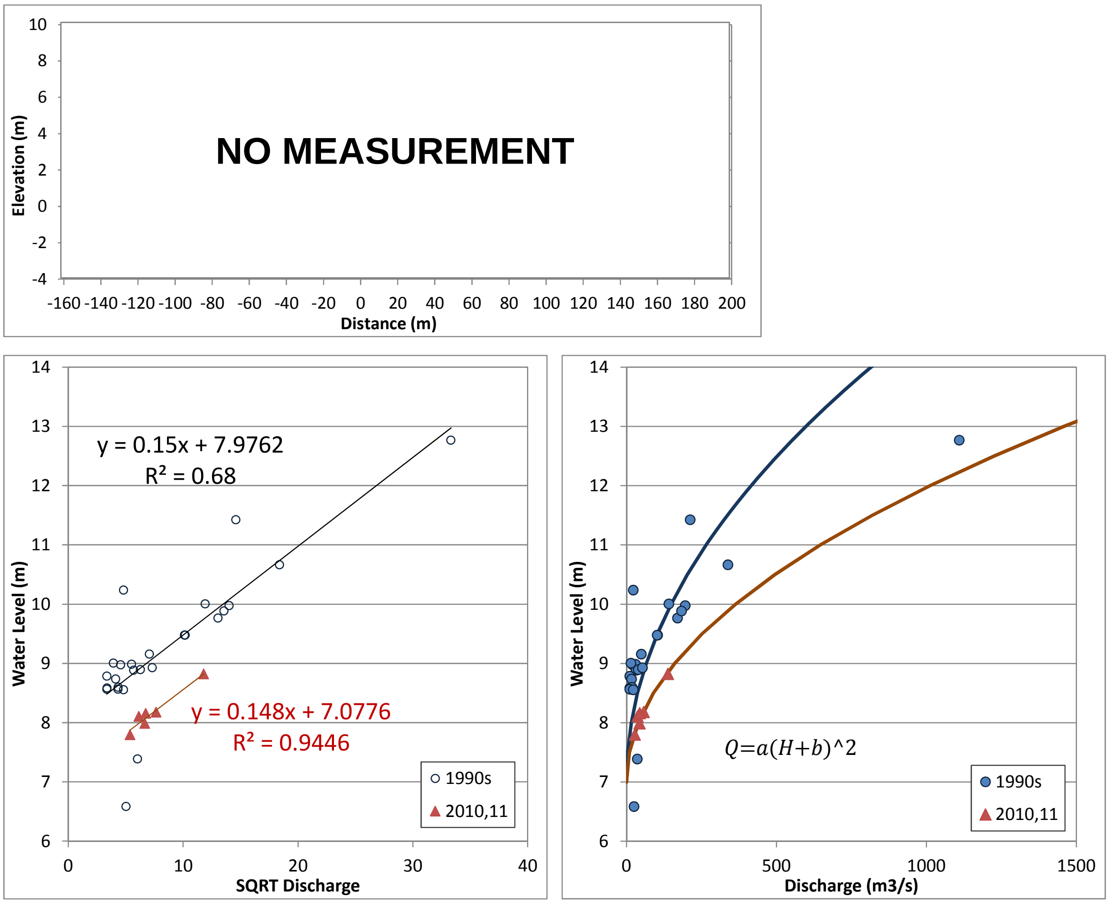


Figure 3-3 Cross-section chart (upper), relationship between water level and square root discharge (left) and relationship between water level and discharge (right) at the San Isidro station

Cross-section, relationship between water level and square root of discharge and relationship between water level and discharge at the Arayat station are shown in Figure 3-4. Cross-section chart

shows the result of cross-section measurement in 2012 at the nearest point to the Arayat. According to Table 2-2 and Figure 2-3, altitude of staff gauge "0" at the Arayat station is 0.077m. As there is the liner correlation in the relationship between water level and square root discharge, the above square equation (2) has been employed as the rating curve. Although there is no significant difference between 1990s and recent measurements in the relationship between water level and discharge, the correlation between water level and discharge is shifted substantially at the height of 6m which is the changing point of cross-section width. Therefore, two different curves are employed at lower and higher 6m. The calculated coefficients "a" and "b" at each station are shown in Table 3-1 as the reference.

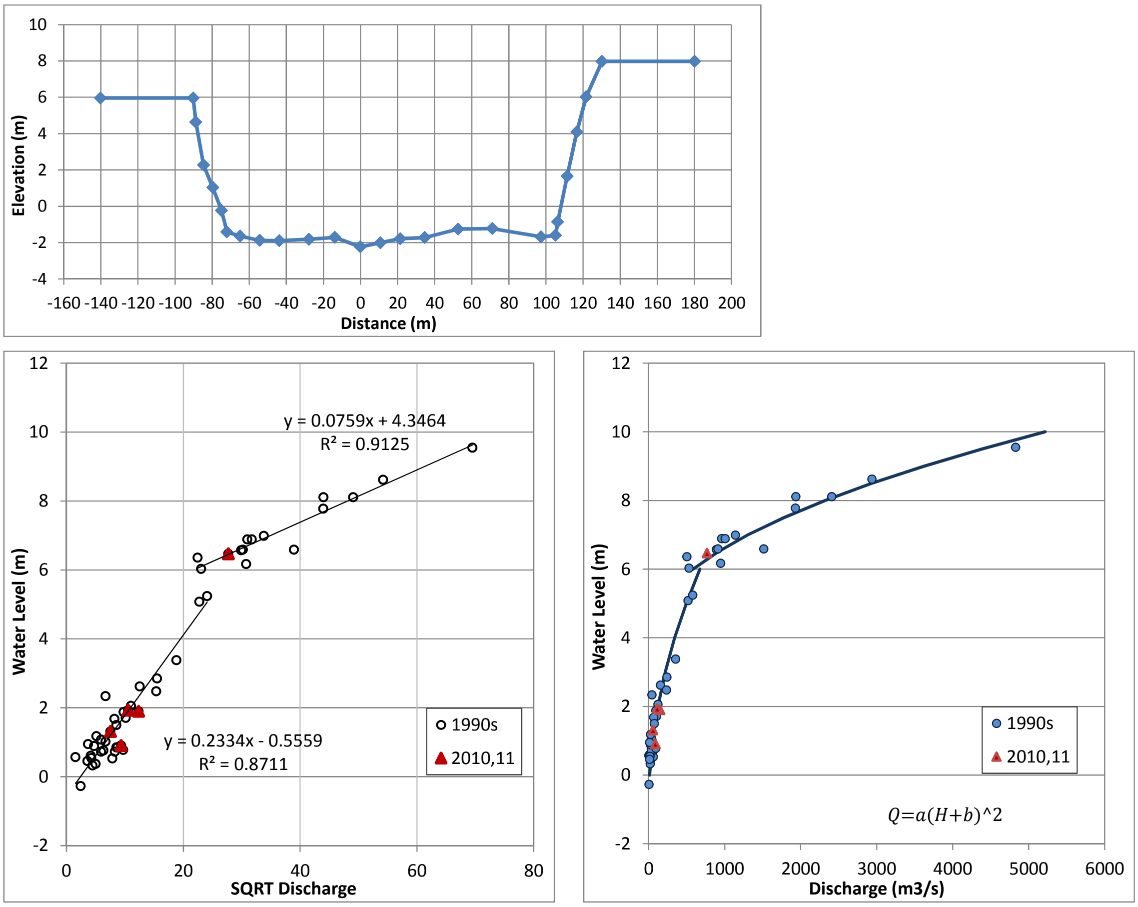


Figure 3-4 Cross-section chart (upper), relationship between water level and square root discharge (left) and relationship between water level and discharge (right) at the Arayat station

Table 3-1 Calculated coefficients "a" and "b" at each station

Station	Description	a	b
Mayapyap	1990s and 2010,11	12.440	-35.754
	only 2010,11	48.474	-35.485

San Isidro	1990s and 2010,11	16.704	-7.013
	only 2010,11	40.709	-7.013
Arayat	less than 6m	13.933	0.953
	more the 6m	144.394	-3.990

3.1.3. Analysis of flood traveling time

In general, flood traveling time is one of the most important factors for both flood forecasting and flood early warning. For example, the water level correlation method which is existing flood forecasting model in PAGASA requires the flood traveling time, and it is also important for the flood warning as a lead-time. Thus flood traveling times of recent floods are calculated in this analysis. There are several kinds of calculation method of flood traveling time; it was calculated using past rainfall and water level data in this report as shown in Figure 3-5 because hydrological hourly data is available. The vertical axis of Figure 3-5 means runoff depth which is the divided discharge by catchment area. Flood traveling time is the time difference between the peak time of rainfall which is calculated as the center of gravity of hyetograph and peak of runoff depth. Figure 3-6 shows the flood traveling time of recent floods from 2009 to 2012 at the Mayapyap, the San Isidro and the Arayat station. Flood traveling time at every station varies widely by flood because of rainfall intensity, rainfall distribution, soil conditions and etc. during flooding. Averages of flood traveling time are 18.0 hours at the Mayapyap, 23.4 hours at the San Isidro and 38.7 at the Arayat as shown in Table 3-2.

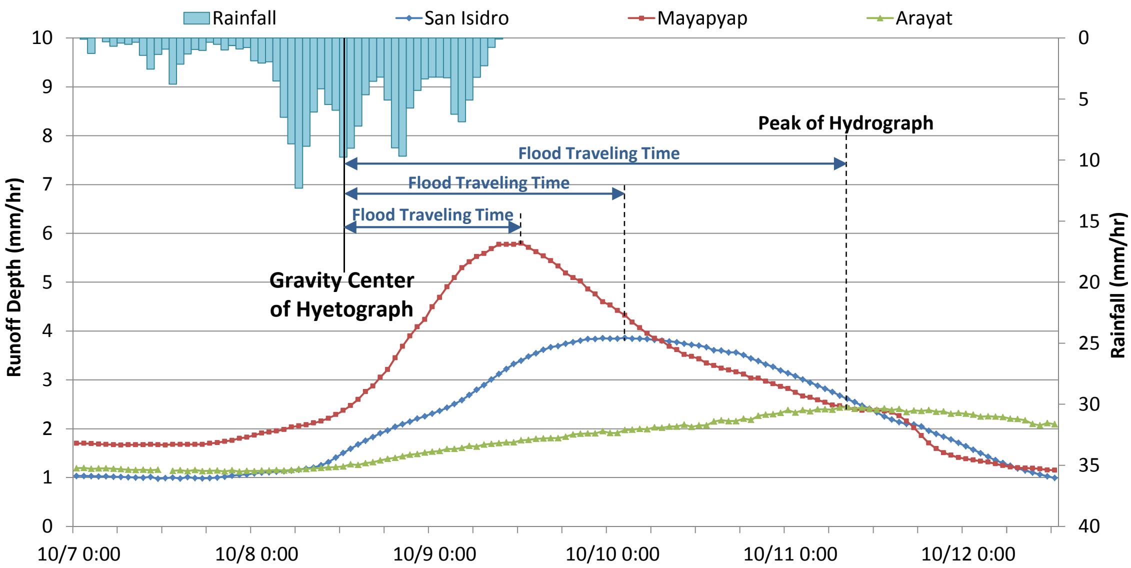


Figure 3-5 Calculation example of flood traveling time

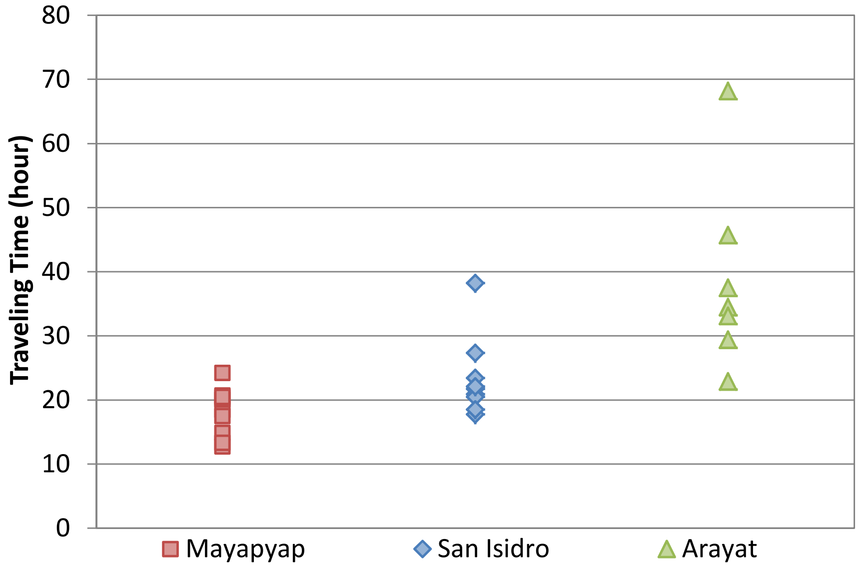


Figure 3-6 Flood traveling time of recent floods at the Mayapyap, the San Isidro and the Arayat station

Table 3-2 Average of flood traveling time at the Mayapyap, the San Isidro and the Arayat station

	Average traveling time (hours)	Propagation time from the Mayapayap (hours)	Propagation time from the San Isidro (hours)
Mayapyap	18.0	--	--
San Isidro	23.4	5.3	--
Arayat	38.7	15.4	20.7

3.1.4. Water level correlation during flooding among stations

From the average of flood traveling time shown in Table 3-2, flood propagation time among 3 stations are assumed as shown in Figure 3-7. Based on the propagation time, water level correlations among 3 stations are analyzed. The 5.4 hours, 15.4 hours and 20.7 hours are the constant values which are applied as the time difference between stations. Figure 3-8 shows the water level correlations of three combinations; one is the water level correlation between the Mayapyap and the San Isidro deducted 5.4 hours, another is the water level correlation between the Mayapyap and the Arayat deducted 20.7 hours, and the last is the water level correlation between the San Isidro and the Arayat deducted 15.4 hours. The correlations among 3 stations differ depending on flood. Especially, it is difficult to find the agreement in the correlations with the Arayat, because there is a largest tributary, the Chico River, flow into main stream at the upstream of Arayat station. The other possible causes of poor correlation are rainfall intensity, rainfall distribution, soil conditions and etc. during flooding as is the case with estimation of flood traveling time.

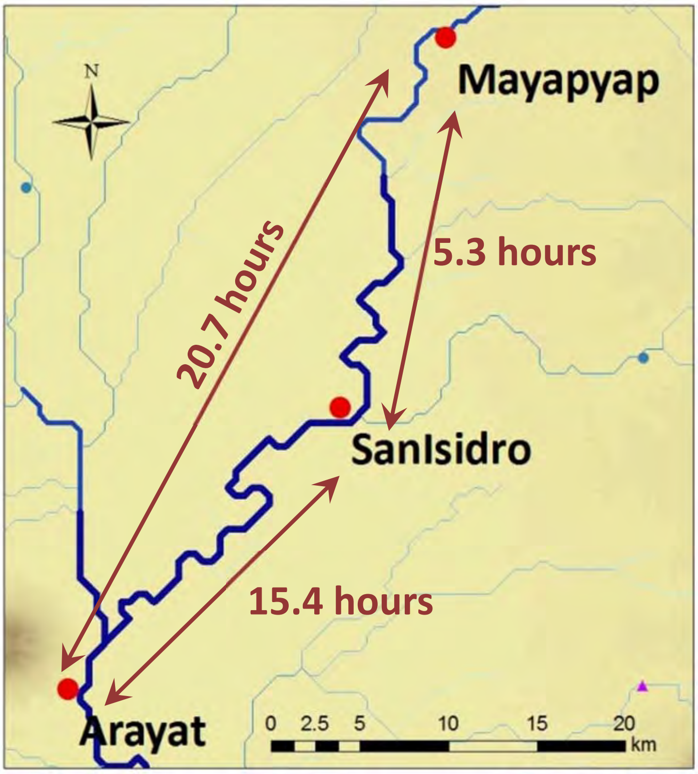


Figure 3-7 Flood propagation time among the Mayapyap, the San Isidro and the Arayat station

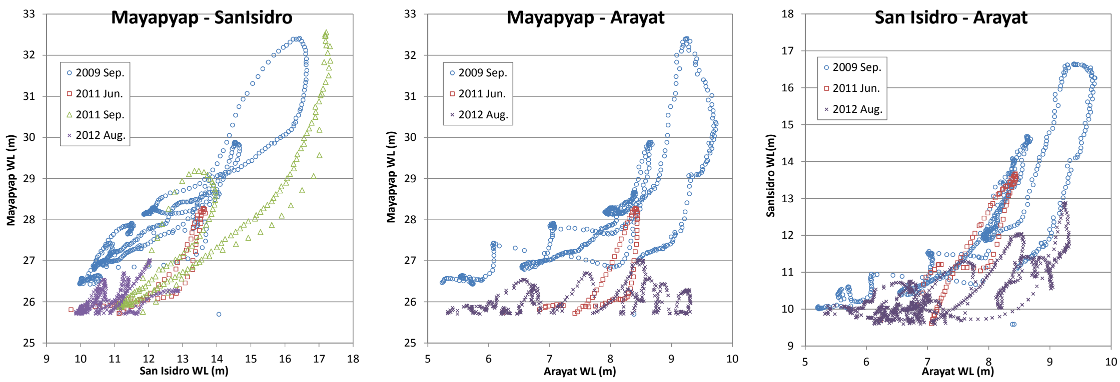


Figure 3-8 Water level correlations among the Mayapyap, the San Isidro and the Arayat

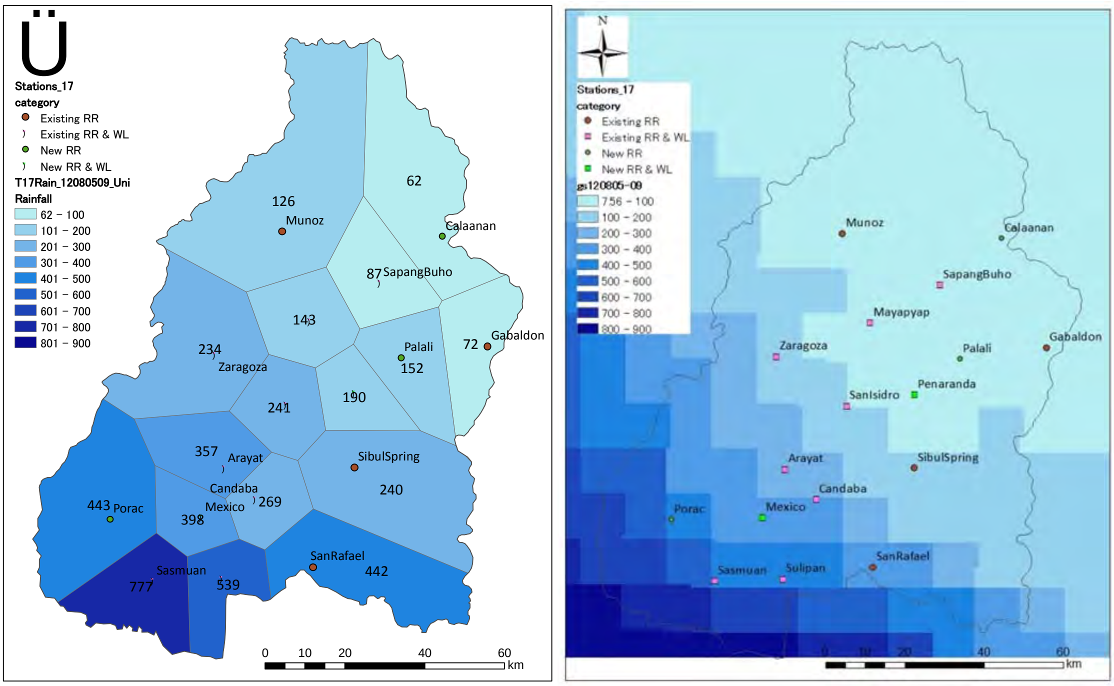
3.1.5. Availability and spatial features of rainfall data

The Pampanga River basin has seventeen ground-gauge rainfall stations and one sub-center as the telemetric monitoring system. Because observed data at every station is delivered in near real-time as has been explained above, rainfall distribution is roughly described even during flooding. On the other hand, satellite-based rainfall data such as Global Satellite Mapping of Precipitation (GSMaP) provided by Japan Aerospace Exploration Agency (JAXA) is also available in this river basin. In case of GSMaP, resolution of rainfall data is approximately 10 km by 10 km, and time delay of

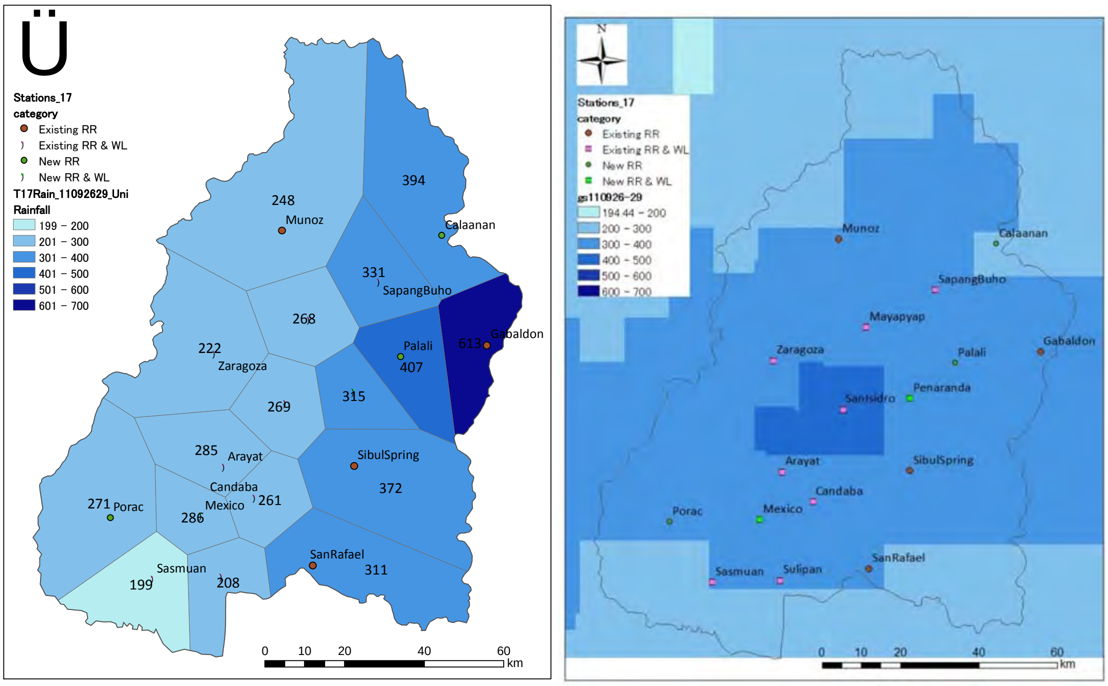
delivery is about 4 hours. In other words, we can download the GSMaP rainfall data which is 4 hours ago. Figure 3-9 shows the distribution of event-total rainfall during recent floods observed by ground-gauge and GSMaP. Although rainfall distributions of ground-gauge and GSMaP are roughly corresponding, amount of GSMaP rainfall is underestimated in some cases such as September 2011 flood. On the contrary, GSMaP has six-fold as high as spatial representativeness than ground-gauge data at the current system in the Pampanga River basin. Incidentally, the mean spatial representation of ground-gauge is about 600 km^2 since there are 17 gauging stations in the area of 10,450km^2.

Next, ground-gauge data at the Arayat, the Palali and the Munoz station and GSMaP data at the same location are compared in Figure 3-10 and Figure 3-11. Figure 3-10 shows the comparison between ground-gauge and GSMaP in case of August 2012 flood, Figure 3-11 shows the comparison between ground-gauge and GSMaP in case of September 2009 flood. GSMaP data is underestimated overall in case of August 2012 flood, however GSMaP data in the northwest area is overestimated about both of intensity and duration in case of September 2009 flood.

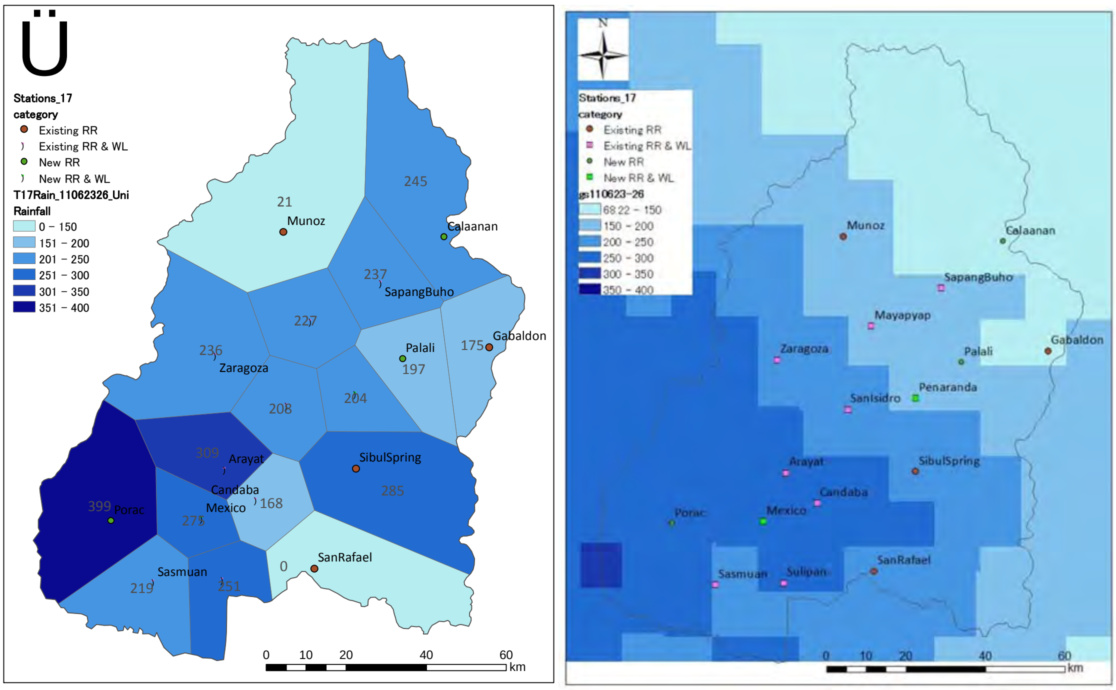
While there are some issues about quantitative accuracy and time delay in GSMaP data as above, GSMaP can be the supplementary information for flood forecasting and flood early warning during flooding.



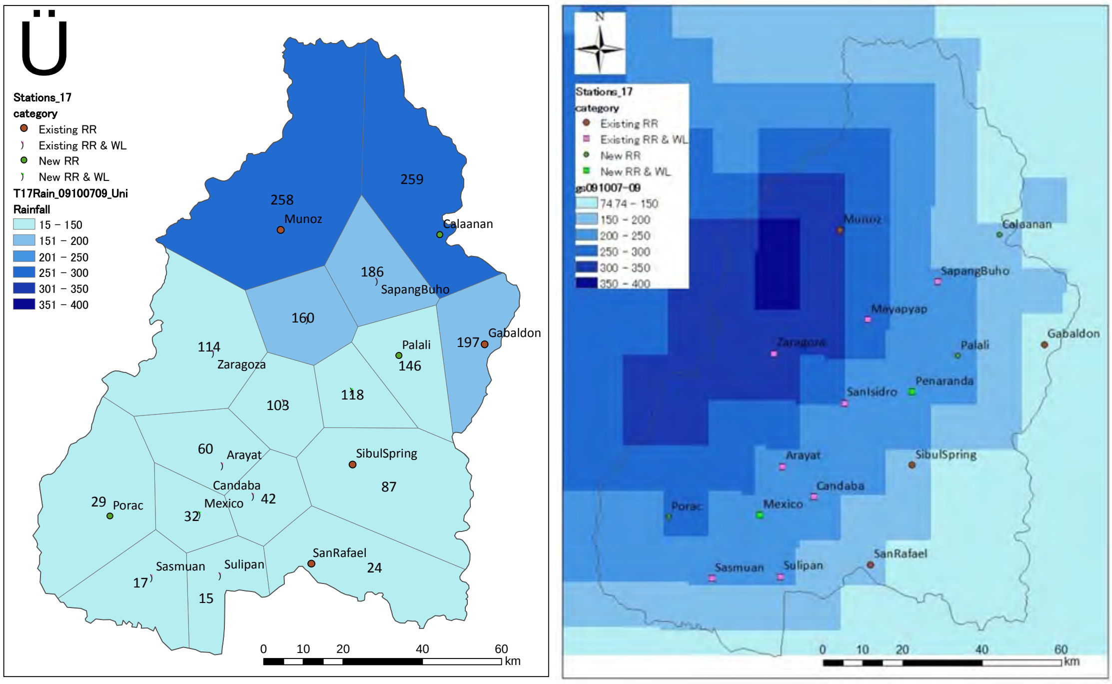
(Flood in August 2012)



(Flood in September 2011)

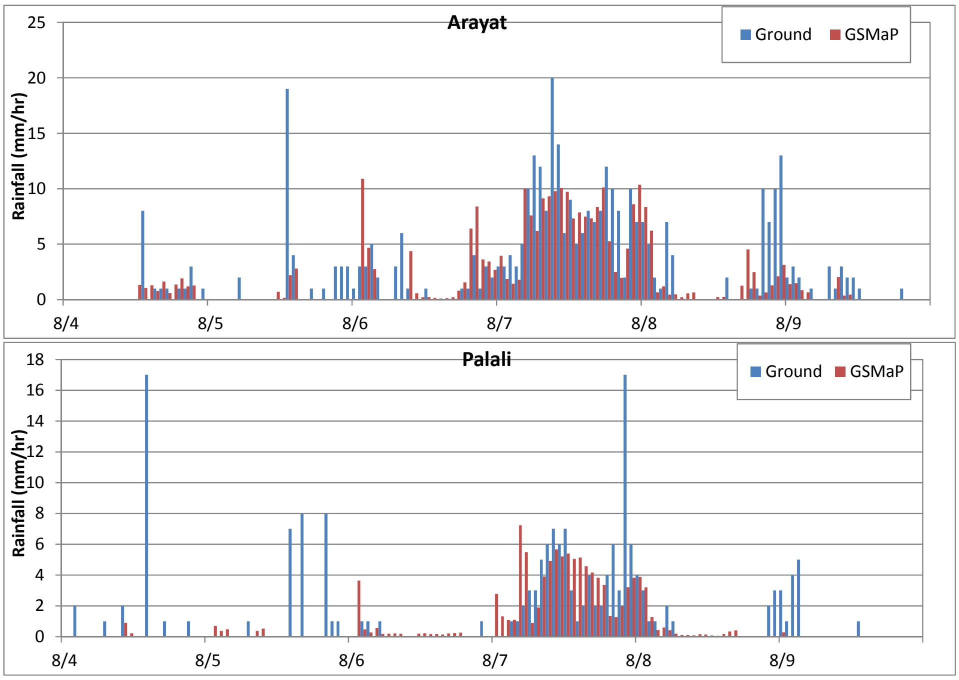


(Flood in June 2011)



(Flood in September 2009)

Figure 3-9 Distribution of event-total rainfall during flooding observed by ground-gauge (left) and GSMaP (right)



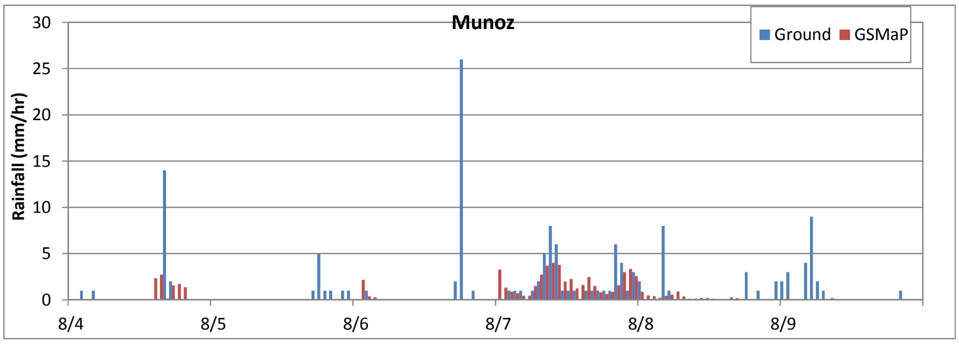


Figure 3-10 Comparison of rainfall between ground-gauge and GSMaP at the Arayat, the Palali and the Munoz station in August 2012 flood

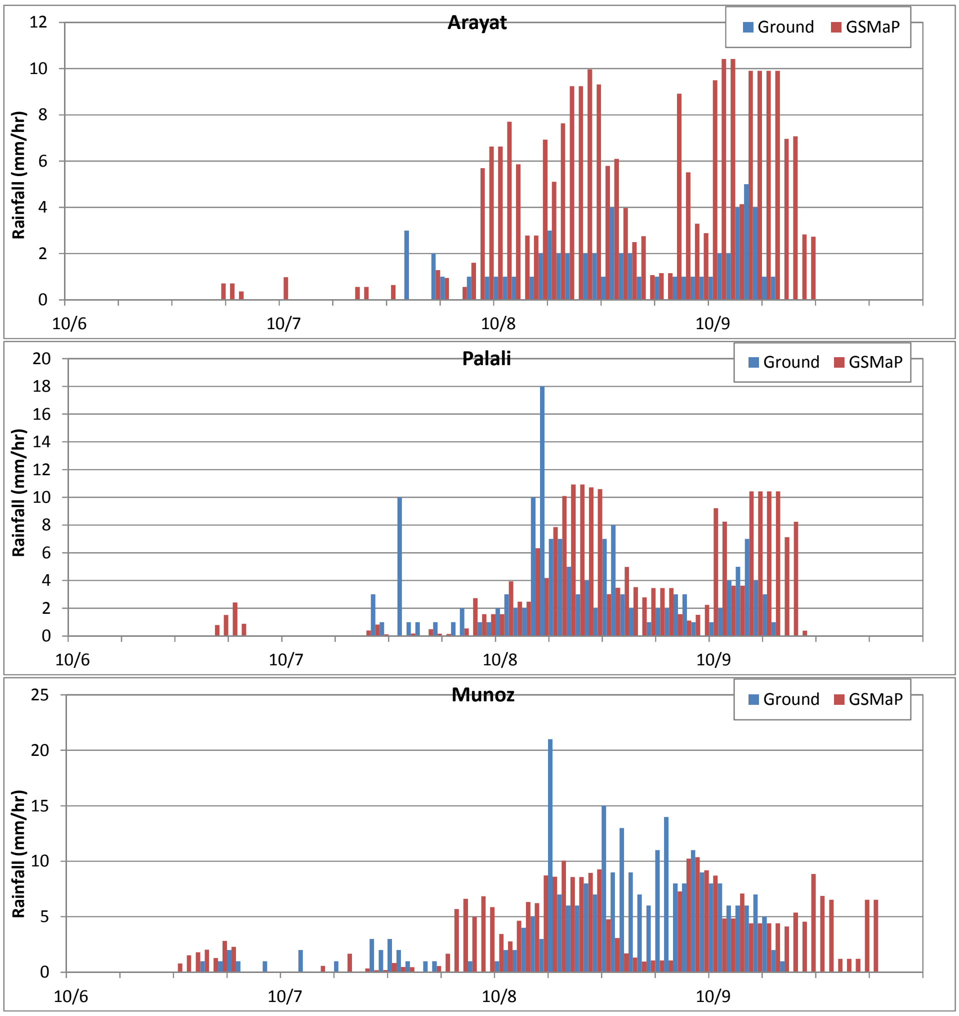


Figure 3-11 Comparison of rainfall between ground-gauge and GSMaP at the Arayat, the Palali and the Munoz station in September 2009 flood

3.2. Flood analysis in the Cagayan River basin

3.2.1. Topographic conditions

The Cagayan River basin shares topographical features of both mountainous and plain as is the case with the Pampanga River basin. Figure 3-12 shows the topographic conditions in the Cagayan River basin. The Cagayan is a vast expanse of plains and valleys, bordered by mountains, running north to south both on its east and west ramparts. It is crisscrossed by rivers and creeks, the largest of which is the Cagayan River, which originates from Quirino, and traverses the province from south to north. The larger tributaries of the Cagayan River are the Pinacanauan River in Peñablanca in the southeast; the Dummun River in Gattaran and the Pared River in Alcala, both in central Cagayan; and the Zinundungan River in Lasam and the Matalag River in Rizal, both in the west. The other rivers in the province are the Chico River in southwest Cagayan at Tuao, the Pata River and Abulug River in the northwest, Buguey River in the north, and the Cabicungan River in the northeast. These rivers drain the plains and valleys of the province, and provide water for domestic and irrigation purposes, as well. Of its total land area, 28.2 percent or 2,538 km^2 are flat to nearly level land. This consists of alluvial plains, river deltas, low wetlands, mangroves, and beaches. Most of these are found contiguous to the bodies of water, especially along the Cagayan, Pared, Dummun, Pinacanauan, Abulug, and Chico rivers. These areas are planted to rice and corn, subjected to frequent floods during the wet season. The gentle and moderate slopes of the province, which constitute 6.1 percent and 13.5 percent, respectively of the total land area of the province are mostly contiguous to the level land, enclosing the plains of the meandering rivers and creeks. This arrangement forms the various.

Regarding rainfall during floods, most of typhoons come through the Cagayan River basin from south-east to north-west statistically. Main stream of the Cagayan River also flows from south to north. In this situation which the major route of typhoons and flow rout of main stream are almost overlapping, the scale of flood can keep growth during flooding. Thus, downstream area such as Tuguegarao and Tumauini is exposed to highly prone to flood disasters.

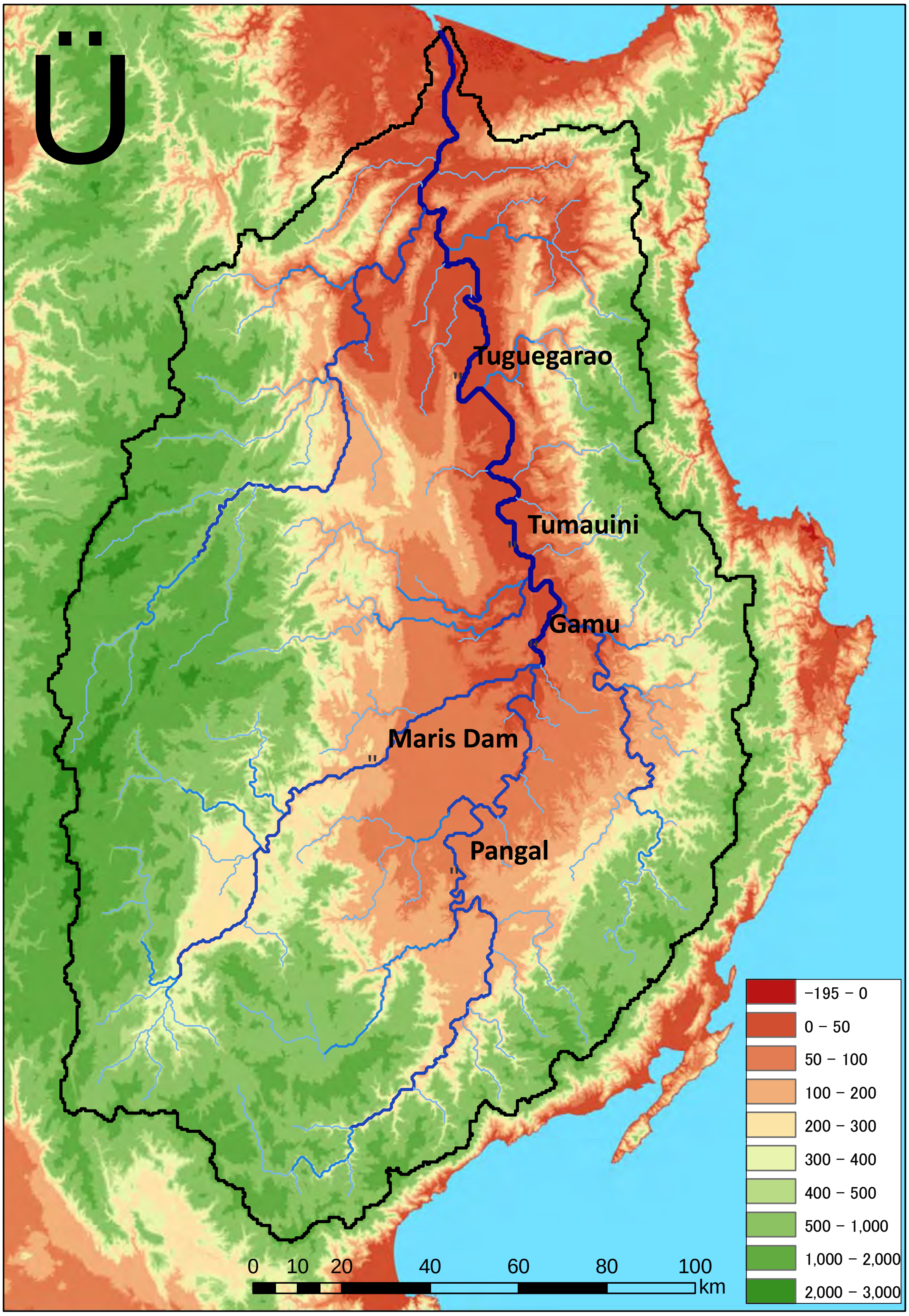


Figure 3-12 Topographic conditions in the Cagayan River basin

3.2.2. Discharge measurements and rating curve

As described in section 2.3.4, discharge measurements by a current meter had been conducted 11 times in all in 2002, 2004, 2010 and 2011 at Gamu station. Photo 2-9 shows the scene of discharge measurement by current meter at Gamu station on January 2011. Based on 11 times measurements, the relationship between water level and discharge is shown in Figure 3-13. Although the number of plots is not sufficient, it is confirmed that correlation between water level and square root discharge is linear. Then equation (2) which is equation of square is employed as a rating curve at the Gamu station. In this rating curve, coefficients a and b are calculated as a=41.319 and b=0.777.

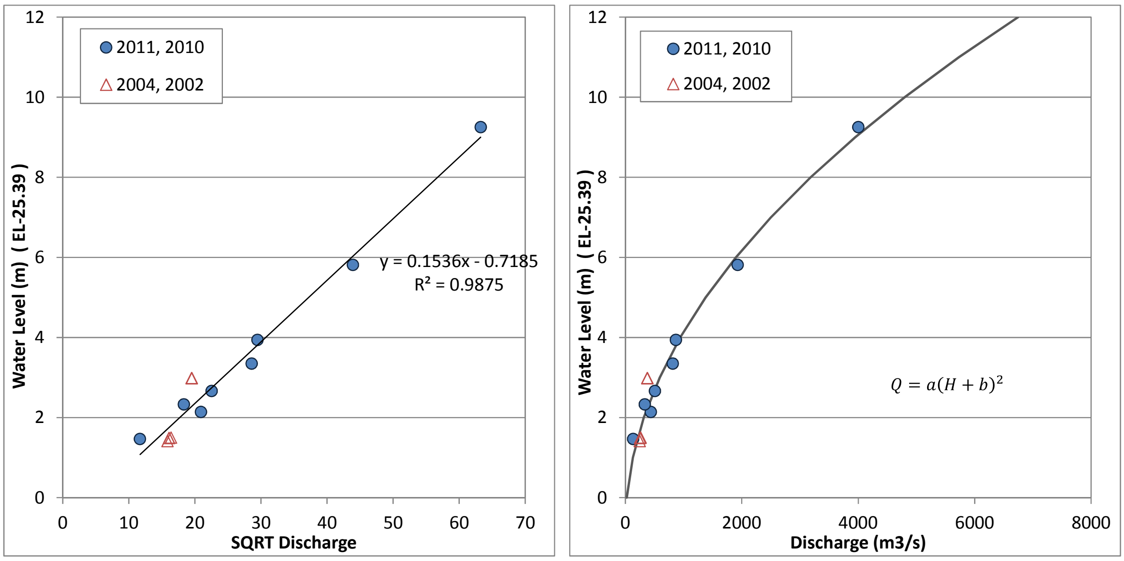


Figure 3-13 Relationship between water level and square root discharge (left) and relationship between water level and discharge (right) at Gamu station

3.2.3. Runoff ratio of recent floods

Based on the rating curve at Gamu station, hydrographs are created as shown in Figure 3-14. In order to investigate the flood characteristics in the Cagayan River basin, runoff ratio which is the ratio of event-total volume between rainfall and discharge, is calculated as shown in Table 3-3. In the calculation of discharge volume, amount of base flow assumed as a constant discharge, is deducted from total volume of discharge. Runoff ratio widely differs from flood to flood, and there are some possible causes about this dispersion of runoff ratio such as accuracy of rating curve, rainfall duration, rainfall intensity and rainfall distribution. However, although only 3 flood cases, it seems that there is correlation between runoff ratio and rainfall type such as total amount and peak intensity. In the case of flood in 2006, runoff ratio 0.68 is the bigger than other flood cases, and not only runoff ration but also total amount of rainfall 227 mm and peak intensity 23.1 mm/hour is bigger than other flood cases.

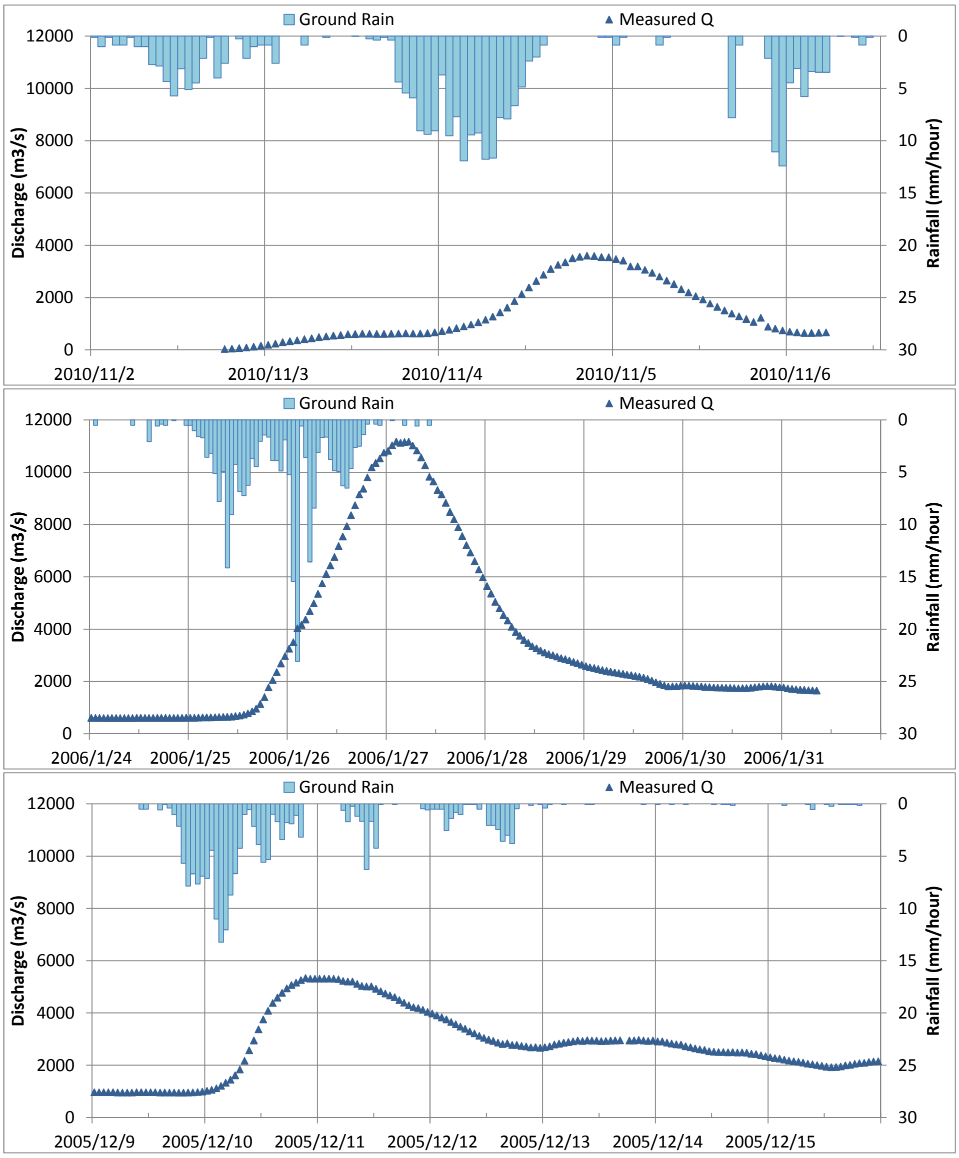


Figure 3-14 Hydrographs of recent floods at Gamu station (2010, 2006, 2005)

Table 3-3 Runoff ratio of recent floods at Gamu station (12,176km^2)

Period	Rainfall		Discharge		**Runoff ratio (ratio of volume)**
	Total amount (mm)	Peak intensity (mm/hour)	Peak discharge (m^3/s)	Total volume ($10^8 * m^3$)	
November 2010	154	11.9	3,600	2.64	**0.14**
January 2006	227	23.1	11,000	18.76	**0.68**
December 2005	187	13.2	5,300	10.84	**0.48**

3.2.4. Estimation of flood traveling time

As already mentioned in Section 3.1.3, flood traveling time is one of the most important factors for the both of flood forecasting and flood early warning. Thus flood traveling times of recent floods are estimated in this analysis with the same method with the Pampanga River basin. Flood traveling time is the time difference between the peak time of rainfall which is calculated as the center of gravity of hyetograph and peak of runoff depth. Figure 3-15 shows the flood traveling time of 12 recent floods from 2003 to 2010 at the Pangal, the Gamu, the Tumauini and the Tuguegarao station. Flood traveling time at every station varies widely by flood because of rainfall intensity, rainfall distribution, soil conditions, influence by dam and etc. during and before flooding. Averages of flood traveling time are 12.5 hours at the Pangal, 22.1 hours at the Gamu, 28.7 hours at the Tumauini and 35.9 hours at the Tuguegarao as shown in Table 3-4.

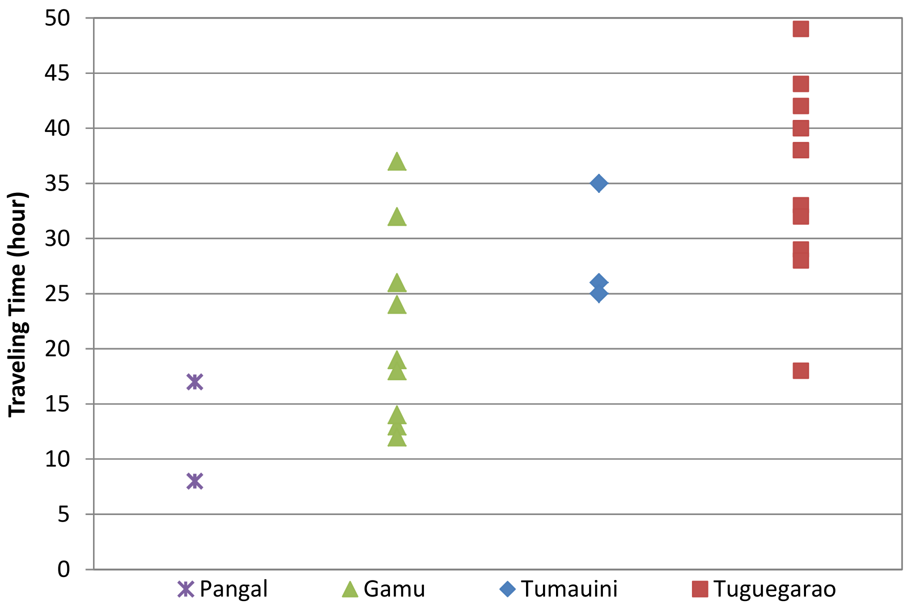


Figure 3-15 Hydrographs of recent floods at Gamu station (2010, 2006, 2005)

Table 3-4 Average of flood traveling time and propagation time at the Pangal, the Gamu, the Tumauini and the Tuguegarao station

	Average traveling time (hours)	Propagation time from the Pangal (hours)	Propagation time from the Gamu (hours)	Propagation time from the Tumauini (hours)
Pangal	12.5	--	--	--
Gamu	22.1	9.6	--	--
Tumauini	28.7	16.2	6.6	--
Tuguegarao	35.9	23.4	13.8	7.2

3.2.5. Water level correlation during flooding among stations

In order to validate the correlation of water level among stations, water level data was compared considering flood traveling time. Following the estimated propagation time shown in Figure 3-16, water level correlations among stations are analyzed. Flood propagation times are dealt with fixed value in this analysis Figure 3-17 shows the water level correlations of three combinations; one is the water level correlation between the Gamu and the Tuguegarao deducted fourteen hours, another is the water level correlation between the Gamu and the Tumauini deducted seven hours, and the last is the water level correlation between the Tumauini and the Tuguegarao deducted seven hours. The correlations among three stations differ from flood to flood. Regarding the correlation between the Gamu and the Tuguegarao, correlations differ from flood to flood, however, it can be realized that water level of two floods in 2010 at Gamu station is lower than previous floods. This deference of water level must be due to river bed change which occurred between 2006 and 2010. It is estimated that degradation of river bed at Gamu station caused lowering of water level during flood. Furthermore, if we focus on peak of each flood as shown in Figure 3-18, we can realize two good agreements in the correlations of peak water level. One is the correlation of peak water level from 2003 to 2006; the other is the correlation of peak water level in 2010. Although it is difficult to explain why the only peak water level has good agreements, this correlation of peak water level is useful for existing flood forecasting model.

Only for peak water level, the rough correlativity is found in the relationships of water level. However, since this correlativity is susceptible to various factors such as river bed variation, flood control by dam, rainfall distribution and breaching of embankment because of lack of physically-based mechanism, it should be treated as supporting information.

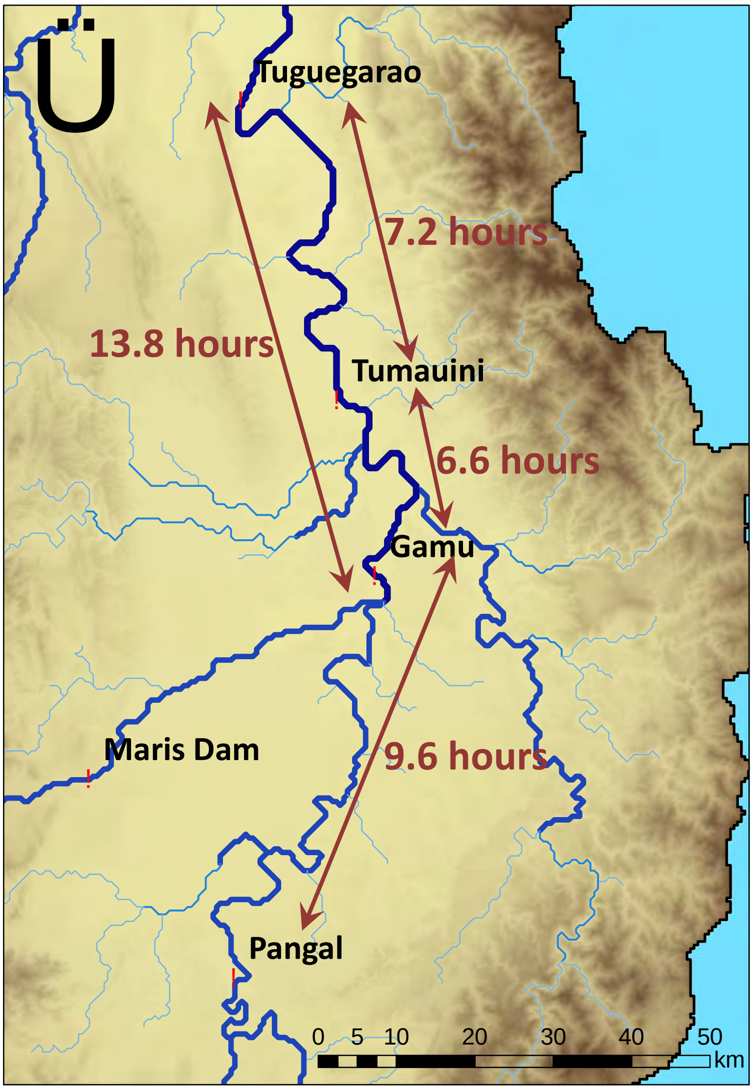


Figure 3-16 Flood propagation time among the Pangal, the Gamu, the Tumauini and the Tuguegarao station

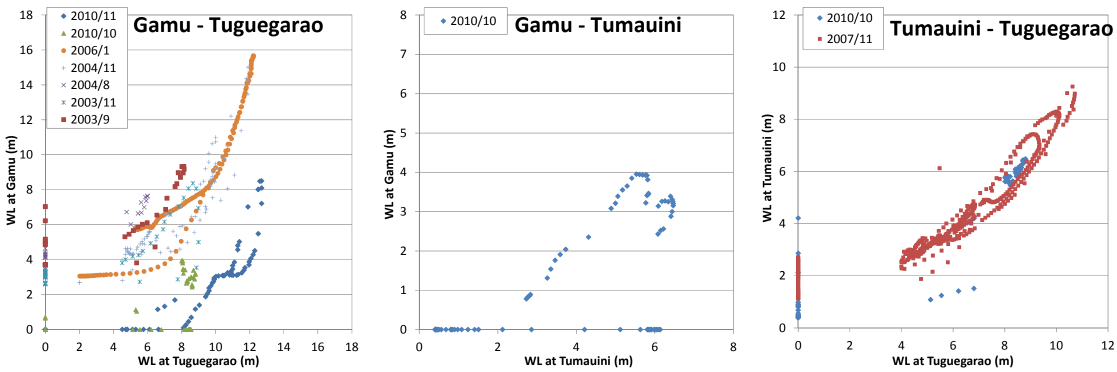


Figure 3-17 Water level correlations among the Gamu, the Tumauini and the Tuguegarao

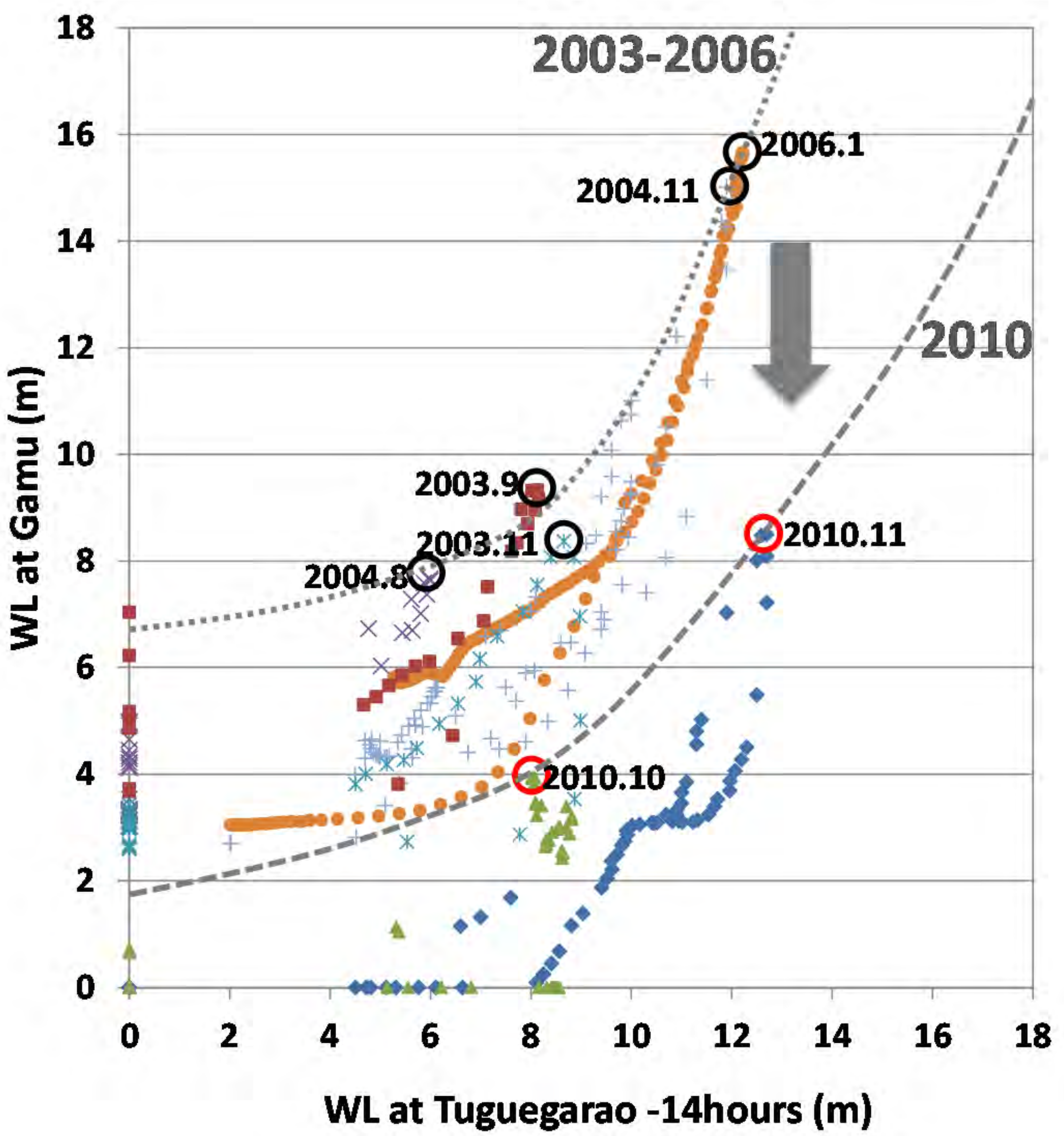


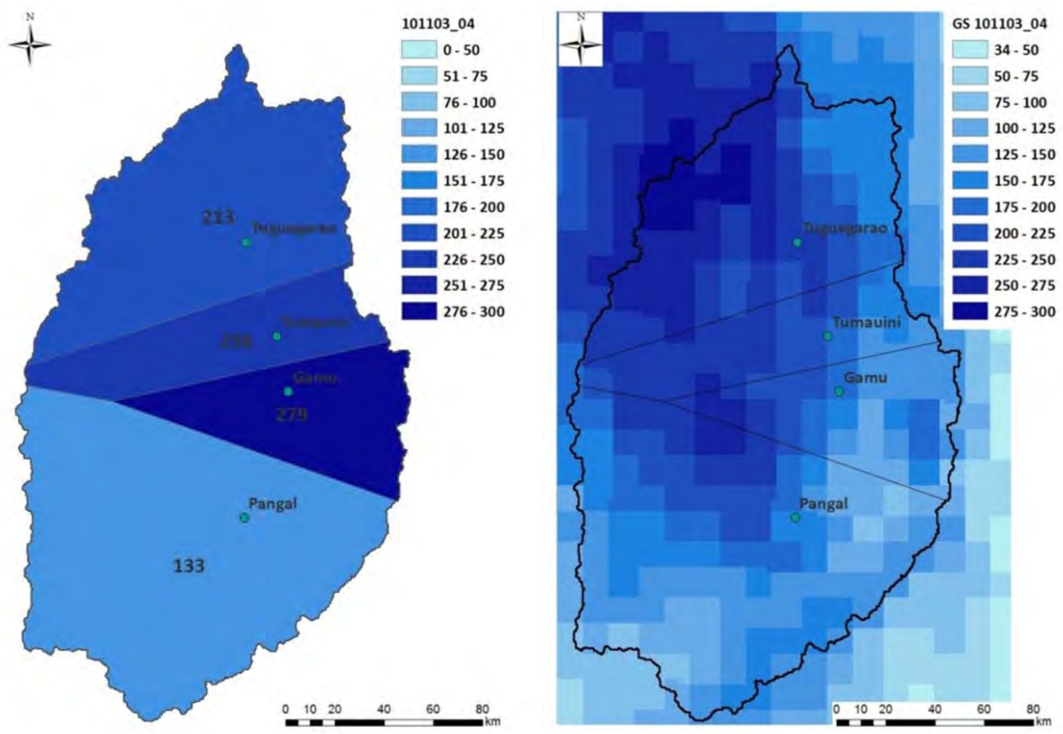
Figure 3-18 Correlations of peak water level between the Gamu and the Tuguegarao

3.2.6. Availability and spatial features of rainfall data

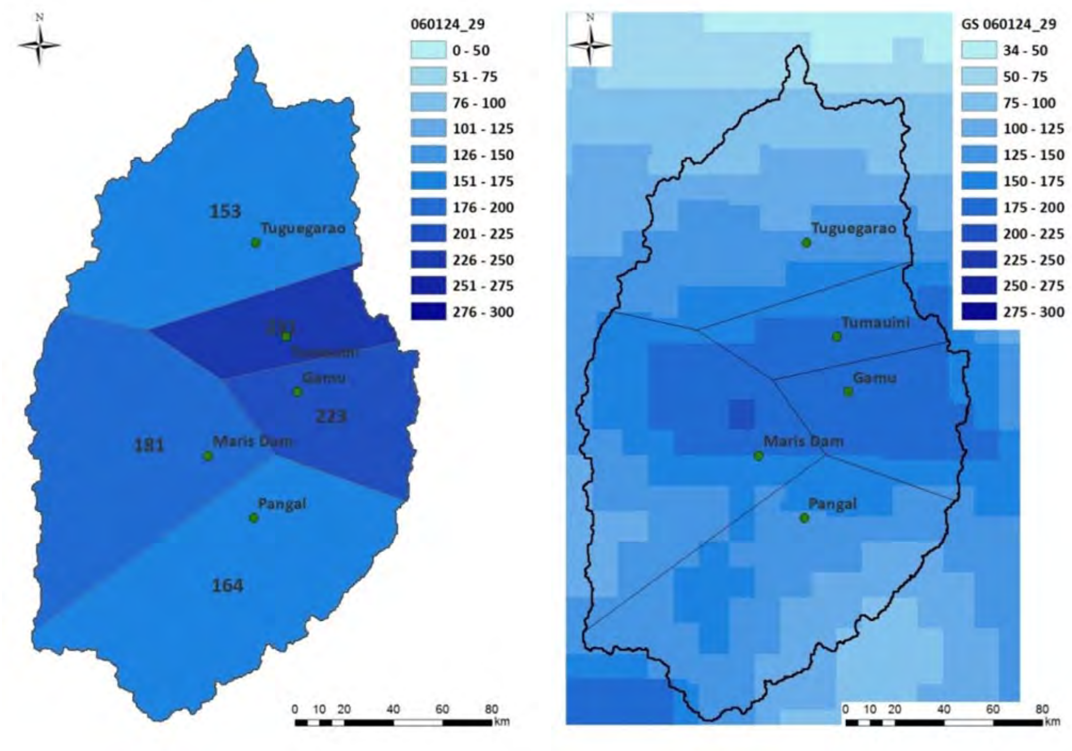
The Cagayan River basin has 11 ground-gauge rainfall stations in all, of which five are utilized as flood monitoring and forecasting system because those are telemetric stations. Because observed data at five telemetric stations is delivered in almost real-time as explained above, basin-distribution of rainfall is roughly described based on 5 point data even during flooding. On the other hand, satellite-based rainfall data such as GSMaP is also available in this river basin. Resolutions and time delay of delivery has been already introduced in Section 3.1.5. Figure 3-19 shows the distribution of event-total rainfall observed by ground-gauge and GSMaP in November 2010, January 2006 and December 2004. The first thing we notice is spatial representativeness of ground-gauge is too big for

flood forecasting as compared with GSMaP. While the Cagayan River basin has other six gauging stations of rainfall besides five stations of real-time monitoring system, it seems that those stations don’t have much effect on improvement of spatial representativeness because those stations are concentrated in the basin of Maris dam which is located in the upstream area of the Cagayan River basin. Incidentally, the mean spatial representativeness of ground-gauge is about 5,460 km^2 since there are 5 gauging stations in the area of 27,280km^2.

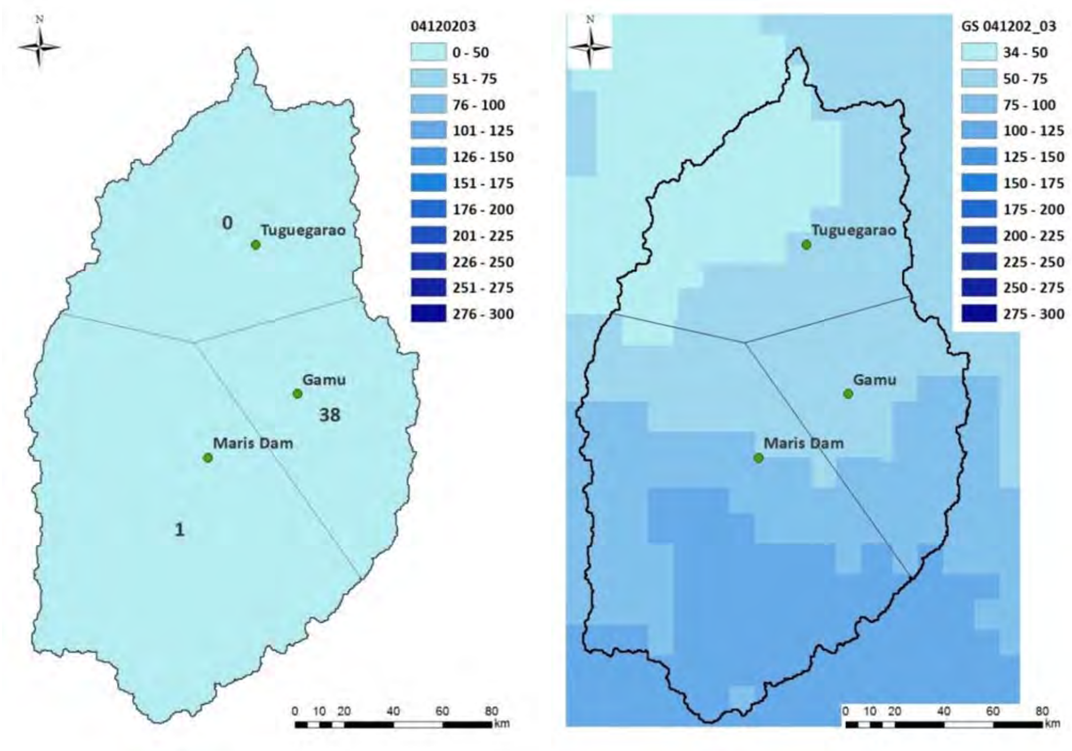
Conversely, quantitative accuracy remains for GSMaP as an issue for improvement. Figure 3-20 shows the comparison of rainfall between ground-gauge and GSMaP at real-time gauging points in case of 2006 flood. While ground-gauge and GSMaP are roughly corresponding, GSMaP is wholly underestimated relative to ground-gauge. In Particular, underestimation of peak intensity may cause major effect on flood forecasting. Conceivably, GSMaP can be the supplementary information for flood forecasting and flood early warning during flooding, while there are some issues about accuracy and time delay as above.



(Flood in November 2010)



(Flood in January 2006)



(Flood in December 2004)

Figure 3-19 Distribution of event-total rainfall observed by ground-gauge (left) and GSMaP (right) in November 2010, January 2006 and December 2004

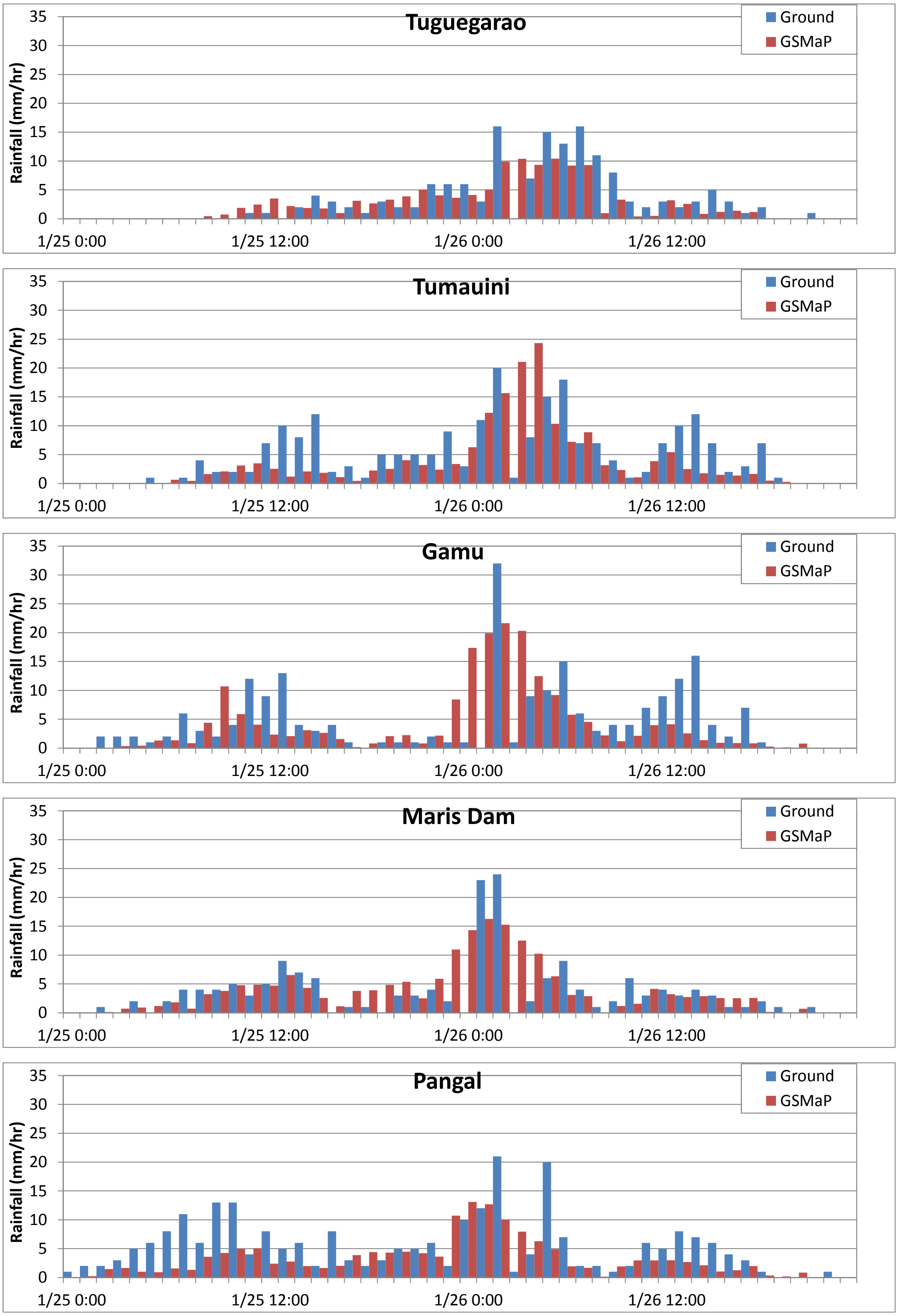


Figure 3-20 Comparison of rainfall between ground-gauge and GSMaP at the gauging points in 2006

4. Building up Flood Forecasting System with IFAS as a Supplement System

4.1. General information and structure of IFAS

4.1.1. General information

For more effective and efficient flood forecasting in river basin with insufficient observation gauged river basin, ICHARM has developed a concise flood runoff analysis system called “IFAS”. It has easy creating function for runoff analysis with some kinds of rainfall data. It can also estimate parameters for a default runoff analysis engine and display output results. ICHARM distributes IFAS executable files to users for free. Figure 4-1 shows the basic schematic of IFAS working flow. The main features of IFAS system are described as follows.

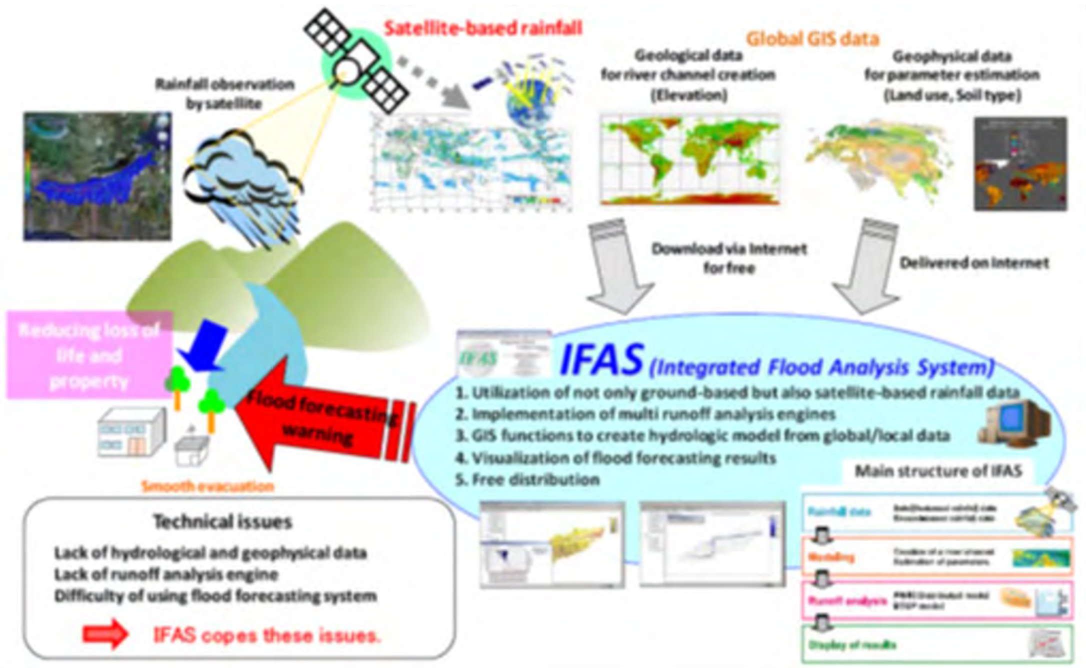


Figure 4-1 Schematic views of IFAS

4.1.2. Utilization of satellite-based rainfall as input data

IFAS has easy input function of satellite-based rainfall data for insufficient ground observation area. In recent years, real time or semi real time satellite based rainfall data, which cover the almost entire globe, have been provided by National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), JAXA and other agencies. These satellite based rainfall data are easily accessible even with a personal computer through the internet. Furthermore, IFAS also has the function which corrects satellite-based rainfall and enhances observation accuracy

for flood forecasting. IFAS has a function also to input ground-based rainfall data.

4.1.3. Distributed run-off analysis engines based on distributed hydrological models

IFAS has adopted runoff analysis engines based on physical based parameter distributed hydrological models. Most parameters for a distributed hydrological model are related to physical basin conditions, such as land use and soil types, and are globally available for public use. In addition, guideline parameters has been also prepared based on past simulation results. Therefore, IFAS is now ready to be easily put into practical use in any insufficiently gauged basin.

4.1.4. Model creation function

IFAS has functions to create a runoff model and estimate parameters using global Geographical Information System (GIS) data including elevation, land use, soil type, etc. With these functions, runoff analysis can be applied to basins with insufficient hydrological and geophysical information.

4.1.5. Visualization of flood forecasting results

IFAS has interfaces to display output results not only in figures and tables but also on a digital map. In this way, users can easily identify flood risks at different locations, looking at visualized simulation results.

4.2. Analysis method

4.2.1. Parameter distributed model

PWRI distributed hydrological model is a runoff analysis model converting rainfall into runoff for a given river basin. It can be classified as both conceptual or parametric and physically-based, fully distributed model (Abbott et al, 1996). Conceptual models are based on assumed physically realistic equations combined with semi-empirical ones to relate rainfall and outflows. The relationships are parametric and parameters have to be estimated. The parameters can be set according to observed rainfall and discharge data, or estimated from similar rivers. Physically-based distributed models treat discharge as a migration phenomenon of rainfall in the river basin and represent the migration process by using infiltration and/or non-equilateral flow equations. Currently, there is no model that can represent the migration process by physical functions perfectly. Generally, physically-based distributed models need a huge amount of information on soil, geology, and river shape for modeling; consequently, the time for calculation becomes too long. However, conceptual models use equations governing “natural laws” in order to estimate outflow (Abbott et al, 1996) that comes from the river basin. This greatly shortens the calculation time and is considered as the appropriate model for flood forecasting.

So far, three versions of the PWRI Distributed Hydrological Model (ver.1 to ver.3) have been

developed with specifications as follow: (i) configured as three tanks or more connected vertically (Table 4-1, Figure 4-2) (ii) configured as two tanks connected vertically; (iii) considering evaporation and transpiration for low outflow calculation. IFAS ver. 1.3 β uses PWRI Distributed Hydrological Model of ver.2 and modified ver.1 as the runoff simulation engine with the features listed below:

- The outflow from each mesh is calculated by non-linear relationships based on the tank model philosophy. The non-linear relationships are not perfect a “Black Box” or system in which only inputs and outputs are viewed (Cauer et al, 2000) but are also based on Manning and hyperbolic approximations.
- PWRI Distributed Hydrological Model has been using a two-layer non-linear tank configuration in order to shorten the calculation time.
- In general, flows simulated from tank model for small and medium floods are poorly fitted.
- For numerical calculation, PWRI Distributed Hydrological Model does not use the convergence calculation to solve the differential equation. It uses approximation functions to solve the time integral equation. For this reason, the system can conduct numerical calculations smoothly and to realize for real-time operation.
- -To calculate discharge in the river course tank, PWRI Distributed Hydrological Model uses Kinematic Wave Model.
- The ver.1 of PWRI Distributed Hydrological Model is configured as three layer tanks or more connected vertically and following the concept described here (Table 4-1).

The lateral connections between mesh depends on the cell type of this mesh. There was an attempt in this model to illustrate how rivers are formed and develop in a catchment. Different cell type categories are then used to represent the different river development stages. Indeed, according to the position of a cell in the catchment, i.e. upstream or downstream in the catchment, it will be classified into one of the four cell type categories, according to the number of cells it has upstream. The cell type category defines the number of tanks at the vertical of each mesh and their inter-connections (Table 4-2).

Cells are connected both vertically and horizontally according to Distributed Hydrological Model engine. Type 0 cells correspond to the most upstream cells where there is no river yet. Rainfall water infiltrates and participates to aquifer discharge after considering evapotranspiration. Type 1 cells correspond to the cells more downstream where a river formed. The water table is too low to contribute to river discharge but the river contributes to aquifer recharge. Type 2 cells correspond to cells even more downstream. Aquifer starts to participate to river base flow. Surface flow, subsurface saturated and unsaturated flows keep on contributing to river discharge. Type 3 cells correspond to the cells in which there is the river channel.

Table 4-1 Model configuration

Model	Functions
Surface tank model	Infiltration to unsaturated layer, surface runoff, surface storage, evapotranspiration, rapid intermediate outflow
Unsaturated tank model	Infiltration to aquifer, subsurface runoff, subsurface storage, low intermediate outflow
Aquifer tank model	Outflow from aquifer, aquifer loss
River tank model	River course discharge

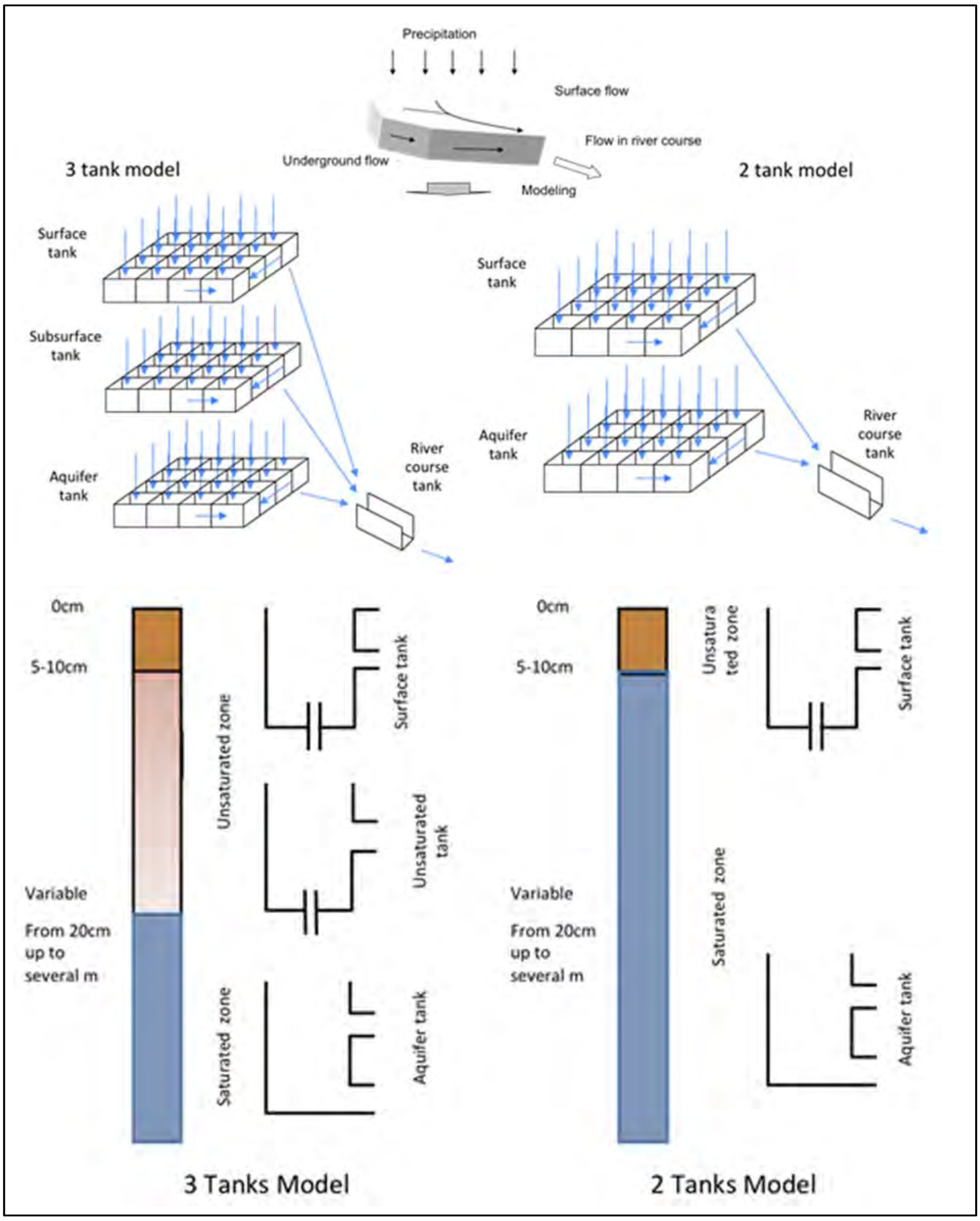


Figure 4-2 Schematic representation of the model

Table 4-2 Cell type and tank organization set accordingly

Cell type	Number of tanks (2tanks model)	Number of tanks (3tanks model)	Tanks
0	2	3	Surface tank, (unsaturated tank), aquifer tank
1	3	4	Surface tank, (unsaturated tank), aquifer tank and river tank type 1 not receiving flow from the aquifer tank.
2	3	4	Surface tank, (unsaturated tank), aquifer tank and river tank type 2 receiving flow from the aquifer tank
3	3	4	Surface tank, (unsaturated tank), aquifer tank and river tank discharge calculated according to the kinematic wave method.

4.2.2. Surface tank model

The surface tank model is a model used to divide the rainfall to surface, rapid intermediate, and ground infiltration flows. The top right, bottom right and central bottom orifices represent the surface, rapid intermediate and ground infiltration flows, respectively. The surface / saturated excess overland outflow is estimated as a fraction 3/5 of storage capacity based on the Manning Law. The rapid subsurface storm flow is also estimated as a fraction of storage capacity. The ground infiltration is estimated as a fraction of storage capacity based on the Darcy Law.

If $h \geqq S_{f2}$, then $$\frac{\partial h}{\partial t} = R - E_{ps} - Q_0 - Q_{sf} - Q_{ri} \quad (3)$$

If $S_{f1} \leqq h < S_{f2}$, then $$\frac{\partial h}{\partial t} = R - E_{ps} - Q_0 - Q_{ri} \quad (4)$$

If $S_{f0} \leqq h < S_{f1}$, then $$\frac{\partial h}{\partial t} = R - E_{ps}/S_{f1} \cdot h - Q_0 \quad (5)$$

If $h \leqq S_{f0}$, then $$\frac{\partial h}{\partial t} = R - E_{ps}/S_{f1} \cdot h \quad (6)$$

where, R is rainfall, E_{ps} is Evapotranspiration, Q_0 is infiltration to lower tank, Q_{sf} is surface outflow, Q_{ri} is fast intermediate outflow, h is water height for the tank, S_{f2} is height from which saturated excess overland flow occurs, S_{f1} is height from which rapid subsurface storm flow occurs and S_{f0} is height where ground infiltration occurs.

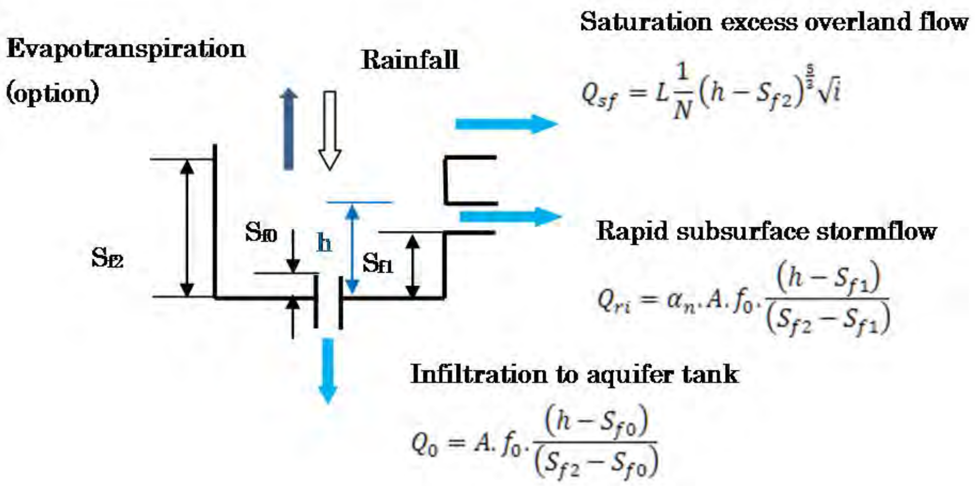


Figure 4-3 Schematic representation of surface tank

4.2.3. Subsurface or unsaturated tank model

The unsaturated tank model makes it possible to simulate low flow conditions as well as long-term periods.

If $S_S > h \geqq S_W$, then

$$\theta_S \frac{\partial h}{\partial t} = Q_{in} - E_{ps} - Q_{S1} - Q_{S2} \qquad (7)$$

If $h < S_W$, then, there is no slow intermediate flow nor infiltration to aquifer

$$\theta_S \frac{\partial h}{\partial t} = Q_{in} - \frac{E_{ps}}{S_W}.h \qquad (8)$$

where, E_{ps} is Evapotranspiration, Q_{in} is flow coming from the surface tank, Q_{S1} is unsaturated lateral flow / slow subsurface storm flow, Q_{S2} is unsaturated vertical flow / slow subsurface storm flow, D is total water height for unsaturated tank, h is water height for this tank, θ is soil moisture content (=h/D), S_S is height when $\theta = \theta_S$, soil moisture is equal to soil moisture at saturation and $\theta_S = S_S/D$, S_W is height when $\theta = \theta_W$, soil moisture is equal to soil moisture at wilting point and $\theta_W = S_W/D$, K_X is horizontal hydraulic conductivity at θ, K_{SX}, the horizontal hydraulic conductivity at θ_S and b is constant depending on soil total porosity and ranging from 0-100.

$$K_X = \frac{K_{SX}}{100}.\frac{\exp(b.\theta) - \exp(b.\theta_W)}{\exp(b.\theta_S) - \exp(b.\theta_W)} \qquad (9)$$

$$K_Z = K_{SZ}.\frac{\exp(b.\theta) - \exp(b.\theta_W)}{\exp(b.\theta_S) - \exp(b.\theta_W)} \qquad (10)$$

Where, K_Z is vertical hydraulic conductivity at θ and K_{SZ} is the horizontal hydraulic conductivity at θ_S and b is constant depending on soil total porosity.

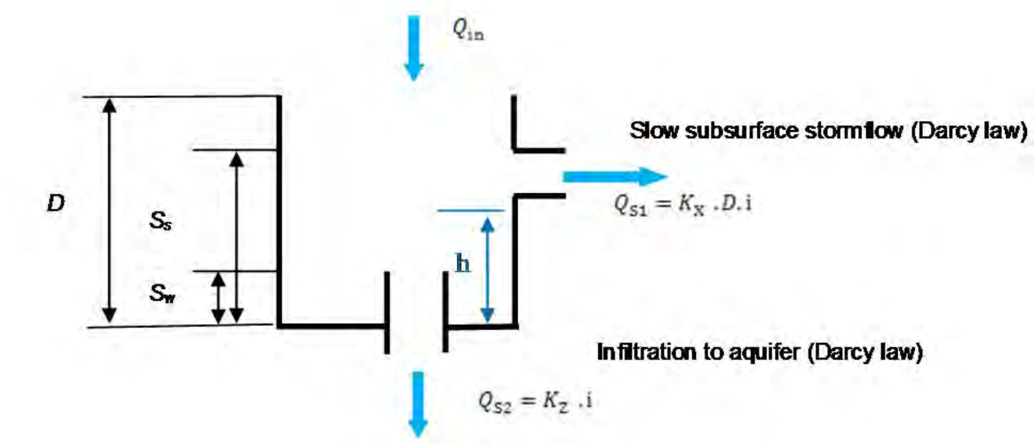


Figure 4-4 Schematic representation of unsaturated tank

4.2.4. Aquifer tank model

The configuration of aquifer model is shown as figure 4-5 below. The top right and bottom right orifices represent the unconfined and confined aquifer outflows, respectively. Outflow of ground water is considered as a fraction of confined aquifer to h, and of unconfined aquifer to h^2.

If $h \geqq S_g$, then

$$\frac{\partial h}{\partial t} = Q_{in} - Q_{g1} - Q_{g2} - Q_{g\_loss} \qquad (11)$$

If $h < S_g$, then

$$\frac{\partial h}{\partial t} = Q_{in} - Q_{g2} - Q_{g\_loss} \qquad (12)$$

Where, Q_{in} is inflow from infiltration mode, h is water height of model, Q_{g1} is unconfined aquifer outflow, S_g is height from which unconfined aquifer outflow occurs, Q_{g2} is confined aquifer outflow / base flow and Q_{g_loss} is unaccountable aquifer loss. The outflows of unconfined and confined aquifer are as follows.

$$Q_{g1} = A_u^2(h - S_g)^2 A \qquad (13)$$

$$Q_{g2} = A_g hA \qquad (14)$$

Where, A_u and A_g being the coefficients used to calculate unconfined and confined aquifer outflows. If the option “unaccountable aquifer loss” is selected, then

$$Q_{g\_loss} = \alpha_{g\_loss} Q_{g2} \qquad (15)$$

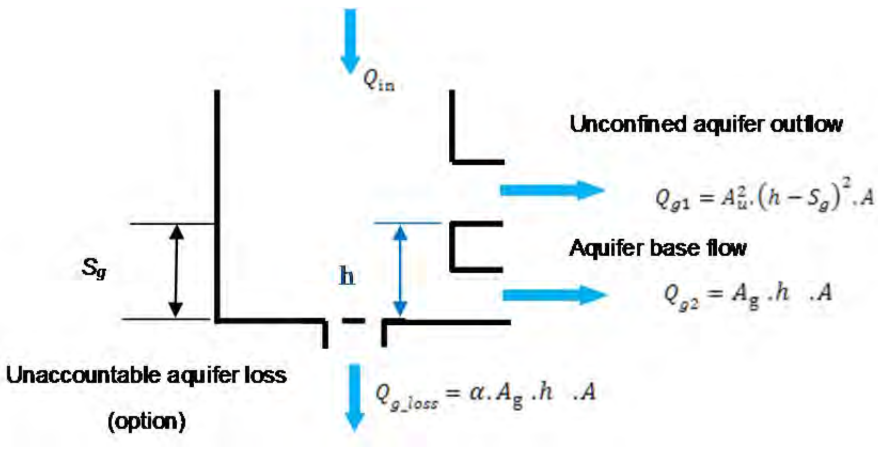


Figure 4-5 Schematic representation of aquifer tank

4.2.5. Aquifer tank model

Outflow from the river course tank is based on Manning equation for cell type 1 and 2.

$$LB\frac{\partial h}{\partial t} = Q_{in}\text{-}Q_r \qquad (16)$$

Where, Q_{in} is inflow from ground water and upstream river course models, Q_r is outflow from river course, L is length of river course and B is breadth of river course. The river course breadth is calculated according to the Resume Law:

$$B = cA^s \qquad (17)$$

where, c and s are constants (generally s<1).

Because the model is considering runoff, the influence on the river course outflow can be omitted. The model is also considering time delay and the basic equations are as follow:

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = 0 \quad \text{and} \quad Q = \frac{1}{n}Bh^{5/3}I^{1/2} \qquad (18)$$

where, Q is the flow, A is the area of the cross-section and $A= Bh$, h is water depth, I is gradient of riverbed, n is coefficient of roughness, x is the spatial variable in the flow direction, t is the time variable.

For river course tank in cell type 3, the river routing method is the kinematic wave method using the difference method.

$$\frac{\partial Q}{\partial t} + C\frac{\partial Q}{\partial x} = 0 \quad \text{and} \quad C = \frac{dQ}{dA} \qquad (19)$$

Differential equation solved is presented here:

$$\frac{1}{2\Delta t}\left(Q_i^{n+1} + Q_{i+1}^{n+1} - Q_i^n - Q_{i+1}^n\right) + \frac{C}{2\Delta x}\left(Q_{i+1}^n + Q_{i+1}^{n+1} - Q_i^n - Q_i^{n+1}\right) = 0 \qquad (20)$$

where, i being the spatial incrementation and n being the time incrementation.

$$Q_{i+1}^{n+1} = \frac{\left(\frac{1}{2\Delta t}+\frac{C}{2\Delta x}\right)Q_i^n + \left(\frac{1}{2\Delta t}-\frac{C}{2\Delta x}\right)Q_{i+1}^n + \left(-\frac{1}{2\Delta t}+\frac{C}{2\Delta x}\right)Q_i^{n+1}}{\frac{1}{2\Delta t}+\frac{C}{2\Delta x}} \quad (21)$$

This model conducts calculation by treating Δx as the mesh length and by shortening the Δt. In addition, river course with compound sections also can be calculated within this model. Furthermore, the model assumes that the flow rate of flood channel is 0 m^3/hour or day, and calculates the discharge of low flow channel section only. Because the section area contains also the flood channel, a storage effect considering the flood channel has been included in the model. Finally, the storage effect of flood channel (considered as flood area) around the river can be optionally selected.

B is set as: $B = RBW \cdot A^{RBS}$ and $hc1 = RHW \cdot A^{RHS}$ (22)

where *B* is river breadth (m), *A* is area of river basin (km^2), *RBW* and *RBS* are constants, and *RHW* and *RHS* are constants.

hc1 is set as: $hc1 = RHW \cdot A^{RHS}$ (23)

hc2 is set as: $hc2 = RHW \cdot A^{RHS} + B \cdot RBH \cdot RBET$ (24)

Because the wave speed when $h \leqq hc1$ is $A = Bh$, then

$$C_0 = \frac{\frac{dQ}{dh}}{\frac{dA}{dh}} = \frac{\frac{5}{3}\frac{1}{n}Bh^{2/3}i^{1/2}}{B} = \frac{5}{3}\frac{1}{n}h^{2/3}i^{1/2} = \frac{5}{3}Q^{2/5}n^{-3/5}I^{3/10}B^{-2/5} \quad (25)$$

Wave speed, when $hc1 \leqq h < hc2$

Because $A = Bh + RBET \cdot (h - h_{c1})^2$, then

$$C = \frac{\frac{dQ}{dh}}{\frac{dA}{dh}} = \frac{\frac{5}{3}\frac{1}{n}Bh^{2/3}i^{1/2}}{B + 2(h - h_{c1})/RBET} = \frac{B}{B + 2\left(\left(\frac{Qn}{BI^{1/2}}\right)^{3/5} - h_{c1}\right)/RBET}C_0 \quad (26)$$

Wave speed, when $hc2 \leqq h$

Because $A = Bh + RBET \cdot (h_{c2} - h_{c1})^2 + 2B \cdot RBET(h - h_{c2})$, then

$$C = \frac{\frac{dQ}{dh}}{\frac{dA}{dh}} = \frac{\frac{5}{3}\frac{1}{n}Bh^{2/3}i^{1/2}}{B + 2B \cdot RBH} = \frac{1}{1 + 2RBH}C_0 \quad (27)$$

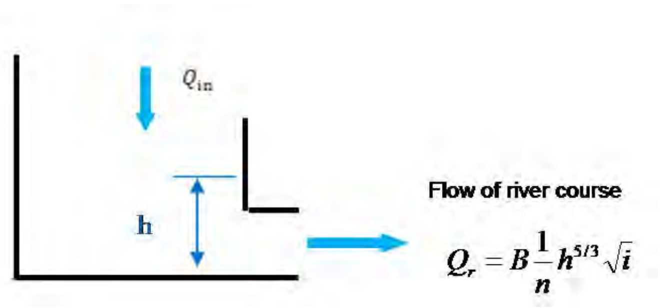


Figure 4-6 Schematic representation of river tank

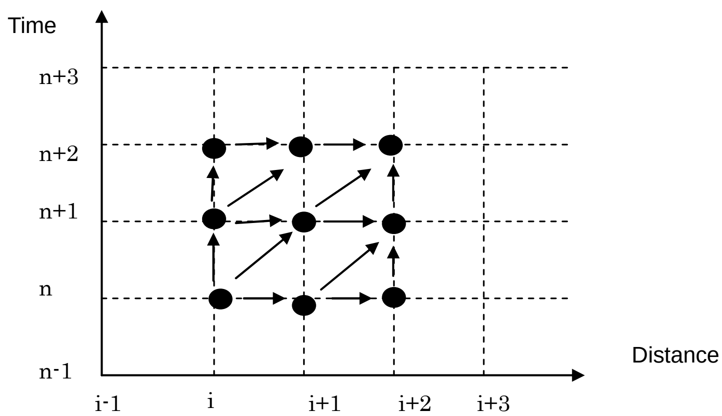


Figure 4-7 Image of Kinematic Wave difference method

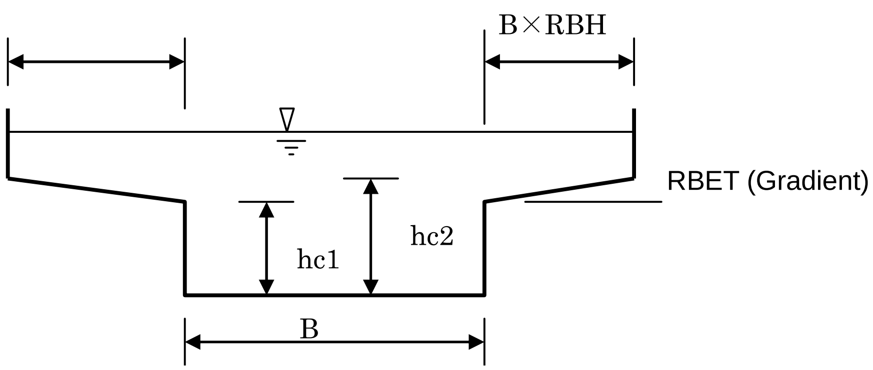


Figure 4-8 Schematic representation of river course with multiple cross-sections.

4.3. Calibration procedures

4.3.1. Calibration definition

Models are simplified representations of reality. Therefore, it is necessary to adjust the model to reality. To do so, model parameters adjustment is necessary. It is advised to conduct calibration within recommended ranges, with the aim to optimize the agreement between measured data and model simulation results. (Tolson et al, 2007)

4.3.2. Description of parameters

The PWRI model (ver.1, 3 layers and ver.2, two layers) is the runoff simulation engine in IFAS. The PWRI model consists in a three or four tanks model, which are surface, unsaturated if three layers, aquifer and river course tanks. The figures below show the outlines and parameters of each tank.

4.3.3. How to set parameters for calibration

This section explains how to set parameters. Default or un-tuned values are set as initial values for each parameter. All parameters have to be calibrated using observed and/or hydrological reference data. Hereafter is the explanation on un-tuned parameters and on how to set parameters for each model.

The un-tuned parameters are used as the initial values of parameter verification and for calculation when there is no observed flood data. Even though IFAS can calculate runoff by using the un-tuned parameters when the historical hydrology data are not available, we recommend the users to check the flood marks data and/or flow ratio data (outflow/basin area) around the target calculation area, confirming the validity of results, and calibrating the parameters with site measurements.

This section explains how to set the parameters for the surface, unsaturated and aquifer tanks. The parameters are set by trial and error, by comparing simulated and measured flood outflow values. The table below shows the principles for setting parameters.

Unsaturated tank parameters are a description of catchment soil hydraulic properties. These properties are related to soil types. Although there are global databases relating soil type (CGWM which can be downloaded in IFAS) and soil texture (Weeb et al, 2000), there are some problems when applying hydraulic properties determined at a different scale (Tartakovsky et al, 2000). Those values from the literature, like Rawls soil water properties estimation (Table 4-5) should be considered to determine ranges for these values and give an order of magnitude.

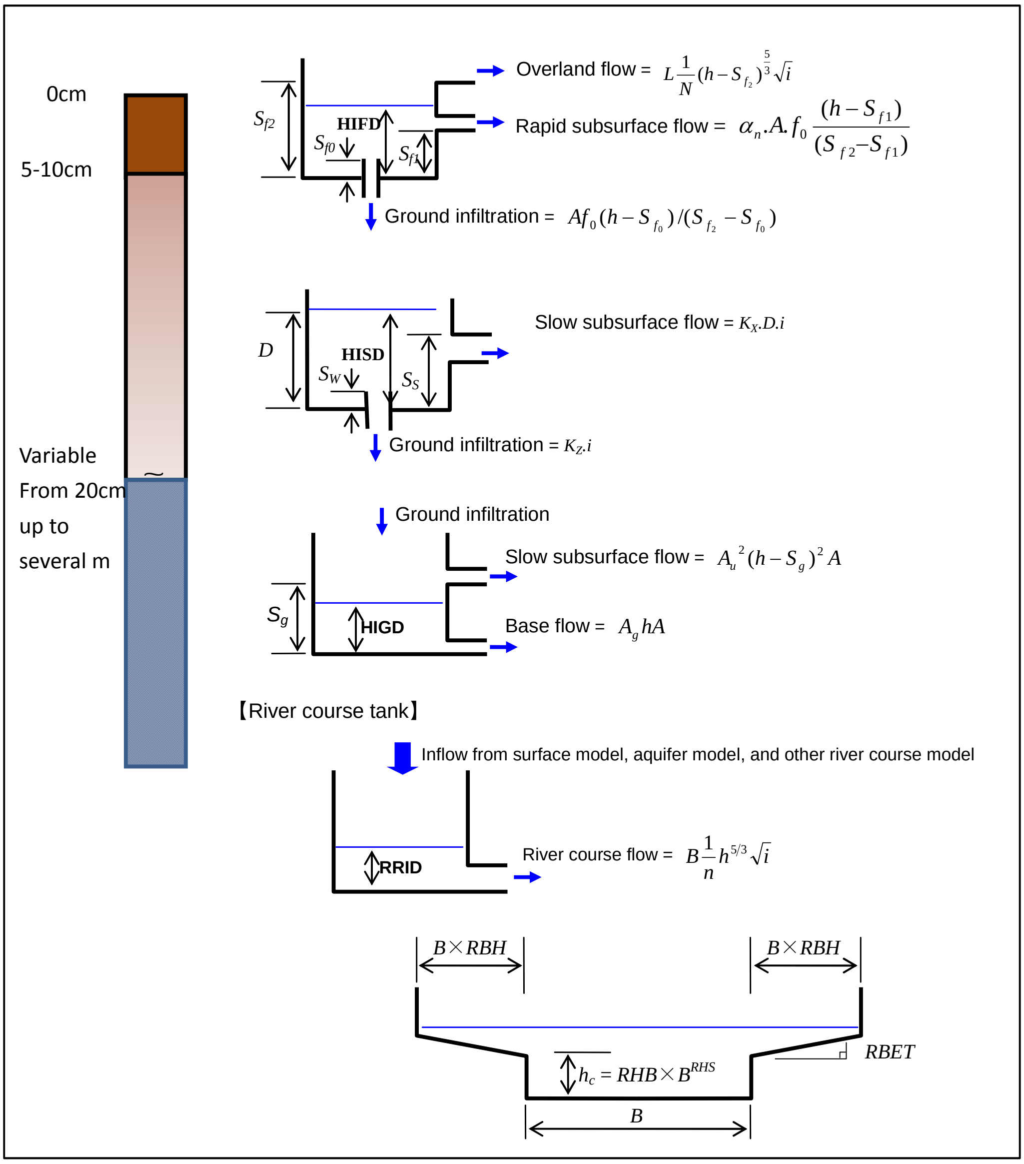


Figure 4-9 Model schematic representation and its parameters (PWRI DHM ver.1: three tanks and ver. 2: two tanks)

Table 4-3 Setting parameters with or without river basin data

		Observed hydrological data	
		With	without
River course data	with	Verification and calculation on parameters of surface and aquifer tanks Setting parameters for river course	Setting parameters for river course Using default values for surface and aquifer tanks
	without	Verification and calculation on parameters of surface and aquifer tanks Using default values for the river course parameters	Using default values for all models

Table 4-4 Surface tank model

<table>
<tr><th>Parameter</th><th>Symbol</th><th>Notation</th><th>Unit</th><th>How to set</th></tr>
<tr><td>Final infiltration capacity</td><td>f_0</td><td>SKF</td><td>cm/s</td><td>Set by trial and error</td></tr>
<tr><td>Maximum water height</td><td>S_{f2}</td><td>HFMXD</td><td>m</td><td>Set by trial and error</td></tr>
<tr><td>Height where rapid intermediate flow occurs</td><td>S_{f1}</td><td>HFMND</td><td>m</td><td>Set by trial and error</td></tr>
<tr><td>Height where ground infiltration occurs</td><td>S_{f0}</td><td>HFOD</td><td>m</td><td>Set by trial and error</td></tr>
<tr><td>Surface roughness coefficient</td><td>N</td><td>SNF</td><td>$m^{-1/3}/s$</td><td>This value refers to equivalent roughness coefficient
Reference equivalent roughness coefficient (N)
<table>
<tr><th colspan="3">Land use</th><th>Std. value</th></tr>
<tr><td colspan="3">Water surface</td><td>0.0</td></tr>
<tr><td colspan="3">Paddy filed</td><td>2.0</td></tr>
<tr><td colspan="3">Mountain forest</td><td>0.7</td></tr>
<tr><td colspan="3">Hills, pastures, parks, golf ground, cropland</td><td>0.3</td></tr>
<tr><td colspan="3">Urban land</td><td>0.03</td></tr>
<tr><td rowspan="4">Urbanization level</td><td>1°</td><td>Road and street are partly paved, lots of bare ground are left.
Drainage network is completed</td><td>0.1</td></tr>
<tr><td>2°</td><td>Road and street pavement is in progress
Sewage nets is not completed</td><td>0.05</td></tr>
<tr><td>3°</td><td>50% road and street are paved
Sewage network is almost completed</td><td>0.01</td></tr>
<tr><td>4°</td><td>Road and street are completely p ve . Sewage network is completed</td><td>0.005</td></tr>
</table>
Source） Hashimoto et., al., 1977. Runoff model and civil technological material for evaluating land use. In Japanese. We added water surface as a new item</td></tr>
<tr><td>Mesh length</td><td>L</td><td>—</td><td>m</td><td>Mesh length of the simulation model</td></tr>
<tr><td>Rapid intermediate flow Regulation coefficient</td><td>α_n</td><td>FALFX</td><td>Non-dimensional</td><td>Set by trial and error</td></tr>
<tr><td>Initial water height</td><td>—</td><td>HIFD</td><td>m</td><td>Basically, as 0 m</td></tr>
</table>

Table 4-5 Soil physical parameters by textural class (Rawls et al, 1982)

Texture Class	**θ_{sat} (-)**	**θ_{FC}(-)**	**θ_{PWP} (-)**	K_{sat} (mm.day^{-1})
Sand	0.437	0.115	0.033	5.040
Loamy Sand	0.437	0.168	0.055	1.464
Sandy Loam	0.453	0.245	0.095	0.624
Loam	0.463	0.279	0.117	0.312
Silt Loam	0.501	0.324	0.133	0.163
Sandy Clay Loam	0.398	0.241	0.148	0.103
Clay Loam	0.464	0.321	0.197	0.055
Silty Clay Loam	0.471	0.350	0.208	0.036
Sandy Clay	0.430	0.311	0.239	0.029
Silty Clay	0.479	0.371	0.250	0.022
Clay	0.475	0.368	0.272	0.014

θ_{sat} volume water fraction at saturation, θ_{FC} volume water fraction at field capacity, θ_{PWP} volume water fraction at permanent wilting point, K_{sat} saturated hydraulic conductivity.

Table 4-6 Unsaturated tank parameters list

Parameter	Symbol	Notation	Unit	How to set
Tank height	D	HMXSD	m	Set by trial and error.
Horizontal saturated hydraulic conductivity	K_{sx}	SKX	cm/s	Estimated first as 10^2-10^4 times bigger than the actual roughness coefficient. Then tuned by trial and error around that value.
Vertical saturated hydraulic conductivity	K_{sz}	SKD	cm/s	Set by trial and error in the same order of magnitude of the value in the literature according to soil type.
Saturated moisture content	θ_S	STS	-	Set by trial and error in the same order of magnitude of the value in the literature according to soil type.
Wilting point moisture content	θ_W	STW	-	Set by trial and error in the same order of magnitude of the value in the literature according to soil type.
	b	SBD	-	Set by trial and error.(value between 1 and 100)
Vertical hydraulic conductivity at wilting point	K_{wz}	SK0D	cm/s	Set by trial and error in the same order of magnitude of the value in the literature according to soil type.
Initial water height	―	HIGD	m	Set by trial and error.

Table 4-7 Aquifer tank model

Parameter	Symbol	Notation	Unit	Explanation
Runoff coefficient of unconfined aquifer	A_u	AUD	(1/mm/day)$^{1/2}$	Set by trial and error
Runoff coefficient of confined aquifer	A_g	AGD	1/day	Set by trial and error
Height where the unconfined aquifer runs off	S_g	HCGD	m	Set by trial and error
Initial water height	―	HIGD	m	Set by trial and error

4.4. Satellite based rainfall “GSMaP”

4.4.1. General information

The GSMaP project was promoted for a study "Production of a high-precision, high-resolution global precipitation map using satellite data," sponsored by Core Research for Evolutional Science and Technology (CREST) of the Japan Science and Technology Agency (JST) during 2002-2007. Since 2007, GSMaP project activities are promoted by the JAXA Precipitation Measuring Mission Science Team.

This chapter describes data format and information of Global Rainfall Map in Near Real Time (GSMaP_NRT) distributed from JAXA Global Rainfall Watch, which was developed based on activities of the GSMaP project. The GSMaP project is promoted for the study "Production of a high-precision, high-resolution global precipitation map using satellite data," sponsored by CREST of the JST.

Table 4-8 Summary of GSMaP_NRT product

No	Parameter [unit]	Data format	Coverage	Grid size	Horizontal resolution	Temporal resolution	FTP directory
1	Hourly Rain Rate [mm/h]	4-byte float plain binary, little-endian	Global (60°N-60°S)	3600 x 1200	0.1 degree grid box	Hourly	Latest 24-hr: /realtime/latest/ Archive: /realtime/archive/ **YYYY/MM/DD/**
2	Satellite Information Flag	4-byte singed integer plain binary, little-endian					/realtime/sateinfo **/YYYY/MM/DD/**
3	Observation Time Flag	4-byte float plain binary, little-endian					/realtime/timeinfo **/YYYY/MM/DD/**
4	Hourly Rain Rate in text format [mm/h]	ASCII, CSV format	Global but divided to 54 areas	200 rows x 400 lines			/realtime/txt/**AAA BBBB/YYYY/MM/ DD/**
5	Daily Rainfall [mm/h]	4-byte float plain binary, little-endian	Global (60°N-60°S)	1440 x 480	0.25 degree grid box	Daily (averaged from 00Z to 23Z of the specified day)	/realtime/daily/00 Z-23Z/**YYYYMM/**
6						Daily (averaged from 12Z of previous day to 11Z of the specified day)	/realtime/daily/p1 2Z-11Z/**YYYYMM** /

Note: **YYYY:** 4-digit year, **MM:** 2-digit month, **DD:** 2-digit day, **AAA:** latitude of the corner of left-top position (2-degit latitude + S or N), and **BBBB:** longitude of the corner of left-top position (3-degit longitude + E or W).

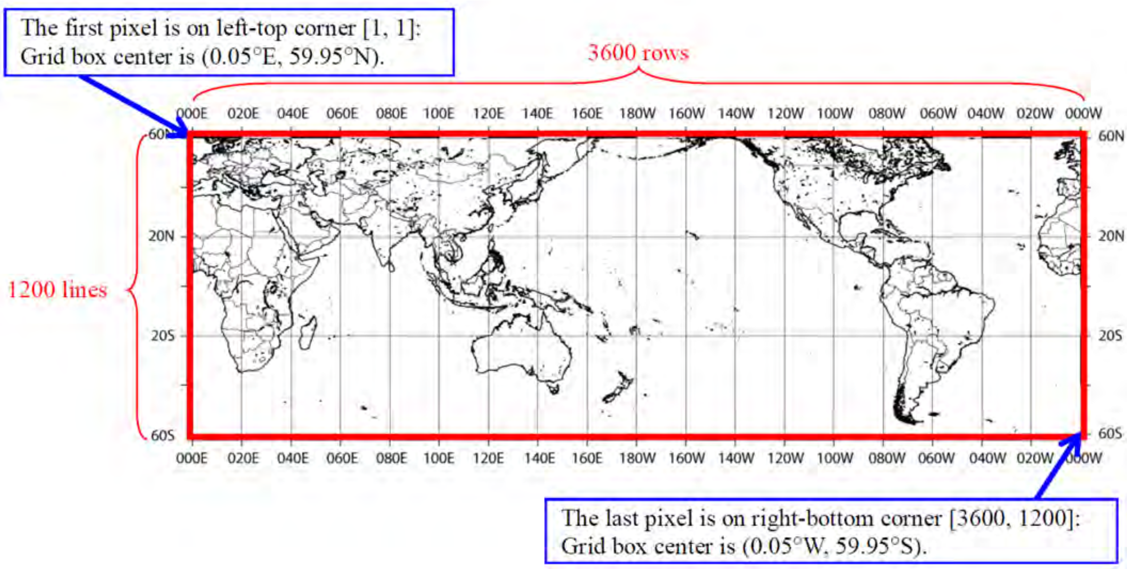


Figure 4-10 Coverage of GSMaP_NRT product

Table 4-9 Stored value of Satellite information flag

Pixel Value		Description	
Value	Bit	Sensor Category	Satellite/Sensor
1	0	Microwave imager and/or sounder aboard low orbital satellite	TRMM/TMI
2	1		Aqua/AMSR-E
4	2		DMSP-F13/SSM/I
8	3		DMSP-F14/SSM/I
16	4		DMSP-F15/SSM/I
32	5		DMSP-F16/SSMIS
64	6		DMSP-F17/SSMIS
128	7		NOAA-19/AMSU-A/MHS
256	8		MetOp-A/AMSU-A/MHS
512-32768	9-15		not used
65536	16	Infrared Imager aboard Geo-stationary meteorological satellite (before 22Z 28 Mar. 2012)	GOES-EAST
131072	17		GOES-WEST
262144	18		INDEX
524288	19		METEOSAT
1048576	20		MTSAT
2097152–536870912	21–29		not used
1073741824	30	Infrared Imager aboard Geo-stationary meteorological satellite (since 23Z 28 Mar. 2012)	
−(negative)	31	No microwave radiometer observation	

4.4.2. Time delay between observation and dissemination

Satellite based rainfall is combined product of Micro Wave Radiometer (MWR) observation data and infrared image. JAXA makes Look-Up table for MWR data to retrieve rainfall data from brightness temperature. JAXA collect MWR data for 3 hours. Then the rainfall data is retrieved from Look-up table. Then MWR data and infrared data are blended to make global rainfall data. It takes for 1 hour to make global rainfall data. Totally, Time delay is 4 hours for GSMaP_NRT. Therefore, user should be careful about the size of contributed catchment area of rainfall. In such small area, it is difficult to produce enough lead time for disseminating flood alert.

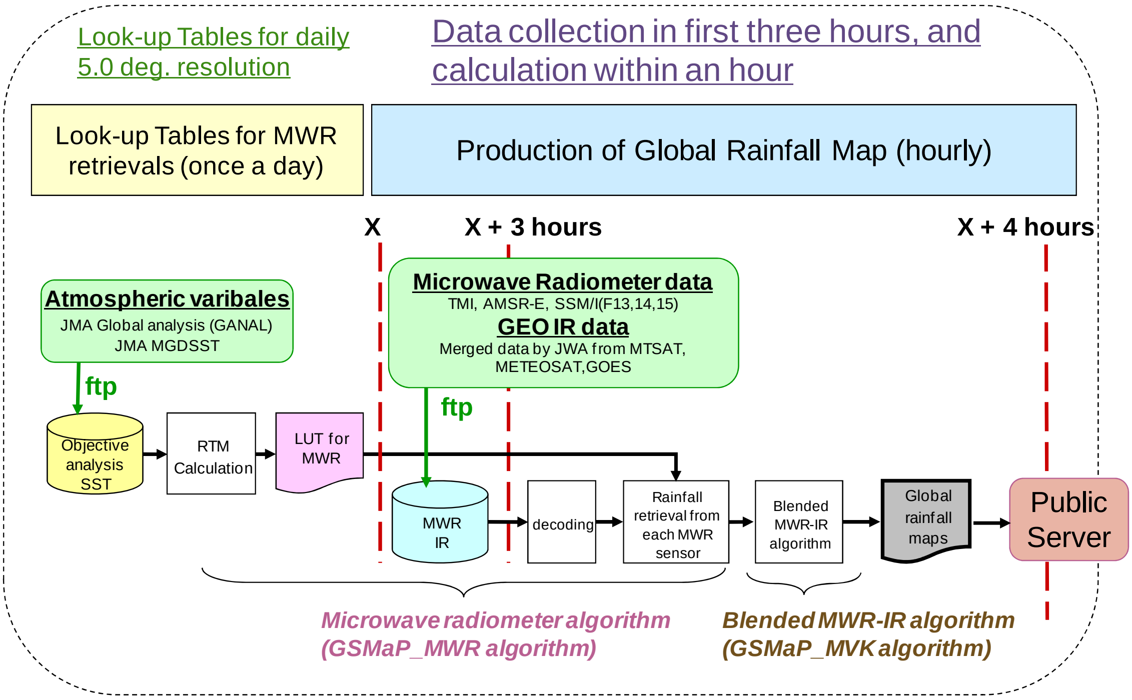


Figure 4-11 Time delay of GSMaP_NRT

4.5. Rainfall-runoff modeling with IFAS for the Pampanga River basin

4.5.1. Automatic river course modeling

IFAS has an automatic function of river course modeling based on Global Map. User can import Global Map (Landcover) as the information for classification of land-use in IFAS. Figure 4-12 shows the imported results of Global Map (Landcover) in IFAS. Information of land-use is used for distribution of various parameters. Not only Global Map (Landcover), but also Global Map (Elevation) can be imported as the information of altitude in IFAS. Figure 4-13 shows the imported results of Global Map (Elevation) in IFAS. Following the elevation data, basin boundary, river course network, type of cell tanks and range of sub-basin can be determined. For creating basin boundary, there are two functions; one is creation using elevation data, the other is creation by importing GIS shape file of basin polygon. The method using GIS shape file is employed in this analysis. Figure 4-14 shows created basin boundary using GIS shape file. After definition of basin boundary, river course network is created automatically based on elevation data. Figure 4-15 shows automatically-created river course network in IFAS

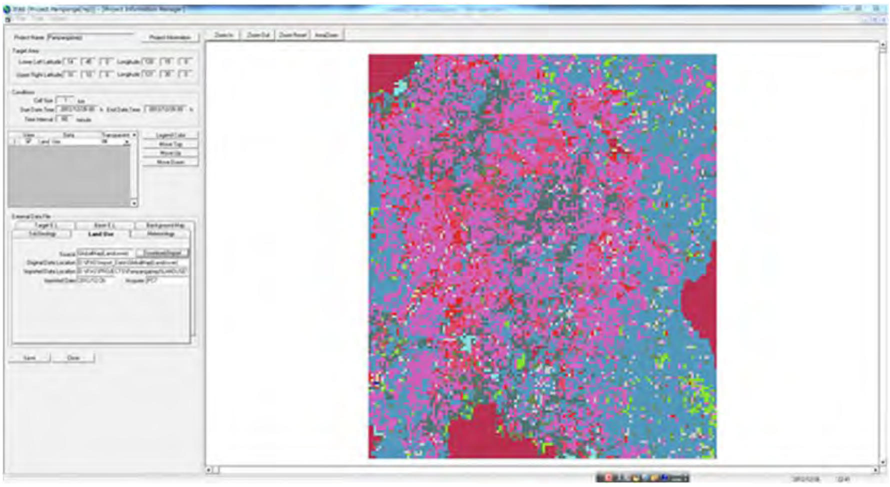


Figure 4-12 Imported Global Map (Landcover) in IFAS

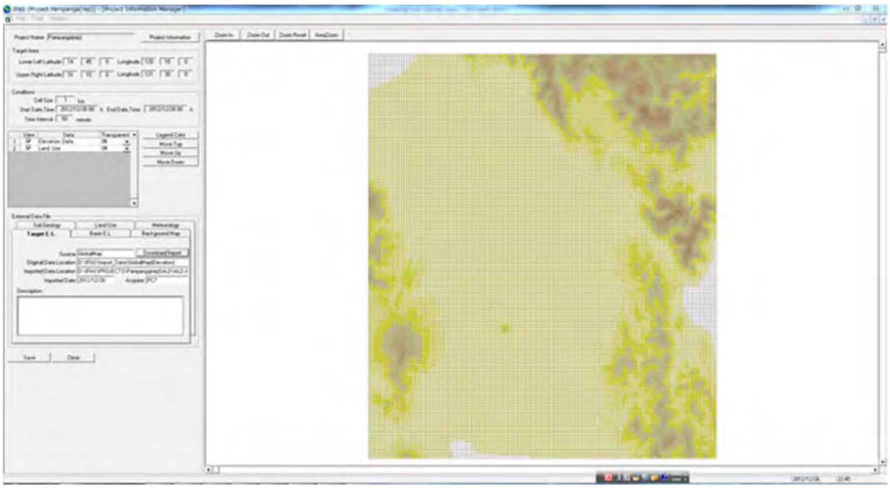


Figure 4-13 Imported Global Map (Elevation) in IFAS

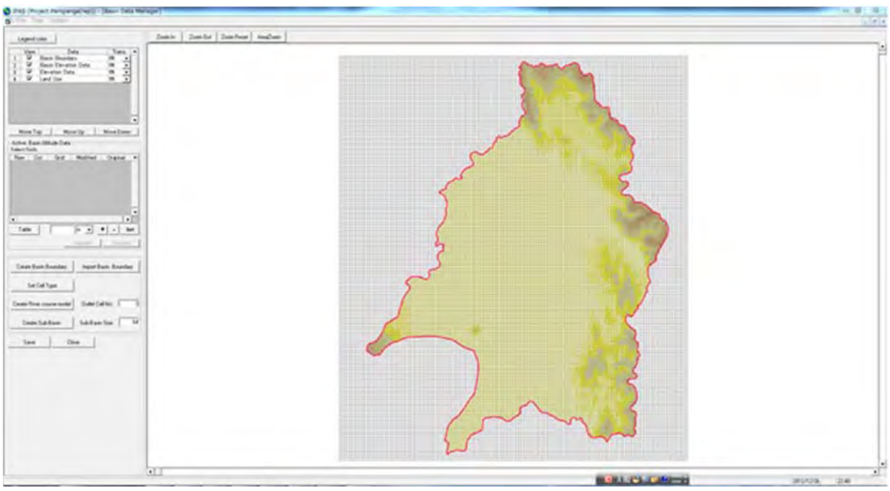


Figure 4-14 Created basin boundary using GIS shape file

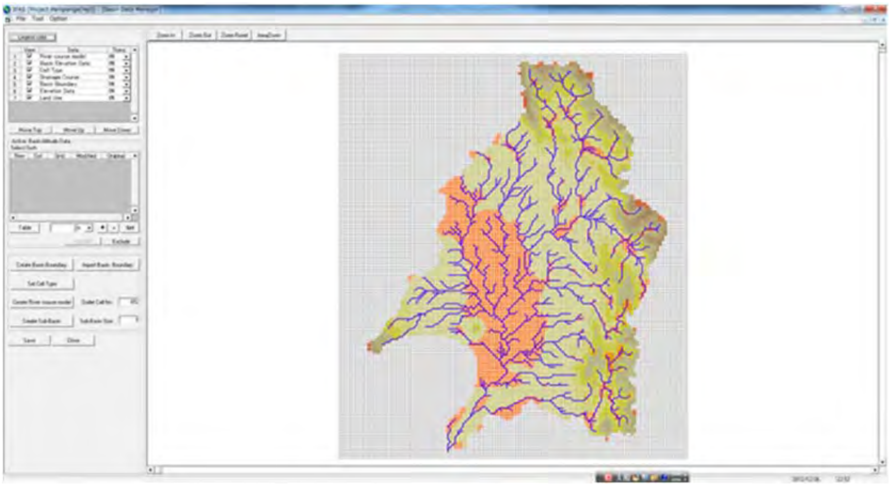


Figure 4-15 Automatically-created river course network in IFAS

4.5.2. Modification of created river course

ICHARM tried to create river course model from Global Map (Elevation) with IFAS. However, it is difficult to create river course model appropriately in Pampanga river basin. Basically river course model is made from elevation data searching the steepest point among eight directions from each grid. Pampanga river basin includes flat area in the west part. Therefore it’s difficult to pick up the steepest point as flow direction. Figure 4-16 shows the result of making river channel network by inputting original Global Map (Elevation). Blue line is river course made from Global Map (Elevation) with IFAS algorithm. Black, Pink and Red colored lines are traced lines on the river course represented on Google Earth. Indicated area by yellow colored circle, the river course was connected inappropriately. IFAS connected all of the cells by river channel network changing the elevation data in the target basin. Therefore, river course and elevation in the target basin are different from actual river course. In that case, size of catchment area up to the target point might be different from actual catchment area. That is why simulated discharge is also not correct.

Elevation data has been dug manually tracing actual river course from river mouse to top of mountain on the Digital Elevation Model (DEM) named Global map (Elevation). The elevation should be rising up from river mouse to top of mountain gradually. Because there is an assumption that water always go down from upstream to downstream in the Kinematic wave method. If there are some depressed points or upwards slope in the target basin, it’s impossible to calculate appropriate river discharge.

Figure 4-17 shows comparison elevation data, river course made by IFAS and actual river course traced referring the image of the Google Earth. Drawing rectangle function is implemented in Microsoft Excel. The rectangle was drawn on the Excel sheet and filled with river course map captured on the screen. Then the rectangle has set transparent cover with elevation data.

The cell “A” should be the downstream point among nine cells according to the actual river course.

Therefore, elevation of cell “A” should be smallest value than elevation value of the red rectangular cell. The elevation data of Red rectangular cell should be smaller among other seven elevation data. And elevation data of cell “B” should be bigger than elevation data of red rectangular cell. The elevation data should be revised repeating the procedure with checking whole elevation in the river course. It’s better to not only checking eight directions but also check all of the elevation. The elevation data of the top of mountain should be biggest value and river mouse should be smallest value. Elevation data should be revised within the maximum value and minimum value on the river course.

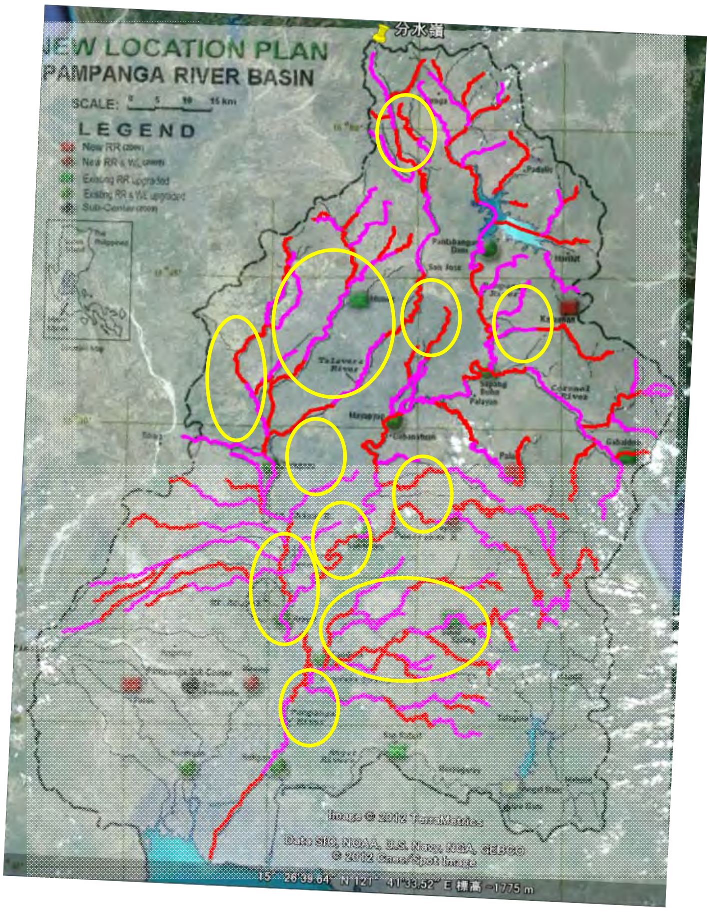


Figure 4-16 River course made from original Global Map (elevation)

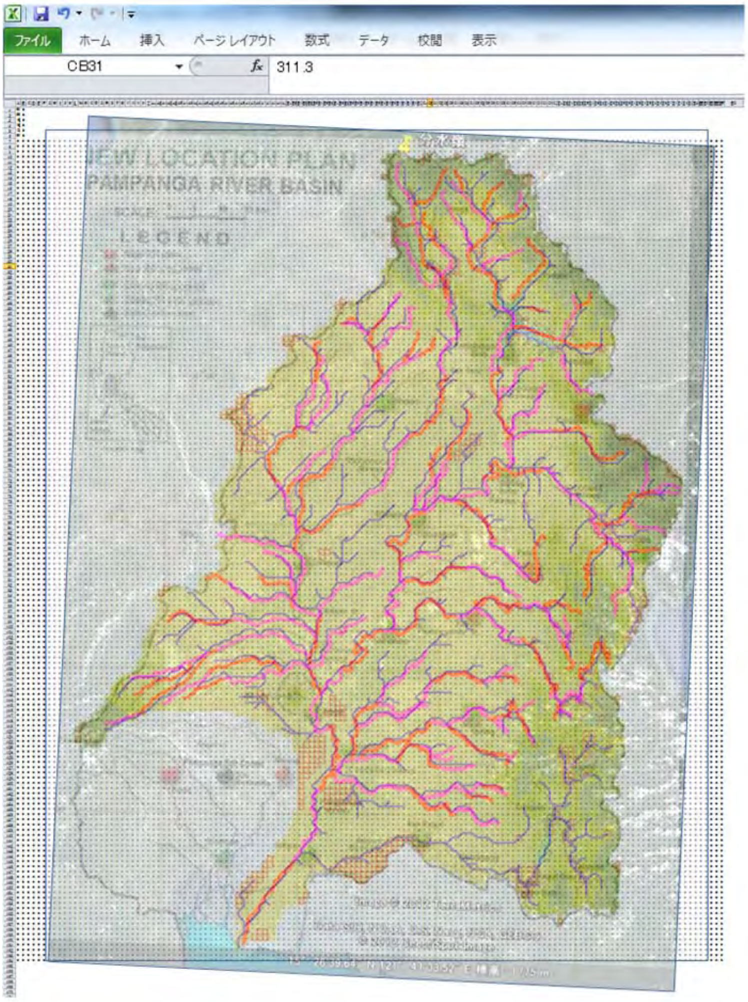


Figure 4-17 Comparison among elevation data, river course made by IFAS and actual river course with Microsoft Excel

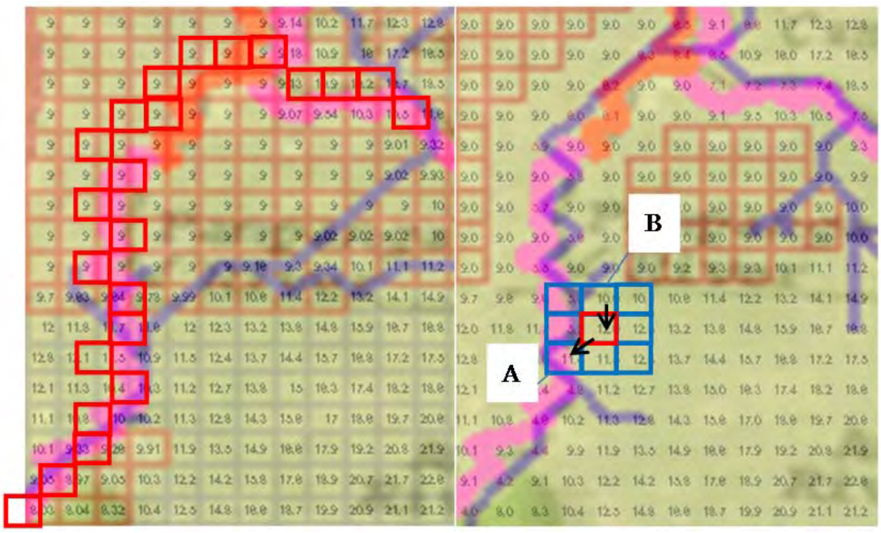


Figure 4-18 Revising target

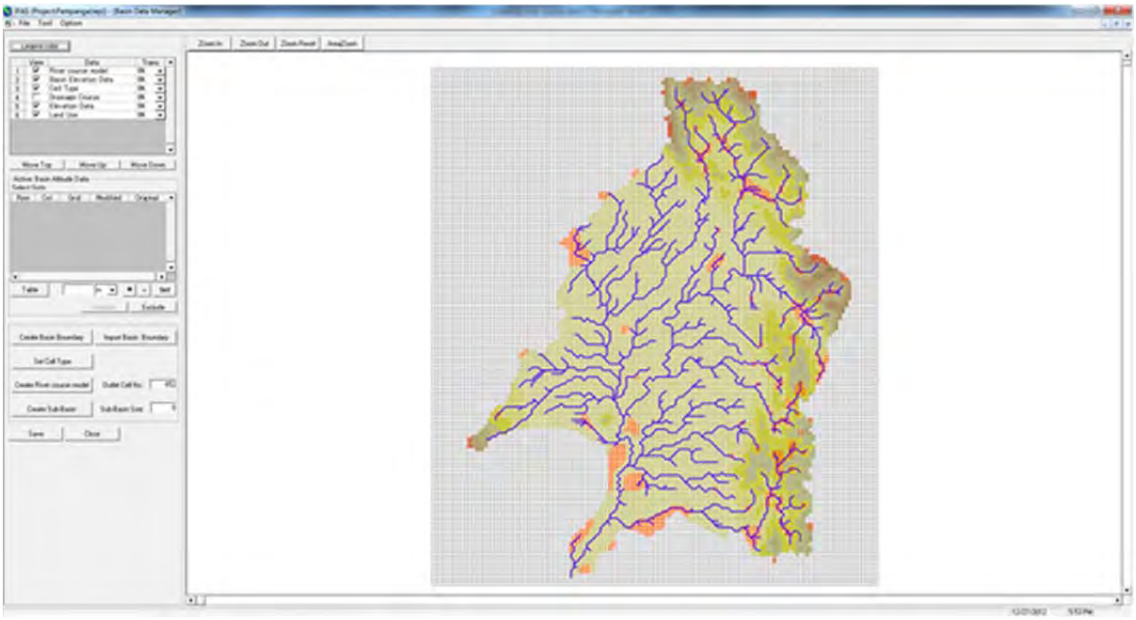


Figure 4-19 Recreated river course corresponding to actual situation

4.5.3. Results of simulation

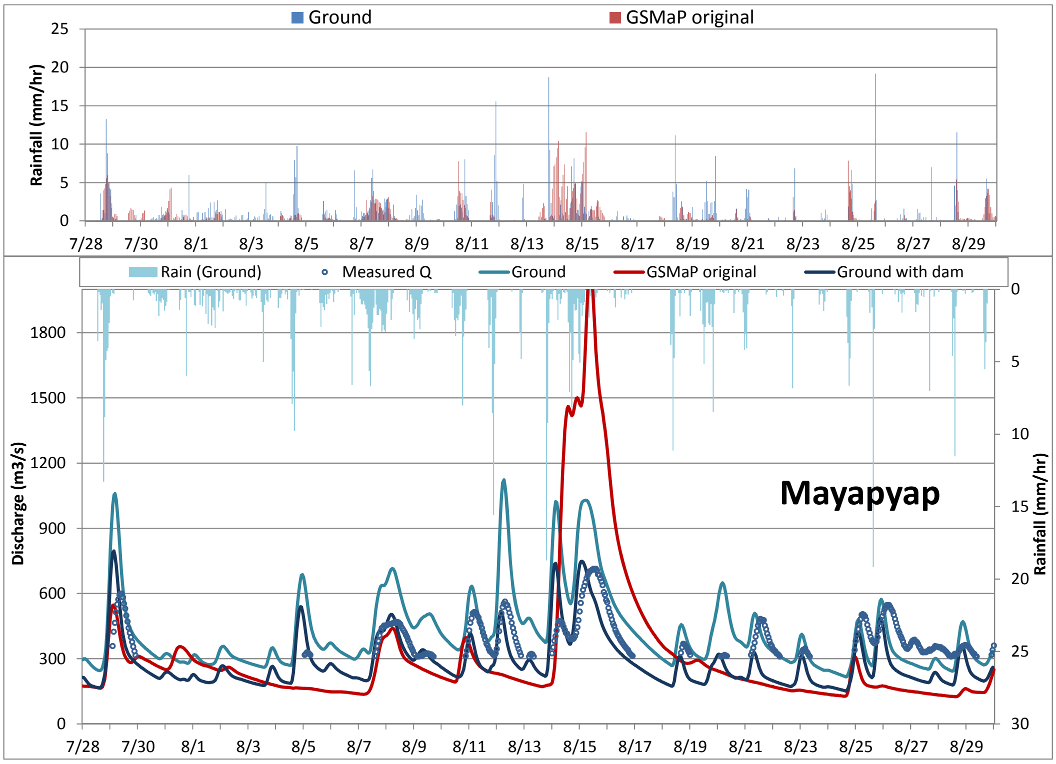
IFAS had been applied to the Pampanga River basin for recent three floods, August 2012, September 2011 and June 2011. Simulation results of IFAS were validated at the Mayapyap, the San Isidro and the Arayat which are important gauging stations for flood early warning. Figure 4-20 shows the observed and simulated discharge on August 2012 at the Mayapyap, the San Isidro and the Arayat. In case of this flood, as the accuracy of GSMaP is indifferent, simulation results with ground-gauge rainfall is more reproductive than GSMaP. Regarding the simulation results with ground-gauge rainfall, the simulation including storage effect by dam is more accurate than without dam. As a dam of flood control, the Pandapangan dam is taken into this simulation, the storage effect by dam is assumed that all inflow discharge can be stored in the dam reservoir. Flood discharge at the Arayat station could not be reproduced even the simulation with ground-gauge rainfall. Occurrence of inundation, inflow of largest tributary, the Rio Chico River, and Cabiao floodway are possible causes of less reproducibility at the Arayat station.

Figure 4-21 shows the observed and simulated discharge on September 2011 at the Mayapyap and the San Isidro. During this flood, water level data at the Arayat station could not observed due to electric power outage. As GSMaP has enough accuracy as much as ground-gauge rainfall in case of this flood, IFAS simulation with GSMaP could reproduce with high accuracy. Regarding the simulation results with ground-gauge rainfall, the simulation including dam effect is more accurate than without dam as is the case with flood on August 2012.

Figure 4-22 shows the observed and simulated discharge on June 2011 at the Mayapyap, the San Isidro and the Arayat. In this flood case, every simulation results cannot reproduce the observed

discharge with high accuracy. The possible causes of less reproducibility are difference of dam operation between actual and simulated, unreliability of observed discharge due to rating curve and inundation at upstream area.

Throughout the all simulation results shown in following figures, calibration procedures of parameters are insufficient; therefore these simulation results should be considered as reference information of IFAS application. Suitable parameters based on calibration would update the simulation results for more corresponding results to observed discharge. The case example of calibration in the Cagayan River basin is introduced in next section “4.4.5. Introduction of calibration”.



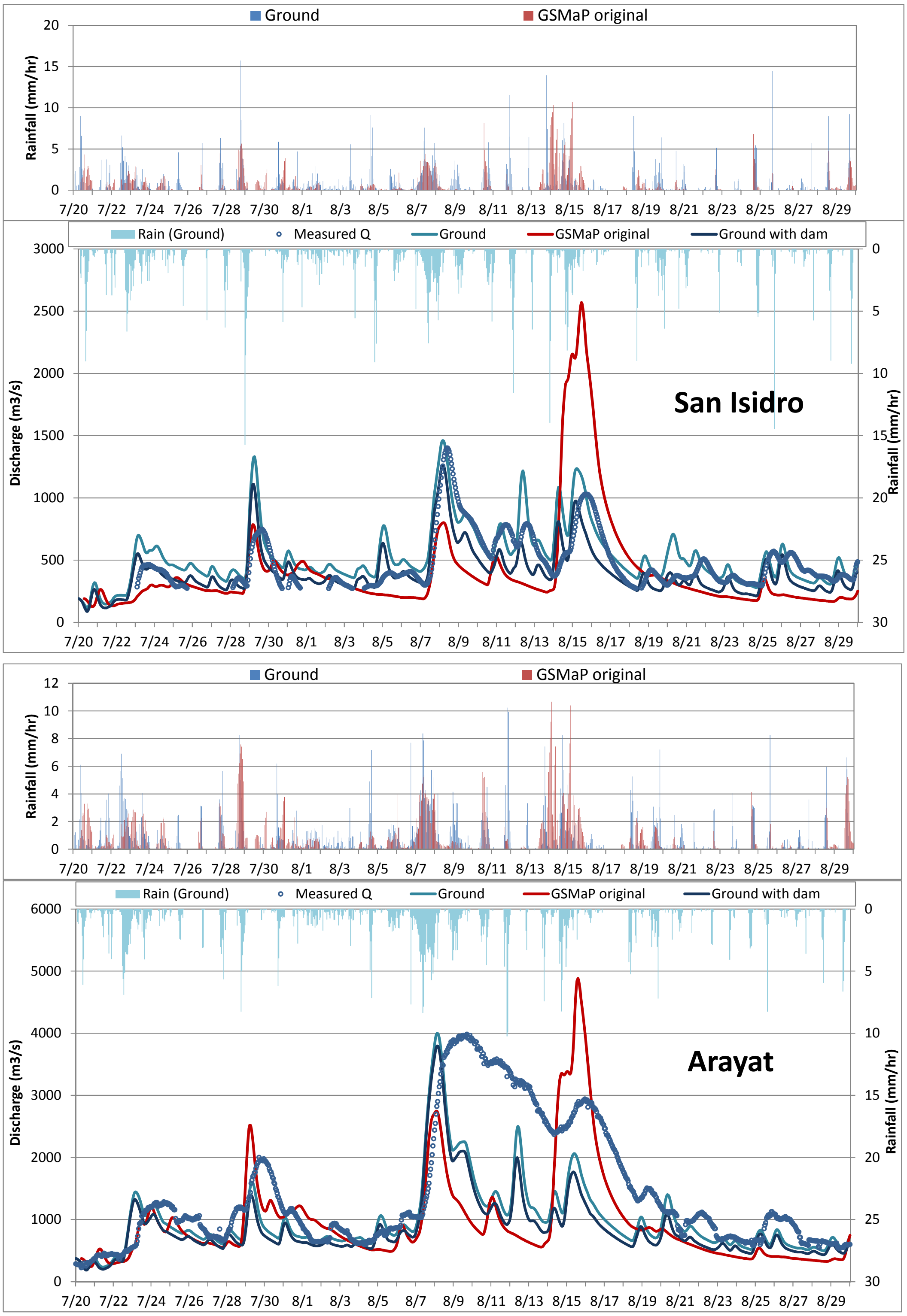


Figure 4-20 Hyetograph of ground-gauge and GSMaP and hydrograph of observed and simulated discharge on August 2012 at the Mayapyap, San Isidro and Arayat

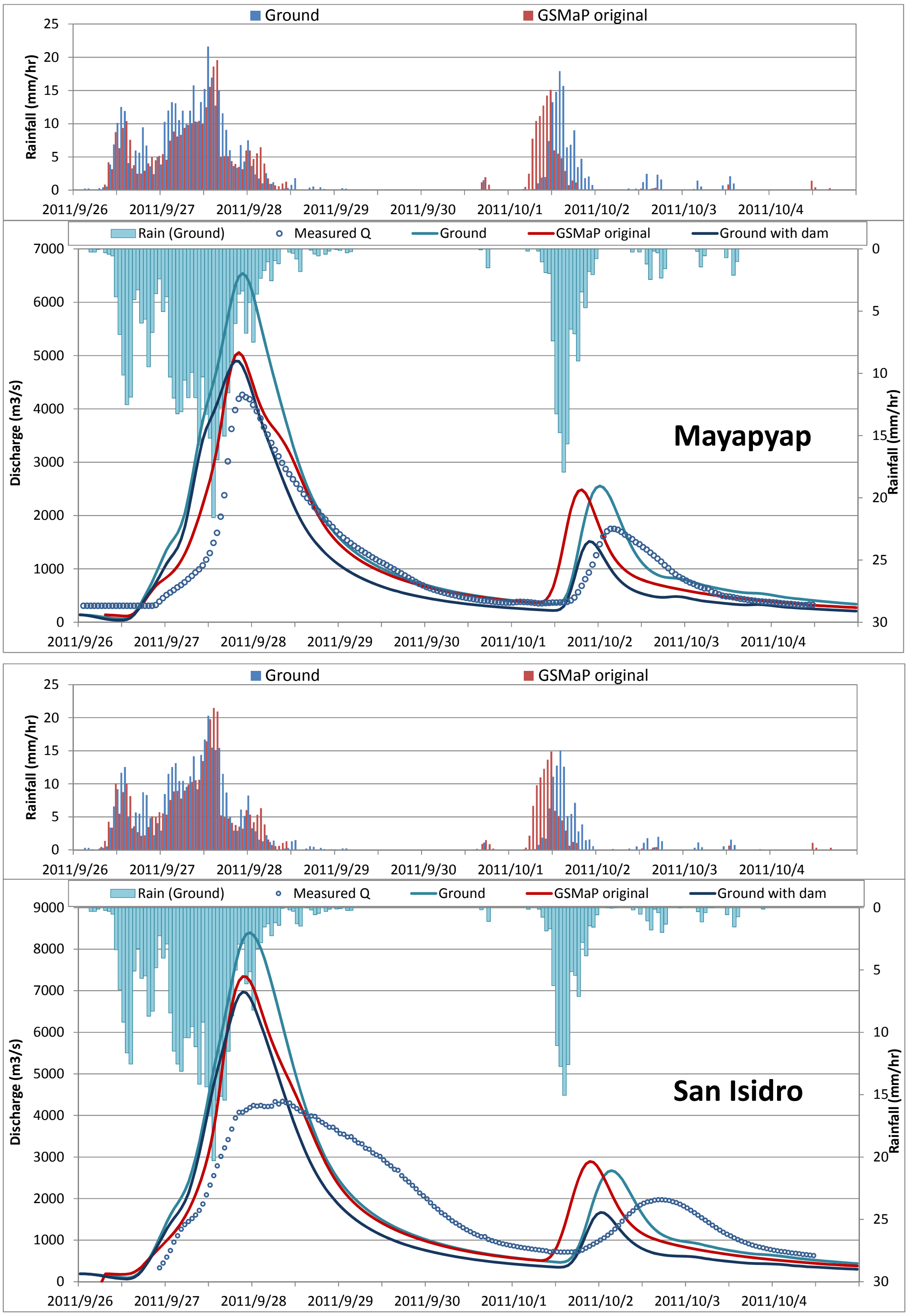
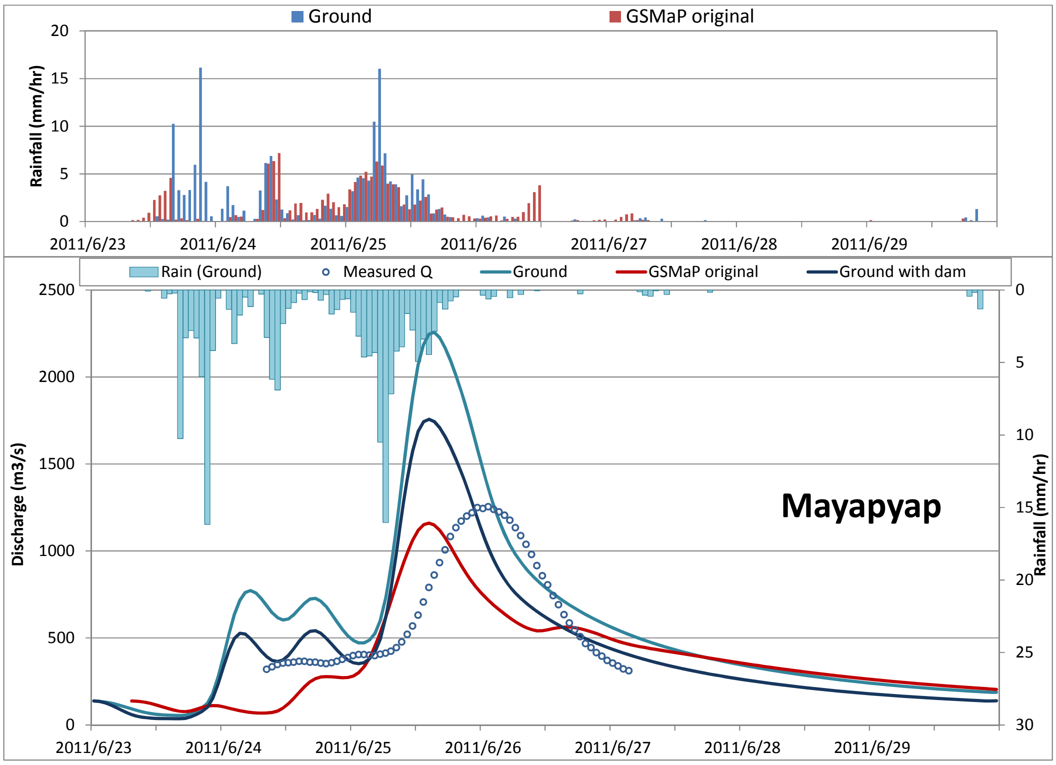
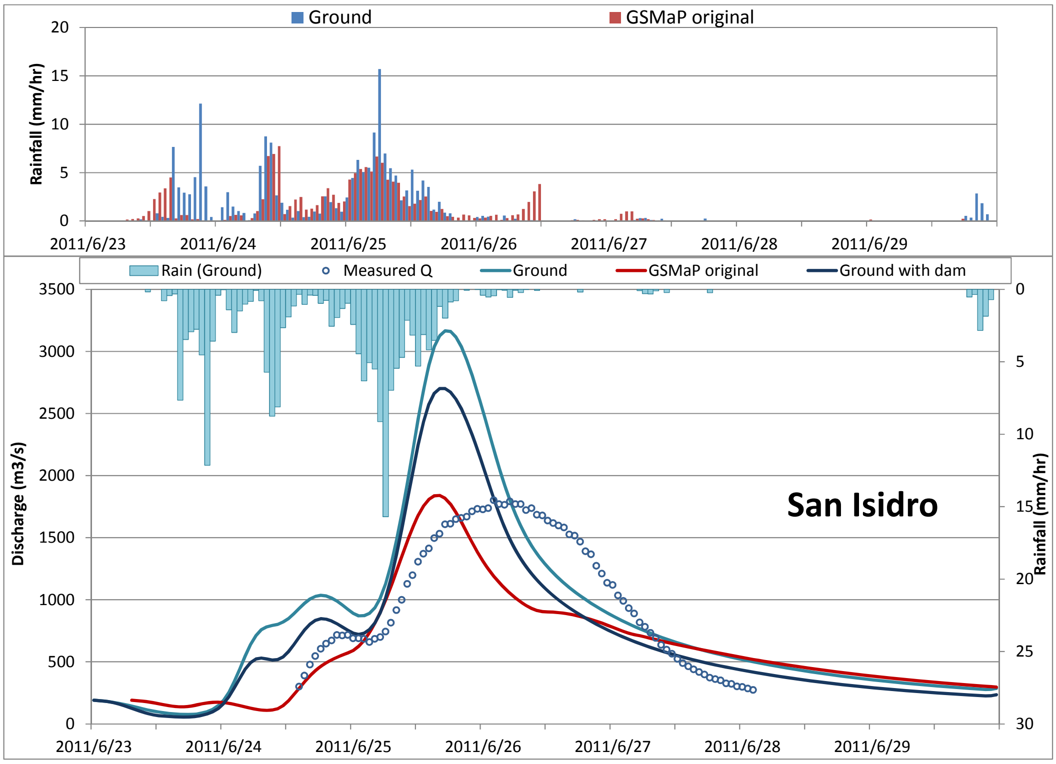


Figure 4-21 Hyetograph of ground-gauge and GSMaP and hydrograph of observed and simulated discharge on September 2011 at the Mayapyap and San Isidro


Ground
GSMaP original
Rainfall (mm/hr)
20
15
10
5
0
2011/6/23
2011/6/24
2011/6/25
2011/6/26
2011/6/27
2011/6/28
2011/6/29
Rain (Ground)
Measured Q
Ground
GSMaP original
Ground with dam
Discharge (m3/s)
2500
2000
1500
1000
500
0
Rainfall (mm/hr)
0
5
10
15
20
25
30
Mayapyap


Ground
GSMaP original
Rainfall (mm/hr)
20
15
10
5
0
2011/6/23
2011/6/24
2011/6/25
2011/6/26
2011/6/27
2011/6/28
2011/6/29
Rain (Ground)
Measured Q
Ground
GSMaP original
Ground with dam
Discharge (m3/s)
3500
3000
2500
2000
1500
1000
500
0
Rainfall (mm/hr)
0
5
10
15
20
25
30
San Isidro

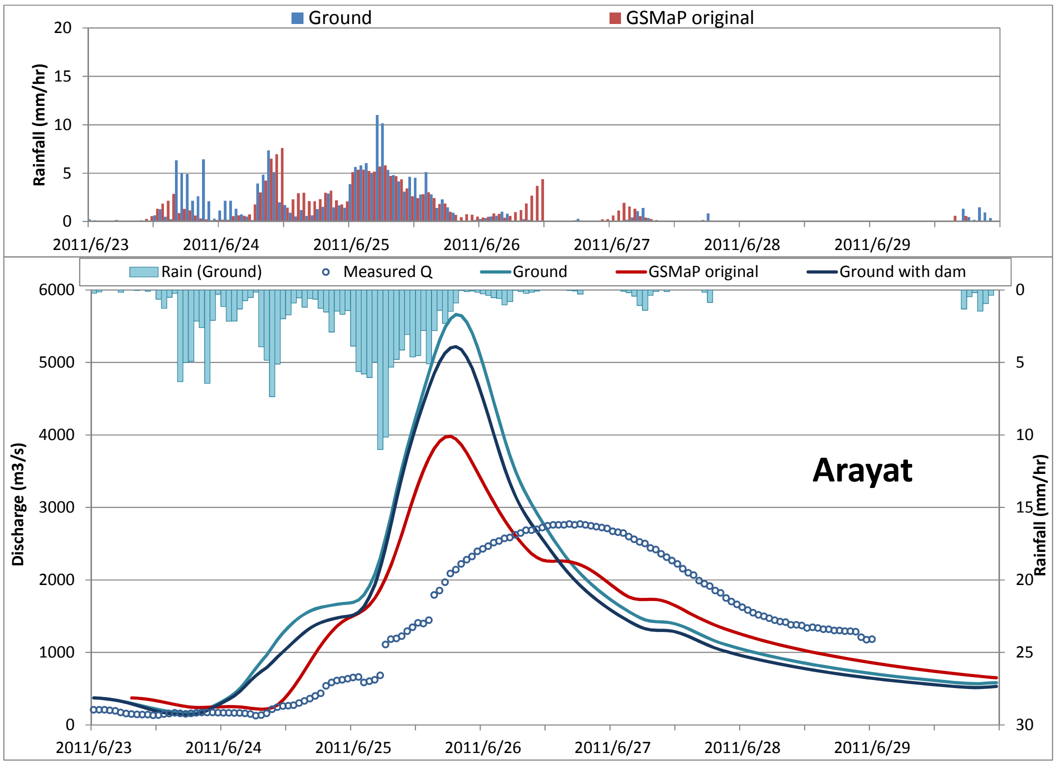


Figure 4-22 Hyetograph of ground-gauge and GSMaP and hydrograph of observed and simulated discharge on June 2011 at the Mayapyap, San Isidro and Arayat

4.6. Rainfall-runoff modeling with IFAS for the Cagayan River basin

4.6.1. River course modeling

River course model in Cagayan river basin should be made by the same procedure as Pampanga river basin described in Chapter 4.5. The Cagayan River basin also includes flat area in the middle of the river basin.

1. Global map (Landcover) was imported in IFAS.
2. Next, Global map (Elevation) was imported in Project information manager
3. Next, Basin boundary data was imported by basin boundary importing function in Basin data manager. IFAS will pick up the elevation data according to the basin boundary data.
4. IFAS made the river course tracing and modifying elevation data.

After revising, elevation data was saved in CSV format comma delimited. After that, “comma” was replaced to “space” to make ESRI/ASCII grid file with text editor. Then the ASC format file was saved in sub folder in IMPORT_DATA folder. Then the saved ASC file was imported by import function of ESRI/ASCII GRID format in project information manager.

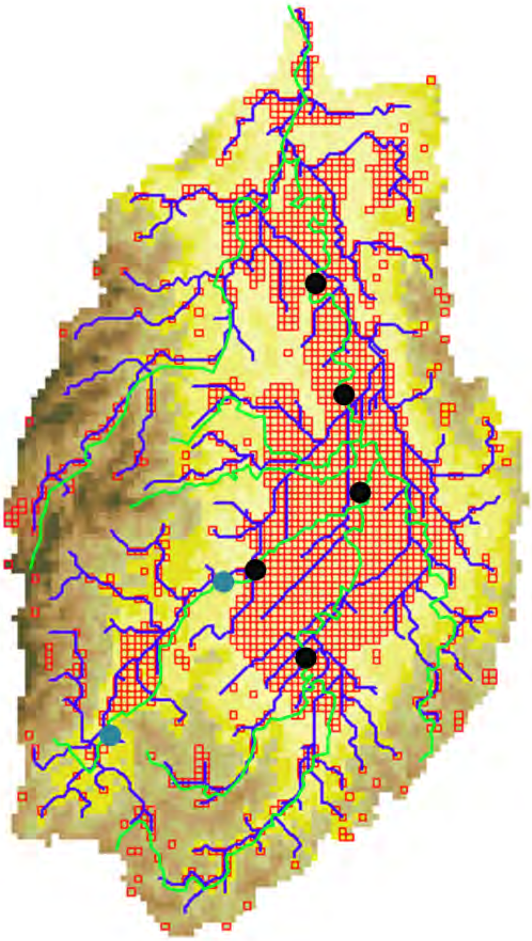


Figure 4-23 Result of created river course in the Cagayan River basin

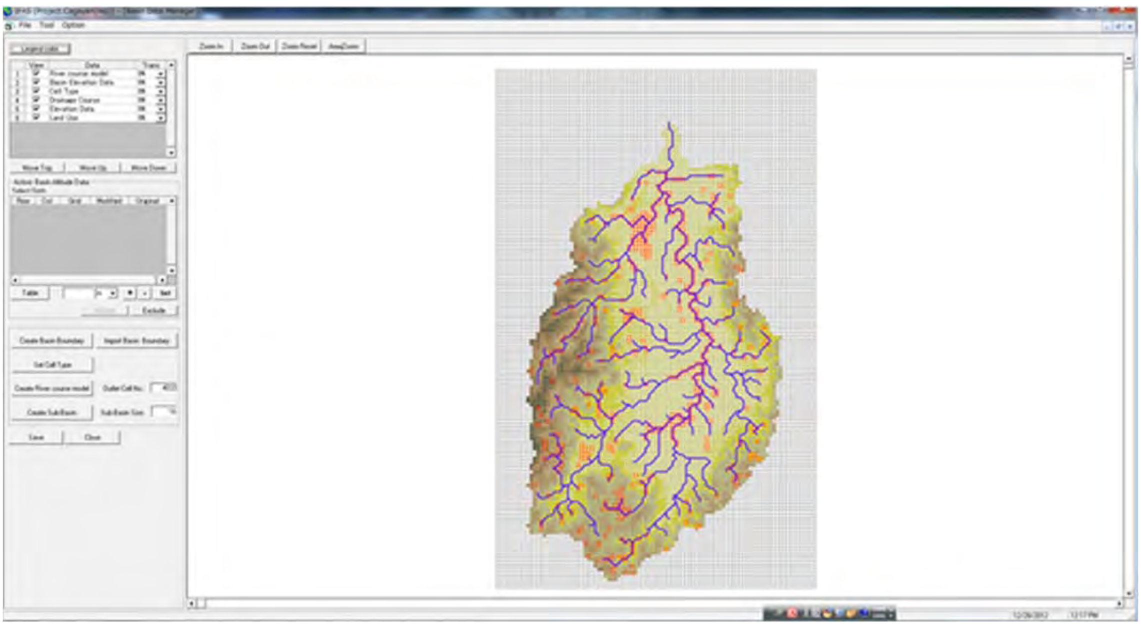


Figure 4-24 River course made from Global Map (Elevation) with revised with IFAS

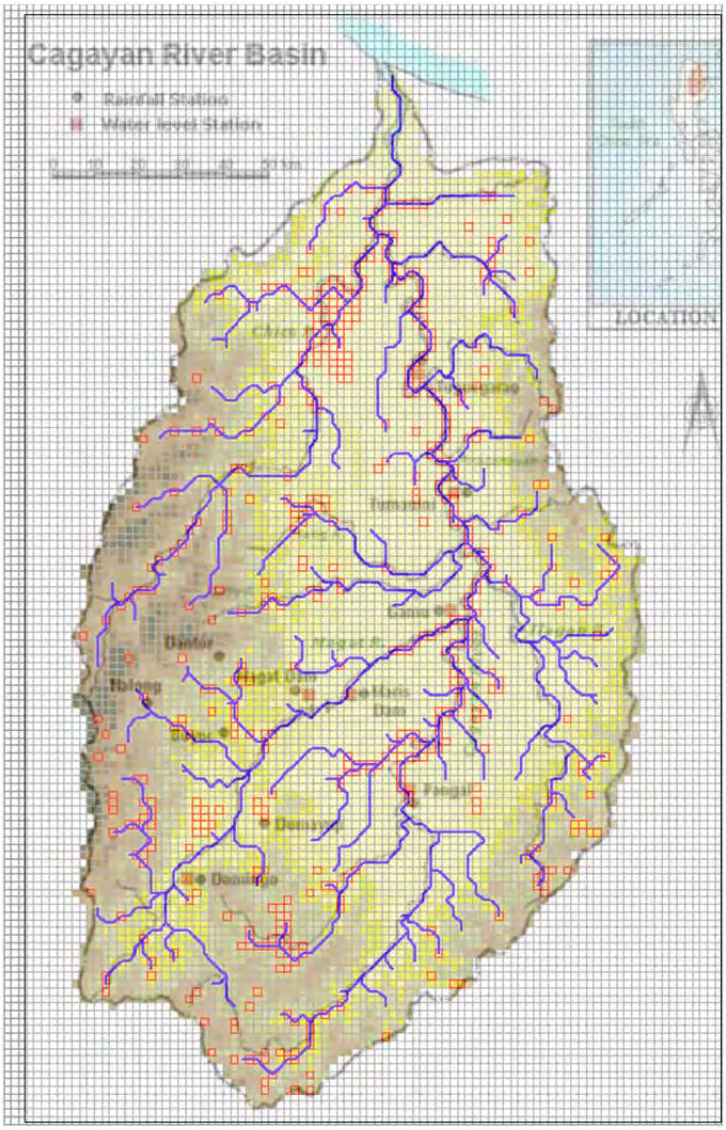


Figure 4-25 Comparison of river course model with published river basin map

4.6.2. Results of simulation

IFAS had been also applied to the Cagayan River basin for recent four floods, November 2010, January 2006, December 2005 and November 2004. Simulation results of IFAS were validated at the Gamu station which is most important gauging station for flood early warning and is the only station rating curve is available. Ground-gauge rainfall, GSMaP and 3B42RT are applied to these simulations as input rainfall data. Figure 4-26 shows the observed and simulated discharge on November 2010 at the Gamu station. In case of this flood, every simulated discharge is overestimated than observed discharge. It is also potentially estimated that observed discharge calculated by unsuitable rating curve due to river bed fluctuation. Furthermore, the heavy intensity rainfall occurred on 7th November 2010 may be observed by mistake, because of no response of

observed water level.

Figure 4-27 shows the observed and simulated discharge on January 2006 at the Gamu station. In this flood, simulated discharge with ground-gauge rainfall is roughly corresponding to observed discharge. However, the simulated discharges with satellite-based rainfall, GSMaP and 3B42RT, are underestimated. According to hyetograph, both of satellite-based rainfall is less than ground-gauge rainfall in terms of peak intensity and event-total amount.

Figure 4-28 shows the observed and simulated discharge on December 2005 at the Gamu station. This flood case is similar to the case of January 2006; while simulated discharge with ground-gauge rainfall is roughly corresponding to observed discharge, however, the simulated discharges with satellite-based rainfall, GSMaP and 3B42RT, are much underestimated due to underestimation of satellite rainfall data.

Figure 4-29 shows the observed and simulated discharge on November 2004 at the Gamu station. In contradiction to above cases, although simulated discharge with satellite-based rainfall, particularly GSMaP, is roughly corresponding to observed discharge, however, the simulated discharges with ground-gauge rainfall is much underestimated. On examining the long-term ground-gauge rainfall data, most of observed rainfall data before 2004 is not reliable because that is much underestimated or recorded almost 0 even though rainfall occurred. In such a case, similar to the poor-gauged river basin, satellite-based rainfall data is quite helpful for flood forecasting and flood early warning.

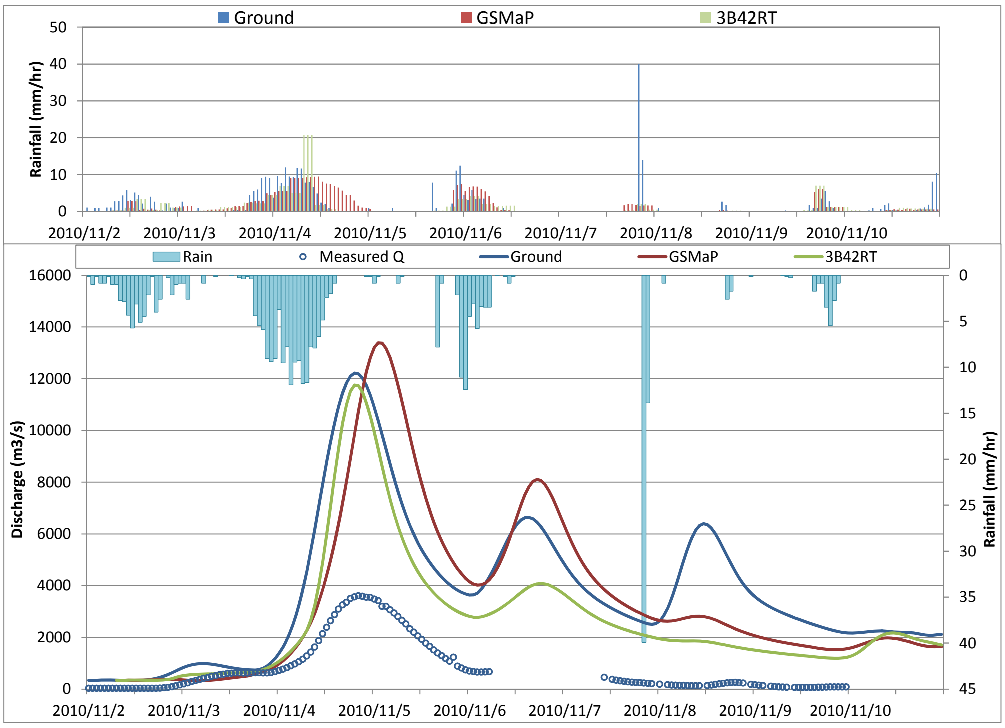


Figure 4-26 Hyetograph of ground-gauge and satellite-based, and hydrograph of observed and simulated discharge on November 2010 at the Gamu station

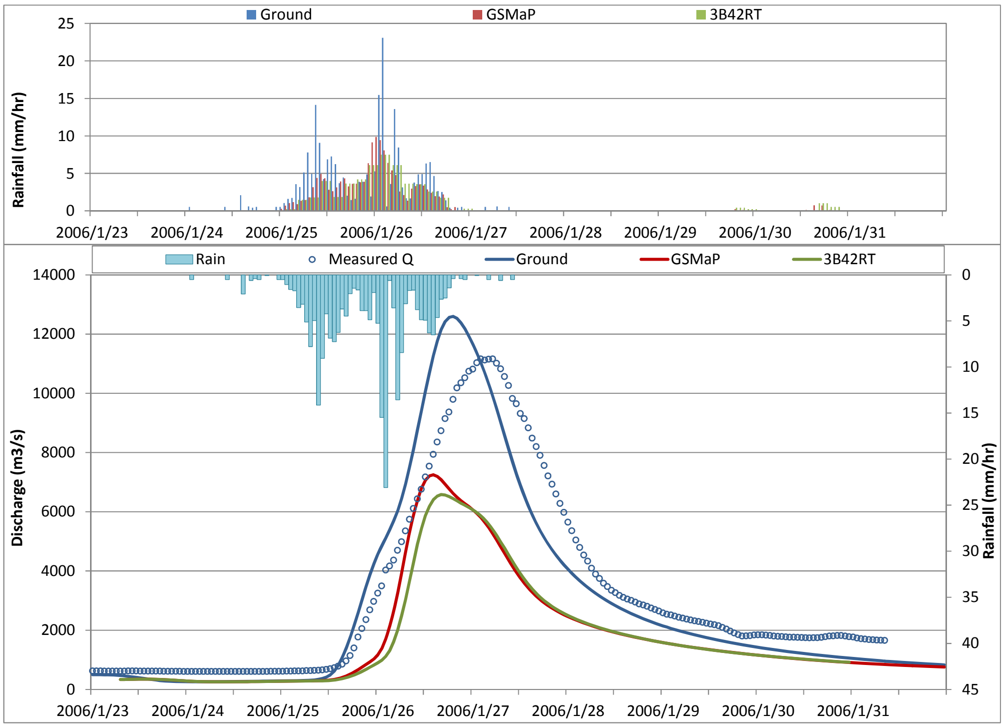


Figure 4-27 Hyetograph of ground-gauge and satellite-based, and hydrograph of observed and simulated discharge on January 2006 at the Gamu station

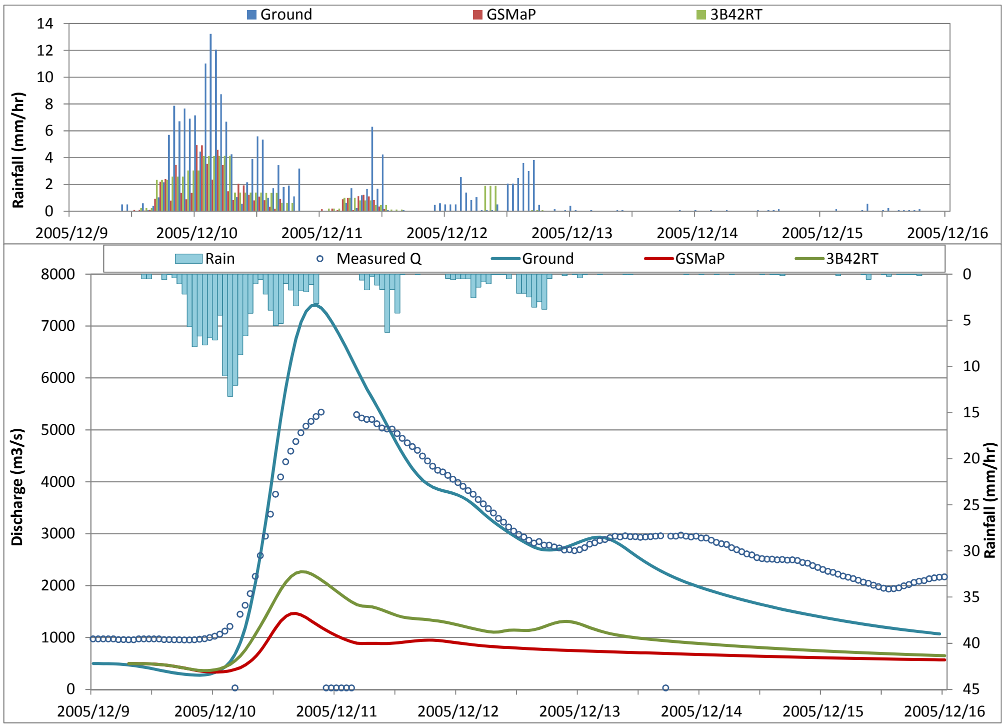


Figure 4-28 Hyetograph of ground-gauge and satellite-based, and hydrograph of observed and simulated discharge on December 2005 at the Gamu station

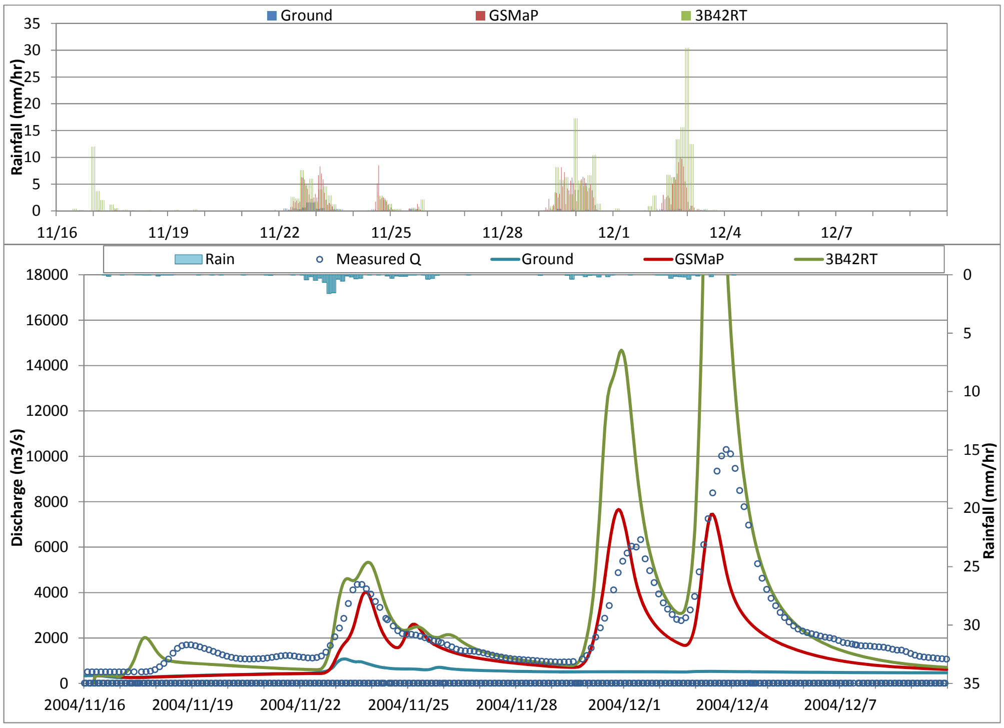


Figure 4-29 Hyetograph of ground-gauge and satellite-based, and hydrograph of observed and simulated discharge on November 2004 at the Gamu station

4.6.3. Introduction of calibration

For more reproductive simulation, calibration procedure is necessary for finding the suitable parameters to target river basin. Table 4-10 shows the updated hydrological parameters and initial conditions. In this calibration, hydraulic conductivity, roughness of slope and river, runoff coefficient of each tank and meander coefficient are mainly updated for better reproductive of simulation results. Incidentally, as the default parameter of roughness of slope is bigger than general values, it is recommended to set smaller value for example approximately 0.6 or 0.7. Figure 4-30 shows the difference of simulated discharge between before and after calibration. It is found from Figure 4-30 that two simulated discharges after calibration are more accurate than default case. For reliable flood forecasting, calibration procedure like this is necessary in order to determine the suitable parameters for the target river basin.

Table 4-10 Updated hydrological parameters and initial conditions

	Parameter		unit	Default	Tuning 1	Tuning 2
Surface	SKF	Hydraulic Conductivity 1	cm/s	0.0005	0.0015	0.0015
		Hydraulic Conductivity 2		0.00002	0.00006	0.00006
		Hydraulic Conductivity 3		0.00001	0.00003	0.00003
	HFMXD	Height of Tank 1	m	0.1	←	←
		Height of Tank 2		0.05	←	←
		Height of Tank 3		0.05	←	←
	SNF	Roughness of Slope 1	$m^{-1/3}/s$	0.7	0.6	0.6
		Roughness of Slope 2		2	0.6	0.6
		Roughness of Slope 3		2	0.6	0.6
	FALFX	Runoff Coefficient 1	-	0.8	←	0.4
		Runoff Coefficient 2		0.6	←	0.3
		Runoff Coefficient 3		0.5	←	0.25
Aquifer	AUD	Runoff Coefficient (intermediate flow)	$(1/mm/day)^{1/2}$	0.1	0.125	0.125
	AGD	Runoff Coefficient (base flow)	1/day	0.003	0.005	0.005
	HCGD	Height of Tank	m	2	2.02	2.02
	HIGD	Initial water level	m	2	←	←
River	RRID	Initial water level	m	0.2	0.15	0.15
	RNS	Roughness of river	$m^{-1/3}/s$	0.035	←	←
	RLCOF	Meander Coefficient	-	1.4	2	2

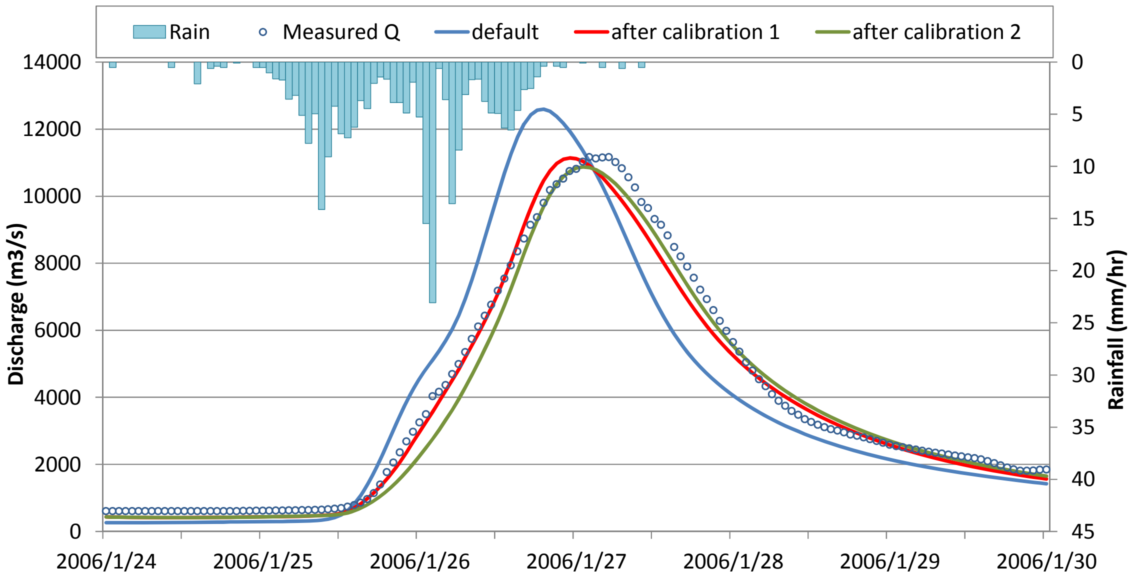


Figure 4-30 Difference of simulated discharge between before and after calibration

5. Capacity Development for Effective Flood Management in River Basin of the Philippines

5.1. Outline of trainings on capacity development

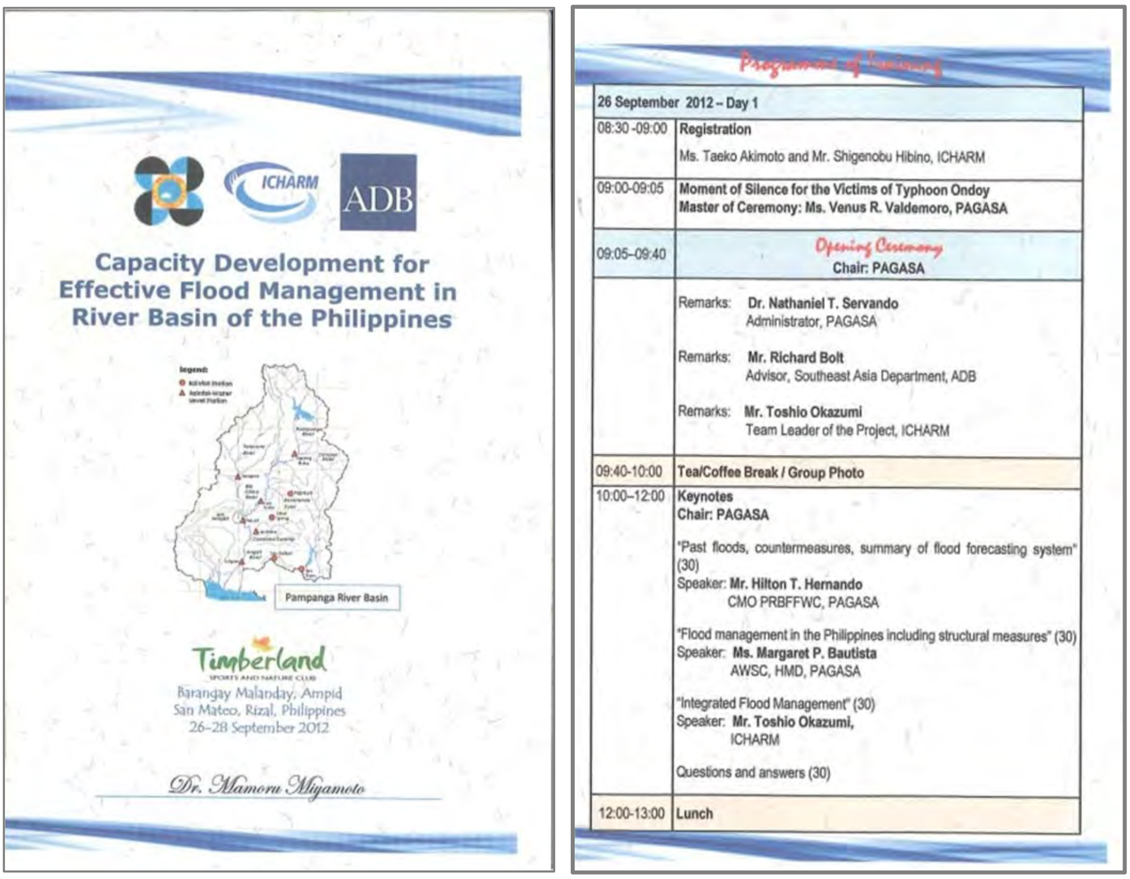
The training programs for flood risk management, “Capacity Development for Effective Flood Management in River Basin of the Philippines”, had been organized on 26-28 September in Metro Manila and on 2-4 October in Tuguegarao City, Philippines for the purpose of capacity development. It attracted a total of 63 administrators and practitioners from different agencies involved in the flood risk management in the Pampanga and Cagayan River basins, such as PAGASA, DPWH, OCD, NIA, as well as local municipalities. The lists of participants are shown in Table 5-1. The training program at Timberland Sports and Nature Club in Metro Manila had 33 participants from DOST, PAGASA, DPWH, OCD, Provincial Disaster Risk Reduction Management Office (PDRRMO), NIA, NPC and Metropolitan Water Works and Sewerage System (MWWSS). The training program at Carmelita Hotel in Tuguegarao City had 32 participants from DOST, PAGASA, DPWH, OCD, PDRRMO, City Disaster Risk Reduction Management Office (CDRRMO), Local Government Unit (LGU)s, NIA and Provincial Social Welfare and Development Office (PSWDO).

Table 5-1 Participants of training program at Metro Manila and Tuguegarao

	Training Program in Metro. Manila			Training Program in Tuguegarao	
	Name	Affiliation		Name	Affiliation
1	Mr.Carl Lorenze G.De Leon	BPDRRMO	1	Mr.JiosenCallo	CDRRMO, Tuguegarao
2	Ms.Felicisima L.Mungcal	BPDRRMO	2	Ms.Jenalyn G.Decena	CDRRMO, Tuguegarao
3	Ms.Rosalinda P.Tapang	DPWH	3	Mr.BenjaminNicado	DOST Region 2
4	Mr.Homer C.Bautista	DPWH	4	Mr.SanchoMabborang	DOST Region 2
5	Mr.Jesse C.Felizardo	DPWH	5	Ms.Leonida S.Santos	DOST Region 2
6	Mr.Galileo V.Fortaleza	DPWH	6	Mr.AldrinJmiquit	DPWH FCSEC
7	Mr.Herminigildo M.Medrano	Maynilad	7	Mr.Edino NonatoNolasco	DPWH Region 2
8	Mr.Fernando DV.Carpio	MWWSS	8	Mr.Noriel ManioDela Cruz	LGU, Enrile
9	Mr.Delfin U.Sespeñe	MWWSS	9	Mr.Fernando BCadangan	LGU, San Pablo, Isabela
10	Mr.Precioso Donato F.Punzalan	NIA, Bulacan	10	Ms.Rosanna G.Ibarra	PSWDO, Cagayan
11	Mr.Felix Y.Robles	NIA, Bulacan	11	Mr.Manuel N.Sebastian	LGU, Enrile
12	Mr.Jaime A.Mananghaya	NIA, Pampanga	12	Mr.Phillip A.Tamayao	LGU, Amulung
13	Mr.Zoilo, Jr. U.Micla	NIA, UPRIIS	13	Mr.AllanVentura	MDRRMO
14	Mr.ErnestoPonce	NIA, UPRIIS	14	Mr.ReynaldoFloria	MDRRMO, Alcala
15	Mr.JaysonIbarra	NIA, UPRIIS	15	Mr.Carlo C.Alban	LGU, Tuguegarao City
16	Mr.IreneoPascual	NIA, UPRIIS	16	Ms.Phoebe B.Canceran	CDRRMO, Tuguegarao
17	Mr.Ramon Jr. M.Araja	NPC	17	Mr.Ryan T.Valentin	NIA, MARIIS
18	Mr.Manuel I.Monteverde	NPC	18	Mr.Roy A.Badilla	NIA, MARIIS
19	Ms.Maria Teresa L.Serra	NPC	19	Mr.PhillipLabugen	OCD, Region 2
20	Mr.Godofredo, Jr.Tolentino	NPC	20	Mr.LeoBunag	PAGASA, CRBFFWC
21	Mr.Darios S.Vallejos	OCD	21	Mr.AntonioPagalilauan	PAGASA, NLPRSD
22	Mr.Dan R.Ragodon	PAGASA, BRBFFWC	22	Ms.AmorBenitez	PAGASA, HMD
23	Ms.ImeldaDavid	PAGASA, HMD	23	Ms.Sonia P.Serrano	PAGASA, HMD
24	Ms.Tarcela A.Tirante	PAGASA, HMD	24	Mr.Grecile CristopherDamo	PAGASA, HMD
25	Ms.Rhonalyn L.Vergara	PAGASA, HMD	25	Mr.Hilario G.Esperanza	PAGASA, NLPRSD
26	Mr.Hilton T.Hernando	PAGASA, PRBFFWC	26	Mr.Loreto M.Lavadia	PAGASA, NLPRSD
27	Mr.Nestor B.Nimes	PAGASA, PRBFFWC	27	Mr.Bernie R.De Leon	PAGASA, NLPRSD
28	Mr.Rommel P.Yutuc	PAGASA, PRBFFWC	28	Ms.Cynthia O.Iglesia	PAGASA, NLPRSD
29	Ms.Ma. Cecilia A.Monteverde	PAGASA, RDTD	29	Mr.Robert Z.Quinto	PAGASA, RDTD
30	Ms.Lourdes R.Sulapat	PAGASA, RDTD	30	Ms.Ophelia Eduardene M.Parallag	PDRRMO, Cagayan
31	Ms.Analiza C.Tuddao	PAGASA, RDTD	31	Mr.EdmondGuzman	PDRRMO, Isabela
32	Ms.Ma. Cristina C.Uson	PAGASA, RDTD	32	Ms.Sarah Cindy C.Yadan	PSWDO, Cagayan
33	Mr.John Paul H.Bautista	PDRRMO, Bulacan			

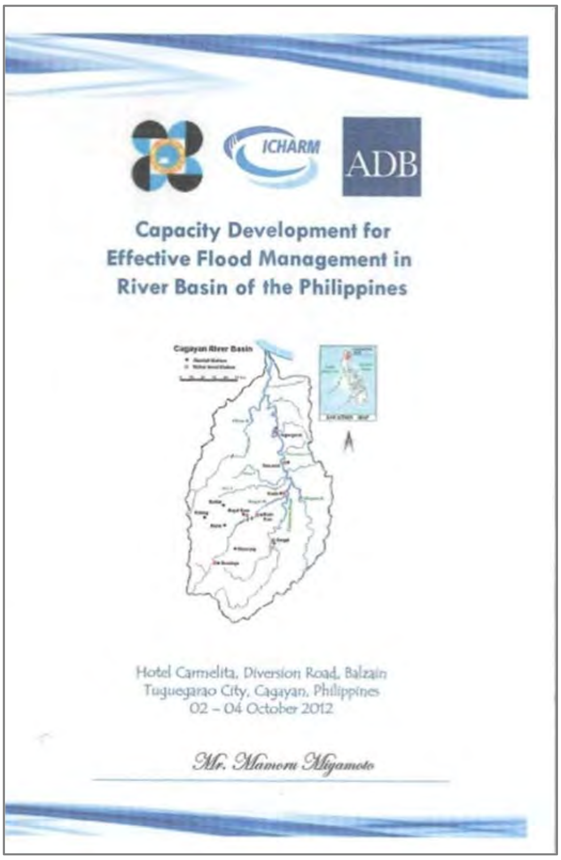
5.2. Objectives and contents of trainings

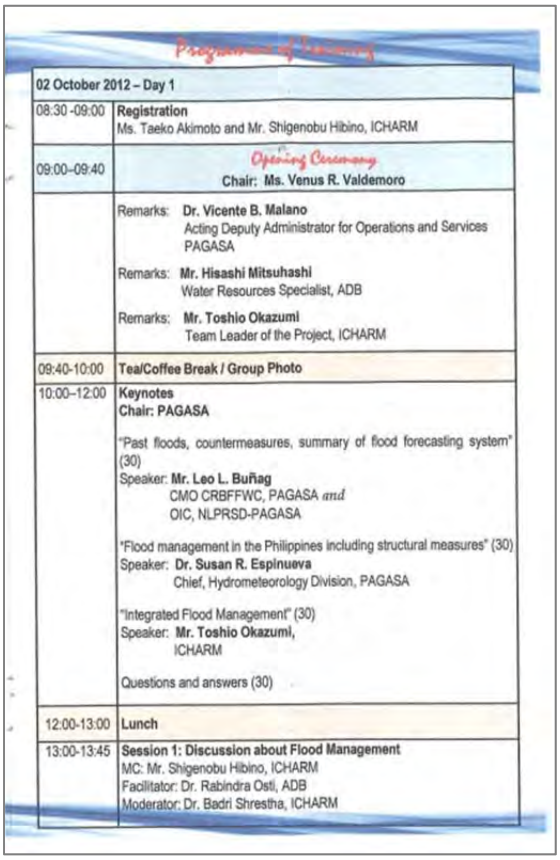
The objectives of training program are to optimize stakeholder’s human and technical resources and experience. The specific key issues are: (i) training on identifying causes of historical floods by incorporating satellite-based and ground observation data, (ii) training on understanding the mechanism of floods in the Pampanga and Cagayan River basin, and (iii) training on utilizing IFAS in practical work as supplementary information for the existing flood monitoring system. Structures of the training program are the same at Metro Manila and Tuguegarao, though target river basins are different: the Pampanga River basin at Metro Manila, and the Cagayan River basin at Tuguegarao. Distributed time tables of training programs at Metro Manila and Tuguegarao are shown in Figure 5-1 and Figure 5-2.



26 September 2012 – Day 1	
08:30-09:00	Registration Ms. Taeko Akimoto and Mr. Shigenobu Hibino, ICHARM
09:00-09:05	Moment of Silence for the Victims of Typhoon Ondoy Master of Ceremony: Ms. Venus R. Valdemoro, PAGASA
09:05-09:40	Opening Ceremony Chair: PAGASA
	Remarks: Dr. Nathaniel T. Servando Administrator, PAGASA Remarks: Mr. Richard Bolt Advisor, Southeast Asia Department, ADB Remarks: Mr. Toshio Okazumi Team Leader of the Project, ICHARM
09:40-10:00	Tea/Coffee Break / Group Photo
10:00-12:00	Keynotes Chair: PAGASA "Past floods, countermeasures, summary of flood forecasting system" (30) Speaker: Mr. Hilton T. Hernando CMO PRBFFWC, PAGASA "Flood management in the Philippines including structural measures" (30) Speaker: Ms. Margaret P. Bautista AWSC, HMD, PAGASA "Integrated Flood Management" (30) Speaker: Mr. Toshio Okazumi, ICHARM Questions and answers (30)
12:00-13:00	Lunch

Figure 5-1 Distributed time table of training program at Metro Manila





02 October 2012 – Day 1	
08:30-09:00	**Registration** Ms. Taeko Akimoto and Mr. Shigenobu Hibino, ICHARM
09:00-09:40	Opening Ceremony **Chair: Ms. Venus R. Valdemoro**
	Remarks: **Dr. Vicente B. Malano** Acting Deputy Administrator for Operations and Services PAGASA Remarks: **Mr. Hisashi Mitsuhashi** Water Resources Specialist, ADB Remarks: **Mr. Toshio Okazumi** Team Leader of the Project, ICHARM
09:40-10:00	**Tea/Coffee Break / Group Photo**
10:00-12:00	**Keynotes** **Chair: PAGASA** "Past floods, countermeasures, summary of flood forecasting system" (30) Speaker: **Mr. Leo L. Buñag** CMO CRBFFWC, PAGASA *and* OIC, NLPRSD-PAGASA "Flood management in the Philippines including structural measures" (30) Speaker: **Dr. Susan R. Espinueva** Chief, Hydrometeorology Division, PAGASA "Integrated Flood Management" (30) Speaker: **Mr. Toshio Okazumi,** ICHARM Questions and answers (30)
12:00-13:00	**Lunch**
13:00-13:45	**Session 1: Discussion about Flood Management** MC: Mr. Shigenobu Hibino, ICHARM Facilitator: Dr. Rabindra Osti, ADB Moderator: Dr. Badri Shrestha, ICHARM

Figure 5-2 Distributed time table of training program at Tuguegarao

5.3. Implementation of trainings

The training programs addressed three key points: (i) aspects of flood damage; (ii) countermeasures; and (iii) necessary data Participants of the training program took part in lectures on the survey results of flood damage and flood risk management in the two river basins, the Pampanga River basin and the Cagayan River basin. They also actively participated in group discussion on flood risk management, application of IFAS, and development of an action plan for future flood risk management.

After opening remarks from representatives from the DOST/PAGASA, ADB, ICHARM, representatives from PAGASA and ICHARM made keynote speeches on three topics; (i) past floods, countermeasures, and summary of flood forecasting system in target river basins; (ii) flood management in the Philippines including structural measures; and (iii) integrated flood management. Then, each participant from stakeholder agencies activity took part in the following five sessions.

5.3.1. Session 1: Discussion about Flood Management

Six groups which comprised 4-6 participants discussed three key topics on flood risk management in target river basin, and shared their opinions with other groups. The three topics are: (a) the causes of

past flood disasters; (b) countermeasures for flood management; and (c) necessary data for effective flood management.

5.3.2. Session 2: Flood Analysis and Flood Forecasting/Early Warning

First, Chief Meteorological Officers of PAGASA regional offices in the target river basins introduced their flood risk management including hydrological observation system, flood forecasting models, warning dissemination, and collaboration with related agencies. Then Dr. Mamoru Miyamoto introduced hydrological characteristics in the target river basins, flood warning system, and river management for early warning. Lastly, there held a panel discussion among representative from PAGASA, the DPWH, the PDRRMO, ADB, and ICHARM on how to improve FFWS.

5.3.3. Session 3: Flood Forecasting Modeling

ICHARM Mr. Seishi Nabesaka demonstrated flood analysis in the target river basins, and instructed IFAS to participants.

5.3.4. Session 4: Flood Simulation by IFAS

Participants reproduced historical flood events by inputting actual rainfall data observed by satellite into IFAS, and shared their results among participants.

5.3.5. Session 5: What’s next? IFAS for practical work (as supplementary information) based on the trials of IFAS

Participants from each related organization discussed on how flood risk management in their river basins will be improved, and produced short and long-term road maps.

5.4. Summary of training in Metro Manila

In the training program at Metro Manila, Dr. Nathaniel T. Sevando, Administrator, PAGASA, Mr. Richard Bolt, Advisor, Southeast Asia Department, ADB, Mr. Toshio Okazumi, Team Leader, ICHARM, and Mr. Takahiro Etchu, Financial Attache, Embassy of Japan in the Philippines, made remarks at the opening/closing ceremony. Photo 5-1 shows the scenes of training at Metro Manila. Notable findings from this training are described in following sections.

Photo 5-1 Scenes of training at Metro Manila

5.4.1. Status of flood risk management in the Pampanga River basin

Flash floods, riverine floods and tide induced backwater floods are the major types of flood in the basin. The flood hazard scenario has been changed significantly due to the increase in rainfall-runoff as well as reduction in conveyance capacity of the river channel and flood plain areas. Increased number of formal and informal settlers in the flood plain with considerable increment in economic activities has increased the exposure to flood, while lack of proper risk management tools and low capacity to tackle with disasters have considerably worsen the flood risk situation in the basin. However, the Pampanga River basin has a functioning flood forecasting sub-station, which has been producing and disseminating considerable flood forecast information to the stakeholders by utilizing information from 18 rainfall and water level observation stations. Angat dam in Bulacan, has a flood control function, however participants concerned about its operation. Some of the flood vulnerable communities in the basin mainly in Isabella are adapting community based flood risk management practices.

5.4.2. Measures for flood risk management in the Pampanga River basin

In addition to structural system, the Pampanga River basin requires robust FFWS with increased lead

time and enhanced forecast dissemination system. Appropriate land-use planning and strict implication of related rules and laws are prerequisite for sustainable flood risk management in the basin. Enhanced dam operation system that closely linked to the flood forecasting system is required to be addressed under the framework of the Integrated Water Resources Management (IWRM), for which a basic set up has already been made. Awareness raising on flood risk management and building local capacity are other important areas to be considered for effective flood disaster risk management. The role of LGU, particularly in information sharing and disaster preparedness, should also be enhanced.

5.4.3. Flood simulation by IFAS

In the Pampanga River basin, hourly rainfall data observed at 18 rainfall observation stations is delivered in real-time to the flood forecasting sub-center. However, it is difficult to estimate discharge precisely due to lack of reliable rating curve. Shapes of cross section have been changed frequently by severe floods. According to ICHARM, lead-time can be extended to 16 hours at Mayapyap if flood forecasting model such as IFAS will be installed. However, reliable rating curve is crucial for its installment as a flood forecasting tool to the Pampanga River basin. Therefore, IFAS parameters need to be calibrated with ground observed data. Participants from each organization considered application of IFAS from their standing points: (i) NIA considered it as an indicative water budgeting tool in catchments of their reservoirs; (ii) PAGASA considered it as a supplementary tool to their existing flood forecasting system; (iii) DPWH considers it as a quick catchment modeling tool, which helps prepare for operation and maintenance of infrastructures not only in gauged but also un-gauged river basins; and (iv) LGUs considered it as an useful tool to prepare for severe floods before official forecasts are delivered, if it can provide accurate forecast.

5.4.4. A way forward

Participants highlighted the knowledge gained through the training program and its implication in their future activities. They realized that IFAS has enough scope to serve their purposes. Likewise, the flood forecasting in the Pampanga requires more hydrological gauging stations, which can be supplemented by satellite-based rainfall observation, if available in a considerable accuracy. Hydrological model like IFAS can be helpful as a backup system, in case if existing system fails during extreme events. Though accuracy is yet to be improved through the parameter setting and model calibration, IFAS-based results can be used as early indication and to develop the confidence level of existing system. The data sources and model introduced in the training program will also help participants to evaluate the climate change impact scenario of any river basin in the Philippines. There may be a need of additional hands-on training on modeling techniques.

5.5. Summary of training in Tuguegarao

In the training program at Tuguegarao, Mr. Sancho Mabborang, Assistant Regional Director, DOST Region 2, Dr. Susan R. Espinueva, PAGASA, Mr. Toshio Okazumi, ICHARM, and Mr. Hisashi Mitsuhashi, ADB, made remarks at the opening/closing ceremony. Photo 5-2 shows the scenes of training at Tuguegarao. Notable findings from this training are described in following sections.

Photo 5-2 Scenes of training at Tuguegarao City

5.5.1. Status of flood risk management in the Cagayan River basin

Although the Cagayan River basin is the largest basin in the Philippines, it is monitored by only five telemetric gauging stations. Among those five stations, Gamu station is the most important to forecast floods at Tuguegarao: it takes approximately 15 hours that flood comes from Gamu to Tuguegarao. However, the Cagayan River basin has 18 tributaries and some of them which have flash floods, are not well observed. There are natural and socio-economic conditions which affects flooding in the Cagayan River basin: deforestation, river shifting, urbanization and sedimentation.

5.5.2. Measures for flood risk management in the Cagayan River basin

It is always challenging to reduce flood risk under the limit of equipment, staffs and budget, both in national and basin level. Two notable planned and ongoing activities in the basin level were introduced at the panel discussion: (i) the relocation of flood vulnerable citizens in Isabela Province and (ii) establishment of a data bank by PDRRMO which will store post-flood analysis so that any stakeholders can extract lesson learned from historical floods in the Cagayan River basin. In addition, participants reached consensus on specific measures which are sure to make a difference in the Cagayan River basin. The most important thing is increasing density of rainfall observation in the basin, by installing new rainfall stations in the upstream or utilizing remote-sensing data which need to be calibrated but can cover the whole basin with relatively higher resolution. They agreed to make good use of traditional knowledge. Information sharing was recognized as important: (i) hydrological and dam operational data to be timely shared among dam operators, flood forecasters, LGUs and citizens and (ii) avoiding miss-communication between warning providers and users. National and basin level organizations are expected to collaborate with each other to improve these issues.

5.5.3. Flood simulation by IFAS

Considering the low density of ground-gauge stations in the Cagayan River basin, satellite-based rainfall data can be effective as supplemental information for flood early warning. Integration of indigenous technology and tributaries effect with results from flood forecasting model would be more reliable for flood forecasting in the river basin.

5.5.4. A way forward

The participants prepared their action plans and showed interest to work out further on calibration and validation of IFAS in the presentation of this training. The LGUs will try to mobilize their resources to support the localized flood forecasting and will coordinate among stakeholders. PAGASA HQs and its regional office will enhance the performance of flood forecast in the Cagayan River basin by utilizing hydrological simulation models. Coordination among stakeholders will be enhanced, which will help sharing experiences therefore coordinating flood risk management operation. The data bank is expected to contribute to the coordination.

5.6. Review and evaluation of trainings

5.6.1. Review of implemented trainings

Through the training program, the participants reaffirmed the importance of collaborations among relevant organizations and the necessity of accurate data. They also had a better understanding of usefulness of flood forecasting, possible uses of satellite-based precipitation data, and importance of

ground observation for flood early warning in the two river basins. According to the post-training questionnaire results, over 90 percent of the participants found the training program “useful for flood early warning” and “informative.” Some participants even requested additional training program to make full use of IFAS in their work. In the Philippines, where serious floods occur every year, flood forecasting technologies are expected to help mitigate possible flood damages. Especially, remote sensing technologies such as IFAS are highly expected to be introduced as supplement information in poorly-gauged river basins. Reflecting such high expectations, the training program in Metro Manila was broadcasted by the national broadcasting network at a news program.

5.6.2. Evaluation by participants

Participants filled out the questionnaires prepared by ICHARM at the end of trainings. Overall, the training program succeeded in providing knowledge, experiences and technologies on flood risk management: 96% participants were satisfied with the training programs. 42% participants of the training program at Metro Manila and 70% participants of training program at Tuguegarao have less than 5 years experiences on river-related work. More than 80% of participants felt that they could easily understand important points and perspectives of flood forecasting and causes of floods. Many participants had already recognized the importance of rainfall data for flood forecasting, but 42% participants of training program at Metro Manila and 30% of participants of training program at Tuguegarao City came to understand it in these opportunities. 54% participants of training program in Metro Manila and 78% of participants of training program at Tuguegarao City understood characteristics of satellite-based rainfall by the training program. 69% participants of training program in Metro Manila and 63% of participants of training program at Tuguegarao City felt that IFAS was user-friendly, and 81% participants of training program in Metro Manila and 88% of participants of training program at Tuguegarao City thought that IFAS was helpful for their flood forecasting work. There were no any participants who felt IFAS is not helpful. Participants could understand the importance of (i) collaborations among relevant organizations, (ii) precise hydro-meteorological data, (iii) advantage of flood forecasting and (iv) utilization and importance of ground observation data for Flood Forecast and Warning System (FFWS).

6. Conclusions and Future Recommendations

6.1. Conclusions

6.1.1. Conclusions on Flood Analysis

In the flood analysis, fundamental flood characteristics such as flood traveling time, runoff ratio and water level correlation between upstream and downstream in the Pamapanga River basin and the Cagayan River basin are clarified. The possible causes of severe flood can be revealed according to flood characteristics clarified by this analysis. The many things such as accuracy of observed data, importance of continuous observation and impacts by the deference of flood forecasting models, can be recognized from the examination of fundamental analysis.

For appropriate flood forecasting by the simulation model, the features of river basin and fundamental flood characteristics should be understood by the stakeholders. Otherwise, simulated results by the flood forecasting model could lead to misunderstand.

6.1.2. Conclusions on training program

The training program was successful in having reached consensus among managers and practitioners of all stakeholders on flood risk management in the Pampanga and Cagayan River basins on the causes and measures for flood risk management in these river basins. Advantage and weakness of IFAS and its effectiveness as supplementary information for the existing flood monitoring system were well recognized. The training program was also broadcasted through People’s TV news program and newspapers. The mission would like to appreciate PAGASA’s technical contributions and logistic arrangement, and participants’ active contributions to discussions.

6.2. Follow-up program

6.2.1. Continuous support of IFAS operation by ICHARM

For more specific operation and progress of IFAS, it is necessary for users that ICHARM continuously supports as a help desk of IFAS operation. For example, in case of real-time forecasting for flood early warning or application to other river basins, ICHARM will provide generous support to users by possible means such as e-mail. This support will be implemented as a follow-up activity of training program.

6.2.2. Proposal from PAGASA

In addition to follow-up of the training on flood management in the Pampanga and Cagayan River basins, PAGASA proposed following new activities at the wrap-up meeting. ADB and ICHARM will elaborate these proposals for future activities under ADB’s TA framework since ICHARM’s interests are research oriented activities in the field of water-related disaster and ADB’s interests are

supporting their Developing Member Counties in capacity development for water-related disaster risk management.

For better flood and drought risk management, there have been strong needs in development of dam operation: (i) dam inflow forecasting and dam operators training (including PAGASA); (ii) rearrangement dam operation rules; (iii) reallocation of dam capacity and (iv) long-term forecast and optimum dam operation to mitigate extreme floods and droughts which are likely to be exacerbated by climate change, for which the WMO shows its interest.

PAGASA has been appointed to install FFWS in 18 major river basins in the Philippines. FFWS has been installed in five river basins (Pampanga, Agno, Cagayan, Bicol and Pasig-Marikina) and will be installed soon in other 13 river basins. According to PAGASA’s plan, PAGASA intends to phase FFWS in for the 13 river basins: (i) establishment of an office in each river basin; (ii) installation if ground-gauge stations; (iii) its telemeterization and (iv) installation of a control system including forecasting model. Until the plan is completed, flood forecasting models which utilize satellite-observed rainfall data can be strong tools for supplementary forecasting information in poorly-gauged river basins. The highest prioritized river basin is the Cagayan de Oro River basin in which is JICA’s supported project, “Flood Risk Management for Cagayan de Oro” has started.

6.2.3. Training program on flood inundation analysis

The training program on flood inundation analysis had been conducted from 12th to 22nd November 2012 at ICHARM in Tsukuba, Japan as one of the follow-up activities of the “Capacity Development for Effective Flood Management in River Basin of the Philippines”. ADB sent two staffs of PAGASA for the purpose of understanding the mechanism of weather conditions and inundation in the Pampanga River basin during severe floods in 2011 and 2012. Topics and work program covered during the training included the basic concepts of flood inundation analysis, simulation of the floods of 2011 and 2012, and analyses of the causes of inundation in the Pampanga River basin. Photo 6-1 shows the scenes of lecture about flood inundation analysis by Dr. Sayama during training program at ICHARM. Photo 6-2 shows the scene of presentation about results of inundation analysis by trainee on the last day of training program.

The flood inundation analysis was mainly focused on the application of the Rainfall-Runoff Inundation (RRI) Model to the Pampanga River Basin specifically looking at the flood events during Tropical Cyclone “Pedring” (September 2011) and the Southwest SW Monsoon of August 2012 for model calibration and validation purposes, respectively. A presentation was given at the end of the training period to personnel of ICHARM as a culminating activity of the whole program. The presentation included a brief on the Pampanga River basin, the flood events of 2011 and 2012, the various results of several model runs, the simulated results for both the floods of 2011 and 2012, and finally proposed plans and activities on the usage of the model. Figure 6-1 shows the examples of

simulation results simulated during training program.

As the results of this training program, it was found that the application of the RRI model to the Pampanga River Basin would definitely contribute to the enhancement of the PRBFFWC’s flood information and warning services. ICHARM would like to enhance follow-up activities like this training program on inundation analysis.

Photo 6-1 Lecture about flood inundation analysis by Dr. Sayama during training program at ICHARM

Photo 6-2 Presentation about results of inundation analysis by trainee on the last day of training program

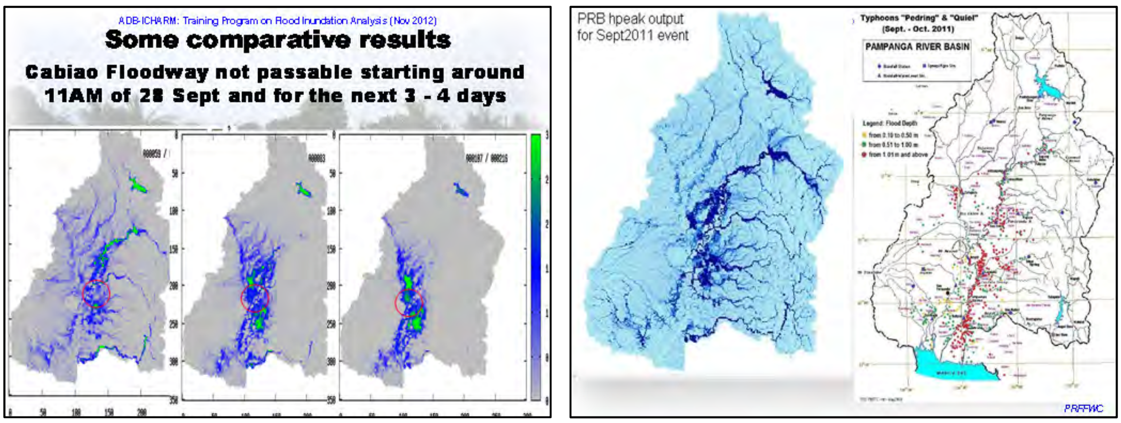


Figure 6-1 Examples of simulation results by inundation model during training program

6.3. Recommendations

6.3.1. Utilization of IFAS as a supplementary model for flood management

IFAS can be utilized not only as a flood forecasting model, but also as a useful tool for decision making, because any flood situation can be assumed in the simulation. In that sense, IFAS must be a supplementary model for existing forecasting system.

6.3.2. Accommodation with PAGASA’s proposals

The basic concepts and fundamental functions are well-understood by the stakeholders through the training program at Metro Manila and Tuguegarao City as the results of questionnaires show. Therefore, further improvement and dissemination of IFAS should be accommodated to PAGASA’s proposals provided in this mission, because the proposals from PAGASA described above are based on understanding the features of IFAS such as advantage in poor-gauged river basin.

6.3.3. Cooperation with another project related to satellite-based rainfall

The Regional Capacity Development TA (TA-8074REG) with JAXA for Applying Remote Sensing Technology in River Basin Management is assisting Bangladesh, the Philippines, and Viet Nam to improve monitoring and warning systems on flood risk management with reasonable cost and practical knowledge. The specific agenda includes (i) developing an application methodology for the use of Space-Based Technology (SBT) and Information and Communication Technology (ICT) for flood risk management, (ii) developing strategies and programs for flood risk reduction by applying SBT and ICT, and (iii) developing capacity for SBT and ICT. The TA will also help developing member countries in the region develop their capacity to fully benefit from the use of SBT and ICT in river basin management by providing additional technical support to ADB projects and surveys, and by disseminating knowledge and best practices.

In above TA, updated GSMaP with high accuracy is expected to provide for flood risk management as an output of mission. After implementation of this TA, ICHARM would like collaborate with TA-8074REG by importing the updated GSMaP in Philippines to IFAS. Utilizing the output of TA-8074REG would enable the flood forecasting with higher accuracy.

Acknowledgements

This final report of Philippines Component is prepared under in-country project support program of Asian Development Bank, Technical Assistance for Supporting Investments in Water-related Disaster Management (TA7276). This mission wishes to express its appreciation to the representatives of PAGASA for their steadfast support and valuable technical suggestions.

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Appendix 1

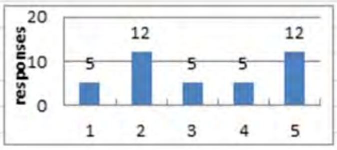
The results of questionnaires of “Cpacity Development for Effective Flood Management in River Basin of the Philippines”

Training program at Metro Manila

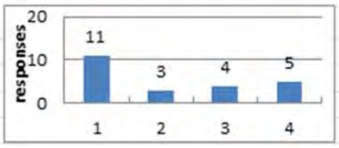
Summary of a Questionnaire

26 people answered, multiple answers allowed

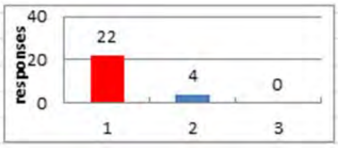
Q.1	1. What is the main duty currently assigned to you? Please check all that apply.	
1	☐Planning	5
2	☐Hydrological observation (rainfall, water level, data management)	12
3	☐Discharge simulation & flood forecasting	5
4	☐River works	5
5	☐Other ( )	12



Q.2	2. How many years have you been involved in river-related work? Please check the one that best applies to you.	
1	☐Less than 5 years	11
2	☐5 to less than 10 years	3
3	☐10 to less than 15 years	4
4	☐15 years or longer	5



Q.3	3. Do you understand the important points and perspectives for flood management (identify causes, effective countermeasure, necessary data)?	
1	☐Easy to understand	22
2	☐So-so	4
3	☐Difficut to understand	0

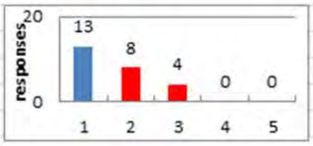


1	Flood and flood model like IFAS is one of the answer
2	More accurate and timely forecast
3	GIS based (a user friendly one).
4	Rn distribution basin characteristics and some man-made intervention. Good modeling tool may help
5	On time data information and dissemination is very much necessary in flood management
6	Well understood
7	Courses: Heavy raifall and socio economic factors like organization clogged drainage and encrossement of informal settelers along the river the water ways. Effective countermeasures: Strong their non-structural measures E.G. early warning system, information dissemination, strong political will priotize disaster XXXXX data: real-time data of rainfall water level and socio economic data, user friendly model that best fit the field condition. Strong application among the basin area XXXX XXXX

Q.4	3. What do you think about the most important your actions for flood management?
1	Good model like IFAS, very interesting so far
2	Timely or easy dissemination
3	The most important actions as hydrologist for flood management is to have a very good forecasting in order to lesser/decrease the flood damages downstream
4	It is very much important to really prepare for the flood so forecasting is very significant
5	1: Quick/Real Information, 2: Derivery of information
6	Accurate information on flood situation and warning
7	Efficient and up to date information of flood occurrence
8	Early warning system and evaccuation. Land use planing
9	Monitering Research, modeling, and forecasting
10	Minimize flood related dameages and casualties
11	no answer
12	Rainfall data + information
13	Accurate forecasting
14	non structure measures
15	Fast data information and dissemination on flood on areas that will be affected for early evacuation.
16	The most important is the provision of a reliable tool that could be used to properry forecast flood and be able to come up w/ timely and accurate flood bulletin and warnings
17	For my part, providing time flood bulletins
18	Accurate early warning and data dissemination
19	Forecast reliable
20	Timely sequence time of flood warning/data dissemination of warning Evacuation.
21	Rainfall spatter model simulation for rainfall distribution share knowledge with the local government units

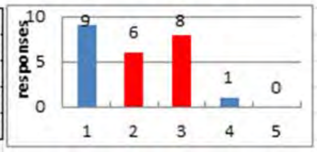
Q.4 4. Check the one that best applies to you in terms of the necessity of rainfall observation for flood forecasting?

1	☐I have already been aware of it.	13
2	☐I now understand it very well.	8
3	☐I now understand it.	4
4	☐I still don't understand it very well.	0
5	☐I still don't understand it at all.	0



Q.5 5. Check the one that best applies to you in terms of the characteristics of satellite-based rainfall.

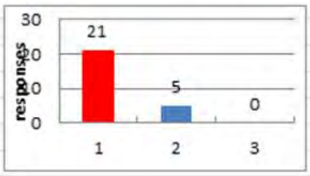
1	☐I have already known about them.	9
2	☐I now understand them very well.	6
3	☐I now understand them.	8
4	☐I still don't understand them very well.	1
5	☐I still don't understand them at all.	0



Q.6 What do you think about the learnability of IFAS (whether or not IFAS is easy to learn)? What do you think about the user-friendliness of IFAS (whether or not it is easy to find commands or menus and make the computer do what you want)? Please check the one that best applies to you.

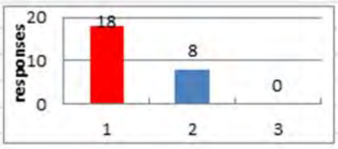
1) Learnability

1	☐Easy to learn.	21
2	☐So-so.	5
3	☐Difficult to learn.	0



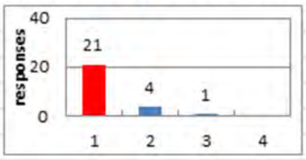
2) User-friendliness

1	☐Easy to find commands or menus.	18
2	☐So-so.	8
3	☐Not easy to use	0



Q.7 Do you think this workshop will be helpful in flood forecasting for rivers in your country? Please check the one that best applies.

1	☐It will be helpful.	21
2	☐It will be helpful to some extent.	4
3	☐It won't be very helpful.	1
4	☐It won't be helpful at all.	



Q.8 Please write your opinion about the applicability of IFAS to your country.

1) Is there anything you want us to improve or add in order to apply IFAS to your country?

1	I just want a more time for the training, for us to learn more although it is nearly easy to learn.
2	Another wonderful/useful tool to enhance the flood forecasting capability in river basin forecasting
3	The computability of the system to almost all of PCs/Lattops
4	Additional practice needed to fine-tuned the tool
5	Improve is to a more high tes application
6	Processing time is too long
7	None I can think of
8	It's applicablity in smaller basin/watershed areas w/ only one dam
9	Please indude all the rivers/tributaries in Pampanga river basin especially in the downdtream areas (Cagant and Hogong)
10	Lower computer comparibicity for us to run and install it faster
11	It is a supplemental tool to PAGASA especially in big river basins
12	Additional training
13	For the training includes it in the inbuilt the system by system ??????
14	Try to make it in a simpler application, meaning not tedious commands and application
15	Hope you can also devise applicable to smaller basin like the Angat river in Bulacan.
16	During the exercize, identifing of the use number or location is a bit difficult. It would be better if you xxxx put
17	It will be very applicable to Pampanga river basin
18	To make the paremeter easier to conficure for non technical participants. Improve runtime process- Run time takes too long ever higher capacity computer
19	identify river basin by including house
20	Very applicable to big river basin since it is a satellite based model
21	Incooperaion of RADAR data in the model Make this more interactive on automatic the system
22	Make improvement for IFAS to be comparible w/ 64 bit PC

2) What difficulties are there on your country side in applying IFAS to your basin?

1	Difficulties in flood is learn the affected one, maybe IFAS is the answer
2	Discharge measurement during high floods, for rating curve poor poor
3	It needs high spec computer in order for it warks effeciently accurately. Needs for further training
4	No difficulties on our there yet, 1st time to introduce IFAS at PAGASA, it will be a big help
5	None
6	for all catchment areas
7	Computer capability and internet speed
8	IFAS is very good tool for flood forecasting. I think there is no difficulties in appling it to our word
9	Download time (and download size) is very long (might need PC's w/ high specs w/c may not be available in some areas, specially in remote/field offices.
10	Non-cooperation of other locals and agencies
11	Political and lack of man power and equipments
12	Additional ground based data. Need more time in training
13	We need the cooperation of LGUs
14	our basin in none all
15	Presence of informal settlers along our river banks which have been increasing instead of decreasing of none at all
16	Angat river has much smaller basin but it is somehow connected to flooding in Hagongon and Calumpit which is the end portion of Pampanga river. They both merge in the town of Calumpint in Bulacan.
17	none
18	I don't see any (immediate difficulties - none)
19	Structures along river basin are not considered on the system. It may give inaccurate (somepart/information)
20	Better familialization
21	There are couses in the Philippines that have very sparse network of rainfall station
22	Needs for facility

Q.9	**Please give us feedback on this workshop. We would also like to ask you for suggestions or requests for future workshops.**
1	Very nice, I love the 3days training the facilitator were very accomodating, they are easily approach anything we ask about the IFAS. That's the learn only we easily graps the training lesson.
2	Very interesting
3	very fruitfull training
4	Very good program, nice accomodating and knowledgable speakers
5	Experiment from Japan (ICHARM) did a very great in transfering them technology, hopefully PPFFWC personal will give them nice tome to teach them everyday. Thank you very much.
6	Very good made of instractions/moderators/speakers
7	It is too interesting and informative
8	Excellent
9	Generally the training was conducted good and successful
10	Very informative training. The speakers are all knowledgeable.
11	Program was very efficint and on time, speakers very knoeledgeable and helpful. Overall very informative.
12	Very well done
13	It is understandable and easy to use and we can apply it in our official for our early warning system in our community
14	very good
15	Over-all training can be classifing as "A" range. Very clean and the speakers can speak English.
16	Cooporative facilitator training arrangement on time
17	It's very interesting. I'm thinking of applying IFAS in our future water souece proceed which is the Kaluva-Kavar river basin where is a big dam (Laiban Dam-MWSS, 120 meter high) will be built along the Kaliwa river for domestic water supply.
18	Nice training - Everything fine and very good. Domo Arigatou Gozaimashita.
19	This training over all is very good and nice be helpful our flood forecasting system.
20	Rate as "very good" over all
21	It was very fun, fruitful and informating
22	Very good
23	Very well arranging, Thanks to the organizations and XXXX counterpart
24	Very good, more inclusive training on the use of IFAS model
25	Trainig is short Need complehensive training to fully grasp the usefullness and application.
26	The training is timely and the facilitators are friendly. IFAS will help us in flood warning system even through I'm assigned in research. IFAS helps researchers experimentary for interpolating rainfall distribution for given stations.
	Blue : Good impression
	Red : Request about more training

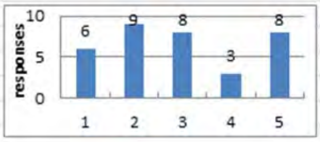
Training program at Tuguegarao City

Summary of a Questionnaire

24 people answered, multiple answers allowed

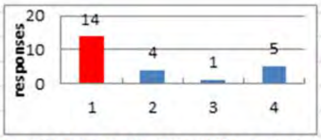
Q.1 1. What is the main duty currently assigned to you? Please check all that apply.

1	☐Planning	6
2	☐Hydrological observation (rainfall, water level, data management)	9
3	☐Discharge simulation & flood forecasting	8
4	☐River works	3
5	☐Other ( )	8



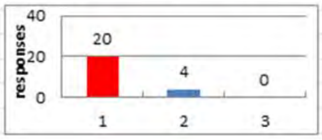
Q.2 2. How many years have you been involved in river-related work?

1	☐Less than 5 years	14
2	☐5 to less than 10 years	4
3	☐10 to less than 15 years	1
4	☐15 years or longer	5



Q.3 3. Do you understand the important points and perspectives for flood management (identify causes, effective countermeasure, necessary data)?

1	☐Easy to understand	20
2	☐So-so	4
3	☐Difficut to understand	0



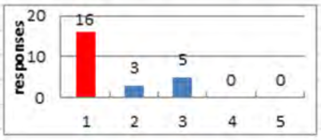
1	one of the main causes of flood is deforestation. The most important things to do is inform the public about the causes and effect of it.
2	Causes/ siltation of Cagayan River basin. Countermeasures/ dredging, Early warning dissemination, IEC campaign. Necessary data/ baseline data (eg. Population at risk/ population likely to be affected)
3	Reliable data gathering is vital for assessment & forecast
4	I now understand the causes of flood, its effective countermeasures and the necessary data for flood management
5	We need more training to understand
6	Monitoring stations I tributaries
7	Minimal monitoring stations
8	Fully understood the importance of the perspectives for flood management from the activities in the training

Q.4 3. What do you think about the most important your actions for flood management?

1	Put more monitoring facilities W/R the extent of the Cagayan River basin and more IEC facilities should be done in the region.
2	1. Dissemination of flood bulletin specially people living in the low-lying areas along Cagayan River. 2. Constant monitoring of the water level. 3. Evacuation or alerted the people living along Cagayan River
3	Effective community-based early warning system
4	Proper waste disposal, sewerage system, land-use
5	It will be an additional time for flood forecasting
6	Continue to learn IFAS and apply it efficiently Educate end users & encourage maximum cooperation
7	Flood forecasting
8	Participating collaborating of all concerned agencies in the implementation of IFAS as a mechanism for accurate flood forecasting.
9	Real-time accurate data that is easy to understand on users-end
10	Research
11	Proper dissemination of the flood forecast and proper understanding of the public about the forecast
12	Observe and disseminate reliable and accurate data
13	Accurate and timely flood forecast
14	Save lives of affected area
15	For me, is my experience in hydrology works. A inflow forecast for the basis/decision making when to release discharge the dam. To minimize dam areas and downstream area
16	Information and knowledge sharing is important to come up with a good flood management
17	Introduce and help my poorness ti understand and operate IFAS model
18	Easy to understand the content of flood forecast

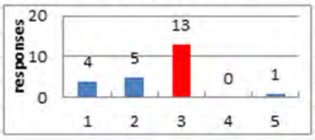
Q.4 4. Check the one that best applies to you in terms of the necessity of rainfall observation for flood forecasting?

1	☐I have already been aware of it.	16
2	☐I now understand it very well.	3
3	☐I now understand it.	5
4	☐I still don't understand it very well.	0
5	☐I still don't understand it at all.	0



Q.5 5. Check the one that best applies to you in terms of the characteristics of satellite-based rainfall.

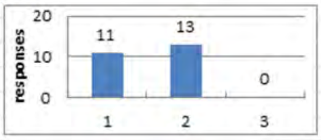
1	☐I have already known about them.	4
2	☐I now understand them very well.	5
3	☐I now understand them.	13
4	☐I still don't understand them very well.	0
5	☐I still don't understand them at all.	1



Q.6 What do you think about the learnability of IFAS (whether or not IFAS is easy to learn)? What do you think about the user-friendliness of IFAS (whether or not it is easy to find commands or menus and make the computer do what you want)? Please check the one that best applies to you.

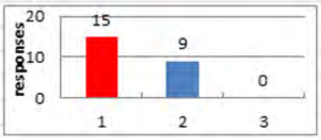
1) Learnability

1	☐Easy to learn.	11
2	☐So-so.	13
3	☐Difficult to learn.	0



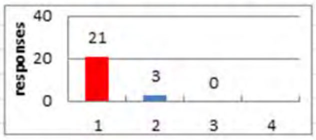
2) User-friendliness

1	☐Easy to find commands or menus.	15
2	☐So-so.	9
3	☐Not easy to use	0



Q.7 Do you think this workshop will be helpful in flood forecasting for rivers in your country? Please check the one that best applies.

1	☐It will be helpful.	21
2	☐It will be helpful to some extent.	3
3	☐It won't be very helpful.	0
4	☐It won't be helpful at all.	



Q.8 Please write your opinion about the applicability of IFAS to your country.

1) Is there anything you want us to improve or add in order to apply IFAS to your country?

1	none so far
2	Follow-up training will be conducted
3	Training time must be done in a week
4	As of now, none will be getting to learn/use this more in coming days.
5	none
6	Right now, IFAS for me is enough tool. Maybe I can contribute some improvement in the future, when needed.
7	It is very helpful for flood forecasting and inundation extent modeling
8	At present, IFAS would be a helpful system to generate information as a basis of decision and policy making particularly flood prevention & preparation
9	Provide more in-depth trainings or follow-up trainings to be able to help us become an efficient forecaster
10	We need more training on IFAS
11	Actually IFAS is applicable and in terms of accuracy. It provides more actual results than other software/programs.
12	Incorporation of radar-based rainfall data
13	None, I think it's already perfect
14	The possible inclusion of forecasting in formation/data through wireless communication to IFAS program
15	The satellite-based rainfall should be a real-time, to be used & compare to observed (measured RF) in flow discharge to the river & inundated area.
16	The IFAS program should have a feature where the user could open/do tasks simultaneously (multi-tasking)
17	Maybe in the near future as I apply the model to our rivers, I can give my insights and comments on the model.
18	Regular coordination with our country with regards to IFAS model.
19	Personnel must be trained more using the IFAS and calibrate so many flood scenarios.

	2) What difficulties are there on your country side in applying IFAS to your basin?
1	In our city Tuguegarao, maybe it's the lack of technical personnel to operate the IFAS
2	There have been a problem in identifying the extent of damage of the incoming flood.
3	Coordination among local government units to encourage the implementation.
4	Satellite-based rainfall data
5	For the people to accept & learn the value of the available system for their own safety & well-being
6	By this time we do not have high end computer
7	Computer literacy for non-technical personnel
8	Lack of hydro-met monitoring stations
9	Absence of accurate data regarding geographical profile of Cagayan River basin Financial capabilities of concerned agencies to implement and operate IFAS
10	Insufficient rainfall gauging stations
11	Downloading real-time data
12	Mastery of the subject matter
13	Lack of coordination of focal personnel of forecasters vis-à-vis different concerned LGU's
14	I think the acquisition of latest satellite data, images and map
15	lacking data or insufficient data needed for the good output or result of the model
16	I think more sufficient data is needed for a better/accurate IFAS output.
17	Maybe the input data will be the problem. Somehow run the IFAS itself. It's easy to simulate & operate.

Q.9	Please give us feedback on this workshop. We would also like to ask you for suggestions or requests for future workshops.
1	The program, arrangement, speakers are very good. Only on the use of IFAS were encountered difficulty because of so many procedures and data. We need to fill up. Mr. Nabesaka is a very good speaker it's just that he is very fast in teaching us
2	The overall training is fine. But there should be more time allowed to hands-on so that participants will have more time to explore the system. The hands- on should be one step at a time so that participants will cope with task given.
3	The approaches of all facilitators in the training are very systematic. Conductive to learning and friendly.
4	The training is useful to disseminate early warning to the populace
5	Excellent
6	Very well organize
7	I really appreciate the
8	Very substantial workshop! Thank you very much.
9	Very excellent!!!
10	It gives additional knowledge and information on accurate flood forecasting & warning system
11	Thank you very much for this great opportunity to learn. Program, arrangement and speakers are at par.
12	It satisfies our expectations but may we request for another training on IFAS
13	The program and the arrangement as well as the speakers were good. It does help us and improve our capability of flood forecasting. And it is our responsibility to wide our understanding with the software given, exploring those options
14	Thank you ADB & ICHARM for such training
15	Excellent
16	All are excellent, only we cannot understand well the pronunciation by the speakers
17	Excellent
18	The whole training was enjoyable. It's fun to learn
19	The training is good, well organize and OK. Accommodation. Good job!
20	The training materials were informative, speakers were very intelligent.
21	The training is very informative, well-organized and all experts are accommodating
22	The moderator is excellent and also the training itself is very useful to us.
23	Overall the training facilities, presentations and facilitation are well performed excellent.
	Blue : Good impression
	Red : Request about more training
	indecipherable