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Main Report

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Cover photo:
Flood Waters & Daily life - lady trying to reach home

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Abbreviations

AAD	Average Annual Damage
ADB	Asian Development Bank
BB	Brahmani-Baitarani river basin in Odisha
BG	Burhi-Gandak River basin in Bihar
CE	Chief Engineer
CGWB	Central Ground Water Board
CWC	Central Water Commission
DDMA	District Disaster Management Authority
DFID	Department for International Development
DPR	Detailed Project Report
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
ESM	Earth System Model
FGD	Focal Group Discussion
FM	Flood Management
FMIS	Flood Management Information System
GCM	Global Climate Model
GDP	Gross Domestic Product
GFCC	Ganga Flood Control Commission
GFDRR	Global Fund for Disaster Reduction and Recovery
GoI	Government of India
IFM	Integrated Flood Management
IFMP	Integrated Flood Management Plan
IFRM	Integrated Flood Risk Management
IMD	India Meteorological Department
INR	Indian Rupees
IWRM	Integrated Water Resources Management
MoEF&CC	Ministry of Environment, Forest and Climate Change
MoWR RD&GR	Ministry of Water Resources, River Development and Ganga Rejuvenation
NDMA	National Disaster Management Authority
NGO	Non Governmental Organisation
NRSC	National Remote Sensing Centre
NWM	National Water Mission
OR	Operational Research
ORSAC	Odisha Space Application Centre
PATA	Policy Advisory Technical Assistance
POCSP	Project Overview Cum Steering Panel
RBO	River Basin Organisation
RCM	Regional Climate Model
SDMA	State Disaster Management Authority
SDRF	State Disaster Response Force
SEA	Strategic Environmental Assessment
SoI	Survey of India
TA	Technical Assistance
UNDP	United Nations Development Programme
WRD	Water Resources Department

Units

MWh	Mega Watt hour – unit of Energy
m	Metre – unit of Length
cm	Centimetre – unit of Length
mm	Millimetre – unit of Length
Cumec	Cubic meters per second – unit of Flow
km	Kilometre – unit of Length
Sq.Km	Square Kilometres – unit of Area

Executive Summary

In this report an integrated approach is advocated, for which a framework and guidance are given. Our research, using river basins in Bihar and Odisha as case studies, provides clear insights into bottlenecks as well as promising interventions that would reduce the losses and burdens of millions of people currently affected by floods. Mathematical modelling as well as social surveys proved to be key to unravel the intricacies of the problem: to quantify what needs to be quantified and to qualify the needs from the grassroots level. Major conclusions can be drawn from these basins which in many ways can be regarded representative for many others:

- As per our model calculations for both river basins it was found that by providing the 1:25 safety standard for rural areas around 90% of the average annual damage could be avoided. This implies that the marginal extra benefits quickly diminish beyond this safety standard.
- In terms of flood hazards, climate change is expected to cause heavier rainfall events and can lead to significant increases in flood extent (in the order of 25% in 2040 and perhaps 30% in 2080 in the case of the Brahmani-Baitarani). To maintain present flood safety standards, embankments should be raised in the order of 80 cm in 2080. Still, most interventions do not take such increase in flood hazard into account.
- Upstream structural flood control measures, such as dams and river diversions, would lead to a significant reduction in flood hazard. Typical reduction factors in flood extent for new upstream projects in the two study basins are in the order of 5 to 10%. Complete flood control is not feasible.
- Flood embankments are currently and will remain the major flood control measure and the preferred option of a majority of the people. Still a large number of people are living in areas between the embankments and the river and are therefore liable to flooding (especially in Bihar). Technical standards, regulations and design guidelines for embankments are in place, but not always followed up during implementation. Safety standards for embankments (return periods) are still not defined using a genuine risk approach, comparing costs and benefits.
- Non-structural measures necessarily complement structural measures, as is well understood by all key stakeholders. However, flood forecasting, early warning and community preparedness are far from satisfactory. Community disaster management plans are still not mainstream practice. Land zoning is not actively implemented as part of flood management as legislation is still not enacted in most States.

This report provides a strategic framework for preparing integrated flood management plans. The framework follows the internationally accepted flood risk approach. An indispensable tool for such approach is a mathematical model to simulate flood hazards from source (rainfall) via pathway (river and floodplain) to receptor (people and their assets). It is only through such tool that effectiveness of measures can be assessed after which fruitful combinations can be built into a basin wide flood management plan.

Our study showed that it proved to be quite feasible to run a complete 1D/2D hydrodynamic model of the entire lower part of the basins (covering some 25,000 km^2 with approximately 100,000 calculation points). Runtime was in the order of 20 min. on a desktop computer. The advantage of running a dynamic 1D/2D model instead of first running a 1D model and then estimating the flood extent through GIS is that it much better includes the storage effect of the flooding itself during a flood event.

To bring about improvements in current flood management practices, the following Framework has been formulated:

Flood Risk Analysis
Risk analysis at *the basin level* produces flood risk maps for different return periods under current conditions and under scenarios of climate change. Such analysis should use a state-of-the-art mathematical model for hydrology and hydraulics. In order to derive validated model results the data on hydrological parameters, elevation, land use and infrastructure should be checked on consistency. In many cases a joint probability analysis needs to be performed in order to derive the appropriate return periods. Failure modes of embankments need to be researched and reservoir operation modes studied. Exposure and vulnerability data should also be made available and validated with community surveys. Fragility or damage functions for various assets as well as agricultural crops can be used from generic (Indian) sources or should be adapted for local conditions in case of significant deviation from the country average.

It is recommended to include possible climate change effects on the flood hazard. Ideally, downscaling of global climate models should be conducted for each basin or state, as has been performed in this study for the two states. Performing such a study might not be feasible for each project. Then, a factor for quantum of increase could be established so all future projects in that area can use those numbers.

Flood Risk Evaluation
The resulting flood risk maps are input for discussions among stakeholders to evaluate the acceptability of the risks and to decide if new measures are needed. Evaluation can be done based on predetermined safety levels (such as 1:25 year return period for agricultural areas and 1:100 year for urban areas), or on a full-fledged economic cost-benefit analysis (CBA). Also community needs and conditions need to be taken into account because there can be other than purely economic reasons for establishing a safety level. A pilot CBA exercise in the Brahmani-Baitarani river basin (near Jenapur) revealed high benefit-cost ratios for embankments with a 1:25 year safety level and higher. These results are encouraging and should be followed up with a more detailed, full fledge CBA.

Selection of flood mitigation measures
The entire gamut of measures, both structural and non-structural, needs to be taken into consideration for choosing the appropriate strategy. Ideally, the combined measures should reduce the hazard, limit the exposure and reduce the vulnerability. It should be kept in mind that there always will be a residual risk for which appropriate (government) intervention is required in the form of emergency response and relief funds. There is no general recommendation to prioritize measures, since each river basin has different physical as well as socioeconomic characteristics. Again, economic analysis as well as stakeholder consultations help making the right decisions. Mainstreaming measures with other policy domains (e.g. urban planning, watershed management, irrigation development) can greatly enhance their feasibility.

In the Indian context, most if not all possible types of measures have been introduced already at least somewhere sometime. The experiences and practicalities have been discussed extensively in this report. The enormous diversity in measures and conditions in which they can be taken precludes generic recommendations or guidelines. However, a multi-criteria analysis, based on the sub-basin studies, provides some guidance to prioritize measures in a river basin flood management plan. The multi-criteria analysis showed that none of the measures reach the maximum score, but neither of them have a very low score, indicating that all have strong and weak points. The highest scores were found for non-structural measures Flood Warning and Community Preparedness & Disaster Management. Although they do not reduce the floods themselves, they score very good in terms of low investments and relatively quick results. Embankments, Crop protection, Watershed management and Urban & Rural Drainage have average scores, but for different reasons. Embankments do reduce floods and often have good BC ratios, but they require substantial government funding and implementation takes many years. Crop protection does not reduce floods but requires little investment. On the other hand, its implementation requires appropriate market conditions which will take time to develop. Watershed management could significantly reduce floods, but its implementation will be a long term process. Urban & Rural Drainage is capable of substantially reducing inundations but requires high investments and results will be visible in medium term only. Dams and diversions have a lower score. Although they can significantly reduce floods, they require massive government funding and implementation will take many years.

In summary we recommend:

- Urgent measures first: these include all kinds of repair and emergency measures, in order to avoid major problems in the next flood season.
- Short term measures: implementing measures which can reduce flood impacts in the coming years and do not require large investments (such as adjustment of reservoir operation rules, improved flood forecasting and warning and community preparedness plans).

Medium to long term measures, which require some kind of study and /or DPR approvals. This includes upgrading embankments, new dams and diversion projects, watershed improvement, land use zoning etc. For embankments the concept of a dike ring should be adopted, which provides a standard safety for the entire area that is enclosed by the embankment.

Institutional recommendations
Ideally IFM is mainstreamed with other policy domains, such as watershed management (forestry), urban planning, agricultural development, infrastructural improvements and land use zoning. As demonstrated in this report a river basin approach should be adopted for managing flood mitigation measures. Existing or newly developed River Basin Organisations are the logical entity for implementing this approach. Functions of the RBO in relation to flood management would include: i) developing flood management plan, with strategies; ii) monitoring of operation of flood control/regulation structures, including dams, by the agencies concerned (like the WRD) to ensure that they are according to the plan; iii) monitoring land use changes (forest cover, agricultural land use), and examining whether zoning regulations are violated; iv) inspection system for the flood control structures, checking and authorization, monitoring the flood fighting system, and providing support systems for flood fighting; v) monitoring the flood warning system, flood preparedness and

maintenance system; and, vi) monitoring the community engagement system, monitoring the resources, and monitoring the communication system.

We understand that setting up RBOs cannot be done overnight. Therefore, we propose that in the interim period in each State WRD a *Project Preparation Cell for IFM projects* should be created, which consists of a multi-disciplinary team drawn on deputation from the line departments/ministries of a State. In fact, such Cells already exist in the State Water Resources Departments of both Bihar and Odisha in the name of Flood Management Cell. At the Central level, the existing Flood Management Organization (FMO) in CWC headquarters can Act as the Project Preparation Cell for developing IFM plans and strategies, for trans-boundary basins/sub-basins.

Specific measures are suggested to improve DPR guidelines used for water-related projects. Basically they reflect the integrated character of IFM to be included in the guidelines: adopting a basin-wide baseline, using mathematical models to analyse impacts on flood extent and potential damages, also under changed climate conditions, and including the community perspective.

Recommendations and actions

Because of the wide range of IFM aspects, many actions need to be taken by many different actors. Based on our results and findings we have therefore prepared a concise list of recommendations, each with practical action points which can be taken by the relevant agencies.

Recommendation	Actions	Actor(s) involved	Short term (within next 2 years)	Medium term (2-5 years)	Long term (5-10 years)
1. Legal and institutional recommendations					
1.1 Create or revitalize RBOs for IFM policy and strategy development	a. Strengthen the FMO in the CWC headquarters for IFM strategies for trans-boundary basins	MoWRRD&GR (GoI), GFCC and Planning& Coordination Department of WRD, State Government	✓		
	b. Revitalise the existing basin organisations of the CWC in their regional offices	ditto		✓	
	c. Create interdisciplinary Project Preparation Cell within State WRDs, wherever they do not exist	ditto	✓		
	d.				
	e. Increase the coordination between CWC basin organizations and the Project Preparation Cells in the State WRDs	WRD / CWC	✓		
1.2 Improvements in legal framework for IFM	a. States are encouraged to follow the recommendations of the National Water Policy 2012 and use the Model Bill on Land use zoning.	State Governments	✓	✓	✓
	b. include flood hazard in the housing and building regulations	State Governments			
	c. integrate the disparate laws addressing the range of issues for a unifying legal perspective	State Governments			
1.3 Institutional coordination	a. Implement clear defined Standard Operation Procedures (SOP) for coordination between institutions in all phases of flood disaster	State Revenue Department coordinates, SDMA to advice	✓		

1.4 Organisational strengthening	a. Greater involvement of NGOs and civil society organizations in disaster preparedness, flood management operations and monitoring of flood control structures	SDMA, DDMA	✓		
	b. Strengthen field level staff of CWC, PWD, WRD, Dept. Health & Local Administration (fill vacancies)	CWC / WRD / PWD / Revenue Dept. / Local administration			
	c. Better equipment for field staff of WRDs and SDMAs	WRD and SDMA			
1.5 Capacity building / training in IFM	a. State should earmark adequate funds for IFM training and capacity building in its budget	State Finance Dept.	✓	✓	✓
	b. Train central staff in IFM issues (flood modelling, probability analysis, hydrology, economic analysis, etc.)	CWC / WRD / IITs /NIDM / NIH and specialised consultants		✓	
2. Economic recommendations					
2.1 Country-wide standardization of damage assessments	a. Guidance and Training in Post-Disaster Damage and Needs Assessments (PDNA)	NDMA, NIDM	✓		
	b. Preparation of a national database for assets (vulnerability / damage functions)	NDMA (IIT providing technical assistance)		✓	
	c. Preparation of a national database of damages at sub-district level and river (sub-)basin level. Valuation of assets in flood prone areas and at pre-determined constant prices to avoid ambiguity in determining scale of damages	NDMA		✓	
2.2 Allocate more funds for flood mitigation projects	a. Enhancing Finance Commission for capital works under IFM	Min. of Finance and Niti Ayog (erstwhile Planning Commission of India)		✓	
	b. Central Plan Budget for capital works under IFM	Ministry of Finance	✓	✓	

	c. Non plan State budget (from state revenue) to meet recurring and maintenance costs of the flood control infrastructure created	State Finance Department			
	d. It is recommended to make an assessment of IFM interventions as how it has improved the economic situation and contributed to creating an enabling environment for investment for GDP growth	Min. of Finance and Niti Ayog		✓	
2.3 Improve economic Benefit-Cost method of flood control projects	a. Identify all benefits and costs association with such projects, both direct and indirect. Decide on an appropriate method to include human casualties. b. Improve benefit calculations (avoided damage), through flood simulation models and appropriate damage functions c. Take into account future economic growth / demographic trends, etc. through scenario analysis d. Introduce NPV, Sensitivity Analysis, FIRR and EIRR	WRD CWC may add a dedicated economic cell for the task of monitoring and approval process.	✓		
3. Recommendations to promote River Basin Planning for IFM					
3.1 Perform risk analysis at the river (sub-)basin level for all major rivers, including future projections due to CC	a. Development of flood models (hydrological/hydraulic) with accurate Digital Elevation Models and appropriate joint probability analysis.	CWC / WRD /IMD		✓	
	b. Preparation of CC downscaling studies for major river basins	NWM / MoWR,RD&GR		✓	
	c. Preparation of flood risk maps based on the flood model results	WRD/NDMA/SDMA		✓	

3.2 Flood risk evaluation at river (sub-) basin level	a. Organise discussions with stakeholders / communities using flood risk maps	RBO		✓	
3.3 Improve systematic selection of flood control and mitigation measures at river (sub-) basin level to arrive at IFM	a. Inventory of promising measures	RBO		✓	
	b. Feasibility assessment using economic tools and community surveys	WRD		✓	
	c. Improve economic BC analysis for flood projects	CWC/WRD		✓	
	d. Update guidelines for DPR	CWC	✓		
Reduce uncertainty in river behaviour	a. Detailed study of river behaviour as a consequence of earthquakes / landslides and morphological changes	CWC			✓
4. Recommendations on flood risk mitigation measures					
4.1 Improvement of lead time for flood early warning	a. Improvement of hydrological forecasting through automated hydromet stations, improved data transmission and mathematical models (instead of gauge to gauge extrapolations)	IMD / CWC		✓	
4.2 Improvement of warning message dissemination mechanism	a. Implementation of advanced technologies such as SMS broadcasting	CWC / NDMA		✓	
4.3 Review the reservoir operation rules for enhanced flood cushioning (15% of live storage is recommended)	a. Study into improved operation of major reservoirs in the country, making use of enhanced rainfall forecasting and clarifying trade-off relations between different reservoir functions	WRD/CWC		✓	

4.4 Upgrade embankments up to required safety level	a. Improve supervision of construction and maintenance	WRD	✓		
	b. Review/update criteria for freeboard	CWC		✓	
	c. Realign embankments which do not adhere to 3 times Lacey's wetted perimeter	WRD / GFCC			✓
4.5 Improve rural drainage to reduce waterlogging problem	a. Maintenance and O&M of sluice gates	WRD / Local administration		✓	
	b. Construction of drains	WRD / Local administration		✓	
4.6 Improve flood cushioning in the basin	a. Promote appropriate land use in the catchment and flood prone areas to reduce rainfall-runoff	Rural Development Department / Forest Department			✓
	b. Provide incentives for conjunctive use of surface and groundwater	WRD		✓	
4.7 Improve urban drainage	a. Implement Master Plans for vulnerable cities and towns	Municipal Corporation		✓	
	b. Ensure proper maintenance of drains, culverts etc.	WRD	✓		
5. Community level recommendations					
5.1 Include communities in major flood management interventions	a. Carry out community needs assessment b. Conduct community consultations for major intervention projects	WRD / CWC		✓	
5.2 Introduce/revitalize disaster preparedness in vulnerable communities	a. Inventory of vulnerable villages / communities with/without Disaster Management Plan	SDMA, DDMA	✓		
	b. Formulate DM committees with sub-task committees	DDMA			
	c. Prepare DMP's together with civil society groups (NGO's and CBO's)	DDMA			
	d. Monitor roles and responsibilities of the DM committees	DDMA and Local Administration			

5.3 Protect livelihood to increase resilience	a.	Promote flood/salt resistant crops, crops suitable for waterlogged areas and remove obstacles for adoption (market value chain, storage etc.)	Department of Agriculture		✓	
	b.	Promote affordable crop insurance	Department of Agriculture and Private sector		✓	✓
	c.	Provide agro-advisories	IMD / Department of Agriculture	✓		
	d.	Extension and implementation of District Agriculture Contingency Plans	Department of Agriculture	✓	✓	

Chapter 1 Introduction

1.1 Background and project objectives

The PATA Operational Research for Mainstreaming Integrated Flood Management under Climate change was included in ADB's country operations business plan, 2012-2014 under the 2012 pipeline in December 2011. The ADB fact-finding mission was conducted on 15 February 2012 and 9 March 2012 to consult the Government on the preliminary design of the TA, including expected impact, outcome and outputs: the financing modality; cost estimates and implementation schedules and arrangements. Thus the present PATA-8089 IND has emerged. The PATA is co-financed by UK aid, whereas the Executing Agency is the Ministry of Water Resources.

The PATA was implemented in two phases. It started with Phase I from March 2013 to February 2014 which comprised Scoping and Planning studies. The present Phase II addresses and elaborates the Operational Research to support the mainstreaming of Integrated Flood management (IFM) in a way that takes into account projected future conditions and climate change uncertainties. This phase was executed between 19th February 2014 and 31 October 2015.

The Overall Objectives of the study are:

a) *To demonstrate that flood risks can be reduced through a broad mix of flood management measures, typical for the Indian context, with specific considerations for Climate Change;*

b) *To demonstrate to central and state government the benefits of such an integrated flood management and planning process;*

c) *To provide guidance on such planning process, and*

d) *To translate results into updated CWC guidelines and regulations relevant for future DPR approval.*

The overall objectives encompass the combination of structural and non-structural measures as well as increasing the resilience of the communities in flood prone areas of the selected two basins (Burhi-Gandak, Bihar and Brahmani-Baitarani, Odisha), such that the selection of such measures can be replicated or adapted in other basins/sub-basins[1]. The selection process should enable the evaluation of investment programmes based on scientific reasoning and economic efficiency.

The ultimate outcome of the project is to support *risk informed decision making for flood hazards* in India. We define this as decision making based on estimates of flood risk as well as the costs and benefits of flood mitigation and management. This implies giving emphasis on a 'proportionate' response to risk as well as a process of estimating risk which is transparent and the results being accessible, so that risk estimates may be used to inform multiple decision makers, including the general public. Risk informed decision making has become a new approach to floods in the past decade and has been incorporated in what we call *Integrated Flood Management* (IFM).

[1] The two basins were selected during Phase 1 of the PATA8086 program after a careful consultation process. The basins in Bihar and Odisha met the selection criteria, among which was their representativeness for natural river and coastal flood issues.

1.2 What is Integrated Flood Management?

Previously policies in most countries including India were predominantly based on flood control, implementing structural measures such as dikes and embankments. However, there currently is an increasing trend in flood damages worldwide, mostly driven by an increasing vulnerability of societies to floods caused by population growth and increasing investments leading to an increase in exposure to floods. There is reason to believe that structural measures alone cannot reverse this trend, because:

- Structural measures are costly and not always feasible from an economic point of view
- Operation and maintenance of structural measures is not always guaranteed
- Structural measures are not flexible and can be less robust in view of future uncertainties (climate change, socioeconomic developments)
- Structural measures could harm the ecological integrity and socio-cultural functions of floodplains, rivers and estuaries.

Also in India the engineering-focused approach employed up to now does not adequately incorporate the benefits and opportunities of integrated flood management (IFM). Therefore, a more holistic range of measures and options is necessary. Examples of such (non-structural) measures include a wide range of hazard and vulnerability reduction measures such as spatial planning, floodplain zoning, flood early warning, provision of refuge areas and evacuation, ecosystem based protection measures and flood insurance and compensation programmes. The aim of IFM for a specific river basin or region is to arrive at a well-balanced optimal combination of measures (= a strategy) providing a reduction of flood risk to a societal acceptable level at minimum economic and societal cost.

1.3 Reporting

The reporting of the project consists of 9 volumes including this Main Report as well as two research papers. Abstracts of these papers are included as Appendix B and C to the Main Report. The other volumes are:

Vol. 2 Draft Basin Flood Management Plan for Brahmani-Baitarani in Odisha
Vol. 3 Draft Basin Flood Management Plan for Burhi-Gandak in Bihar
Vol. 4 Data compendium (IFM GIS based Information System and databases)
Vol. 5a Modelling report Brahmani-Baitarani
Vol. 5b Modelling report Burhi-Gandak
Vol. 6a Community Survey report Brahmani-Baitarani
Vol. 6b Community Survey report Burhi-Gandak
Vol. 7 Quarterly Reports
Vol. 8 SOBEK Training Report
Vol. 9 Consultation session Report (Round table conference)

Titles of the research papers are:

- *Downscaling GCM data for climate change impact assessments on rainfall: a practical application for the Brahmani-Baitarani basin.*
- *Review of Design Standards for Flood Protection in the Brahmani-Baitarani River Basin in India*

The Draft Final Report was submitted on 1 October 2015 to the National Water Mission, ADB and DFID, and subsequently to other National and State Organizations in Bihar and Odisha. This Final Report was prepared after the Project Overview-cum-Steering Panel meeting at 4 November 2014 and after comments were received from all relevant organisations. A list of comments is provided as Appendix I to this report.

1.4 Guide for the reader

Chapter 2 provides a review of Flood Management Initiatives in India, describing the existing flood management legislation, policies and strategies, the community flood issues and needs as well as current practice of embankment construction, one of the most common flood mitigation measures in India. It also reviews economic, environmental and institutional aspects of flood management.

Chapter 3 presents the method and results of climate change downscaling for both basins and the subsequent impact on flood hazards. This is followed by Chapter 4, which provides a strategic framework for Integrated Flood Management. By using the results of the flood risk model for both studied sub-basins it illustrates how flood risks can be reduced through a broad mix of flood management measures (Objective a). The benefits of such a process are demonstrated through a cost-benefit analysis as described in section 4.3 of the Chapter (Objective b).

Chapter 5 gives conclusions and recommendations for integrating IFM in the planning process, providing specific attention to economic analysis, agriculture, legal aspects, community needs and environmental conservation (Objective c). It also gives proposals to integrate IFM into CWC guidelines for DPR approval (Objective d).

The report ends with Chapter 6 on the legacy of the project. Here we describe stakeholder involvement, capacity development in the field of modelling and disclosure of data used for the study.

The main report is supported by the other volumes, which provides more in-depth information on the key aspects of the study. Results from the community survey and modelling exercises are used to substantiate the main report and reference is made to the corresponding volumes if the reader would like to know how these results have been derived. Volumes 2 and 3 provide draft Basin Flood Management Plans for both the sub-basins, respectively, and can be read as stand-alone Reports.

Chapter 2 Review of existing Flood Management Initiatives in India

2.1 Floods in India

River floods are one of the most common natural disasters in South Asian Countries. India, Bangladesh and China top the list of people across the world worst affected by river flooding where about 5, 3.5 and 3.3 million people are exposed every year, respectively. The potential national economic consequence of river floods is highest in India which has by far the most GDP exposed, at $14.3 billion. Bangladesh is a distant second, at $5.4 million[2].

Floods can result in huge economic losses due to damage to infrastructure, property and agricultural land, and indirect losses in or beyond the flooded areas, such as production losses caused by damaged stock or roads, or the interruption of power generation and navigation. India as a country faces more potential change in exposed GDP than any other country and it is estimated that India's current $14 billion in GDP exposed annually could increase more than 10-fold to $154 billion in 2030. Approximately 60 % of that increase could be caused by socio-economic development[2].

The major flood prone areas of India cover almost 12.5% area of the country. The chronic flood prone basins are Ganga and Brahmaputra covering northern and north-eastern parts of the country. The five most flood prone states are Uttar Pradesh (U.P.), Bihar, West Bengal (WB), Assam and Odisha (Gupta, Javed, & Datt, 2003). In Bihar state alone, up to 6.8 million hectares are prone to floods (Mishra, 1997) while in Odisha this equals over 1.4 million hectares. The 2007 Flood was one of the most disastrous flood in the history of Bihar which affected over 24 million people (Sinha et al., 2012). In Odisha, spilling over of river banks by Mahanadi, Baitarani and Brahmani causes floods in the thickly populated deltaic area formed by these three rivers.

Moreover, climate change could become a key driver of change in population exposure to river floods in India in the coming decades. Future climate studies based on climate model simulations suggest that global warming is likely to intensify the monsoon precipitation over a broad region encompassing South Asia (Lal et al., 2000; May, 2004; Meehl and Arblaster, 2003; Rupakumar, 2006; Trenberth, 2011). Likewise, a recent World Bank Report (2013) predicts that India will be threatened by a more erratic monsoon season, extreme floods, rising sea levels and very high temperatures due to climate change.

Physical considerations and model studies indicate that tropospheric warming leads to an enhancement of moisture content of the atmosphere and are associated with an increase in heavy rainfall events causing floods, landslides and flash floods. These extreme rain events are triggered in the background of synoptic disturbances and preferentially located around the tracks of monsoon lows and depressions. Recently, Goswami et al. (2006) indicated significant positive trends in the

[2] Data based on The Aqueduct Global Flood Analyzer, a new online tool, developed by WRI with four Dutch organizations: Deltares, the Institute for Environmental Studies of the VU University Amsterdam, Utrecht University and PBL Netherlands Environmental Assessment Agency. The tool estimates current and future potential exposed GDP, affected population and urban damage from river floods for every state, country and major river basin in the world (WRI, March 2015, www.floods.wri.org)

frequency and the magnitude of extreme rain events and a significant negative trend in the frequency of moderate events over central India during the monsoon seasons from 1951 to 2000.

It is against this background of existing flood risks and their likely increases due to climate change that we have reviewed the existing flood management practices in India. In the next sections such practices are described from all relevant angles, ranging from the legal aspects to the community perspective as well as from technical, economic and environmental viewpoints.

2.2 Performance review of current FM strategies

Before Independence in 1947, flood was mostly treated as a local problem. After independence, the Government of India has been looking into flood management in a wider perspective by way of developing policies, constituting Working Groups, High Level Committees, Ministers' Committees and the Rashtriya Barh Ayog (National Flood Commission). Various aspects of Flood Control and Management approaches have been deliberated from time to time to refine the approaches of flood management. The various Committees and similar authorities are:

- National Flood Policy-1954,
- High Level Committee on Floods-1957,
- Policy Statement-1958,
- Ministers Committee on Floods-1964,
- Ministers Committee on Floods and Flood Relief-1972,
- Working Group on Flood Control-1978,
- Fourth conference of State Ministers of Irrigation-1979,
- Rashtriya Barh Ayog (National Flood Commission)-1980, and
- Working Groups for each 5-year Plans (Planning Commission, Government of India).

Based on the findings and recommendations of these committees, initially mostly structural measures were taken up. So far about 35,200 Km of flood embankments and about 38,810 Km of drainage channels have been completed. Further a number of multi-purpose reservoirs with provision for flood control have been constructed. The dams and various other structural flood measures completed up to date have helped in providing flood defence to about 18.22 million hectares. Flood mitigation works for 2,458 towns have also been completed. In addition flood proofing measures for 4,716 villages have been achieved by raising the villages or by ring bunds, in addition to the construction of raised platforms in flood and cyclone affected areas.

Nevertheless, flood damages, losses and deaths continue to be an annually recurrent phenomenon and seem to be increasing. Does that imply that the current measures and strategies have failed to curb the floods? Not necessarily, because without these measures the damages would no doubt have been much higher. The actual causes of the increasing trend in natural disaster damages are not easy to unravel, because over time many factors that contribute to damages have changed. Most importantly there have been societal changes, including demographic and economic growth. For instance, in a study on Odisha, Bahinipati (2010), calculated that the occurrence of higher damages in the past decade compared to previous periods (his data goes back to 1972) is at least partly due to societal factors. The higher number of people affected in the current decade could be partly attributed to the population growth.

So, many results achieved over the past decades have been impressive. For instance the Damodar Valley dams have absorbed 75% of the incoming floods on an average of 38 flood events[3] (the role of dams and reservoirs in flood mitigation is fully detailed in Section 4.4.4). Embankments have been constructed along many rivers (section 4.4.6) and disaster management has come to maturity with National and State Disaster Management Authorities installed. Flood preparedness in terms of disaster shelters, raised platforms / flood shelters and flood proofing is being undertaken. Flood forecasts have been successful, but need further improvements (section 4.4.10).

Integrated Flood Management is a continuous process where improvements are needed, such as with respect to dam operation for floods, land use planning and floodplain zoning, flood frequency analysis for determining return periods and design water levels for embankments[4], institutional arrangements for and community participation in IFM (sections 2.4 and 2.8), accounting for climate change, etc. Guidelines for flood management are existing, but not always used or incomplete for an integrated flood risk assessment and planning. For instance, the National Disaster Management Authority (NDMA) has brought out the "National Disaster Management Guidelines: Management of Floods" (2008). This is a very comprehensive document that follows the paradigm shift from the relief oriented approach of the past to an approach that focuses on prevention, mitigation and preparedness. The NDMA guidelines were expected to be used as the basis for preparation of flood management plans (FMPs) by central ministries and concerned departments, and by the state governments. These plans were expected to be holistic, inclusive, environmentally sensitive and gender sensitive, resulting in a flood resilient India. Unfortunately, the guidelines have not been used for flood management plans, possibly because responsibilities for preparing FMPs were too widely spread (Phase 1 Report).

Subsequently, the GFCC "Guidelines for the Preparation of a Comprehensive Plan for Flood Management" prescribes the following planning procedure:

- Step 1. Identification of the problem.
- Step 2. Possible alternatives, solutions and alternative recommended for adoption with justifications. Care to be taken to incorporate works executed or under progress as far as practicable.
- Step 3. Prioritisation of works.
- Step 4. Estimation of balances works to be dealt with likely annual expenditure.

The plan outline mentions both structural and non-structural measures. In fact the entire range of "*strategies to modify flood, strategies to modify the susceptibility to flood damage, strategies to modify the loss burden and strategies to bear the loss*" are mentioned. What is not mentioned is a

[3] S. K. Sinha-Chief Engineer, BPMO and Rishi Srivastava , Deputy Director, Central Water Commission: Role of large dams in flood moderation – Case Studies. Powerpoint presentation 2006.

[4] In actual practice, some of the important criteria are seldom followed, such as on the spacing between the embankments based on Lacey's wetted perimeter, adopting the appropriate return periods and providing appropriate free board. In some states, the High Flood Level (HFL) is not at all based on the flood frequency approach and the historically observed maximum HFL is adopted till a higher HFL is observed. This is the case with the embankments in the Brahmani-Baitarani basin. In other states/basins the flood frequency analysis has been carried out to determine appropriate HFL, but this was done long ago with inadequate data available at that time. This is the case in the Burhi-Gandak basin. Now the data is available for 30 to 40 years, but still nothing has been done to review the HFL based on proper flood frequency analysis.

method how to prioritize between these strategies and measures. Which measures are preferred? Which are most (cost-) effective? What are the criteria to select measures?

In this report we will show how such selection process could be arranged, using a risk based decision making as a starting point. This is explained in Chapter 4. Before doing this, a current status of a number of key aspects for IFM will be reviewed hereunder.

2.3 Review of current legal arrangements

The Constitutional Context of Flood and Water Management
A key feature of the Constitution of India is the existence of separate lists demarcating central (the Union List) and state responsibilities (State List). This demarcation restricts the role of the Government of India and the government itself has clarified its role in the Parliament on Flood Management on a few occasions in the recent past. For example, in a reply to a question in the Parliament the Government had stated:

> *"Flood management being a State subject, the schemes for flood control are planned, funded and executed by the State Governments themselves as per their own priorities out of their State plan funds which are made available to them through Planning Commission. The assistance rendered by Central Government is technical, catalytical and promotional in nature."*[5]

Therefore, the States have been very conscious of their powers on water management and the limits of the power of the central government as laid out under the Constitution of India. Thus, a review of the legal regime on various aspects of flood management must take into account that different States have different laws, dealing with whole range of issues, from land use planning, compulsory evacuation of land in case of floods, suitability of lands for construction of flood works, remission and suspension of land revenue in case of agricultural calamity caused by floods, to levying of betterment contribution for recovering the cost of flood control work.

The Constitution also empowers both the rural and the urban Local self-Governance Bodies to carry out 'water management' at local levels and this opens up a legal space for community flood management all across the country. Specifically, the 73rd Amendment of the Constitution enables States to endow Panchayats with such powers and authority to enable them to function as institution of self-government and goes on to list 'Drinking water', 'Water Management', Minor Irrigation' and Watershed Development' as subjects under the jurisdiction of Panchayats.

Review of the legal regime at the state level with special reference to Bihar and Odisha
Several of the most important laws are those on irrigation which in most States address the issue of floods, in some way or the other. All the state legislations vest the State machinery with the duty to identify the areas that can be potentially affected by floods and thus requiring drainage or embankment works. Examples are *The Bihar Irrigation Act, 1997, The Orissa Irrigation Act, 1959* and *The Orissa Public Embankment Construction and Improvement Act, 1951*. Through the *Land Acquisition Act, 1894* the State has been provided with powers to acquire the land in case it is satisfied that such work is required, subject to the procedural safeguards, like notice to the affected

[5] Lok Sabha Starred Question No 78 Regarding Damage To Cultivable Land Due To Floods Answered On 06.12.2004 By The Minister Of Water Resources

people, enquiry into the objections or compensation for losses suffered as a result of survey work & execution of the scheme. To make the process speedier, the Act vests special powers in the District Collector to take immediate possession of any land in cases of emergency.

In certain States, there are legislations providing for the levy of betterment contribution from the owners of lands who are benefited by flood protection works constructed by the government, as for instance *The Bihar Irrigation & Flood Protection (Betterment Contribution) Act*, *1959.* Restrictions on land use in view of flood hazard (in unprotected floodplains for instance) are only marginally taken up in legislation, as is further discussed in Section 4.4.9 (Land zoning). With regard to urban development, some examples of legislation need to be mentioned which empower municipalities to restrict building constructions for the purpose of safety (such as *The Patna Municipal Corporation Act, 1951, The Asansol Municipal Corporation Act, 1990* and *The Uttar Pradesh Regulation of Building Operations Act, 1958*).

The present legal regime deals inadequately with the rehabilitation of people affected by flood. *The United Provinces Acquisition of Property (Flood Relief) Act*, 1948, however, deserves mention, as it provides for requisition of land and property so as to provide for the village sites and houses for flood-affected people. Having said that, even this Act is inadequate, as it deals with provision of houses only, and overlooks other aspects like livelihood and development. It is also notable that details with respect to such relief works have not been elaborated like the criteria to determine who is a flood affected person and how should the houses be allocated to those people. *The Bihar and Orissa Natural Calamities Loans Act*, 1934 follows a similar scheme. The Act enables the State Government to grant loans to the owners of buildings, which have been damaged or destroyed by natural calamities .

More details on current legislation with respect to flood management can be found in Appendix D.

2.4 Review of community flood issues and needs

Community needs related to floods in India are diverse as physical and socio-cultural characteristics are bound to vary from basin to basin. Even within each basin the needs and problems of local communities differ between the upper, middle and downstream parts, as has been clearly found in our two case study rivers. The following are the key community flood issues and needs as observed during our field work and are more or less common to both the basins and may well be representative for other parts of India too.

Communities of both basins are of the opinion that effectiveness of the existing flood early warning system and access to information related to flood management need to be improved. Warning dissemination through electronic media is not reliable during heavy rains due to power failures. As a consequence, presently the lead time of flood warning is very low for people to respond adequately.

It was found from the survey that many houses, livelihood and even public infrastructure assets are exposed to flooding as they are located in the floodplains. A significant amount of permanent structures were found to be located on the river side of the embankment which are highly vulnerable to flood hazards (Figure 1). Flood mitigation measures are in need to protect these assets or enforcing mechanisms to relocate the permanent structures from the riverside of the embankment.

Figure 1 Houses and other structures located between embankment (red) and Burhi-Gandak River

Most of the floodplain agriculture, which is a key livelihood for millions, consists of rainfed (Kharif) crops which are vulnerable to flood in case of heavy monsoon rain. Flood waters often stay for more than a week in agricultural fields affecting crop yield. Long duration flood also affects fodder which on its turn is impacting livestock. In many places heavy floods also cause sand deposition on fields making it unsuitable for agriculture.

Post-flood environmental and health issues were found to be also a serious problem in both basins. Poor sanitation and environmental conditions are causing a high incidence of water borne and vector borne diseases during and after the peak floods have receded.

Both basins lack adequate flood shelter facilities and godowns for storing food and seeds for communities. For shelter the communities resort to schools, community halls, terraces of pucca houses, and even roads and embankments.

Detailed descriptions of community needs based on our Focal Group Discussions as well as the household survey under nearly 500 households can be found in Report Volume 6. Best practices of community involvement in flood control and management can be found in Appendix E-2.

2.5 Review of current practice of embankment construction

Embankments are a major flood protection measure throughout India and are also a common feature in both studied sub-basins. Breaches and other failures have been found to occur frequently and it is therefore highly relevant to consider the current practice of their design and construction. Planning and design criteria are stipulated by the CWC (*Handbook for flood protection, Anti erosion, River Training Works*, June 2012) and by the Bureau of Indian Standards (IS11532-1995). In addition, criteria have been evolved by GFCC and the Water Resources Departments according to the local / regional conditions. However, for the actual construction of embankments, specific criteria cannot be given easily as in the case of Planning and Design. For example, in one location the testing of the material may be more important and in some cases the foundation treatment could be predominant. Also for certain activities such as site clearance or for removing the debris, tree roots and organic materials from the construction material picked up from the borrow areas, quality criteria cannot be quantified. Only in some cases manuals on construction supervision and quality control have been developed. These need to be updated continuously by encompassing modern technologies and based on the lessons learnt. Therefore thorough construction supervision is always required. In the case of the Burhi-Gandak basin, the construction is monitored by the GFCC for all the Central Sector Projects and those executed with Central Sector assistance.

Box 1 provides an overview of the process of embankment construction.

Box 1: Embankment construction

Embankments are constructed using materials such as earth available near the site. During the construction of these embankments, which are generally homogenous, soil material is placed in thin layers (15 to 30 cm) and then compacted by using rollers. The entire construction process broadly involve the following stages:

- Construction Planning
- Invitation of tenders
- Identification of the borrow areas and procurement of all other materials
- Transportation and storing of these materials
- Carrying out all the required field and in-situ tests
- Carrying out the detailed designs in parallel during the pre-construction stage and preparing the construction drawings in the tendering stage
- Supervision of the actual construction activity.

Specific important aspects to be carefully monitored during the construction are as below:

- Internal drainage system
- Foundation
- Slope protection on both the sides of the embankments
- Stability of the slopes
- Use of the material conforming to the specified properties
- Wetting the borrow areas before excavation to get the right moisture content
- Placing of the material only on the well prepared foundation surface as per stipulations
- Resumption of construction after shut down period needs to be proceeded with the rolling of the earlier compacted surface with smooth wheel rollers
- Carrying out the field tests for density by core cutter method, water content, gradation and permeability.

Both in Bihar and Odisha the predominantly used construction material is sandy clay or coarse sand free from organic materials. In Bihar good quality soil material for embankment construction is not always easily available, which makes their construction relatively expensive. Also there is concern about the proper execution of soil compaction. But the main problem is the meandering nature of the rivers, such as the Burhi-Gandak, which exerts a force on the embankments which reduces their strength. This can cause breaching due to the seepage of water, which slowly eats away the embankment material. Improved design and construction methods are in need to cope with this problem, such as composite sections of embankments with an appropriate inner core as well as checking of the hydraulic gradient. In Section 4.4.6 such improvements as well as the use of modern geo-synthetics are discussed.

In Odisha there are set procedures (local criteria) and human resources available for monitoring the construction. Compaction is mandatory for the embankment under construction, during which for each layer core samples are collected and analysed in the WRD lab to check the density achieved. During construction there is one junior engineer in charge of each section of the embankment who will monitor and does the core cutting. It is mandatory to have at least one roller at the construction site. In addition to the core cutting analysis, an independent team in WRD monitors the quality of the construction and the material used. In general there is no issue of getting good soil, except in some reaches with predominately black soil, which is unsuitable.

In both states independent discussions by the study experts revealed that the construction supervision needs to be improved. The present status is perhaps due to inadequate manpower coupled with inadequacy of resources, which the Governments at Central and State levels need to provide to the WRDs. Further, for the compaction stricter monitoring seems to be required (at least in Bihar). At present mere rollers and even some primitive methods are followed for compaction. This needs to be upgraded with more modern state of the art compaction machines.

Though some of the deficiencies do exist in the construction of the embankments, there is not much evidence to show that these constructions have been executed in an unsatisfactory manner. The typical major failures due to improper construction material or construction process have not occurred, except minor aspects of development of surface cracks in some reaches, which could be attended to in routine maintenance activity. In the case of the meandering Burhi-Gandak basin, it is fully appreciated that the recommendations of GFCC for hydraulic/physical modeling are very important for proper planning, design and implementation of embankments (see also section 4.4.6.2). In both basins timely maintenance works should be taken up with adequate resources.

2.6 Review of economic impacts of floods

There is no doubt that the recurrent floods in States such as Bihar and Odisha have a profound economic impact. But to estimate its magnitude is a complex matter. Even when we could make a complete picture, the question then arises: what do we do with this information? Does it give a direction towards solutions? Decisions on flood management measures are only partially driven by economic rationality. What is the economic value of a life? Is protection of a poor man's house less urgent than of a factory? This exemplifies that the distributional effects in economy should also be taken into account. And that finally the decision should be taken with due attention to economic as well as social arguments.

Nevertheless, the economic consequences of floods need to be factored in, not in the least because flood management requires investments of limited resources, such as capital and human resources. Floods cause damages and losses of all sorts. In economic terms, these are usually divided into direct and indirect effects. Direct effects such as material damage are relatively easy to quantify. However, losses due to disruption of businesses are often more difficult to assess. Indirect effects consist of both positive and negative feedbacks, are extremely difficult to quantify and therefore often ignored in economic assessments:

Direct effects:	Indirect effects:
Direct material damage: - houses and assets - vehicles - capital goods from enterprises - agricultural crops and livestock - infrastructure	Damage at suppliers and customers Substitution by production outside the flooded area Demand impulse through repair and reconstruction
Disruption of businesses	Permanent impact on productivity and competitiveness
Costs of rescue, evacuation and relief	

Damages

Damages after floods are recorded by the government and published, for instance by the Special Relief Commissioner of the Revenue and Disaster Management Departments in the states. Usually these records include damages to houses, crops, livestock and public infrastructure. Also the rescue and relief efforts are documented, although not always quantified in economic terms. Indirect effects are not included.

Annual flood damages in Bihar and Odisha amount to INR 2470 and 784 crore, respectively. The number of Bihar is somewhat distorted by the year 2007-08, which has nearly 150 time the average. An example of crop damages recorded over the past decades for Bihar is given in Figure 2 and shows an erratic pattern (some years with heavy floods) and an average loss of approximately INR 120 crore. This excludes the loss of livestock, which can also be substantial. The loss of cattle is of significant economic consequence to the rural poor living in flood-prone areas. Both states show an increasing trend in total flood losses which is correlated with increasing population densities and cropped area in flood prone areas. For instance, compared to the period 1980-93 the average annual damages in Odisha nearly doubled for the period 1997-2012 (see Vol. 2 Basin Plan).

The impact of flood damages on a state economy could be significant. For instance the Phailin cyclone caused a negative growth of 9.78% in the agriculture sector of Odisha and also affected several other sectors. This resulted in a slowdown of GDP growth in 2013-14. Furthermore, it is well understandable that the recurrent floods in states such as Bihar and Odisha hamper the modernisation and growth of the agricultural sector.

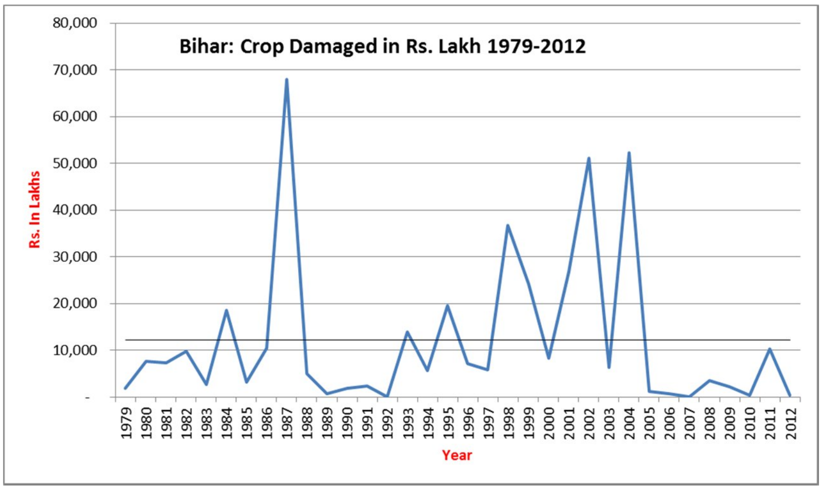

Figure 2 Crop damage in Bihar
Source: http://fmis.Bih.nic.in/River_Basin.html

Compared to these damages, the state expenditures on flood control are surprisingly low. Although expenditure in Odisha has risen significantly since 2007-2008, it amounts to only 3% of the flood damages averaged over the period 2000 to 2010 (Figure 3). The same percentage is found for Bihar. This provides a clear indication that an increase of investments in flood control seems highly justified from an economic point of view. This is also illustrated by the pilot study for the Jenapur floodplain (see Vol. 2 Basin Report section 4.3) which finds high benefit-cost ratios of around 5 for embankment improvements.

Although flood protection measures are the primary responsibility of the State, the Central Government supports the implementation of flood management works with both financial and technical assistance, especially in the case of inter-state rivers. But the flood issue has never been considered as a priority sector in the planning process or in the process of funding either in the State Plan or the Central Plan. Current levels of provisions under Five Year Plans and Finance Commission do not match desired capital investment in the IFM, as is evidenced above for the case of Odisha and Bihar.

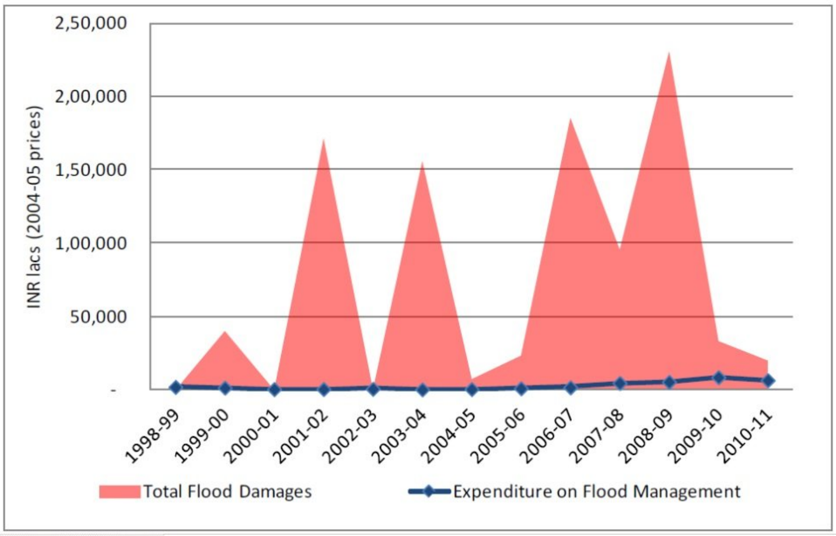

Figure 3 Flood damages and expenditures on flood management in Odisha
Source: "Financial Aspects of Flood Control, Anti-Sea Erosion and Drainage Projects", CWC (2013), OSDMA, Odisha, Phase 1 report (2014).

Expenditure on Relief and Rescue

The Relief Commissioner offices in both states have indicated that there is significant gap in the assistant sought and received from Government of India under National Calamity Contingency Fund, National Disaster Relief Fund for different calamities. The trend is to receive assistance less than 10% in most years with some exceptions.

Damage databases

Reliable flood impact and damage data are essential for the planning, monitoring and evaluation of flood risk management schemes. However, there is much confusion and inaccuracy regarding actual damage data. There is a basic need to improve the consistency and accuracy of collected data, as well as the storage and use of these data. Damage assessments are collected using a prescribed format (format 9) of the Disaster Management Departments in Bihar as well as in Odisha. These data are further compiled by the District Authorities and shared with the State DM Department for compilation. In this process there is no uniformity in database format at the state level. In In Odisha, monthly reports are generated and at the end of year, these reports are aggregated, after which it is difficult to find disaster or calamity specific data. In Bihar however, the data base is maintained on an annual basis with a flood specific damage inventory.

Thus there is need to evolve a standard uniform information system across all the states showing disaster specific damage inventory and assessment. To this end, capacity building and institutional strengthening programs are required, together with hardware, software and training in the use of a flood damage database.

2.7 Review of environmental impacts of flood management strategies

Various structural measures adopted to mitigate flood risks and optimise benefits from flood plains have impacts on natural hydrological and consequently ecological processes. Dams / reservoirs, detention basins, embankments and bypass channels all have impacts on the natural hydrological and morphological regimes either in upstream, downstream or in the location of the measure. Especially in the case of dams many studies and reports have been written on their environmental side effects. Also the environmental consequences of flood control, leading to a reduction of flood frequencies in floodplains and subsequent impacts on soil fertility, floodplain fisheries and original vegetation are relatively well documented.

Environmental impacts of non-structural measures tend to be mostly positive. Land use regulations for instance play an important role in catchment management and in reducing the risk due to flooding. They may involve interventions that affect the hydrological processes and include the introduction of suitable soil-protecting vegetation and crops, forestation, better forest management, controlling of shifting cultivation in conjunction with minor engineering works, e.g. trenches, contour bunds etc. Such regulations through bylaws for instance, can help in preventing negative consequences due to urbanisation or restricting development in such a manner that the hydrological response characteristics of the catchments are not changed.

Although floods themselves are a natural phenomenon and tend to have little or no environmental, impact, some effects can arise that result from anthropogenic activities in the floodplain. Those impacts are for example the spread of pollutants and chemicals from households, industries and utilities (sanitation treatment plants, power stations, fuel deposits, etc.), impeded fertility of land due to spread of sand or chemicals and spreading of disease and weeds.

2.8 Review of the current institutional arrangements

2.8.1 General

Several central and state level organizations in India are concerned with flood control and flood management (see Table 1 for the main national level organisations). The Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWRRD&GJ) is the policy making body and provides the overall governance of water resource sector for the country. The Central Water Commission (CWC), under the Ministry, is the apex body for planning, development and management of surface water resources in India and provides technical support services on water resource development to various agencies at the State level.

Table 1 Key organisations for flood management at national level

Sl. No.	Name
1.	Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWRRD&GJ)
2.	National Water Mission (NWM)
3.	Ganga Flood Control Commission (GFCC)
4.	Central Water Commission (CWC)
5.	National Disaster Management Authority and National Disaster Response Force
6.	National Remote Sensing Agency (NRSA)
7.	Indian Meteorological Department (IMD)

The State Water Resources Departments (WRD) are engaged in planning and executing specific water resource projects, including those on flood control, after receiving approval from CWC. The National Disaster Management Authority is the apex policy making body for disaster management related issues in the country, but also undertakes disaster rescue and relief operations through its field arm, i.e. the National Disaster Rescue Force. The State Disaster Management Authorities and the Disaster Response Forces are their state level counterparts. In addition, the agricultural and livestock departments of the respective states are also concerned with flood control. The next section describes the institutional capabilities at central (national) level. State level organisations for Bihar and Odisha are described in the respective basin reports (Vol. 2 and 3).

2.8.2 Institutional Capabilities at the central level

Central Water Commission

The CWC is administered through three wings and 17 organizations (see Figure 4). Each wing is headed by a Member-CWC. Each organization is headed by a Chief Engineer at CWC headquarters, New Delhi, and each organization has several directorates, headed by an officer in the rank of Director. For instance, the Hydrological Data Directorate is a directorate under the Information Systems Organization. Furthermore, there are 13 regional offices, each headed by a Chief Engineer. Two of the regional offices are in Patna and Bhubaneswar. The organization has around 1500 engineers to carry out its functions, which are displayed in Box 2 and Box 3. An important activity of CWC is flood forecasting and management at national level. A review of this activity is provided in section 4.4.11.

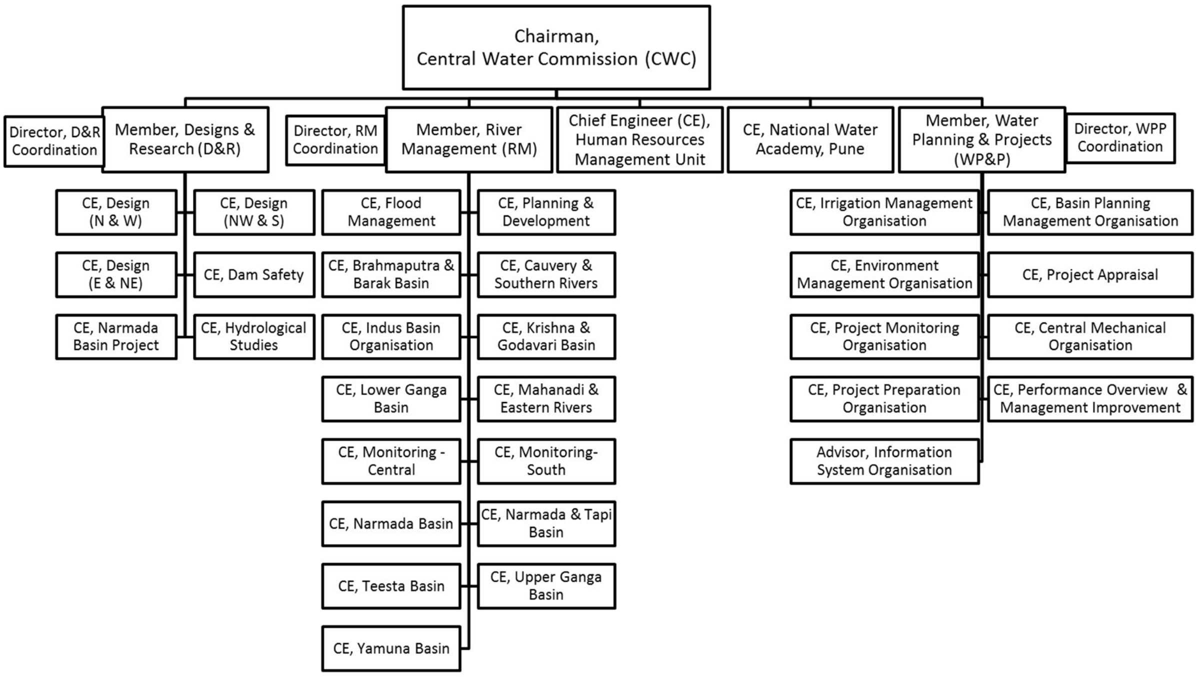

Figure 4 Organogram of Central Water Commission

From the list of activities being performed or expected to be performed by the Commission, it is evident that CWC remains as a technical agency in the field of (surface) water resources investigation, planning, design and development. Many of the CWC functions are unique and not available with any other technical agency of the Central and State governments. The capabilities to carry out these functions are technical in nature and have been enhanced over the period of decades. But, with the growing problems of water shortages and floods vis-à-vis their direct and indirect impacts on the society, water management is increasingly falling in the domain of multiple disciplines. A greater understanding of the socio-economic and environmental aspects of water resource use, and land use-hydrology interactions in river basins is needed, not in the least for implementing integrated flood management. This calls for better understanding of integrated water resources management in river basins.

Box 2. Key functions of Central Water Commission

1. Hydrological data gathering and validation
2. Analysis of hydrological data for estimating floods of different return periods
3. Developing models for flood forecasting; acquisitions
4. Techno-economic appraisal of water resource projects planned by the State governments
5. Training officials of state level agencies through National Water Academy on flood forecasting; flood management planning; and flood management strategies
6. To provide flood forecasting services to all major flood prone inter-state river basins of India through a network of 175 flood forecasting stations (see section 4.4.11 for more details).

Box 3. Other activities of the Central Water Commission

1. To collect, maintain and publish statistical data relating to water resources and its utilization including quality of water
2. Monitoring of selected major and medium irrigation projects, to ensure the achievement of physical and financial targets
3. To advise the Government of India and the concerned State Governments on the basin-wise development of water resources
4. To undertake necessary surveys and investigations as and when required, to prepare designs and schemes for the development of river valleys
5. To provide design consultancy including hydrological studies in respect of water resources projects, when so requested, to the state governments concerned/project authorities
6. To undertake construction work of any river valley development scheme on behalf of the Government of India or State Government concerned;
7. To advise and assist, when required, the State Governments in the investigation, surveys and preparation of river valley and power development schemes
8. To advise the Government of India in respect of water resources development, regarding rights of and disputes between different States which affect the conservation and utilization of water from any scheme, and any matter that may be referred to the Commission in connection with river valley development
9. To impart training to in-service engineers from Central and State Organizations in various aspects of water resource development
10. To initiate studies on socio-agro-economic and ecological aspects of irrigation projects for the sustained development of irrigation
11. To conduct and coordinate research on the various aspects of river valley development schemes such as flood management, irrigation, navigation, water power development, etc., and the connected structural and design features
12. To promote modern data collection techniques for water resources development, flood forecasting and development of related computer software
13. To conduct studies on dam safety aspects for the existing dams and standardize related instrumentation for dam safety measures
14. To carry out morphological studies to assess river behaviour, bank erosion/coastal erosion problems and advise the Central and State Governments on all such matters.

The 13 river basin organizations in CWC only carry out data collection and basin-wise compilation, and the Basin Planning Organization only undertakes planning for the un-utilized surface water resources. The additional capabilities required for IFM, such as (social) cost-benefit analysis of flood control projects, flood inundation mapping, water resource economics, environmental impact assessments, etc., are mostly lacking in CWC.

Capacity Building

The National Water Academy, formerly known as Central Training Unit, was set up by the Ministry of Water Resources in the year 1988 and is responsible for capacity building of officers within CWC and the State WRDs. It has state of the art facilities and undertakes training on almost every aspect of water resources planning, water resources development, water resource management, water conservation and agricultural water management (CWC, 2014). It was established under USAID assistance and subsequently strengthened with the assistance received from the World Bank.

Flood management and flood forecasting are among the many training courses conducted by NWA. Between 2009-10 and 2013-14, NWA organised a total of 9 training programmes on the topics of flood disaster management, design flood estimation and flood forecasting techniques. Each training programme lasted for about 5 days and was attended by an average of around 25 officers. Overall, 228 officers were trained on various aspects of flood management.

CWC is developing MIKE 11 models for flood forecasting in basins viz., Sankosh, Godavari, Brahmaputra and Yamuna. Development of these models is in progress and their performance is being monitored. The organization has around 20-25 hydrological modellers, some of whom are trained in flood modelling as well. The modelling capabilities of the organization are being strengthened under various projects, such as the 'Hydrology Project' and PATA 8086 (see Chapter 6 for training on SOBEK flood model during this project).

Ganga Flood Control Commission (GFCC)

The Ganga Flood Control Commission (GFCC) was created in the year 1972 to deal with floods and its management in the States located in the Ganges basin. The basin covers 11 States which include Bihar, Chhattisgarh, Haryana, Himachal Pradesh, Jharkhand, Madhya Pradesh, NCT of Delhi, Rajasthan, Uttaranchal, Uttar Pradesh and West Bengal. GFCC is a subordinate office of the Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWRRD&GJ) and is headquartered in Patna, Bihar. It acts as the Secretariat and executive wing of Ganga Flood Control Board (GFCB), which is headed by the Union Minister for Water Resources[6] .

Presently, the Commission is headed by a Chairman, who is assisted by two full time Members, four Directors and four Deputy Directors. The representatives of the concerned Central Ministries as well as Chief Engineers of the basin States are either part-time Members or permanent invitees of the Commission. Against a total sanctioned strength of 101 officers and supporting staff, only 59 posts were filled during 2014-15.

GFCC has prepared plans for flood management of all the 23 river systems of the Ganga basin and had sent the reports to the State Governments for taking follow up actions on the recommendations made in these reports. GFCC has also prepared the reports for adequacy of waterways under road and rail bridges for all the 23 river systems. Another important activity of GFCC is a techno-economic appraisal of flood management and anti-erosion schemes received from the Ganga basin States.

A Flood Management Programme (FMP) was launched by MoWRRD&GJ on the recommendations of the Task Force which was constituted in 2004 by the Prime Minster to look into the problem of

[6] The Board of the Commission consists of the Ministers of State for Water Resources; Union Minister of Finance, Railways, Road Transport and Highways, Agriculture or their representative; and, Chief Ministers of the basin States or their representative. Chairman, GFCC acts as the Member-Secretary of the Board.

recurring floods in the Ganga Basin[7]. A budget allocation of INR 8,000 crore during XI Plan and INR 10,000 crore during XII plan period were made for the programme. The programme covers the works related to flood management, river bank-erosion, sea erosion, drainage development and flood proofing.

To implement the programme, detailed schemes for flood management are formulated and submitted by the respective States to the Commission. Schemes which are estimated to cost in the range of INR 12.5 crore and INR 25 crore are examined by GFCC for their techno-economic viability, and if found feasible are cleared for funding. Schemes costing less than INR 12.5 crore are cleared at the State level by the State Flood Control Boards. Schemes costing above INR 25 crore, if found acceptable after appraising them for their techno-economic viability, are recommended by GFCC to the Advisory Committee for Irrigation, Flood Control and Multi-purpose Projects of the Ministry of Water Resources for clearance. GFCC also monitors all the schemes implemented under its FMP.

Till 2014-15, a total of 114 schemes were approved under the FMP, out of which only 63 have been completed. The maximum number of schemes was approved for Bihar (50), followed by Uttar Pradesh (26), Uttarakhand (21), West Bengal (12), Jharkhand (3) and Himachal Pradesh (2). However, West Bengal (INR 1,679 crore) had the largest share from the approved Central funds. This is followed by Bihar (INR 1,392 crore), Uttar Pradesh (INR 646 crore), Uttarakhand (INR 288 crore), Himachal Pradesh (INR 31 crore) and Jharkhand (INR 29 crore). Out of the total approved Central Government share of INR 4,066 crore for these schemes, about INR 2,130 crore has been released by the MoWRRD&GJ as per the monitoring reports and recommendation of GFCC.

Hence, it could be argued that the utilization of funds from the GFCC has been very poor, with an approved budget for works standing at INR 4,066 crore against a budgetary allocation of INR 18,000 crore. Further, in Bihar, where the annual flood damages are the highest, the utilization of central funds is very poor. More importantly, the larger concerns associated with structural interventions used for flood control such as 'shifting the area affected by floods' as noted in some of the recent research on north Bihar floods are not addressed in GFCC's flood management plans, which focus only on structural interventions.

National Disaster Management Authority (NDMA)

National Disaster Management Authority (NDMA) was established under the Disaster Management Act (DMA), 2005 of Government of India (GoI) and is headed by the Prime Minister. Various State Disaster Management Authorities (SDMAs) are headed by the respective Chief Ministers and the District Disaster Management Authorities (DDMA) are headed by the respective Chief Executive Officer. Operationally, NDMA is organized into the following divisions: policy & planning; mitigation; operations & communications; administration; and capacity building.

The main task is to spearhead and implement a holistic and integrated approach to disaster management in India. For this, NDMA is entrusted with framing policies and approval of the National

[7] This Task Force for Flood Management/Erosion control was formed in August, 2004 to address the recurring situation of floods in Bihar, Eastern Uttar Pradesh, West Bengal and Assam and its neighbouring States. The Task Force was headed by Chairman, CWC and in cognizance of the prevailing situation on the ground, suggested various measures for controlling flood/erosion. The report of the Task Force was submitted to the Ministry of Water Resources in December, 2004. Based on the recommendations of the task force, a plan scheme titled 'Flood Management Programme' was drawn up by the MoWR which was implemented during XI and XII Plan period. The schemes under the Programme were monitored by the Central Water Commission (CWC), Ganga Flood Control Commission (GFCC) and Brahmaputra Board (BB) in their respective jurisdictions.

Plan on Disaster Management, which includes prevention, mitigation, and preparedness. Further, NDMA guides various SDMAs to draw up their respective State Plans. Thus, it acts as a nodal agency to coordinate enforcement and implementation of the policy and plans on disaster management in the country. Capacity building is also an important role of NDMA. It equips and trains government officials, institutions and the community in mitigation and for response during a crisis situation or a disaster. It operates the National Institute of Disaster Management (NIDM), which develops practices, delivers hands-on training and organizes drills on disaster management. It also equips and trains disaster management cells at the State and local levels.

For the rapid collection, assessment and dissemination of information pertaining to natural disasters (such as floods) to the concerned parties for appropriate action, all the State and District Disaster Management Authorities have Emergency Operation Centres (EOCs) which are connected to the National Emergency Operation Centre (NEOC). The 'Level 0' disasters are mainly handled by the districts, 'Level 1' by the State Government and 'Level 2' by the Central Government. EOC plays a vital role in the emergency operation activation. During the normal times, it maintains a systematic database of the resources available, important phone numbers, names and addresses of important government and non-government officials, international bodies, and NGOs. During crisis, it functions as a centre for decision-making and help the flow of information to the respective departments for smoother relief operations. All the EOCs function on 24 x 7 basis and are functional round the year.

The NEOC, which is under the Disaster Management Division of the Ministry of Home Affairs (GoI) is responsible for monitoring the disaster or disaster like situation. It receive updates from central agencies like the IMD and the CWC and after processing the information, it submits its report and updates to affected States and concerned Central Ministries and organizations. Thus, NEOC act as a nerve centre for the States and districts for coordinated disaster response, recovery, rehabilitation and reconstruction.

National Disaster Response Force (NDRF)

The National Disaster Response Force (NDRF) was constituted in 2006 under the Disaster Management Act for the purpose of specialized response to natural and man-made disasters. The NDRF has a unique distinction of being the only dedicated disaster response force in the world. Presently, NDRF consist of ten battalions (see Box 4 for details).

Box 4. Details of NDRF battalions

Each battalion has 18 self-contained specialist, search and rescue teams of 45 personnel each including engineers, technicians, electricians, dog squads and medical/paramedics. The total strength of each battalion is 1,149. All the ten battalions have been equipped and trained to respond to natural as well as man-made disasters. Four battalions of them are also trained and equipped for response during chemical, biological, radiological and nuclear (CBRN) emergencies. The NDRF is headed and supervised by its Director General and the direction and control of the force is with NDMA.

On the basis of the country's vulnerability profile, the battalions are located at ten different locations to cut down the response time for their deployment at a disaster site. Between 2007 and 2013, about 1.3 lac people were rescued and thousands of food packets were distributed to affected people during various operations undertaken by the NDRF personnel in response to floods in different parts of the country.

One of the other important tasks of NDRF is to continuously engage themselves in the community capacity building and public awareness programmes on floods and other natural disasters. These programmes include training of people (the first responders) and concerned government officials at different levels in the areas with high vulnerability. Till 31 March 2010, NDRF has already trained more than 6.5 lac community volunteers throughout the country. Along with these, NDRF is also actively engaged in area familiarisation exercises for its force. Such exercises provide first-hand knowledge about the topography, access route to various disaster prone areas, availability of local infrastructure/ logistics which can be used in disaster response operations.

2.8.3 Summary of the institutional arrangements

The review of institutional capabilities for IFM showed that the existing institutions are not fully adapted to IFM requirements for various reasons. Below a summary is provided regarding the main deficiencies.

- Current institutional practices – such as state budget allocations, project planning, land use – address different sectors separately and are often not linked to the holistic needs of IFM. A clear example is the lack of flood proofing and land use regulations in the floodplain. Agencies that have a flood mitigation mandate, such as GFCC lack powers to enforce land use regulations to reduce flood damages.
- Many existing agencies still fall short in understanding of IFM principles, especially in relation to community needs. For instance the forecasting of 'water levels' or 'inflow volumes' provides information that is of no use from the community perspective of reducing flood risk. Instead, the community should be given information 'which area' and 'how much area' gets inundated during a flood hazard and what is likely to happen to their assets and properties. CWC is still a technical organisation and lacks the interdisciplinary capacities needed for IFM.
- Still the main focus of many agencies is on structural flood mitigation measures. For instance, while the GFCC develops flood management plans and supports flood control activities of various States falling in the basin through funding, the activities are all structural, and lack components for flood prevention and flood proofing. Also the WRDs remain mostly engaged in structural solutions to flood management, mainly the construction of embankments and dams (MoWR, 2014), and there is little integration of community concerns in the decision making (Sinha et al., 2012 for Bihar).
- The institutions are typically disconnected from the reality on the ground, as they do not maintain a dialogue with the local communities. The rigid hierarchies within each institution, their bureaucratic constraints, their lack of responsiveness to the needs of other institutions, and their dis-engagement with the communities render adaptation to IFM requirements very difficult (MoWR, 2014). This is evident from the reducing strength of field level staff involved in hydrological monitoring and monitoring, repair and maintenance of flood control structures.
- There is considerable overlap in the functions of various agencies. Often, the same agency is involved in multiple functions--from flood control measures to flood preparedness to issuing flood warnings to flood fighting. More importantly, none of the existing institutions have the knowledge, skills, human resources, legislative and administrative powers and financial muscle required for operationalizing integrated flood management concepts.

In contrast with the above described behaviour pervasive in most other institutions, the State Disaster Management Authorities do have taken a leadership role in drawing up protocols, conducting mass campaigns and training programs. They have also produced large amount of materials in Hindi, on basic steps to be taken by the community at times of emergency situation including floods. For instance in Bihar the BSDMA organises a 'disaster safety week' every year, in which children from 125,000 schools, including private schools from across the State come and participate. It is also co-ordinating well with other departments on flood mitigation activities.

Chapter 3 The impact of climate change on flood hazards

3.1 Introduction

It is now clear that enhanced climate variability and climate change due to continued emission of greenhouse gases in the earth's atmosphere will alter the key characteristics of summer monsoon rainfall and could significantly impact water supply and demand throughout the Indian subcontinent (Lal et al., 2000; May, 2011; Meehl and Arblaster, 2003; 26 Rupakumar et al. 2006; Trenberth, 2011). Typically, climate change is described in terms of long term average changes in temperature or precipitation. Given that weather extremes are directly affected by climate change, it is important to understand the degree to which the adverse impacts of these could exacerbate the flooding intensity and frequency in major river basins in the future. Attention is increasingly being paid to climate adaptation strategies at the regional and basin level. However, the current paucity of information regarding the potential risk to hydrological systems at this scale presents a substantial challenge for effective water resources planning and investment.

Across India, under future climate change, the frequency of years with above normal monsoon rainfall and of years with deficient rainfall is expected to increase. More rainfall is projected in the monsoon season, the traditional wet period, and less in the already dry months, highlighting difficulties for sustaining crops throughout the year. At the same time, rainfall events are projected to be more intense and possibly less frequent, with predictable implications for flooding and drought.

In the above context, the present study has attempted to assess the possible impacts of climate variability and climate change on the flood hazards in the two selected basins of India (i.e., Burhi-Gandak basin of Bihar and Brahmani-Baitarani basin of Odisha). This approach could be used as an example for similar studies for estimating the climate change impact on flood hazards in Indian basins.

It must be emphasized here that global climate models generally provide consistent and reliable simulations of climate variables only at large continental to global scales. This is because the variability of the climate increases at smaller geographic and shorter temporal scales. Additionally, the grid cells of the models are usually more than 100 km wide, which is larger than important features that matter for local climate like mountains and land cover. Therefore, in this study much effort has been given to properly downscale climate change from global models.

3.2 Method used in the climate change study

The investigations used the following steps:

i. Selection of CMIP5[8] Climate Models;
ii. Selection of the scenario for likely increase in greenhouse gases (Representative Concentration Pathway - RCP);
iii. Assessment of confidence level in the climate models i.e., validation of new CMIP5-based rainfall projections for the two selected river basins by comparing the CMIP5-based model

[8] CIMP5 = Fifth Coupled Model Inter-comparison Project (Taylor et al., 2012; Knutti and Sedláček, 2013)

simulated climate for the period 1961–1990 with that of APHRODITE-based observed climatology[9] over the same period;

iv. Approach to bias correction;
v. Assessment of CMIP5-based mid (2040s representing climatology over 2030–2059) and long-term (2080s representing climatology over 2060–2099) climate change projections (temperature and precipitation) for the two selected river basins; and
vi. Assessment of the projected change in frequency of extreme rainfall events over and around the two river basins based on CMIP5 projected climate change.

Details on our approach to climate models considered, validation exercise performed and data analysis approaches as well as the details on climate change scenarios are discussed in the following sections.

3.2.1 Selection of climate models

Almost all Fifth Coupled Model Inter-comparison Project (CMIP5) models show a fair skill in simulation of surface air temperature averaged over South Asia and the Indian Sub-continent, with MIROC-ESM (developed by Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute, University of Tokyo and National Institute for Environmental Studies) as one of the models closest to the observations. Yet, for area-averaged annual and seasonal rainfall the models significantly deviate from observations over India (Chaturvedi et al., 2012). Here, GFDL-CM3 (developed by National Oceanic and Atmospheric Administration, United States) is one of the best performing models. In addition, HadGEM2-ES (developed by Hadley Centre, UK) will be selected because it is one of the most commonly used GCMs (Sondergard, 2009). For India, the three abovementioned GCMs, that will be selected for the generation of the climate change projections in this project, nearly span the uncertainty band for annual mean rainfall and temperature that was obtained with 18 Earth System Models (ESMs) used in a validation exercise (Mondal and Mujumdar, 2014). Interpreting Menon et al. (2013), HadGEM2-ES could be regarded as ‘too dry’, GFDL-CM3 as ‘representative’, and MIROC-ESM as ‘quite wet’.

3.2.2 Selection of the emission scenario (RCP)

The Representative Concentration Pathways as considered in IPCC AR5 (Vuuren et al., 2011) are compatible with the full range of stabilization, mitigation, and baseline emission scenarios, and span a full range of socio-economic driving forces (Hibbard et al., 2011). In this study, we will consider RCP6.0 for the generation of the climate change projections as it follows a stabilizing CO_2 concentration close to the median range of all four policy pathways and will give us a not too extreme indication of what might change. Most likely the spread and uncertainty in projections will increase when including additional RCPs and changes may become more pronounced when using the extreme RCP8.5 (Hibbard et al., 2011).

[9] Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation of Water Resources, Japan (Yatagai et al. 2012).

3.2.3 Assessment of confidence level in climate models

Assessing climate projections is quite different to assessing weather forecasts. Weather forecasts are initialized with current observations and provide predictions of the next 1-10 days that can be continually assessed against observations. Climate is the average weather. Climate projections are simulations that are largely independent of the initial conditions and designed to show the long-term response of the climate system to hypothetical, but plausible, scenarios of external forcings into the future. Climate projections are not expected to give accurate predictions of individual weather events into the far future. However, it is expected that the projections will show a plausible change to multi-decadal climate statistics if a particular RCP is followed and natural climate variability is taken into account.

Confidence in projections can be assessed by comparing the skill of the models in simulations of the current climate and past climate changes with observations. Further, in reality, projections for 2030 and beyond can never be fully assessed against observations, the concentrations of greenhouse gases in the atmosphere will probably not play out exactly as specified in any one RCP, and there is likely to be more unpredictable natural forcing factors such as volcanic eruptions. These factors affect what constitutes confidence in climate projections, and how it is assessed. Confidence comes from multiple lines of evidence including physical theory, past climate changes, and climate model simulations.

In this study we have compared baseline (i.e., 1961-1990) simulations of rainfall simulated by the three GCMs with the observation to assess the confidence level of GCM's skill in simulating the present day rainfall. Here we used observed rainfall data obtained from the APHRODITE long-term daily gridded precipitation dataset version V1101 for Monsoon Asia (Yatagai et al., 2012). The APHRODITE dataset is a long-term (1951-2007) continental-scale product that contains a dense network of daily rain gauge data for Asia including the Himalayas, South and South East Asia. The dataset consists of 0.25° × 0.25° resolution gridded daily precipitation derived from the Global Telecommunication System (GTS), precompiled datasets and APHRODITE's individual data collection. The data is quality controlled and corrected for orographic effects. It includes over 2000 stations over India and captures the large scale features of monsoon rainfall over the Indian region well (Rajeevan and Bhate, 2008).

The comparison results indicate that baseline simulations of the three GCMs have a fair skill in simulating the observed rainfall during monsoon season rainfall (Figure 5). Overall baseline simulations show an over-estimation of average seasonal rainfall by about 13% in Burhi-Gandak basin and about 8% in Brahmani Baitarani basin, respectively as compared to observed monsoon season rainfall.

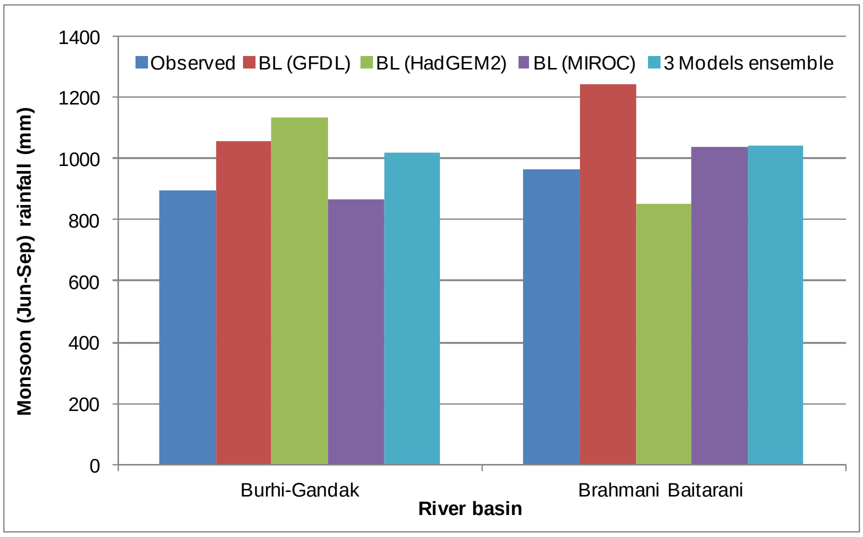

Figure 5: Comparison of monsoon season (Jun-Sep) mean rainfall between observed (APHRODITE) and simulated by the three GCMs for the baseline period (1961–1990)

3.2.4 Approaches to Bias Correction

Because of the bias from observations in the results produced by GCMs as shown in Figure 5 these GCM outputs can therefore not directly be applied for impact studies at the catchment scale (Fan et al., 2010). Dynamic downscaling, statistical downscaling, and bias correction are the most commonly used methods to generate locally applicable climate data (Schoof et al., 2009). Dynamic downscaling includes nesting of high resolution Regional Climate Models (RCMs) with GCM outputs at boundaries which ensures consistency between climatological variables. However, they are computationally expensive, their skill strongly depends on GCM boundary and for India we do not have any ready to use RCM scenarios for the RCP emission scenarios at hand. Statistical downscaling models, on the other hand, are based on statistical relationships between large-scale climate variables (predictors) and local-scale climate variables (predictant) and hence require less computational time. Yet, for the establishment of reliable statistical relationships long historical observed records of both predictor and predictant variables should be available.

Simpler bias correction procedures consisting of general transformation techniques for adjusting the GCM output time series are often used. They assume a stationary bias between GCM output and observations for the baseline period and future climate (Teutschbein and Seibert, 2012). There are several bias correction approaches from which we have chosen the Delta Change (DC) approach to generate rainfall daily time series data for the future time slices centred around 2040s and 2080s[10]. The Delta Change method transforms historical observations into future projections using monthly change factors that are derived from the GCM simulations for the current and future climate (Camici et al., 2014; Chen et al., 2013; Teutschbein et al., 2012b) according to:

$$\Delta P_m = \frac{\overline{P\_GCM^{fut}{}_m}}{\overline{P\_GCM^{BL}{}_m}} \qquad (1)$$

$$P\_OBS^{fut} = \Delta P_m \,.\, P\_OBS^{BL} \qquad (2)$$

[10] For a comparison of the Delta Change method with the Linear Scaling bias correction methods, please see the article which was prepared in this study (Appendix B).

where *fut* refers to future climate, *BL* refers to baseline (i.e. 1960-1990) climate, *GCM* refers to GCM simulations and *OBS* refers to either observations (*BL*) or future projections (*fut*), *P* refers to daily precipitation values and P_m refers to monthly long term average precipitation values (see Box 6).

Box 6. The steps followed are detailed below:

- As a first step, 30 years (1961-1990) daily time series of observed high resolution (0.25° × 0.25°) global gridded rainfall climatology data of APHRODITE, model simulated baseline (1961-1990) and projected rainfall data for two future time horizons (2030-2059 and 2070-2099) were extracted from global data sets of three above-mentioned climate models. Following this, a multiplication factor was calculated by dividing the monthly aggregate rainfall value of the modelled baseline data by the monthly aggregate rainfall value of projected rainfall data for two time horizons. This exercise was carried out for monthly total rainfall (RF) of each year (as per the given example for 2040s here under):

  $RF\,(2030_{Jan})_{2040s}$ /$RF\,(1961_{Jan})_{BL}$,....................., $RF\,(2030_{Dec})_{2040s}$ /$RF\,(1961_{Dec})_{BL}$
  .
  .
  $RF\,(2059_{Jan})_{2040s}$ /$RF\,(1990_{Jan})_{BL}$,....................., $RF\,(2059_{Dec})_{2040s}$ /$RF\,(1961_{Dec})_{BL}$

- Subsequently the multiplication factor for 2040s for each month arrived at was applied in observed daily rainfall data series to obtain the projected bias corrected daily rainfall time series for 2040s. Say month-wise multiplication factors for $RF\,(2030_{Jan})_{2040s}$ /$RF\,(1961_{Jan})_{BL}$,..................... $RF\,(2030_{Dec})_{2040s}$ /$RF\,(1961_{Dec})_{BL}$ are Jan_{2030},......,Dec_{2030} then bias corrected daily level rainfall data for 2030 will be 1^{st} Jan* Jan_{2030}, 2^{nd} Jan* Jan_{2030},.......,31^{st} Dec_{2030}* Dec_{2030}.

- Similar exercise was applied for obtaining the projected bias corrected daily rainfall time series for 2080s as well using the multiplication factor inferred for each month of 2080s.

The bias corrected daily time series rainfall data for the future time slices thus derived have been used to calculate future projections of likely changes in annual and seasonal monsoon rainfall and various indices such as events of light rain, moderate rain, heavy rain, maximum rainfall intensity, etc. This daily rainfall data for the future time slices at each grid point over the identified river basins in Bihar and Odisha have also been appropriately applied in the hydrological modelling exercise undertaken in this project.

3.3 Key Results

Higher temperatures

Not surprising perhaps is that model results show a rise of surface air temperatures (day and night) for both basins (Table 2). But the increases are substantial and these scenarios suggest that the intensity of heat waves in and around both river basins should become stronger with time during peak summer months and high temperatures could be experienced here more often in future.

Table 2 Changes in mean annual maximum and minimum surface air temperature over selected river basins

	2040		2080	
Sub-basin	Day-time max. temperature	Night-time min. temperature	Day-time max. temperature	Night-time min. temperature
Burhi-Gandak	+2.0°C	+2.2°C	+3.5°C	+4.0°C
Brahmani-Baitarani	+1.7°C	+2.1°C	+3.0°C	+3.7°C

Source: based on GFDL-CM3 Model generated data

Increase in rainfall during monsoon

An examination of the change in rainfall patterns as inferred from an ensemble of three models considered here suggests (Table 3 and Figure 6) that the total rainfall during the South-West (S-W) monsoon season is projected to increase during the middle of the century with 9 and 21 % for both basins, respectively. By the end of the century increases in monsoon rainfall go up to 20 and 27% for the basins. On annual basis, the total rainfall could increase over the Burhi-Gandak basin by 20% at the turn of the century. For the Brahmani-Baitarani basin this total could even increase with 40%.

Table 3 Changes in seasonal and annual rainfall due to climate change over selected basins

	Seasonal monsoon rainfall (mm)			Increase in annual total rainfall (%)
Sub-basin	Current	2040	2080	2080
Burhi-Gandak	896	974 (+9%)	1085 (+20%)	20%
Brahmani-Baitarani	1017	1230 (+21%)	1291 (+27%)	40%

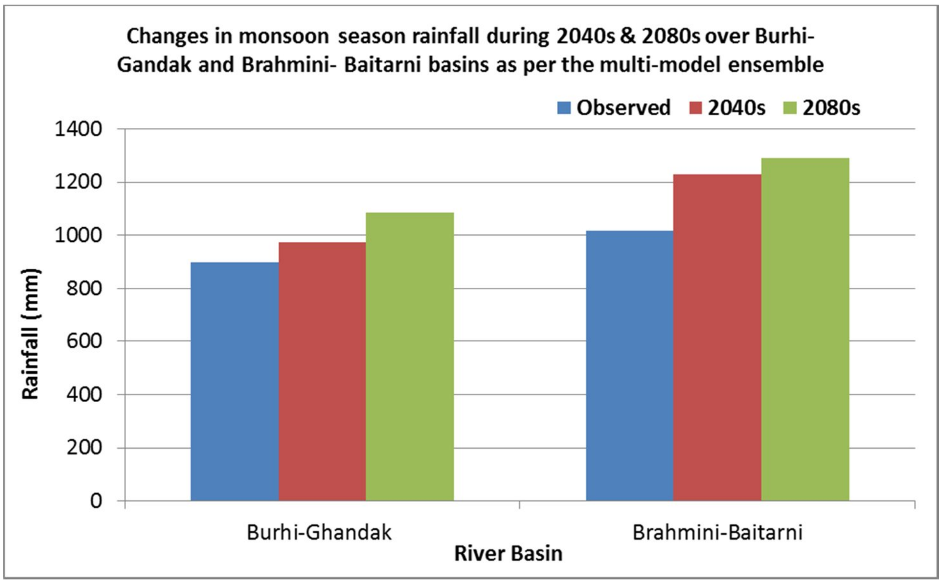

Figure 6. Changes in monsoon season rainfall during 2040s & 2080s w.r.t. baseline period (1961-90) over Burhi-Gandak and Brahmani-Baitarani basins as per the multi-model ensemble (HadGEM2, GFDL, & MIROC)

Increase in moderate and heavy rainfall events

Next to the increases in seasonal or annual rainfall also the nature of rainfall intensity over the basins is important, especially in view of the occurrence of (extreme) flooding events. Each of the climate models simulate a decline in the frequency of light rainy days and increases in moderate and heavy rainfall episodes in future decades (Figure 7). It is thus evident that as the total seasonal rainfall as well as the episodes of heavy rainfall incidences is projected to increase, the river catchments are likely to face more widespread flooding by the end of the 21st century.

The projected rise in maximum surface air temperature over both basins further suggests the occurrence of warmer air with higher water holding capacity and stronger convective activity during May – June. This can lead to more intense spells of rainfall associated with thunderstorm activity just prior to the S-W monsoon season which may contribute to faster stream flow and result in flash floods in parts of the catchment area.

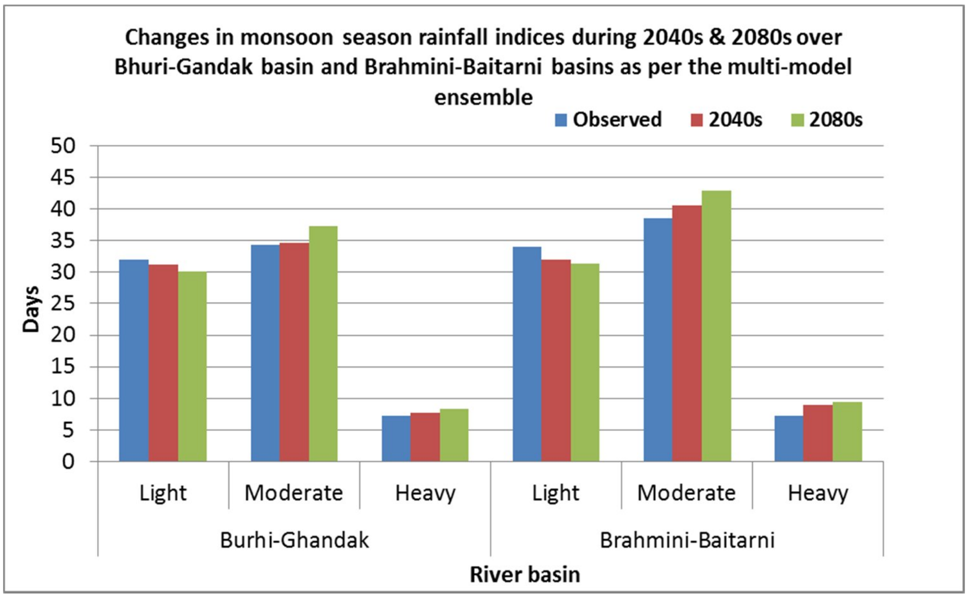

Figure 7: Changes in rainfall indices during monsoon season of 2040s & 2080s w.r.t. baseline period (1961-90) over Burhi-Gandak and Brahmani-Baitarani basins as per the multi-model ensemble (HadGEM2, GFDL, & MIROC)

The models' representations of annual rainfall cycles and its projected changes are highly varied over the selected river basins (see Chapter 3 in Volumes 2 and 3). Whilst the climate models capture the July–August peak in rainfall over India as well as the selected river basins realistically (although with tendency to over-estimate the magnitude in June and/or September), the seasonal cycles as well as a set of metrics describing the climatological and inter-annual / intra-seasonal variability in some of the sub-regions is generally much poorer.

The future scenarios presented above provide an indication of an overall increase in the intensity of mean rainfall during monsoon season. The analysis of 30 years of daily rainfall data further indicates that most intense spells of rainfall in a season could increase in future. However, caution must be applied in making strategic decision on local scales based on these climate projections.

3.4 Impacts of climate change on flood extent in the two basins

The projections on change in rainfall within the two river basins and associated statistics on indices were used as forcing for the hydrological model SOBEK in order to infer the future climate induced changes in surface runoff and flood characteristics for time slices of 2040s and 2080s in this study. The results of the modelling are tabulated in Table 4. It shows that for the Burhi-Gandak an increase of 5% in flooding extent could be expected in 2040 and even 22% in 2080 for annual floods (occurring once every 25 years).

For Brahmani-Baitarani, these percentages are 25% and 29% increase in flooded surface, during a 1:25 year flood event, for the two time horizons. Partly, this increase is caused by increased rainfall, and partly because of a projected sea level rise of around 50 and 77 cm for 2040 and 2080, respectively.

Table 4 Impact of climate change on flood extent for two basins

Basin	Baseline (current)		2040		2080	
1:25 year	Maximum flooding extent (km^2)	Max. flood volume (Mm^3)	Maximum flooding extent (km^2)	Max. flood volume (Mm^3)	Maximum flooding extent (km^2)	Max. flood volume (Mm^3)
Brahmani-Baitarani	3151	9306	3933 (+25%)	12508 (+34%)	4070 (+29%)	13712 (+47%)
Burhi-Gandak	1571	2590	1644 (+5%)	2650 (+2%)	1911 (+22%)	2972 (+15 %)

Chapter 4 Strategic framework for integrated flood management

4.1 Introduction to integrated flood management

4.1.1 Risk informed decision making

Our strategic framework for integrated flood management is based on a risk approach. As mentioned earlier, risk informed decision making is decision making based on estimates of flood risk as well as the costs and benefits of flood mitigation and management. We therefore need to be well informed about the risks of flooding, for which first of all a good definition is needed (section 4.1.2). The planning approach is based on three steps: risk analysis, risk evaluation and strategies & measures. These three steps are to be followed in an iterative way, not only within one planning cycle, but also over the years as flood plans need frequent updating (section 4.1.3).

4.1.2 Hazard, vulnerability and risk

Hazard, vulnerability and risk are closely related terms and therefore should only be used once properly defined, thus avoiding overlapping meanings. In this project we will use broadly accepted definitions (e.g. GFDRR, World Bank, EU). We consider a hazard as a potentially damaging physical event (in this case flood) that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. A hazard does not necessarily lead to harm: this depends on the exposure of people, buildings, infrastructure, etc. to this hazard. Combining the hazard with the vulnerability of people and assets gives the risk:

Risk = Hazard x Vulnerability

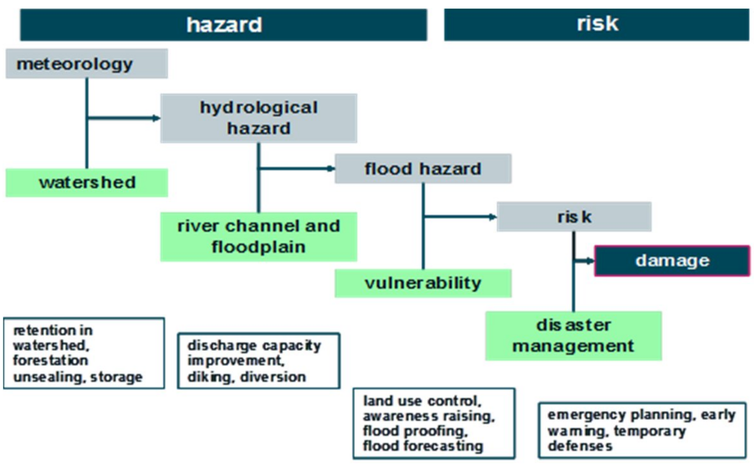

Figure 8 Hazard, risk and vulnerability explained (Source: Deltares)

Importantly, hazard includes the probability of occurrence: therefore we can also describe the risk as the product of the probability of the event and the consequence of that event. Such events need to be described in terms of the nature and probability of the hazard. Flood risk can be expressed as the (annual) expected impact (e.g. an average annual damage). In Figure 8 the relation between hazard and risk is illustrated for floods.

For vulnerability analysis we will use the framework of Turner et al. (2003). From this figure (Figure 9) it can be seen that vulnerability is driven by the interaction between the human conditions and environmental conditions. Most important message is that vulnerability can be described in terms of exposure, sensitivity and resilience (coping capacity). Hence, we can use these elements for identifying non-structural measures to reduce vulnerability and (therefore) risk.

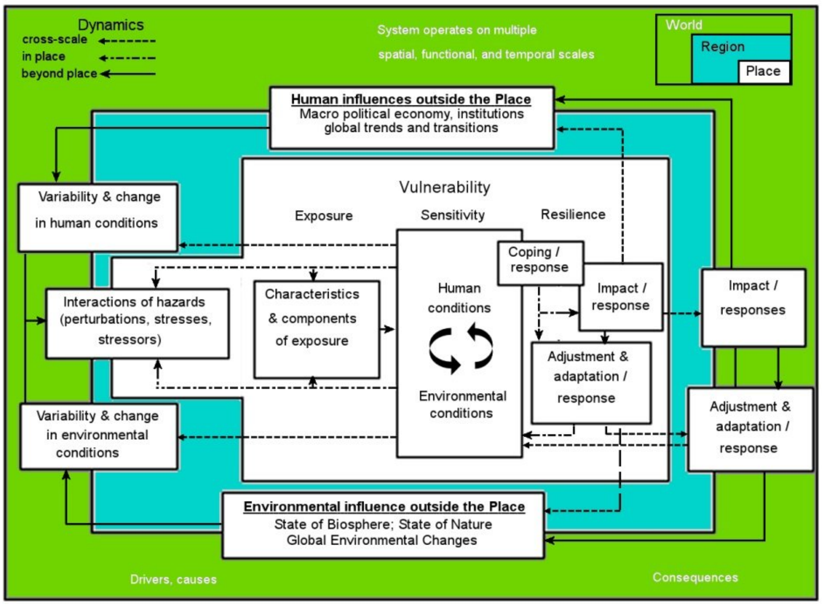

Figure 9 Vulnerability framework (Source: Turner et al., 2003)

Poverty is one of the main factors that influence vulnerability to floods. Poor people are often living in hazardous areas (e.g. in the floodplain), which makes them exposed. The housing conditions are often bad which makes them sensitive, while their resilience to shocks is low because they do not have a buffer e.g. in the form of capital. This makes it therefore very important to take into account the human conditions, livelihood and household situation when making plans for flood management. Vulnerability assessments are especially important for preparing disaster preparedness plans and should determine the vulnerability of people of different age groups, income levels, education, capabilities and coping capacities to hazards. In our study we therefore executed both a household survey among approx. 500 households and a number of Focal Group Discussions. It was found for instance through these consultations that communities in the two basins generally lack disaster preparedness plans and are also in need of more timely warnings when floods are imminent (see section 4.4.10).

4.1.3 IFM planning approach

Integrated Flood Management (IFM) planning is an iterative process towards risk based decision making. Basically it consists of three steps: i) Risk Analysis, ii) Risk Evaluation and iii) Strategies and measures (Figure 10). Risk Analysis includes modelling required for preparation of risk maps. Risk Evaluation is essentially a societal and policy process in order to answer the question: how safe is safe enough? The inputs to this discussion are the risk maps and the potential measures to reduce the risk. It includes stakeholder views, local risk perceptions as well as economic considerations regarding the acceptability of damages and the cost-benefit or cost-effectiveness of risk reducing measures. The result is a recommended (set of) safety level(s) leading to planning and design of the measures.

In order to develop an IFM strategy, based on a recommended safety level, various structural and non-structural measures are to be analysed and implemented. This includes economic feasibility and financing of measures, social and cultural aspects, environmental considerations (sometimes requiring an Environmental Impact Assessment) as well as operation and maintenance aspects. In the next sections the three steps of IFM will be elaborated.

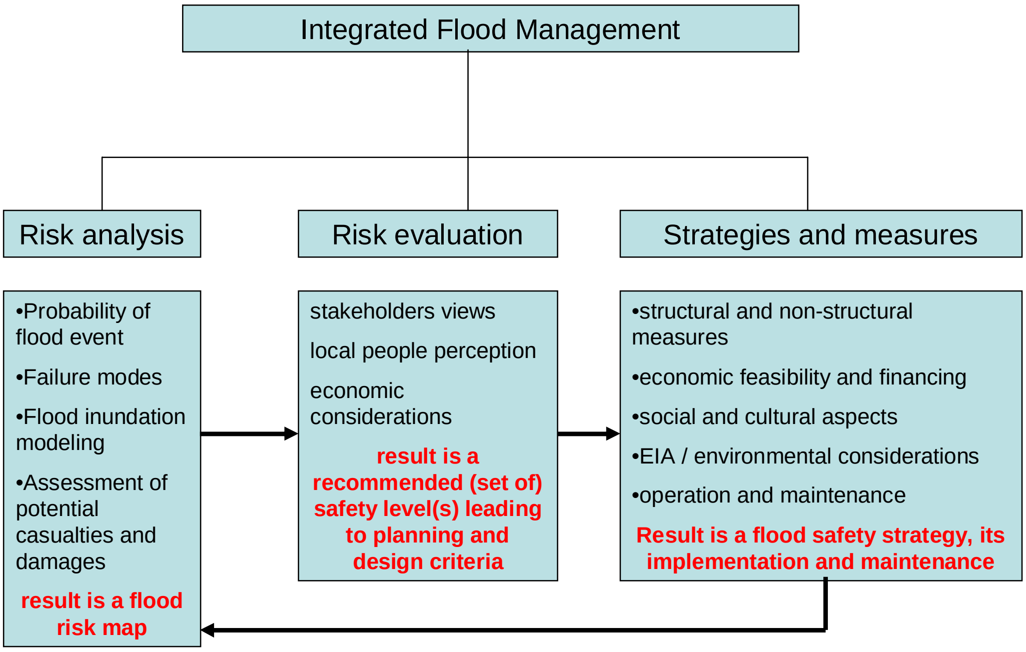

Figure 10 Sequence of planning for flood risk management (Source: Deltares)

4.2 Flood risk analysis

For the calculation of a risk it is crucial to have knowledge about the possibility that an extreme event will happen. This could be a high river discharge caused by heavy rainfall in the catchment, a deadly storm surge generated by a combination of spring tide and strong winds, or a tsunami triggered by an earthquake. Essentially, many of these phenomena are stochastic, which means that their occurrence is difficult to predict. Luckily we have historical records of past events, and therefore we can use (extreme value) statistics to identify the threat[11]. Such extreme event could cause landslides and flash floods on the spot, but may also cause flooding far downstream. But in order to assess the flood extent we need to calculate what happens between the source (somewhere in the watershed) and in the floodplain or delta areas downstream. We may use models or empirical rules to calculate the high water levels which threaten the existing flood control structures, such as embankments. Geotechnical information on the strength of the embankments and its height can tell us if a breach or overtopping is likely, leading to actual flooding. All these are technical aspects of the risk analysis, and are depicted as blue boxes in Figure 11. In our study we prepared for the two studied basins a hydrological and 2D hydraulic model to simulate various conditions (see Box 7). The set-up of the model is documented in Vol. 5, whereas the results of the model simulations are described in the two basin reports (Vol.2 and Vol.3). Examples of flood modelling studies are given in Appendix E-1.

Information about the socioeconomic conditions in the affected areas enables us to assess the exposure and vulnerability component of the risk. Different flood characteristics, such as flood depth,

[11] However, we must be aware of the assumption of stationarity: that the occurrence and recurrence intervals of floods in the observed past are assumed to represent occurrence in the future, thus permitting extrapolation. This assumption presupposes that the system is stationary, and that the observed record provides an exhaustive sampling of all possible events. That is clearly invalid if, for instance, drainage basins are changed by human activities and other events, or if rainfall patterns are affected by local or global climate variations (Klemeš 2000).

flow velocity, presence of debris or contamination, duration of inundation, rate of rise and timing result in different damages. Flood characteristics interact with characteristics of elements at risk of damage, such as building material or growing stage of crops, to generate damage. In the commonly used flood risk assessment approach (Marchand et al. 2009; Merz et al., 2010; Ward et al., 2011; Budiyono et al., 2015) this complex relationship is represented in a highly simplified way by a vulnerability (or fragility) curve. The curve typically represents the relation between flood depth and damage for a specific land use category representing elements at risk.

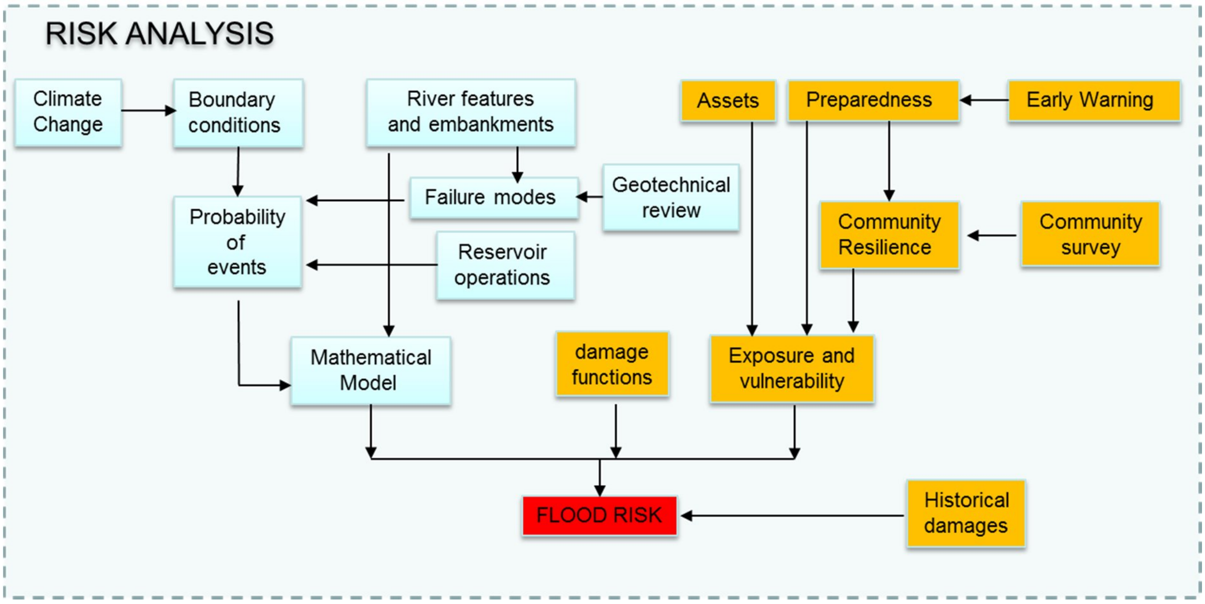

Figure 11 Steps in the risk analysis (Source: Deltares)

Multiplying this damage with the probability (return period) gives us the average annual damage (AAD). For instance a damage of INR 10 crores incurred by an event with a return period of once in 10 years would equal an annual damage of INR 1 crore. But of course there could also be more extreme events with a much lower frequency and higher potential damage. So in order to derive risk estimates, the calculated flood damages are combined with information on the probability of such events and then plotted as an risk curve, whereby the risk is approximated by the area under the curve (Meyer et al., 2009) (Figure 12). In practice, pragmatic considerations of time and resource availability dictate the number of data points used to develop such a risk curve (Ward et al., 2011).

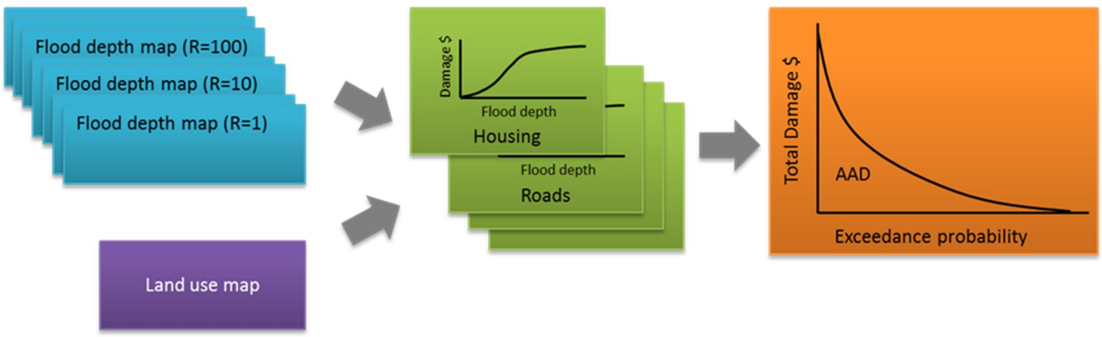

Figure 12 Calculation of a flood risk curve

A similar procedure can be followed regarding the potential fatalities. Instead of fragility curves for damages we use fatality curves, relating the loss of life to one or several flood parameters (usually depth but also velocity is important here). It is common to keep the risk to (economic) damages separated from the risk of loss of life, although sometimes lives lost are monetised into an economic value.

Box 7. The importance of a good modelling practice

Flood hazard and risk mapping consists of the application of flood modelling software using hydro-meteorological data as well as topographical data, such as elevation, cross sections, embankments, dam operation and infrastructure, and exposure data, such as houses and crops. Usually two different models are required for this: a hydrological model (rainfall-runoff) and a 1D/2D hydraulic model. Flow over flat terrains is best described by the 2D equations, whereas channel flow and the role of hydraulic structures are satisfactorily described in 1D. In our study we have used a fully dynamic two dimensional hydraulic model, which deploys a DEM (Digital Elevation Model) and calculates the flood extent and depth at every time step.

Because the concept of risk includes a probability of a flood, the necessity arises to assess return periods of certain flood events to be able to prepare flood risk maps. The floods in both Burhi-Gandak basin and Brahmani-Baitarani basin are the result of several, sometimes independent factors. For instance in the case of the Brahmani-Baitarani three forcing factors are important: rainfall in the catchment, the operation of the Rengali dam and the tidal levels (storm surges) along the coast.

This necessitates a joint probabilistic approach. The principal approach is to define the range of potential (extreme) events that may cause floods and then to subsequently:

1. Simulate these events with the hydrological-hydraulic model to obtain the inundation depths in the project area, and
2. Derive the probability of occurrence of each event.

Based on the combined information of 1. and 2. the probabilities of water levels and inundation depths in the project area can be determined by using an appropriate probabilistic computation technique. With the resultant model framework both scenarios (such as climate change scenarios) and measures and strategies can be simulated and analysed.

4.3 Evaluation of flood risks

4.3.1 Is there a need for new measures?

Evaluation of flood risks involves deciding whether the EAD and expected number of fatalities is acceptable socially and economically or not. The easiest situation is when there is already an accepted safety standard for flood risk. For instance, in India the design standard for embankments is stipulated to be based on return periods of water levels of 25 and 100 years for protecting rural and urban/industrial areas, respectively. Ideally, the height of the embankment and the corresponding cost and B/C ratio should be worked out for various flood frequencies taking into account the damage likely to occur. The degree of protection which gives the maximum benefit cost ratio should be adopted (BIS, 2000). This would entail a Cost Benefit Analysis, which allows for calculating this optimum (see next section).

Importantly, as per our model calculations for both river basins it was found that by providing the 1:25 safety standard for rural areas around 90% of the average annual damage could be avoided. This implies that the marginal extra benefits quickly diminish beyond this safety standard.

Also the community needs and conditions need to be taken into account in the evaluation. There can be other than purely economic reasons for establishing the safety level. This is further elaborated in section 4.3.3. The outcome of the evaluation should determine whether or not additional (new) measures need to be taken (Figure 13).

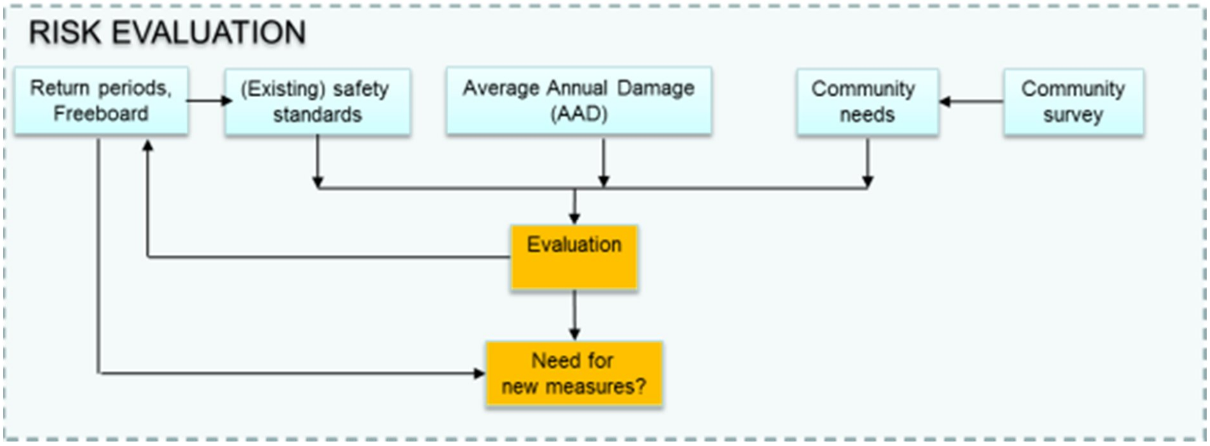

Figure 13 Steps in the risk evaluation (Source: Deltares)

4.3.2 Economic evaluation

Flood protection competes with other public investments under limited budgets. Efficient allocation of budget requires an economic analysis in addition to social, ethical and other considerations. Economically efficient flood protection requires that the benefits of the investments are equal or greater than the costs as expressed by Net Present Value (NPV), Benefit Cost Ratio (BCR) or Internal Rate of Return (IRR) criteria. Determining the costs of flood protection measures is usually straightforward and involves estimating construction and other implementation costs and estimation operation and maintenance costs over the project life cycle and discounting them to a present value. The benefits of flood protection are basically the avoided damage – the expected damage that would have occurred without flood protection. Determining expected damage is not a straightforward task as several types of damages need to be determined for a range of floods with different characteristics in a data and information scarce situation.

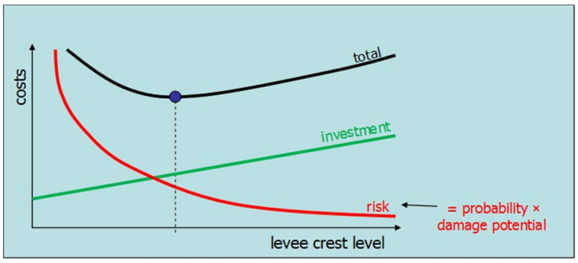

Figure 14 Cost Benefit Analysis for of determining the levee crest level (example)

The economically optimal level of flood protection is the point where the marginal costs (costs of additional infrastructure or measures) is equal to marginal benefits (reduction in AAD)(Figure 14). Although conceptually simple, this point is difficult to determine, especially if changes over time, such as economic growth, are to be included (Kind, 2014). To find the economically optimal level of protection several approaches can be followed. Firstly, the impact of individual flood protection measures on flood depth or the vulnerability curves (in case of for instance early warning systems) and hence reduction in AAD can be determined (see Figure 15). In this manner it can be assessed if the costs are lower than the reduction in AAD for the associated return period. This will result in a location and measure-specific optimal level. For homogeneous infrastructure, such as dikes, the optimal protection level for specific areas can be calculated in this manner (see for instance Kind, 2014).

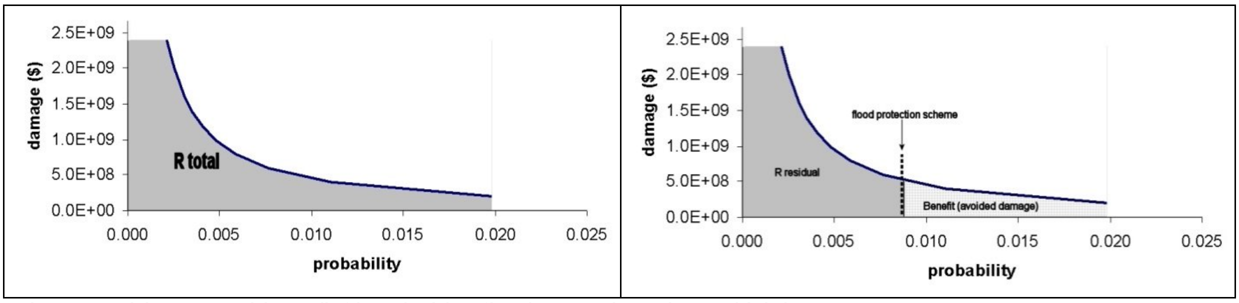

Figure 15 Risk curves without (left) and with a flood protection scheme (right)

4.3.3 The community perspective

Although the risk based approach is very logical and rational, this is not the same as how people perceive risk. It is generally acknowledged that there is a discrepancy between how risks are formally quantified and how people perceive risks and whether they accept it. Firstly, people distinguish between risks from natural hazards and hazards caused by human activities. Natural hazards are accepted more easily to a great extent since they see it as something beyond their control.

In the case of BB and BG river basins, extensive interaction was carried out with various sections of the communities to understand their perceptions towards flood in addition to understanding their needs and problems. Both the river basins are flood prone, although the frequency, intensity and the exposed elements vary. People are living in these basins for generations and are aware of the flood risk. Traditionally, people stock firewood, fodder for cattle and traditional food like *Sattu* (roasted *channa powder*), *Chuda* (beaten rice), and *Mudhi* (puffed rice), etc. However, less frequent hazard events seem to have more impact since the community is not expecting them.

Community places more emphasis on earning a livelihood and ready to take risks due to disasters. Economically weaker communities choose to live in flood prone areas as land is either relatively cheaper or is government land. Basically, economic factors force the community to choose hazard prone areas to live in, which lead to further economic problems when disasters affect the area. This then becomes a vicious cycle. The community within the basin (mid and downstream) also has different opinions about floods. Early floods (before the cropping season starts) and mild floods, according to farmers, are useful. As is seen in the BG basin, they see that flood regulation has also reduced the silt carried into fields and has led to an increase in the use of fertilizers. However, in general, community sees heavy floods as damaging since they interrupt life and livelihood activities and also have long standing environmental and health impact.

Both states have put in efforts to increase community preparedness through preparation of village level disaster management plans and formation of DM committees. However, these DM committees are not functional in most of the villages and communities need to be encouraged through incentive mechanism or enforced through legislative mechanism.

Communities prefer to have flood protection structures (construction of dikes) and expect government to support in flood proofing of houses. Preferences towards flood protection also varies from people where they live – those living close to the embankment on the landward side face water logging problems as flood water cannot escape to river due to embankments. However, communities living away from the river, prefer to have flood protection (embankment) to protect them from flood. Level of awareness on agriculture insurance among community is also poor.

Figure 16 Example Village Disaster Management Plan

The coping capacity depends of the economic well-being of the people. Poor people tend to give preference to livelihood than taking extra measures for coping to disaster. Any adaptation mechanism is driven by market force. People will go for high yield hybrid crops which are more vulnerable to flood than choosing flood/drought/saline tolerant varies which are more sturdy but less in yield. Alternate cropping mechanism also will be driven by market force. Unless the supply chain is not properly linked, the community will not adopt new crops or cropping patterns. For instance, growing sugarcane is a good choice for waterlogged areas, but farmers will only choose it when there is a demand in the market for their produce. This actually happened in Jajpur (Odisha) when a sugar factory was established.

Additional considerations regarding flood safety may come from the community survey, which identify specific community needs and which could adjust the purely economic CBA result. For instance, the proximity of a hospital or other critical infrastructure could be a reason to increase the safety level in that area. Interestingly, our CBA results for the two rivers indicate a good ratio for increasing the safety standards through embankments, which is in line with the communities' wish for those.

4.4 Selection of measures

4.4.1 Method

Selecting the right combination of measures for a river basin IFM plan is perhaps the most difficult part of the planning process. The reason is that we have to take into account all possible measures as well as a range of criteria, such as costs, effectiveness, social acceptance and environmental sustainability. Because capital intensive measures are built for a long period of time, we have to account for likely changes in future boundary conditions, such as climate change.

The general selection procedure is depicted in Figure 17. It shows the pathway from a shortlist of promising measures via pre-feasibility analysis to promising measures which then can be subjected to detailed feasibility studies. Important part of the pre-feasibility analysis is a quantitative analysis of the effectiveness of the (set of) measure(s), preferably using a modelling approach.

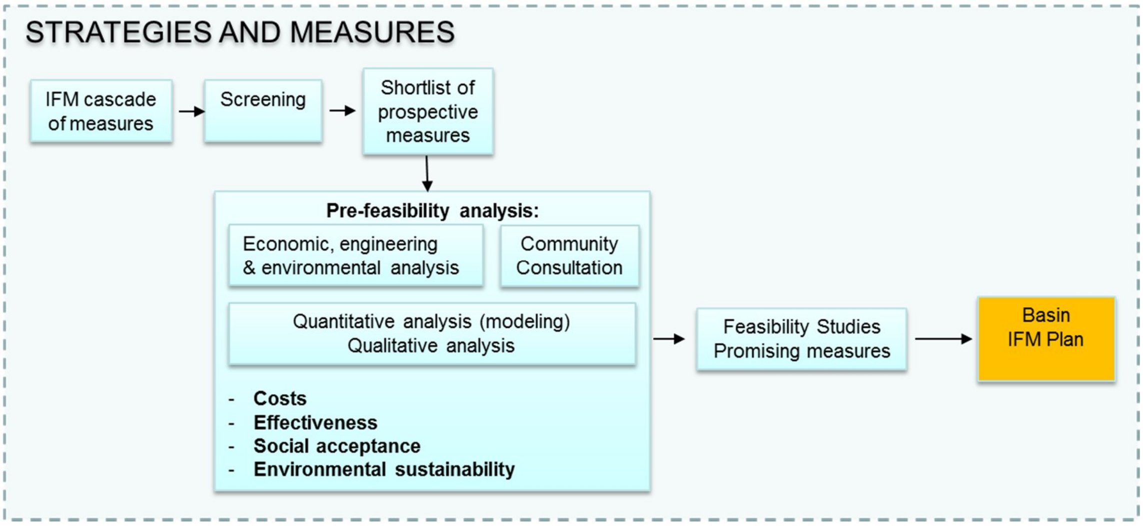

Figure 17 Steps in the Strategies and measures formulation (Source: Deltares)

After the feasibility studies have completed, the next step is the preparation of a DPR (Detailed Project Report) which then can be evaluated by the responsible agencies after which funding can be released.

4.4.2 The IFM cascade and prefeasibility analysis

For the identification of measures we will use the IFM cascade (Figure 18). This cascade shows from source, via pathway to receptor of a flood different types of measures, both structural and non-structural. It also shows the adjoining policy domains, such as spatial planning and watershed management in which measures should be mainstreamed.

It shows that each of the measures reduces the risk, but to what extent is highly context dependent. Because the figure is generic it assumes each step of equal height. As we know, the flood risk cannot be entirely addressed by any one of the above measure. Effective flood risk management requires therefore a balanced mix of structural (e.g. embankments) and non-structural flood risk management measures, such as land-use zoning, flood early warning and building controls. The importance of proactive planning and implementation of preventive methods and measures is long understood in India and voiced by past flood committees for over 50 years.

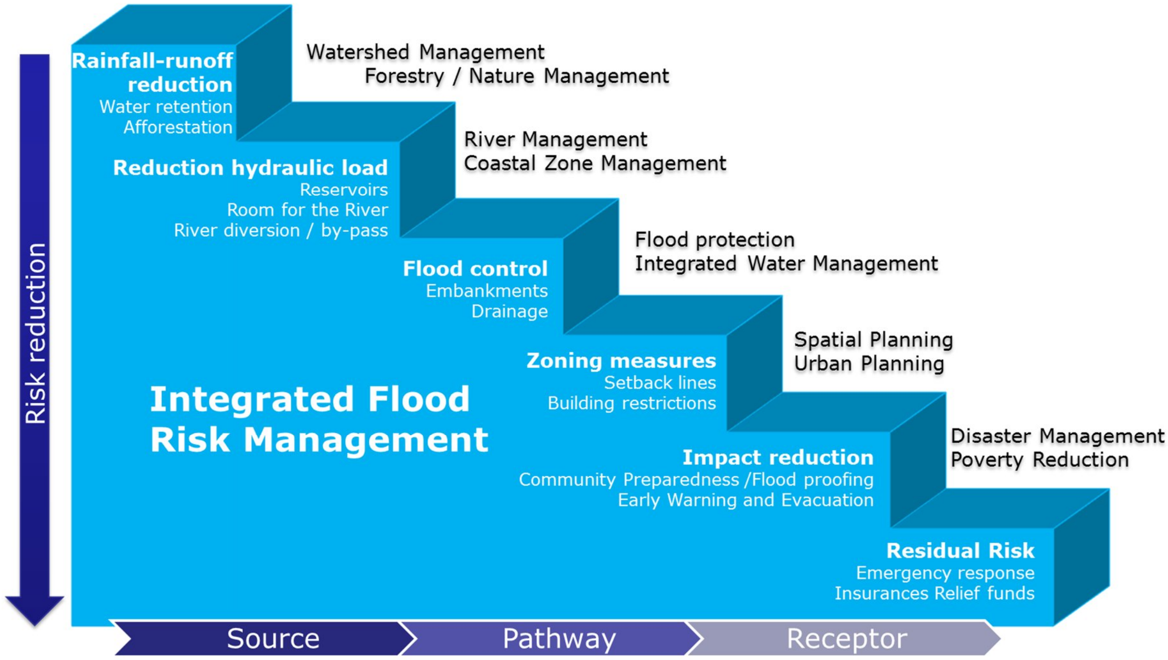

Figure 18 IFM cascade of measures (Source: Deltares)

The way to address the problem holistically is also captured in the cascade. Measures are arranged from left to right in accordance to the risk formula: reduce the hazard (Source), limit the exposure (Pathway) and reduce the vulnerability (Receptor). In the next sections each of the main measures will be described in the context of current Indian practices and circumstances.

4.4.3 Watershed management

Floods can be caused by man-made activities such as deforestation on hill slopes, shifting cultivation and overgrazing by domestic animals. These factors cause quick runoff from the steep hilly slopes, and flash floods are often caused by the sudden descent of landslides into downstream reaches (Dhar and Nandargi, 2002). Watershed management is therefore a major non-structural method of managing floods. This becomes vital especially in case of rivers that origin from Himalaya as the Himalayan mountain system is comparatively new and is yet to stabilize. Further, it is also a seismic zone with frequent earthquakes. This results in unstable loose soil and boulders which at times of heavy rains are washed along with the water. Proper and effective watershed management will prevent this soil erosion and hence decrease the sediment load in the river stream. This also mitigates the problem of diminishing reservoir capacity through siltation in case of dams and barrages in the catchment.

Deforestation in India

It is not easy to get a clear picture of the rate of deforestation in India (Reddy, 2013). According to the State of Forest Report (2011) produced by the Forest Survey of India (FSI), area under forests in India is estimated to be 69.20 m ha (during 2009), making up 21% of the total geographical area of the country. The progressive forest policies and programmes have significantly contributed to reduced rates of deforestation, increased afforestation and overall stabilization of area under forests, and even increase in gross area under forests in the recent decades. Nevertheless, India has experienced significant loss of natural forests during the last few years, even though total area estimates as reported by FSI show a gain of 1.49 million ha during the period from 2005 to 2009 (Ravindranath, 2012). The dense forests in almost all the major states have reduced and forest degradation is a matter of serious concern. About 35 million hectares of forests, some 55 % of the forest area, are affected by fires annually. Other factors leading to forest degradation are transfer of forest lands for other land uses, encroachment on forest lands for agriculture and other purposes, grazing, and pests and diseases (FAO, 2015).

The Ministry of Environment, Forest and Climate Change of the Government of India has issued detailed guidelines for the diversion of forest land for non-forest uses. Some of the salient features of these guidelines are as follows:

- Comprehensive afforestation is one of the most important conditions stipulated for providing proposals for diversion of forest land to non-forest uses. Steps proposed to compensate for the loss of forest area, therefore, have to be specified.
- The norms normally laid down for compensatory afforestation are that (a) where non-forest land is available, compensatory afforestation should be undertaken over the equivalent area of non-forest land, and (b) where non-forest land is not available, compensatory plantation should be undertaken in degraded forests over twice the extent of the area being converted.
- Stipulation has been made for identifying the equivalent non-forest area or degraded forest land, the agency responsible for afforestation, the provision of funds, the monitoring mechanism, and the preparation of detailed work schedule.
- Lands identified for compensatory afforestation are to be transferred to forest Department.

Forests and floods

The role of forests in sustaining water supplies, in protecting the soils of important watersheds and in minimizing the effects of catastrophic floods and landslides has long been discussed and debated (FAO, 2005). The conventional wisdom is that forests act as giant ‘sponges’, soaking up water during heavy rainfall and releasing freshwater slowly when it is most needed, during the dry months of the year. The reality is far more complex.

Contrary to this conventional wisdom, forests have only a limited influence on major downstream flooding, especially large-scale events. During a major rainfall event (like those that result in massive flooding), especially after prolonged periods of preceding rainfall, the forest soil becomes saturated and water no longer infiltrates into the soil and instead runs off the soil surface.

However, the impact of tree cover in the forest land on evapotranspiration will be much higher as compared to a situation where the forest land is covered by grass and shrubs. In hot tropics, the water required for transpiration, especially during the lean season, might be obtained from the deep strata (i.e., from the vadoze zone and the shallow groundwater). This could result in significant water loss, creating greater space in the strata for storage of the rainwater which infiltrates. Loss of tree cover can result in sharp reduction in water loss from the deep soil strata in the form of evapotranspiration (ET), resulting in rising of water table (as observed in the Murray Darling basin in Australia), thereby reducing the flood cushioning effect.

As studies indicate, while grasses will have effect on erosion control, it may not increase the ET ‘outflows’ from the catchment and soil moisture storage as significantly as in the case of deep-rooted trees, though this is subject to the leaf area index and tree density (Oliveira *et al*., 2005). More importantly, unlike trees, grasses do not survive during the dry seasons in hot tropics, thereby bringing down the ET losses during the season to zero. During dry season, the ET losses through trees under natural conditions will be lesser than that of wet season, as in the former case, due to soil drying leads to closing of stomata, thus reducing transpiration (Forestry Commission, 2015)

The water for meeting ET demand of trees can come partly from precipitation 'interception', partly from the moisture in the active root zone, partly from the unsaturated zone underlying the soil, and partly also from shallow groundwater in the catchment. While its impact on overall yield of the catchment would be negative, depending on how the increased demand is being met from the hydrological system, the impact will be seen either on runoff or groundwater or both. If the deep soil strata (vadoze zone) along with top soil contribute to evapotranspiration of trees, then the impact will be on both groundwater system and runoff, whereas if shallow groundwater contributes to ET, then the most significant impact will be on base flows and groundwater. The higher the leaf area index, the higher will be the transpiration (Hamilton and King, 1983; Oliveira *et al*., 2005).

Hence, the impact of forests on flood control would depend heavily on the climatic conditions, the geophysical environment (soil strata, geo-hydrology) and the type of forests.

The erosion control function of forests is also complex. While forest cover does tend to check erosion, it is not the tree canopy that is directly responsible for this; rather it is the undergrowth and forest litter (Hamilton and King, 1983). Experiments indicate that the erosive power of raindrops under trees actually tends to be very high because the raindrops merge before dripping off the leaves and therefore hit the ground with greater force. This sometimes leads to particularly serious erosion problems in plantations where the soil has been cleared of vegetation and litter to reduce fire hazard or where litter is collected for livestock bedding or fuel. If the soil surface is adequately protected by a well-developed litter layer and complete vegetative cover, other vegetation types can offer equivalent protection against erosion. Therefore, land degradation and soil erosion that are often associated with the loss of forest cover are not necessarily the result of the forest removal itself, but of the poor land-use practices (overgrazing, litter removal, destruction of the organic matter, clean weeding) implemented after forest removal. Also, much of the erosion that occurs after timber harvesting is due to the movement of soil during logging operations (e.g., road construction) and compaction, which results in lower water storage capacity of the soil and increased surface runoff (FAO, 2005). This makes integrated watershed management all the more important.

Hence, deforestation is not the only factor of importance. Much of the retention capacity depends on the type of land cover and land use which replaces the forest. Watershed management should therefore pay specific attention to:

- Soil conservation measures, to reduce the erosion and subsequent sediment transport downstream, which affects the river drainage capacity;
- Be careful with constructing forest roads and hard-surfaced roads, since the road network not only generate surface runoff through providing a relatively impermeable surface but will also intercept and convey surface runoff quickly to the stream channel through its associated gutters and drains, factors which may proportionally increase in importance as storm inputs increase (Calder & Aylward, 2006).

In India, three ministries at the Centre, the Ministry of Agriculture (MoA), Ministry of Rural Development (MoRD) and Ministry of Environment, Forest and Climate Change (MoEF&CC) along with some respective departments in the States are involved in policy formulation and implementation of watershed development programmes. MoA started this programme way back in 1960s and mainly dealt with issues such as to check soil erosion, optimizing production in rain fed areas and reclaiming degraded lands. Subsequently, the MoA approaches were broader and the attention was broadened to other areas such as soil and water conservation in the catchments of River Valley Projects (RVPs) and Flood Prone Rivers (FPRs).

MoRD has been implementing watershed development projects only since the late 1980s. It deals with non-forest wastelands and poverty alleviation programmes having components of soil and water conservation. Watershed programmes implemented by MoRD include the Drought Prone Areas Programme, Desert Development Programme, Integrated Wastelands Development Programme, and Externally Aided Projects (EAPs). Since 1989, the MoEF&CC has been implementing the National Afforestation and Eco-Development Project, with the intention of promoting afforestation and development of degraded forests within an integrated watershed approach (Singh et al, 2009).

The recent large earthquake that hit Nepal in 2015 also impacted parts of Bihar. These and other geological events, such as big landslides, could shift a river course and affect the sedimentation pattern. The neotectonic movements in combination with the tectonic subsidence of the Bihar plains cause exceptionally high rates of sedimentation in sections of the river systems which are triggering sudden and rapid shifting of channels (avulsions) (Sinha, 1998). It is therefore advised to study the behavioural pattern of the flood prone rivers (especially the North Bihar Rivers), to examine the possible effect of such disasters on the river course – disappearing and emerging elsewhere –, on sediment generation and transportation and subsequently on the river morphology.

4.4.4 Reservoirs

There is evidence about the positive role of reservoirs for downstream flood reduction/control in a flood prone river basin. If a vast area is available for productive cultivation in the vicinity of the storage dam, the water storage in the reservoir can be used for further advantage. It can also be utilised for hydro-power in case of sufficient head, whereas the tail race waters can be sensibly utilised for irrigation. Such situations are very common in the Indian context with large areas starving for water for agricultural production: there is ever a scope for extensive irrigation.

Yet, dams could also increase the flood problem downstream. This could happen even in normal routine floods in case dam operational rules have not been established scientifically. Also under Probable Maximum Flood conditions, for which most of the major dams are designed in India, the flood situation downstream could get aggravated. At that Probable Maximum Flood level (which is estimated as the physically maximum flood, not through a flood frequency method) the flood peak generated might correspond to a 1,000 or 10,000 year return period peak or even more. In such a catastrophic flood event even without the dam the entire downstream area would have faced the serious flooding conditions. In the context of Integrated Flood Management a protection at such a high flood level is often not considered at all.

Most dams are single-purpose dams, but there is now a growing number of multipurpose dams. Using the most recent publication of the World Register of Dams, irrigation is by far the most common purpose of dams. Among the single purpose dams 48% are for irrigation, 17% for hydropower (electricity generation), 13% for water supply , 10% for flood control, 5% for recreation and less than 1% for navigation and fish farming. In India irrigation dams make up over 90% of large dams (Duflo & Pande, 2007).

Flood control

Dams and reservoirs can be effectively used to regulate river levels and flooding downstream of the dam by temporarily storing the flood volume and releasing it later. The most effective method of flood control is accomplished by an integrated water management plan for regulating the storage and discharges of each of the main dams located in a river basin. Each dam is operated by a specific water control plan for routing floods through the basin without damage. This means lowering of the reservoir level to create more storage before the rainy season. This strategy eliminates flooding in combination with other flood control/flood reduction steps. The number of dams and their water control management plans are established by comprehensive planning for economic development and with public involvement.

Flood control is already a significant purpose for many of the existing dams in India, for instance the Hirakud dam in Odisha, inaugurated in 1957. Out of past major 24 flood events, the dam has absorbed on an average 26% of the incoming floods. In the earlier mentioned Damodar valley, dams have moderated in 1961 the inflow flood peak of 14,600 m^3/s to 4630 m^3/s and in another high flood year 1978, the inflow flood peak of 22,036 m^3/s was moderated to 4,612 m^3/s. Another good example is the Bhakra dam (Indus basin), which has absorbed an average of 76% of the inflowing flows in the past 11 major floods in the period from 1991 to 2001[12].

The Working Group on Flood Management and Region Specific Issues for XII Plan advised to provide adequate flood cushion in all water storage projects, wherever feasible, to facilitate better flood management. In highly flood prone areas, flood moderation should be given overriding consideration in reservoir regulation policy, even at the cost of sacrificing some irrigation or power benefits. As a policy minimum, flood cushion of 10 per cent of live storage is advised to be provided in all new dams and if affordable with respect to other purposes, the flood cushion could be considered up to 20 per cent. A portion of the capital cost of the reservoir allocated to flood control could be shared by all beneficiary States.

Nevertheless, there is also criticism questioning the flood mitigation effects of dams. Much depends on how the reservoir is operated and whether or not sufficient storage capacity is kept available before the onset of the monsoon. This often conflicts with other water uses, for instance irrigation, which would like to keep the reservoir as full as possible. An example of such conflict is given in Box 8.

[12] The flood control effects of structural measure by Dams are based on a detailed study by S. K. Sinha-Chief Engineer, BPMO and Rishi Srivastava , Deputy Director, Central Water Commission.

Box 8. The 2011 flood downstream of Hirakud Dam (Choudhury et al., 2012)

In 2011, in spite of a warning of low pressure formation in the Bay of Bengal, no depletion plan was prepared by the dam authorities right from 1st of September, 2011, and water levels were kept close to 624 feet near FRL. The water level remained nearly at this level right up to the 6th of September. Even though heavy rains in certain pockets of Chhattisgarh in the catchment were reported, and it was predicted that there would be peak inflow into the reservoir, water discharge from the dam was reduced by closing the sluice gates. Only on 7th September, when the inflow into the reservoir started to increase and the water level rose to 628 feet, was the water discharge from the reservoir increased. From 8th to 11th of September, 55 sluice and 4 crest gates were opened, and there was a peak outflow of more than 9 lakh cusec. This resulted in a peak flow of 13.64 lakh cusec of flood water at the Mundali gauge site near the delta, leading to one of most devastating floods in the state, which badly damaged 19 out of 30 districts, affected 5 million people and taking a heavy toll on life (80 human casualties), and property (1.5 lakh ha of crops affected; INR 21 billion loss).

Dams in Burhi-Gandak and Brahmani-Baitarani

Several dam projects have been identified for the sub-basins under study, either by the State Water Resources Departments or by the NWDA (National Water Development Agency) under the Ministry of Water Resources. These have multi-objectives such as irrigation, hydro-power and flood control. Their dimensions and effectiveness have been described in the respective River Basin Plans (Vol. 2 and Vol. 3).

The flood mitigation of the proposed Masan Dam in the upstream part of the Burhi-Gandak is expected to be in the order of 5 % (Table 5). In other words, a one in 25 year flood event would have 5% less area inundated and 3.8 lakh less people affected.

In the Brahmani-Baitarani basins the potential flood reduction effect of storage reservoirs is especially significant. Increasing the flood cushion in Rengali could reduce the flood extent with 12%. Together with the commissioned Kanupur project around 15% reduction could be achieved. It is noticeable from the 2D model output (Figure 19) that this has no effect on most of the delta to the east.

Table 5 Flood mitigation effectiveness of several dams in the basins

1:25 year flood events	Baseline (current) flood extent (km^2)	With project situation flood extent (km^2)	Difference (%)
Burhi-Gandak:			
Masan Dam (B-G)	1571	1489	-5%
Brahmani-Baitarani:			
Rengali dam flood cushion optimization	3151	2771	-12%
Kanupur project	3151	3048	-3.2%
Samakoi	3151	3129	-0.7%
Ananpur	3151	3012	-4.4%
Balijhori	3151	2895	-8.1%

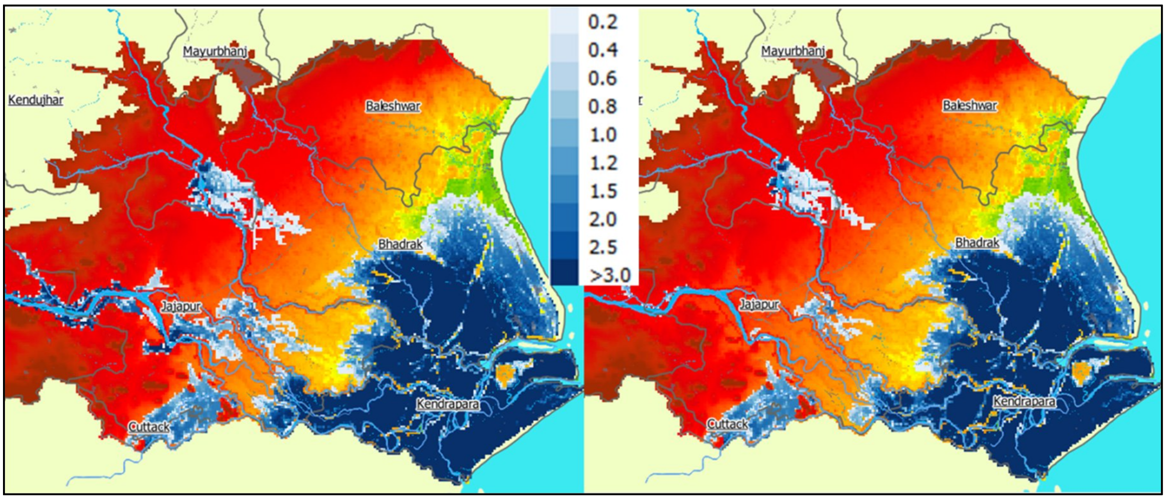

Figure 19 1:25 year flood extent (left) and impact of Rengali flood cushion increase and Kanupur project (right)

4.4.5 River diversions through diversion channels

Diversion channels are constructed to divert waters from the main channel for purposes such as flood control, municipal water supply, and irrigation. A type of diversion channel used for flood control is a flood bypass channel or floodway. It is a separate channel into which flood waters are directed to lessen the impact of flooding on the main river system. Control structures may be located at the head of the diversion channel to divert flows during periods of high water and return flows during low water in some cases. Some diversion channels bypass the flood flows into an adjacent waterway, while others return the flows back into the same stream a distance downstream from the point of the diversion. Diversion channels are often used in urban areas where it is not possible to widen the existing channel due to development. Such need comes even in non-urban areas where active agricultural practices exist.

Major design considerations for diversion channels include: 1) determining if the channel should convey partial or all flows 2) design of appropriate controls 3) sizing of the channel to convey the design discharge and 4) design to reduce maintenance. Additionally, it is essential to consider potential morphologic effects on both the main channel and receiving (adjacent) waterway.

The feasibility study for one such river diversion has been completed by NWDA (National Water Development Agency) in the Burhi-Gandak basin (Burhi-Gandak-Noon-Baya- Ganga link, see Volume 3 Report). The effect on flood mitigation is about 7% (see Table 6).

Table 6 Flood mitigation effectiveness of the BG-N-B-G Link

1:25 yr flood	Baseline (current) flood extent (km^2)	With project situation flood extent (km^2)	Difference (%)
Burhi-Gandak:			
Burhi-Gandak-Noon-Baya-Ganga link	1571	1466	-7%

4.4.6 Embankments

4.4.6.1 Advantages and disadvantages of embankments

Embankments are widely used in India as a measure to control floods. They are often the main means of preventing inundation during high river discharges. One of the main reasons is that these measures are relatively easy to construct, using locally obtained material and cheap, unskilled labour. The costs are therefore relatively low. The design procedures are straightforward (see section 4.4.6.2).

However, embankments also have some demerits and may cause unintentional side problems. Embankments or dikes can fail due to a number of reasons (see also Figure 20 and 21):

- *Overflowing / wave overtopping*, which could lead to local erosion and subsequently cause a breach in the embankment. In the event of such a breach, there is a sudden and considerably inflow of water to the protected land which may cause serious damage due to high flow velocities. This also causes a significant risk of human fatalities. Furthermore, the fast flowing water may deposit considerable amounts of sand making the land infertile. This is a serious problem in the lower reaches of the Brahmani-Baitarani rivers.
- *Piping,* the development of erosion channels under dikes, is thought to be one of the most important failure mechanisms. The reasons for this mechanism are not always fully understood, but the undermining of the bank through bore holes of animals are an important factor. Therefore the embankments must be closely supervised during floods and repairs made as soon as they are in danger.
- *Erosion* of the outer slope may occur due to direct attack of the river and may result in undermining of the embankment.
- *Instability of inner or outer slope* could occur if the material is not suitable or the embankment has not been designed according to the standards (see section 4.4.6.2).

Furthermore, the construction of embankments along a river would generally result in higher river water levels during high discharges, simply because the water cannot expand laterally. In heavy silt laden rivers the embankments could lead to significant river bed aggradation which causes higher risk of overtopping. Last but not least, embankments could lead to waterlogging of the areas that they are supposed to protect, if no consideration is given to prevent blocking of natural drainage channels from the floodplain back to the river.

Several of these problems associated with embankments can be overcome adopting the 'Room for the River' concept. The essence of this concept, which has been successfully adopted in the Netherlands (see Appendix E-1), is to reduce high water levels by reducing the hydraulic resistance in the river channel and floodplain. A promising measure in the case of the Bihar and Odisha rivers is channel improvement by dredging at some critical reaches.

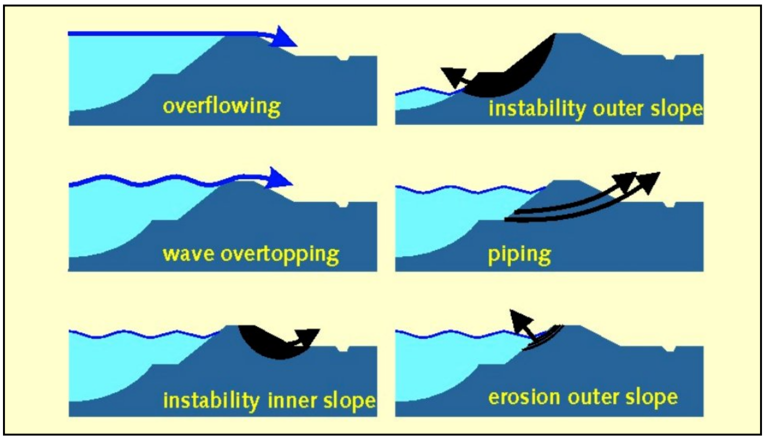

Figure 20 Failure mechanisms of an embankment (Source: Deltares)

Breaches are a common phenomenon in India. For instance, during the 2004 major flood in Bihar in total 53 breaches occurred, resulting in flooding of a large part of North-Bihar. For the Burhi-Gandak breaching and not overtopping is a major cause of flooding. So this raises the question why the embankments are not always strong enough (see section 4.4.6.2). Besides technical failure embankments are also sometimes purposely cut by local people. This is for instance the case along the Burhi-Gandak. Although it may seem irrational, several reasons have been found for this practice, such as releasing trapped water between the embankment and another raised obstacle such as a road or railway or directing the flood to elsewhere in order to safeguard another low lying area downstream.

Figure 21 Overtopping of an embankment (Source: Deltares)

Model results from the two basins suggest that raising and closing the embankments result in a substantial reduction in flood extent. For the Burhi-Gandak it would imply a reduction of 26% and for the Brahmani-Baitarani rivers 17% (Table 7). It may be surprising that the floods are not completely controlled during a 1:25 year event. This is because embankments in several tributaries of the Burhi-Gandak are not included in the model, for instance the Bagmati northeast of Samastipur. Also downstream in the area of Kamwar Lake near Garhpura the model shows inundations, mainly because of the backwater effect of the Ganga.

The relatively small reduction for the Brahmani-Baitarani river system is due to the fact that high waters from the sea can still penetrate deeply into the delta. Only tidal barriers would significantly reduce the flood risk, but that involves a considerable investment.

Table 7 The flood mitigation effectiveness of closing embankments

1:25 year flood	Baseline (current) flood extent (km^2)	With project situation flood extent (km^2)	Difference (%)
Burhi-Gandak	1571	1156	-26%
Brahmani-Baitarani	3151	2617	-17%

4.4.6.2 Suggestions for improved design of embankments

The various criteria by CWC, GFCC, BIS Codes and NDMA cover a range of embankment design aspects (see Figure 22). Several of these are crucial for the design of the embankments in the perspective of climate change as this may affect the design flood discharges. These parameters include the degree of protection (HFL), freeboard, spacing of the embankments, side slopes and stability analysis, and are suggested to be reviewed to improve embankment design.

Degree of Protection

The BIS Code 12094:2000 stipulates that the height of embankments and the corresponding benefit-cost ratio should be worked out for various flood frequencies taking in to account the damages likely to occur. The degree of protection, which gives the optimum benefit cost ratio should be adopted. In fact this is a risk approach, as explained in Section 4.3.2. However, in case the details of all the relevant parameters are not available, the degree of protection for agricultural areas may be defined by the High Flood Level (HFL) obtained by a flood frequency analysis corresponding to a 25-year Return Period, whereas for township areas/industrial establishments the HFL should correspond to a 100-year Return Period.

At present, however, neither of the above is followed effectively. In Odisha, the historically observed highest HFL is followed as the design HFL and in Bihar, though the HFL has been estimated by flood frequency analysis, the database used in the past is inadequate.

The HFL is highly dependent on the rainfall (i.e. flood producing intensity of rainfall), which in turn is going to be affected by climate change. When climate change induces a higher frequency of intense rainfall events the HFL corresponding with a 1:25 year probability would become higher. Hence, in order to account for future climate change a procedure of downscaling global climate models needs to be followed, as has been described in Chapter 3. By using a flood model such as developed under this project, the probable increase in HFL for different return periods can be assessed and subsequently used for embankment design in order to maintain the safety level. For coastal areas the probable rise in sea levels needs also to be taken into account by determining the recommended HFL (which can lead to a substantial increase in the order of 50-80 cm, depending on the time horizon and climate scenario).

Spacing of the embankments

As per the existing criteria, the spacing between the embankments along the jacketed reaches should not be less than 3 times *Lacey's wetted perimeter* [13] (under design flood discharge condition).

[13] Lacey's wetted perimeter is a sub component of his elaborate analysis in bringing out the silt theory. The analysis carried out by him based on justified assumptions and the resulting semi-empirical equations are still followed in almost all

Also, the minimum distance of the embankment from the river bank and the midstream of the river should be one time and 1.5 times of Lacey's wetted perimeter, respectively. However, in almost in all the river embankments these criteria are not followed. Especially in the Burhi-Gandak basin the spacing is much less than the criteria stipulation, about which GFCC is also concerned. The various States do not follow these criteria because of the extra cost to be incurred in acquiring costly lands. But as a result the embankments are facing increasing attacks from the river, resulting in erosion and the need for expensive anti-erosion works as a routine every year.

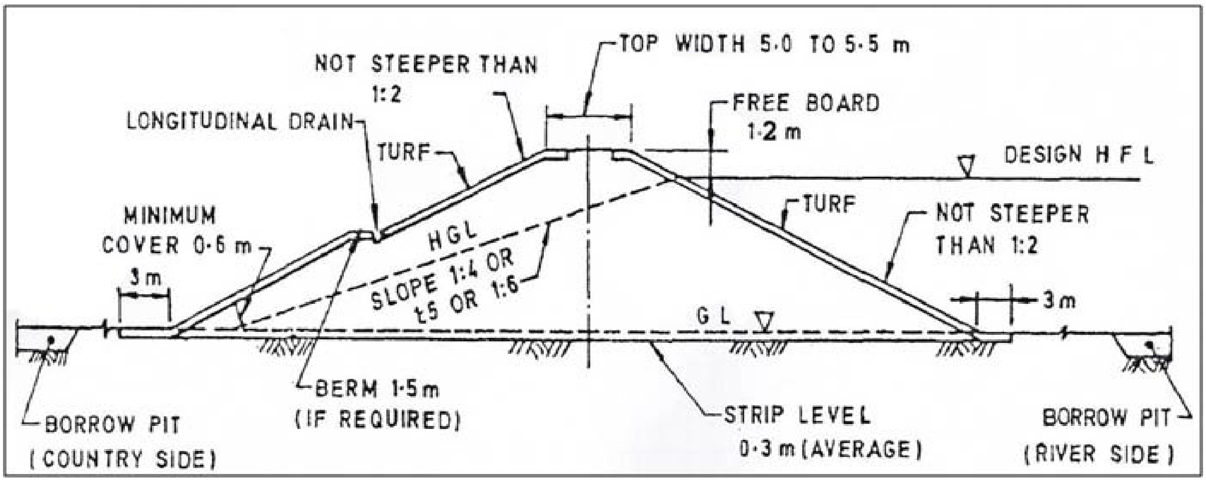

Figure 22 typical embankment section showing minimum design requirements
(Source: BIS 2000)

It is recommended to carefully study the alternatives between i) the cost of annual anti-erosion works and slope protection works with riprap (if criteria not followed) and ii) the cost of additional requirement of land (if criteria are followed). This could lead to improved criteria on the lay-out of embankments.

Slopes

Generally speaking, steep slopes will reduce the stability of an embankment. Therefore, the criteria for the river side slope stipulates a slope of not steeper than 2H:1V (two times horizontal length for each unit of vertical height) for embankment heights up to 4.5 meters and for higher heights the slope should not be steeper than 3H:1V. In both the basins under study the embankment heights are generally in between 4 to 6 m and the slope adopted in most of the reaches is 2H:1V. Hence, this partly complies with the criteria. However, for the heights between 4.5 and 6 m the slope of 2H:1V is allowed if the embankment protection measures like riprap are provided which is sometimes the case.

Dike strength and ideal slope are also dependent on the construction materials. From discussions in the field it was understood that the slope is designed to be flatter than the angle of repose of the construction material.

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countries. Further improved equations are yet to be developed. During his analysis Lacey has established an equation for the wetted perimeter as a function of the design flood discharge. This is

$$P_w = 4.825\, Q^{1/2} ,$$

Where P_w is the wetted perimeter in meters and Q is the design flood discharge in m^3/sec. This is the wetted perimeter referred to in the criteria.

For heights of more than 6 m the current criteria recommend detailed geotechnical analysis methods for determining the river side slope. These methods are described in Appendix F. We would recommend to use these methods for embankments lower than 4.5 m as well, which would avoid present arbitrary slope values and allow for economic optimal designs. The State WRDs have in principle the capability to use the method but would need to have access to state-of-the-art laboratories to perform soil properties analysis.

Freeboard

Freeboard is the height added to the design water level (HFL) of an embankment to prevent overtopping by water due to wind waves, a sudden change in river course or gradual subsidence of the dike. The required freeboard for a specific embankment can be determined by calculating the expected wave heights considering local conditions. A formula can be found in the *CWC Handbook for flood protection, Anti erosion, River Training Works* (June 2012) (Box 9).

Box 9. Calculation of water wave for determining freeboard

The height of the water wave depends upon the wind velocity (V) in the units of Km/hr and on the fetch or straight length (F) of water expanse in km. The H_w wave height is computed by the following formula:

$$H_w = 0.032(V.F)^{1/2} + 0.76 - 0.27\,(F)^{1/4} \quad (1)$$

$$H_w = 0.032(V.F)^{1/2} \quad (2)$$

In which:

V is wind velocity in Km/hr
F is the fetch in Km.
H_w is the required wave height in meters

Equation (1) is applicable for F< 32 Km whereas equation (2) is applicable for F> 32 Km. The freeboard is given by 1.50 times of the wave height computed as above. This freeboard is added to the Design HFL to fix the crest level of the embankment.

In practice this method is seldom followed, due to the paucity of sufficient data in the past. In fact, existing criteria offer an alternative of a uniform value of 1.5 m for rivers discharging less than 3,000 m^3/s and 1.8m for discharges above. As we found in Odisha, even these criteria are not followed and an arbitrary value of 1.2 m is used instead.

Therefore we recommend to update the criteria for estimating the freeboard based on the wave height with the formula given above. Sufficient data on wind velocity are available at IMD (India Meteorological Department) and the expanse length (fetch) can be easily ascertained by maps based on satellite data. Such approach could even result in lesser values than presently adopted and may reduce embankment construction and land requirement costs.

Construction material and recommendations for the use of geo-synthetics

Different construction materials each have their own uniqueness and selection depends on specific site conditions, availability, transportability, effectiveness and maintenance cost considerations. At present, both in Bihar and Odisha the construction material used predominantly is sandy clay or coarse sand free from organic materials. The borrow pit location is scooped out for about 1 meter depth and then the sandy clay or coarse sand of required quality falling below this 1 meter depth is used as construction material. The required laboratory and in-situ tests are carried out for checking the adequacy of various parameters of the soil, before using in the actual construction. On average, the parameter values as indicated below are accepted for embankment construction according to the site conditions:

- Cohesion of the soil for embankment body 2.4 t/m^3
- Cohesion of the foundation material 5.4 t/m^3
- Dry weight of the soil for embankment body 1.8 t/m^3
- Submerged weight of the soil for embankment 1.2 t/m^3
- Dry weight of the soil for embankment foundation 1.8 t/m^3
- Angle of internal friction in embankment soils 25 degrees
- Angle of internal friction in foundation material 12 degrees
- Co-efficient of permeability in embankment soils $1x10^{-4}$ m/s

Figure 23 Embankment with revetments in stone (Jajpur district, Odisha)

Although there is no evidence of construction failures in Bihar and Odisha due to the quality of construction material and process, there are good reasons for improving the strength and performance of the embankments to withstand more extreme conditions in the future. This performance improvement can be achieved by opting for durable geo-synthetics. Another reason for using these materials is the likely future reduced availability of conventional material as these are also in high demand in other construction sectors of society.

A variety of such useful and easily adoptable geo-synthetics are indicated in CWC's "Handbook for Flood Protection, Anti-erosion and River Training Works-2012".

Nowadays new innovative materials like Geo-textiles, in the form of Geo-textile bags, Geo-textile tubes, sand filled Geo-mattresses, Geo-web, submerged vanes and reinforced concrete porcupines are being increasingly used in embankment construction and strengthening. These measures have become popular due to their unique characteristics such as durability, resistance to chemical waste, environment friendly nature and ease of their installation. The details and specifications of various Geo-Synthetics have been elaborately brought out in the Handbook of CWC referred to above. Some of them to be recommended for improved embankment construction as per site specific conditions are:

- Reinforced Concrete Porcupines

- Geo-textiles
- Geo-Membranes
- Geo-grid
- Geo-net
- Geo-synthetic clay liner
- Geo-composite
- Geo-textile tubes and bags
- Erosion control mats.

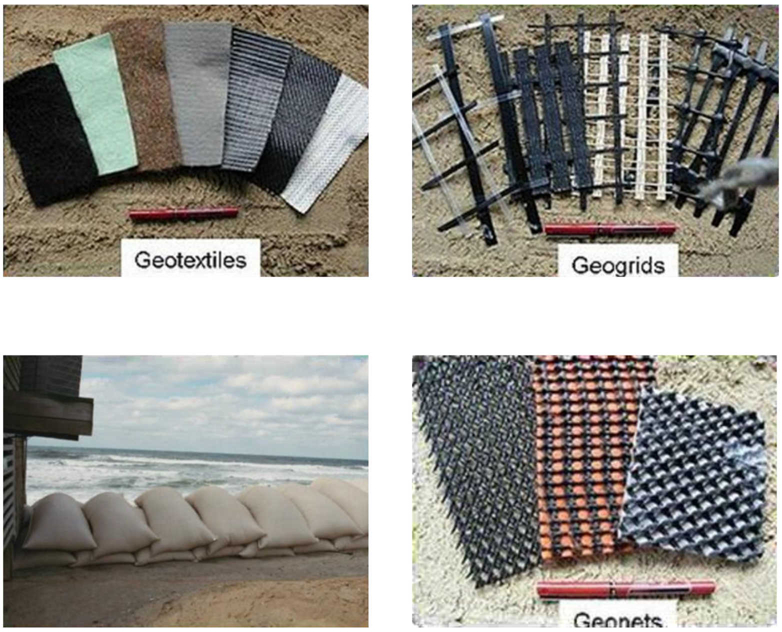

Figure 24 Examples of Geo-synthetics

4.4.7 Combination of structural measures

A strategy which aims at improved flood control would include a combination of all structural measures, such as dams, diversions and embankment raising. The combined effect of such strategy would be 15% reduction in flood extent for the Burhi-Gandak river and 34% reduction for the Brahmani-Baitarani rivers (Table 8).

Table 8 The flood mitigation effectiveness of combined flood control measures

1:25 year flood	Baseline (current) flood extent (km^2)	With project situation flood extent (km^2)	Difference (%)
Burhi-Gandak	1571	1340	-15%
Brahmani-Baitarani	3151	2056	-34%

4.4.8 Urban drainage design

The cities and towns in the country are expanding rapidly due to migration of people from rural to urban areas in search of employment and increased access to services. Often this expansion takes place in relatively low lying areas, because higher land is already occupied. Many of these (new) urban areas are therefore situated in the floodplains. We could clearly observe this pattern through our detailed site visits in Muzaffarpur (in the Burhi-Gandak basin in Bihar) and in Jajpur (in the Brahmani-Baitarani basin in Odisha). The poorest people tend to occupy the marginal land closest to the river channels, as it is often the only available space where they can live on for free or at low cost.

The consequence of this development is an increasing problem of periodic inundation during heavy and even not so heavy rainfall in these urban areas. The rainwater accumulates in depressions in roads and ditches and drains out at a very slow pace only, due to the flat slopes and lack of proper connectivity to storm water drains. Inundation can continue for a large number of days when rainfall coincides with high river stages, especially during the monsoon season. To solve the problem an efficient urban drainage system is required, as is discussed further in this section.

Urban Storm Water Drainage Design

The design principles of an urban drainage system are relatively simple: water is collected at catch pits at roadsides, which are connected to open or underground drains which on their turn discharge into an outfall. Because the rainwater does not require any kind of treatment, generally the water is disposed of in any nearby natural drainage or river. Designs for major components of a robust urban storm water system are given in the *Manual on Sewerage and Sewage Treatment* of CPHEEO[14] of the Ministry of Urban Development (MoUD). Appendix G provides a summary of these steps and guidelines.

Observations on urban storm water drainage in Baitarani Brahmani and Burhi-Gandak

Experts of this study visited two cities, Jajpur City (Baitarani Brahmani Basin) and Muzaffarpur City (Burhi-Gandak), to collect first-hand information. Details are presented in Volume 2 and Volume 3, respectively. Detailed discussions were held with WRD and Municipality officers and revealed that both towns have prepared detailed Storm Water Drainage Master Plans that are under evaluation before approval. A summary of key observations on the existing urban drainage situation at both Muzaffarpur and Jajpur is given below:

- All the existing municipal drains are choked due to solid waste dumped into city drains (see Figure 25). The storm water is mixed with sewage and garbage which creates unacceptable aesthetic conditions and public health concerns.
- The cross sectional size of the existing drains are insufficient to discharge rain water smoothly. In some places houses or compound walls have been constructed either over or very close to drain walls, limiting the ability to widen the drains.
- Water cannot easily be drained out of Muzaffarpur City because the receiving Furdoo river is largely silted up. Also the connections between river and drains are not appropriately constructed, leading to river water entering the town through the drains at high river stages.
- Most of the walls along the drains are earthen or made of laterite and in poor condition. This results in growth of vegetation as well as erosion and contributes to further choking of the

[14] Central Public Health & Environmental Engineering Organisation

drains with sediments. This results in a restricted hydraulic capacity and difficult and costly maintenance.

These observations make clear that any Master Plan for improving urban drainage should not only strictly follow the design guidelines but also be associated with a very good maintenance mechanism.

Figure 25 Choked drain Garibsthan area (Muzaffarpur)

Figure 26 New pukka drain near Mahila Silpakala School (Muzaffarpur)

4.4.9 Land use planning and zoning measures

Non-structural measures such as land use planning, floodplain zoning and flood proofing regulations (for instance through local building bylaws) can be very effective in reducing the consequences of floods. Therefore the National Water Policy (2012) says that "*There should be strict regulation of settlements and economic activity in the flood plain zones along with flood proofing, to minimise the loss of life and property on account of floods*." In other words the floodplain should not be used for residential purposes or public and social institutions such as schools and hospitals. However, the cultivation of seasonal crops may be permitted.

The States have not responded with regulation for flood plain zoning so far even though a plea to do so (along with a model Bill) was made by the Union Government almost 30 years ago. The Bill was drafted and circulated to the States in 1974 by the Government of India and again in 2000, but has failed to elicit any good response. Only three States have a specific law in this regard and even there the law has not been implemented.

One example is the State of Manipur, which has passed a specific Act for this purpose: *Flood Plain Zoning Act, 1978*. The Manipur Act empowers the State to notify and demarcate the floodplain area after proper survey and to prohibit or restrict the use of land therein. The Act also provides for the constitution of a Flood Plain Zoning Authority. This Authority is responsible for carrying out the surveys of land and rivers, classifies the land with reference to relative risk and permitted land use and publishes them for reference.

A similar floodplain zoning regulation has been more recently passed by the State of Uttarakhand in 2012. Rajasthan also has such a law but that has remained on paper and has not been implemented on the ground. Other states, including the major flood prone states of Assam, Bihar, West Bengal, Orissa and Uttar Pradesh, have made no enactment.

Another form of land use planning for flood mitigation is the use of protection which nature provides. Mangroves, for instance, are famous for providing coastal protection. In the Brahmani-Baitarani basin near the coast, the growth of mangrove forests is encouraged by the Ministry of Forest and Environment of the Government of Odisha. These forests provide resistance to cyclonic storm surges and heavy winds, besides sustaining livelihood for the local communities.

4.4.10 Community preparedness

For a country like India, with its monsoonal rainfall, the livelihood is to a large extend influenced by the rainfall pattern. Rains bring prosperity and flood risks. As mentioned earlier, non-structural measures are essential to complement structural measures. Therefore, improved community preparedness is important to allow people to adapt to the flood risk and *to live with flood.* The three pillars for community preparedness include:

- Flood forecasting
- Disaster preparedness
- Resilience increase

Flood forecasting
The last two decades has witnessed reasonable improvement in the flood forecasting system in the country. Technological innovation has improved the lead-time forecast and dissemination of information to rural areas. However, in both the basins we observed during the community consultations that communities demanded an efficient flood forecasting and better dissemination system that reaches the last mile. As floods often coincide with continuous rain, leading to power outings, television is not an effective early warning dissemination media. Cell phone penetration is very high in the rural areas and proves to be more effective for early warning. Taking the low literacy rate into consideration it would be worthwhile to have voice SMS as well.

Disaster preparedness
As many communities live in floodplain villages with poor road access, local level disaster preparedness is critical to reduce their vulnerability. Community Based Disaster Risk Preparedness and Management is well tested in both States and has proven its value. However, this effort lost momentum and Disaster Management (DM) committees are not active (anymore) in most of the villages. As detailed in Volume 6a and b reports, both States have developed village level DM plans and DM committees with the support of UNDP. However, the DM committees formed under this programme are mostly not existing anymore. Only in villages where external interventions (NGOs and CBOs) worked with the communities, DM committees are existing and are helping a lot during and post flood events. This is further explained in the volume 2 of BG report.

Resilience increase
Improving the resilience of households and communities can be achieved through bettering their economic status which can help them to get back to normalcy quickly after the shock. This can be achieved through alternative livelihood, a proper price for farm products, added value to enhance the price of farm products, etc. Improving the economic well-being will also lead to better houses that are more resistant to floods.

4.4.11 Flood forecasting and early warning

The main goal of an forecasting and early warning is to prevent hazards from becoming disasters (see Appendix H). The River Management Wing (RMU) of CWC is responsible for flood forecasting and management at the national level in India. The activity commenced on a small scale in 1958 and by 2012 there were 954 hydrological and hydro-meteorological sites being operated by CWC across the country, covering 20 river basins for rainfall, water level, discharge, sediment and water quality observations. Wireless communication systems, installed in 550 stations across the country, form the backbone of the flood forecasting activities.

Presently, flood forecasts are issued at 175 stations, comprising of 'level forecasting' (147 stations) and 'inflow forecasting' (28 stations). The level forecasts help State agencies for disaster management to decide on mitigating measures, such as issuing flood warnings and the evacuation of people and their movable properties to safer locations. Inflow forecasting is used by various dam authorities to optimize reservoirs operations for safe passage of a flood downstream as well as to ensure adequate storage in the reservoirs for meeting demand during non-monsoon period. Reservoir optimization can be further improved through an integrated reservoir release information system, particularly in case of cascade dams located in series in a river basin.

CWC's flood forecasting system is quite accurate. In 2010, out of a total of about 7500 flood forecasts nearly 98% were found to be within an accuracy limit of +/- 0.15 m for level forecast and +/- 20% for inflow. And during the flood season of 2013 95.75% of the forecasts were found accurate. However, a weakness is that a majority of the flood warning systems in India are not timely, primarily due to poor transmission. Delays that could result in enormous damage to property and lives. It is therefore of paramount importance to have real-time data collection, automatic data transmission, flood forecast preparation, and quick information dissemination.

Therefore, the CWC has undertaken modernization of its data collection and flood forecast network. During the IX Plan, 55 satellite based telemetry stations were installed in Mahanadi and Chambal Basins besides setting up of two Earth Receiving Stations (ERS) at Jaipur (Rajasthan) and Burla (Odisha). During the X Plan, modernization of 168 stations was undertaken and 11 modelling centres were set up. During XI Plan, additional 222 stations and 10 modelling centres were proposed. In addition, the work of 175 stations is in progress (CWC, 2014). The Twelfth Plan will draw up a concrete plan for extension of CWC's flood forecasting network in consultation with the State Governments and IMD to cover A, B-1, B-2 and C-class Cities located near rivers under the network of automatic data collection, transmission and flood information dissemination. Also it is planned to extend the inflow stations network to cover an additional 160 reservoirs. This would cover 80-90 % of the total live storage capacity in India.

CWC has also established a Flood Forecast Monitoring (FFM) Directorate as a nodal centre for flood forecasting and monitoring in the country. The Directorate operates the Central Flood Control Room (CFCR) during monsoon season on a twenty four hour basis. It also collects flood forecast data from field offices of CWC and compiles it for preparation of daily flood bulletins during the monsoon season. Further, it handles the installation, operation and maintenance of the wireless telemetry network. It is recommended to explore opportunities for broadcasting flood warnings through modern telecom technologies using mobile phones. Voice SMS, Cell Broadcasting Service (CBS) and

Interactive Voice Response (IVR) are being applied in several countries already[15], each having their pros and cons. The advantage of SMS is that it can be more targeted to the user, while CBS can be targeted to a geographic area, voice SMS allows for push-based messages and IVR allows one to access information based on one's own demand. The challenges are both from the end users' side, to actually be open to and pay attention to the message and from the provider's side, to make the information accessible to all end users in a useful and understandable way.

The flood forecasts are shared with the State WRDs, the State DMAs, the NDMA, and also with the media (print and audio visual) in public interest. However, it is up to the WRDs of the respective State governments to use this information in the manner which it deems fit. CWC cannot exercise powers on these State agencies when it comes to matters pertaining to operation of reservoirs and other structures for flood control.

One limitation of the current flood forecasting system is that it does not indicate the area likely to be inundated by floods, as it only provides 'inflow forecasts' and 'water level forecasts'. The data on flood discharge and water levels from the existing gauging stations is used to predict the flood discharge and water levels in the base stations downstream, using calibration curves. These calibration curves are updated every year to take into account the changes in river morphology. However, the agency is now developing skills to forecast flood inundation, using mathematical models, such as also being used in this Study (PATA8086).

4.4.12 Emergency response

If a flood occurs, immediate action needs to be taken to save lives and minimise the damage as much as possible. Here the State Disaster Management Authorities play an important role. States have set up Disaster Response Forces (SDRF) with the assistance of the National Disaster Response Force (NDRF). For instance in Odisha the State Disaster Management Authority (OSDMA) set up Odisha Disaster Rapid Action Force (ODRAF) units in ten places. A detailed description of the activities of the NDRF is given in Section 2.8.2.

4.4.13 Strategies for agricultural systems to address floods

Background

The agricultural sector still plays an important role in the overall Bihar and Odisha economy and social well-being. It contributes roughly 21% to GDP (Gross Domestic Product) of the two states (UNDP, 2012), which is somewhat higher than the national average (around 17%). In both river basins rice is the predominant crop during the Kharif season, and in Bihar also a lot of maize is cultivated, besides a significant amount of pulses. But it has been noted during the field visits that in some parts of both basins during the Kharif season rice is the only crop cultivated due to water stagnation problems. Although pulses, which serve as staple as well as cash crop in the BB basin and

[15] In Bangladesh the Department of Disaster Management has an official system of disseminating bulk SMS, has IVR operational and is piloting with CBS. Also other countries, such as the UK and Australia have experience in using mobile warnings.

stand second in terms of acreage (occupying almost 8% of cropped area), they cannot survive in submerged conditions even for couple of days[16].

In the Rabi season the picture is more diverse and different between the basins. In the Burhi-Gandak basin wheat and maize are the staple cereal crops and occupy about 80% of total cropped area. Pulses and oilseed make up for most of the remaining crops. The field survey revealed that also during the Rabi season waterlogging prevented cultivation in some parts of the basin and in other parts wheat occupies about 70% of the total cultivated area with the remaining area used for the cultivation of potato and maize.

In the Brahmani-Baitarani basin only about 50% of cultivable land is used for the cultivation during the Rabi season. In this season, oilseed occupies about 55% of total cropped area with pulses stand second (about 35%) in terms of cropped area. The field survey revealed that recently farmers have started growing sugarcane after the establishment of some sugar mills in several districts.

Assessment of flood induced impact on agriculture

Floods can damage agricultural crops leading to a reduction in crop productivity. The severity of crop damage depends on the flood intensity (flow, depth and duration) and season. Aerobic crops (e.g., maize, pulses, and groundnut) cannot survive under standing water and submergence. Anaerobic crops (e.g., rice) can resist standing water due to supply of oxygen to root through aerial parts but cannot tolerate submergence longer than 7 days, although special varieties such as deep water rice can resist a flood up to 15 days. However, a sudden rise of water level or inundation during the early stages of crop growth would harm most of the varieties.

From an agricultural point of view floods can be classified as Early Cropping Season Flood, Mid Cropping Season Flood and Late Cropping Season Flood.

Early cropping season flood (June-July): For all major crops, June is the beginning of planting season in both basins. Normally before the onset of the monsoon, farmers sow rice on the lowland and some medium land which grows to a certain height to resist standing water during the month of July and August. After the monsoon onset pulses, oilseeds, and upland rice are sown along with nurseries for transplanted rice. An early season flood would cause:

- Damage to rice in nursery, standing crop of vegetables, pulses, and oilseeds.
- Damage to early-transplanted and directly sown rice.

Mid cropping season flood (August-September): When a flood arrives during this period the extent of losses is often severe and irreparable as the crops are in active growth stage and the farmers have already spent a lot of money on the management of their crops. Besides, farmers loose the season of cultivation and the land cannot be used to cultivate immediately again. Normally a mid-season flood causes:

- Incidence of pest and diseases to standing crop that escaped or resisted flood.
- Damage to upland crops like vegetables, pulses and oilseeds at fruiting stage.
- Damage to short duration rice at maturity stage and medium and late duration rice at growth stage.

[16] Tobisa, M., Shimojo, M., and Masuda, Y. (2014). Root Distribution and Nitrogen Fixation Activity of Tropical Forage Legume American Jointvetch (Aeschynomene americana L.) cv. Glenn under Waterlogging Conditions. Hindawi Publishing Corporation International Journal of Agronomy Volume 2014, Article ID 507405, 10 pages.

Late cropping season flood (October-November): A late flood causes severe damage to medium and long duration rice at maturity and grain filling stage. Farmers bear complete loss of money they invested in their crops. The winter vegetables, oilseeds, and pulses sown in uplands are also seriously affected at growth stages. A late season flood causes:

- Lodging and germination of grains in the field.
- Incidence of disease and pest in crops that escaped or resisted water logging.
- Damage to high value vegetables.

Flood mitigation measures and strategies to protect the crops

Damage to crops and livelihood can be highly significant in terms of cost to the government as well as to the farmers themselves. Although the floodplain is ideal for agriculture, measures can be adopted to prevent seasonal crop losses. These can include a shift in timing for the planting and harvesting of crops, change in the cropping system, etc. Different feasible remedial measures can be given for the early, mid and late cropping seasons.

A farmer that sees its young crop lost due to an early season flood would try to make best what's left of the growing season. However, there is often an acute shortage of seed for re-sowing and replanting operations. Therefore, making seeds for both rice and non-rice crops available would be a useful mitigating intervention from NGO's and Government. Especially seed of short duration varieties would be important because of the shortened season left. Closer spacing and a higher rate of manure application for late planted crops is also advisable.

Mid-season flood usually affect most of the crops at mid-growth stage causing damage in different degree depending upon submergence. Upland paddy which is at maturity stage has to be harvested from top due to standing water in field. Left over seedlings in nursery which have become aged can be utilized for gap filling or replanting in affected rice fields.

In case of complete damage of the crop in rainfed areas during mid-season, direct sowing should take place of horse gram, sesame, green gram and black gram in uplands and relay cropping of pulses in medium and low land once the flood has receded. Cultivation of high value crops in the irrigated areas not affected by floods will generate revenue to farmers and grain crops will help in meeting the requirements of food and fodder needs.

Other remedial measures for mid- and late cropping season floods include replanting of vegetables, oil seeds and pulses in uplands, planting under zero tillage condition, harvesting of paddy from panicle under standing water conditions and nursery raising of vegetables in plastic trays for replanting. Also control measures against swarming caterpillars that sometimes become problematic in rice that escaped or resist the flood should be taken.

Furthermore, reference need to be made to the District Agriculture Contingency Plans which have been formulated for ready reference for management of extreme weather situations, including floods and heavy rainfall. So far 580 district plans have been prepared (Rao et al., 2015). These Contingency Plans are available on the website of the Department of Agriculture. General flood mitigation measures and strategies to protect the crops are listed in Box 10.

Box 10. Mitigation measures and strategies to protect crops

- Making high soil beds in the flood free areas to sow seeds of rice, vegetables and other crops.
- Selecting varieties that can withstand flooding better, such as long stem paddy and hard straw paddy in flash flood areas.
- Prepare floating seedlings in raft.
- Ensure rapid drainage to remove water which is still stagnant.
- Sow seeds, such as molasses, lentils, coriander, maize, mustard, and khesari without cultivating lands after the recession of floodwater.
- Selecting short duration crops with high yield varieties (HYV). The shorter the growing period is the lower the risk of flood loss becomes.
- Improving early warning, to inform farmers well ahead in time about the chances of flood so that they can make appropriate precautionary measures.
- Introduce agriculture insurance schemes in the flood prone areas
- Improving land levels. Fields normally consist of a succession of broad ridges and depressions varying in size and shape. The cultivation of crops on each of the various levels determines the frequency of floods, effectiveness of drainage, and the amount of silts deposited by floods.
- Construction or improvement of embankments protecting agricultural land.

4.4.14 Earthquake resistant design of buildings and river valley projects

When implementing structural measures for flood mitigation care should be given to earthquake risk, especially in high risk zones, such as northern Bihar. The concern on the earthquake resistant design of buildings and river valley projects is not new in the Indian context. Design improvements have been taking place since 1962 periodically. The various IS codes, the National Building Codes have been constantly contributing for these improvements. Because of this concern and improvement activities, river valley projects such as dams and embankments have in-built earth-quake resistant designs. Indeed, there have been no major (flood) disasters due to earthquakes in the past. The main codes of practice and improvements herein are shown briefly below.

1) (IS) 1893:1984 Criteria for Earthquake Resistant Design of Structures

This standard deals with earthquake resistant design of structures and is applicable to buildings, elevated structures, bridges, dams etc. It also gives a map which divides the country into five seismic zones based on the seismic intensity. IS 1893 was initially published in 1962 as `Recommendations for Earthquake Resistant Design of Structures' and then revised in 1966. As a result of additional seismic data collected in India and further knowledge and experience gained, the standard was revised in 1970, 1975 and then in 1984. After the publication of this standard, on account of earthquakes in various parts of the country including those in Uttar-Kashi, Latur and Bhuj as well as because of technological advancement in the field, the Sectional Committee of the Indian Standards decided to revise the standard into five parts which deals with different types of structures: These are

- Part 1 : General provisions and Buildings
- Part 2 : Liquid Retaining Tanks – Elevated and Ground Supported
- Part 3 : Bridges and Retaining Walls
- Part 4 : Industrial Structures Including Stack Like Structures
- Part 5 : Dams and Embankments

2) Further updating in the IS code of 1984

Further updates incorporated in 1993 included:

- IS 4326:1993 Earthquake Resistant Design and Construction of Buildings - Code of Practice. This standard provides guidance in selection of materials, special features of design and construction for earthquake resistant buildings including masonry construction, timber construction and prefabricated construction.
- IS 13827:1993 Improving Earthquake Resistance of Earthen Buildings – Guidelines: The guidelines covered in this standard deal with the design and construction aspects for improving earthquake resistance of earthen houses, without the use of stabilizers such as lime, cement and asphalt.
- IS 13828:1993 Improving Earthquake Resistance of Low Strength Masonry Buildings – Guidelines: This standard covers the special features of design and construction for improving earthquake resistance of buildings of low-strength masonry.
- IS 13920:1993 Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces – Code of Practice: This standard covers the requirements for designing and detailing of monolithic reinforced concrete buildings so as to give them adequate toughness and ductility to resist severe earthquake shocks without collapse.
- IS 13935:2009 Seismic Evaluation, Repair and Strengthening of Masonry Buildings – Guidelines: This standard covers the selection of materials and techniques to be used for repair and seismic strengthening of damaged buildings during earth-quakes. It also covers the damageability assessment and retrofitting for upgrading of seismic resistance of existing masonry buildings covered under IS 4326 and IS 13828. The provisions of this standard is applicable for buildings in seismic Zones III to V of IS 1893 (Part-1).

3) Major Update of Part 1-The General Provisions (2002)

Several major modifications have been incorporated in the new edition of 2002 of the code. It included a new seismic zone map with four zones, compared to the five zones earlier (Figure 27). More importantly, the code now provides realistic values of acceleration from which the design forces are obtained by dividing the elastic forces by a response reduction factor.

4) National Building Code of India 2005 (SP(7):2005

The National Building Code covers the various loads, forces and effects which are to be taken into account when designing buildings. Besides seismic loads the Code also cover dead load, imposed load, wind load, snow load, special loads and load combinations. The code was first published in 1970 and revised several times, also to stay in line with the Indian Standard on earthquake resistant design of structures (i.e. IS1893).

Development of Codes with Focus on River Valley Projects.

There is a basic difference between the load bearing behaviour of buildings and bridges on the one side, and dams on the other. Under normal conditions buildings and bridges have to carry mainly vertical loads due to the dead load of the structures and some secondary live loads. In the case of concrete dams the main load is the water load, with a vertical upstream face acts in the horizontal direction. In the case of embankment dams the water load acts normal to the impervious core or the upstream facing. Earthquake damage of buildings and bridges is mainly due to the horizontal earthquake component. Concrete and embankment dams are much better suited to carry horizontal loads than buildings and bridges. Large dams are required to be able to withstand an earthquake with a return period of about 10,000 years, whereas buildings and bridges are usually designed for an earthquake with smaller return periods.

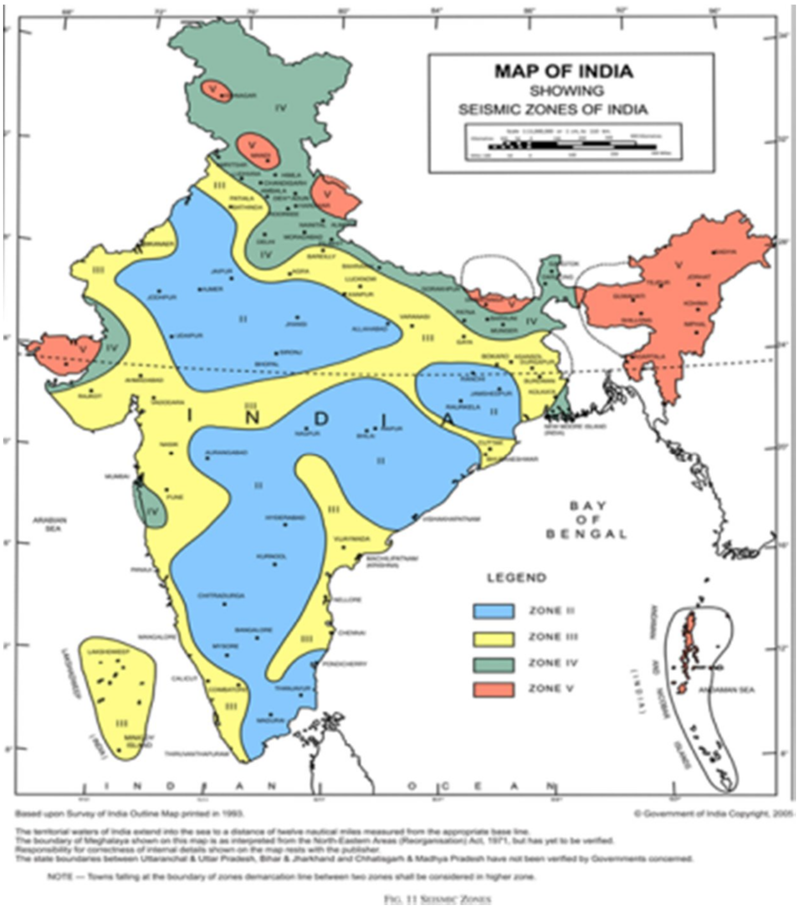

Figure 27 Seismic zones of India

In 2011, the CWC has issued guidelines for the design of earthquake resistant designs particularly for river valley projects, which are of more relevance to this study. These form part of DPR preparation guidelines stipulations and unless these guidelines are followed no DPR is approved (CWC, 2011). These guidelines deal with the preparation of site specific seismic study report of a river valley project and its submission to the National Committee on Seismic Design Parameters (NCSDP) for necessary approval. The guidelines will help in estimation of the parameters to be used in seismic design, analysis and safety evaluation of new or existing dams and their appurtenant structures. It is also expected that the guidelines will bring uniformity in site specific seismic studies being carried out by different expert organizations.

The site specific seismic studies need to be carried out and submitted for the approval of NCSDP in respect of all such river valley project/dams that are classified under 'high' or 'extreme' hazard potential categories. It is mandatory for the large dams that fall in seismic zone III, IV or V to get the approval of NCSDP for site specific seismic studies for the assessment of design earthquake parameters. However, for the projects in seismic zone II, the approval of NCSDP for the site specific seismic studies will be mandatory for dams that are more than 30 meters in height. As such the earthquake resistant designs of all the river valley/flood control projects are fully taken in to account.

Recommendations on seismic instrumentation for River Valley Projects

The Recommendations for Seismic Instrumentation for River Valley Projects (IS 4967:1968) were issued as early as in 1968, considering various type of observations, stages of observation and accuracy of observations. This standard covers recommendations for instrumentation for investigation of seismicity, study of micro-tremors and predominant period of a dam site and permanent installation of instruments in the dam and appurtenant structures and in surrounding areas. These standards also provide guidelines in designing and repairing of buildings under seismic forces. These are invariably followed in the river valley projects, except in the case of small flood control embankments.

4.4.15 Groundwater recharge

In India groundwater is a signification hydrological component of watershed and river basins due to the nature of river discharge, topography and soil characteristics. Because almost 80% of the annual flow in the most of the rivers occurs in the country during the 4 months of July through October, groundwater plays a crucial component in any river basin management. Average drainage from aquifers is estimated in the order of 30% of stream flow (Rivera et al., 2002).

Groundwater recharge has the double advantage in reducing surface run-off (and thereby reducing possible floods i.e. flood cushioning) and storing water for the dry season. It is a natural process but can be enhanced through man-made measures. Artificial groundwater recharge is becoming increasingly important in India, and states like Maharashtra and Gujarat are using this to replenish depleted groundwater resources. However, for BB and BG basin where Rabi crops contribute less that 30% it has a different dimension of improving economic resilience if there is a mechanism to increase use of groundwater. Increase in use of groundwater (mainly unconfined aquifer) will also act as flood cushioning as it will absorb part of the surface run-off. However, this requires basin specific investigation as for instance the downstream district like Bhadrak in BB basin has issues of saline water intrusion and groundwater extraction is not recommended. In this regard, it is important to note that the CGWB support States in developing broad policy guidelines for development and management of ground water resources including conjunctive use of surface water and ground water resources. As part of the conjunctive use studies already mathematical modelling have been completed for Kosi, and Gandak Command Areas of Bihar to providing scenario of sustainable conjunctive use of surface and ground water[17].

The extent of which artificial groundwater recharge can reduce flooding is a widely debated topic in India since early 1970s when Revelle and Lakshminarayana in their paper in 1975 introduced the concept of “Ganges water machine” or GWM. The idea of the GWM is that intensive dry season pumping in narrow bands along rivers lowers the water table. Infiltrating river water raises the water table during the following monsoon season. This induced storage is pumped out during the following dry season, creating a cycle of storage and release that eventually reaches dynamic equilibrium. In a recent paper Khan et al. (2014) examined the effectiveness of the GWM and similar interventions through a (groundwater) model study. With respect to the impact on flood reduction their qualitative assessment revealed that infiltration during the early part of monsoon season would result in a lower river stage before peak flood flow, so channels would accommodate more peak

[17] http://www.cgwb.gov.in/hindi/GroundWater/conjunctive_use.htm

flow. Additionally, flow reduction would occur because of river flow diversion for canal-based monsoon irrigation. Further, an increase in irrigation activity is likely to increase groundwater recharge thereby decreasing immediate runoff generation from overland flow. Lastly, in GWM, since the water table along river channels where flooding occurs would be deep, floodwater could infiltrate the subsurface quickly, reducing flood duration.

Clearly, there will be some impact, but it requires an in-depth domain specific study to estimate peak flow reduction during a particular flood event rather than a percentage of average monsoonal flow reduction (being in the order of 6-20%) which was prepared by Khan et al. The effect of groundwater recharge will be most prominent for small peak flows with high return periods and reduces for more extreme floods.

4.5 Institutional arrangements for planning and implementation

4.5.1 Proposals for appropriate legal framework for IFM

The review in Section 2.3 shows that states have already enacted laws with provisions to deal with matters connected with flood control works. There is a very useful legal space in terms of laws that already exist which can be utilized for better flood regulation in the country. The fact that states also have laws, some of which date back to colonial times regulating various aspects of flood management and control has been almost hidden from the public discourse on floods. Nevertheless, even while the states have provisions in various laws that could be utilized to deal with flood management there is a need to integrate the disparate laws addressing the range of issues for a unifying legal perspective for flood management in India.

A Working Group on Flood Management & Region Specific Issues of the Planning Commission constituted for the 12th Five Year Plan also notes *"[However], the present structure of the State level flood control departments needs to be revamped to discharge their role as prime flood managers in the State*." Clearly there needs to be greater political and legislative will to give effect to plans on flood management as we move ahead.

Based on the key gaps and constraints in the legal regime that exists in States including in Bihar and Odisha, the following proposals and recommendations are presented point-wise below:

- Legal provisions on various aspects of flood management in different states including states of Bihar and Orissa exist but they are spread very unevenly across the States. Some of the best practices, in terms of enactment of useful legal provisions in one State, have not led to adoption of similar provisions by other flood prone States. *Hence, there is a need to integrate the disparate laws addressing the range of issues for a unifying legal perspective*.
- There is a mismatch between institutional powers and obligations. While on one hand the relevant laws give substantial power to authorities to take all possible measures in times of floods, there are no enforceable obligations that they are committed to in times of such emergencies. *Since the responsibilities of authorities in times of flood are not couched in mandatory terms the correlative rights with the flood affected people is of limited value.*
- The legal regime on control of land use with respect to flood risk is still inadequate. Only three States have Flood Plain Zoning Acts but they haven't been given any operative effect. There are general laws in some states that could be invoked for regulating land use in flood

prone areas but these legal spaces also haven't been utilized. *States are therefore encouraged to follow the recommendations of the National Water Policy 2012 and use the Model Bill on Land use zoning.*

- Flood insurance and financial incentives for incorporating flood considerations into personal / institutional behaviour are still blind-spots in the existing legal regime. *Flood insurance and financial incentives are critical law reform areas that need to be taken up urgently.*
- The existing legal regime on the housing and building regulations does not specifically provide for considerations to minimize flood damage. *It is recommended to include flood hazard in the housing and building regulations.*
- A disaster management mechanism has been introduced through the enactment of the Disaster Management Act, 2005. The Act provides for National Plan and Department Wise Plan but does not speak about local plans. This is a critical omission because the limits of technical expertise need to be supplemented with native intelligence. This intelligence needs to be tapped for devising approaches to management of disasters and thus *policies and laws for flood management need to provide space for such intelligence to be counted.*
- Generally speaking, the involvement of Stakeholders in decisions making on flood management in all area and levels have been inadequate. This is notwithstanding the constitutionally and legally mandated role of the Panchayat Raj Institutions and the Municipalities. *Therefore it is recommended to make more use of the existing legal opportunities to involve communities in flood management and planning.*

4.5.2 Appropriate institutional strategies and requirements for IFM

There are multiple agencies whose work has implications for flood management--right from the acquisition (IMD, NRSA, CWC, WRD) and analysis (WRD, CWC, ID) of meteorological and hydrological data relating to floods for flood forecasting, to the application of the knowledge so generated for planning, design, execution and operation of flood prevention (Forest, Agricultural, Groundwater, Watershed Departments) and flood control works (WRD), executing the early warning system (District Administration, the National and State Disaster Management Agencies), and mitigation and relief works. Their approach is highly 'sectoral' and their actions 'segmented', without caring for the un-intended outcomes they produce elsewhere in the basin for other sectors of water and land based economies or in the same sector. Proper coordination of the functions of various line agencies is crucial to achieve the desired outcomes in terms of environmentally sustainable flood management measures that are cost effective.

There are three pre-requisites for institutional development. *First*: the existing institutional arrangements need restructuring, with roles and responsibilities of individual organizations and relationship between various organizations redefined. This is to increase transparency and accountability. *Second*: the capabilities of various organizations/institutions need to be strengthened so that they perform their functions well. *Third*: the new institutional arrangement should facilitate a coordinated action by all players on the basis of a basin level plan for water resources management and flood management, with 'incentive structures' in place for the individual actors to perform.

Institutional Design Principles

1. The agency which develops flood management plans (FMP) should not be executing it to avoid creation of vested interests and biases. For instance, if an agency which is independent of the WRD, develops a food management plan, it would explore all possibilities, such as regulations with respect to land use zoning, reservoir operations, catchment land use etc., for flood risk mitigation.
2. The agency which executes work for flood control/prevention (such as WRD) should not be doing flood forecasting—as there are likely chances of over-estimating the flood volume, in an effort to hide their operational inadequacies.
3. The agency executing flood control work (the WRDs) should not be engaged in flood damage assessment—as it might try and show less damage. Instead, it would be most appropriate for the NDMA to appoint a scientific/technical committee do the flood damage assessment.
4. The agencies doing flood relief operation (SDMAs) should be responsible for issuing flood warnings and community awareness and education about floods--as they have strong incentive to do it to reduce the amount of rescue and relief work
5. All agencies working on issues such as flood management need to have an inter-disciplinary orientation by design, rather than a pure technical orientation.

Creation of River Basin Organizations (RBO)

River basin organizations would be the ideal legitimate institution for implementing flood management programmes. Creation of RBOs will be part of the institutional reform process and can be effected through the enactment of legislation at the State level. The RBO, which is envisaged here, shall be an independent body to be constituted through the enactment of a law, with statutory powers required to coordinate the flood management functions. The Act can be in the lines of the RBOs to be formed under the provisions of Water Resources Regulatory Authority Act (MWRAA, 2005) of Maharashtra, but with different types of functions, due to the reasons explained above. The idea is that the flood management plans, developed by the agency, would become a statutory document to be followed by all agencies, which are active in the basin, and whose activities have implications for flood control and management.

A River Basin Organization (RBO) should be constituted on three design principles. i) The operational boundaries of the governance units created for effective management should match with the hydrological system boundaries; ii) The institution that is responsible for enforcing norms and regulations on water releases and use (including pollution) should be responsible for investment in water quantity and quality management; iii) The governance/management structure will integrate local water management interventions with larger basin management actions and promote involvement of user groups / communities in the governance and management (Figure 28). The proposed management structure enables cooperation between national, state and local organisations as well as communities living in a river basin (Kumar, 2006).

In relation to flood management we suggest the RBO to have the following functions: i) developing a flood management plan, with strategies; ii) monitoring of operation of flood control/regulation structures, including dams, by the agencies concerned (like the WRD) to ensure that they are according to the plan; iii) monitoring land use changes (forest cover, agricultural land use), and examining whether zoning regulations are violated; iv) inspection system for the flood control structures, checking and authorization, monitoring the flood fighting system, and providing support systems for flood fighting; v) monitoring the flood warning system, flood preparedness and maintenance system; and, vi) monitoring the community engagement system, monitoring the resources, and monitoring the communication system.

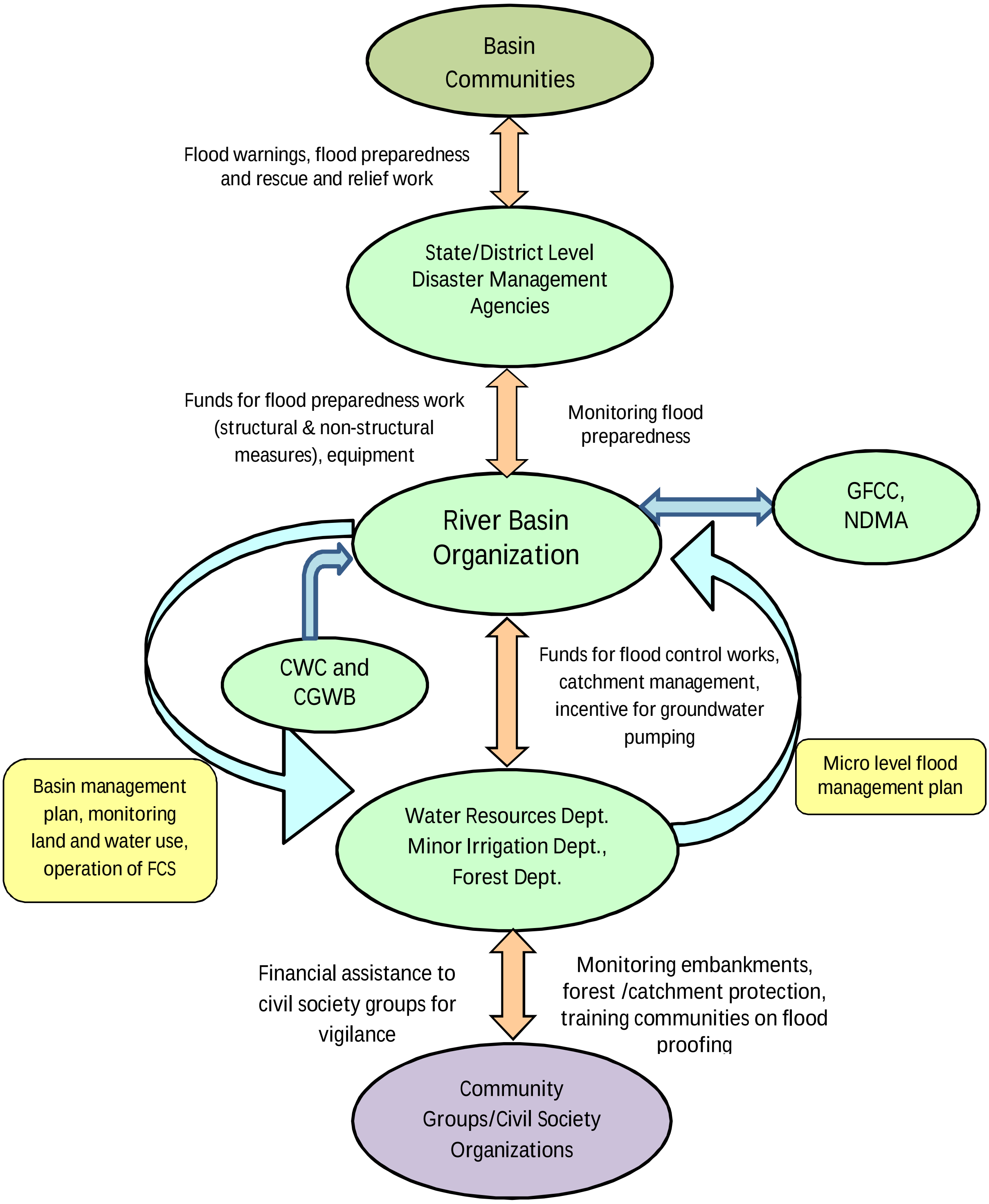

Figure 28 River Basin Organisation and its role in IFM (Source: Kumar 2006)

Developing the flood management plan is not a one-time activity. The flood management plan, once developed by the RBO, shall be shared with the various stakeholders in the basin starting from the local communities to various state level (SDMA, WRD, GWD, Forest Department, etc.) and central level agencies (CWC and Central Ground Water Board - CGWB) for their inputs and feedbacks, to improve the plan. Inputs from the stakeholders could be in terms of the following: To what extent is flood prevention possible through catchment land use changes and groundwater draft? Up to what floods intensity, flood control work should be resorted to? Which are the localities where embankments can be constructed? To what extent land use regulations would be feasible? The planning for flood management therefore would be an iterative process. Here, specific inputs from CWC can be sought for understanding the functions of catchment management in flood reduction and specifications for the design of flood control structures, apart from obtaining forecasts on flood discharge and water levels in the basin. Specific inputs from CGWB can be sought for understanding the impact of groundwater draft in reducing floods in the basin.

While developing strategies, it should use the policies and guidelines for flood control developed by the GFCC (1986) as well as the planning approach described in section 4.1.3 of this report. The NDMA can assess flood damages with the help of NDMI and release funds, other resources and equipment for rescue, resettlement and rehabilitation works; the SDMAs can issue flood warnings and also carry out flood rescue and relief operations; the CWC regional office and RBOs can jointly undertake flood forecasting. This is in accordance with the institutional design principles discussed earlier.

Since floods have both beneficial and destructive aspects, Integrated flood management, while reducing the 'risks' associated with floods, should also take advantage of the beneficial aspects. Some of the benefits of floods are recharge of groundwater in the flood plains; depositing of nutrient laden silt on agricultural land, augmenting of wetland, increase in fish production and rejuvenation of river ecosystems (WMO, 2006). The flood management strategies, so developed by the RBO should therefore include: structural and non-structural measures for flood proofing, for floods of low magnitude which occurs with high frequency; and strengthening of flood forecasting and enhancing the early warning system. The idea is to strengthen adaptive capability of the communities to floods of low magnitudes rather than completing controlling them. Flood proofing of the housing infrastructure and communication links can be possible by raising the height, in areas which have sparse population and where flooding is very frequent. Good flood forecasting and early warning would ensure that the communities are informed well in advance of the magnitude of risks associated with the incoming floods and are able to take the right precautionary measures including evacuation.

Inter-basin coordination of the RBOs would be necessary for operationalizing strategies such as diversion of food waters from one basin to another, at times when one of the basins experiences excessive floods and a neighbouring basin has enough flood cushion.

We understand that setting up RBOs is a long and arduous process. Therefore, we propose that in the interim period in each State WRD a *Project Preparation Cell for IFM projects* should be created, which consists of a multi-disciplinary team of professionals with specialization in water engineering, economics, catchment hydrology, flood control, environmental management, a hydropower, ground water and rescue/relief operations. These could be drawn on deputation from the line departments/ministries of the respective States. In fact, such Cells already exist in the State Water Resources Departments of both Bihar and Odisha in the name of Flood Management Cell, which are operational during the flood season. They can be strengthened with adequate human resources for developing basin-wise IFM plans. At the Central level, the existing Flood Management Organization (FMO) in CWC headquarters can Act as the Project Preparation Cell for developing IFM plans and strategies, for trans-boundary basins/sub-basins. The administration of the functions of the regional offices of CWC are already organized around river basins (such as the Mahanadi Basin Organization, Eastern Ganga basin organization etc.), and these offices can work with the newly created *Project Preparation Cells* within the respective State WRDs to prepare plans and strategies for IFM. This arrangement would not require legislative procedures and could therefore be implemented immediately by the WRD and CWC. It would also speed up the DPR process if officers in the State Cells are trained in making compliances in their respective domains.

4.5.3 Strategies for mainstreaming CC scenarios in state and national planning

Mainstreaming suggests a more effective use of available resources, rather than designing, implementing and managing climate change adaptation separately from on-going management (Klein et al. 2007). For guiding mainstreaming of climate change adaptation into the water sector in flood prone States such as Bihar and Odisha in India, we have looked at several available documents that have emerged from practical experiences (UNPEI, 2007; Dalal-Clayton and Bass, 2011; ADB, et al., 2003; Munasinghe, 2002; King, 2010; ECAWG, 2009; UNDP, 2011; Benson, 2009; OECD, 2012; Mitchell, et al., 2006; McGray, et al., 2007; OECD, 2006; and Prabhakar, 2010). Because successful adaptation hinges upon synergy across sectors, it is useful to develop a strategic view to avoid mal-adaptation and incoherent approaches within and between sectors. Such strategy should provide a integration framework on the mainstreaming of climate change adaptation at the State and sectoral levels (primarily water resources).

Such a framework would cover government policies, because formal governance systems determine the overall space for the system's adaptive capacity and set the limits for successful adaptation (Brockhaus *et al.,* 2009). Strengthening of the regulatory institutional or economic mechanisms can contribute to effective adaptation in the relevant policy areas. The extent to which this space is used depends on individual decision makers and their understandings. Hence, lack of knowledge and experience can act as a significant barrier to adaptation. Lack of connectivity between national and local levels can lead to isolated political processes and a reduction of adaptive capacity at the local level.

A good way to start would be to formulate a framework for capacity improvement, including the capacity to align all policies, programs and activities and to make the efforts measureable (verification system). Possible entry points are the pro-food policy (food security), energy and water, pro-poor policy (poverty reduction programs) and pro-growth policy. To ensure effective coordination on adaptation it is recommended to establish regular communication or a consultation forum between key institutions and to monitor, evaluate and improve the status of adaptation policies. It is easier to begin with on-going practices rather than opting for new approaches. The policy component, in terms of mainstreaming, could be extracted from existing policies or government policies to address climate change issues.

The Climate Change Adaptation Strategies for local impact should include the following:

1) Prioritize adaptation efforts in communities where vulnerabilities are highest and where the need for safety and resilience is greatest.
2) Build projected climate change related trends in today's risk and vulnerability assessment (such as for flood risk assessments).
3) Fully integrate adaptation into longer term national and local sustainable development and poverty reduction strategies.
4) Prioritize the strengthening of existing capacities – among local authorities, civil society organizations, and the private sector – to lay the foundations for the robust management of climate risk and the rapid scaling up of adaptation through community-based risk reduction and effective local governance.
5) Develop robust resource mobilization mechanisms for adaptation that ensure the flow of both financial and technical support to local actors.
6) Leverage the opportunities in disaster prevention and response, through improved early warning systems, contingency planning and integrated response, to promote effective community-based adaptation and risk reduction.

The checklist to monitor climate change adaptation mainstreaming (UNFCCC, 2009) is given in Box 11. To include climate change in local flood risk management it is recommended to follow the approach given in this report, by estimating the increase in risks using rainfall projections from downscaled CC models in flood risk models. As can be seen in the modelling results for the two basins (section 3.4), an increase in flood risk in 2040 is significant for Brahmani-Baitarani and less so for Burhi-Gandak. These outcomes should guide the adaptation measures to be taken as part of flood control and vulnerability reduction projects.

Box 11. Checklist to monitor climate change adaptation mainstreaming (Source: UNFCCC, 2009)

Finding the Entry Points

- ✓ Entry points for adaptation mainstreaming agreed on and related road map taken into account in the work plan for the next stage of the effort,
- ✓ Key ministries and other non-governmental actors (e.g. representatives of communities and the private sectors) relevant to the agreed entry points are members of the steering committee or task force of the adaptation mainstreaming effort,
- ✓ Adaptation mainstreaming champions liaising with in-country donor coordination mechanisms,
- ✓ Increased awareness of food security and vulnerable people/areas – e.g. poor people in coastal areas are likely to be the most affected by climate change,
- ✓ Activities to be implemented in collaboration with finance and planning or relevant sector ministries included in the work plan for the next stages of efforts.

Mainstreaming Climate Change Adaptation into Policy Processes

- ✓ Country-specific evidence collected on the costs and benefits of climate change and adaptation (e.g. impact, vulnerability and adaptation assessment, socio-economic analysis, demonstration projects),
- ✓ Adaptation and its links to food security strategy, poverty reduction, and pro-growth development included in the working documents produced during the targeted policy process (e.g. documents produced by the working groups of the relevant national, sector and sub national planning processes),
- ✓ Adaptation and its links to food security strategy, pro-poor policy, and pro-growth development included as a priority in the completed policy documents of the targeted policy process (e.g. poverty reduction strategy paper, MDG strategy, relevant sector or sub national plan), and

- ✓ Climate-proofed and specific adaptation policy measures for climate change adaptation costs by finance and planning or sector ministries and sub-national bodies.

Meeting the Implementation Challenge

- ✓ Adaptation-related indicators linked to policy documents of national development planning integrated in the national monitoring system,
- ✓ Increased budget allocations and public expenditures for adaptation policy measures of non-environment ministries and sub-national bodies, and
- ✓ Adaptation mainstreaming established as standard practice in government and administrative processes, procedures and systems (e.g. budget call circulars, systematic inclusion of adaptation in public expenditure reviews, coordination mechanisms, systematic climate-proofing, monitoring).

Long-Term Outcomes

- ✓ Institutions and capacities strengthened for long-term adaptation mainstreaming, and
- ✓ Conditions for simultaneous improvement of adaptation and poverty reduction enhanced.

Chapter 5 Conclusions and Recommendations

5.1 Conclusions

In this report an integrated approach is advocated, for which a framework and guidance are given. Our research, using river basins in Bihar and Odhisa as case studies, provides clear insights into bottlenecks as well as promising interventions that would reduce the losses and burdens of millions of people currently affected by floods. Mathematical modelling as well as social surveys proved to be key to unravel the intricacies of the problem: to quantify what needs to be quantified and to qualify the needs from the grassroots level. Major conclusions can be drawn from these basins which in many ways can be regarded representative for many others:

- As per our model calculations for both river basins it was found that by providing the 1:25 safety standard for rural areas around 90% of the average annual damage could be avoided. This implies that the marginal extra benefits quickly diminish beyond this safety standard.
- In terms of flood hazards, climate change is expected to cause heavier rainfall events and can lead to significant increases in flood extent (in the order of 25% in 2040 and perhaps 30% in 2080 in the case of the Brahmani-Baitarani). To maintain present flood safety standards, embankments should be raised in the order of 80 cm in 2080. Still, most interventions do not take such increase in flood hazard into account.
- Upstream structural flood control measures, such as dams and river diversions, would lead to a significant reduction in flood hazard. Typical reduction factors in flood extent for new upstream projects in the two study basins are in the order of 5 to 10%. Complete flood control is not feasible.
- Flood embankments are currently and will remain the major flood control measure and the preferred option by a majority of the people. Still a large number of people are living in areas between the embankments and the river and are therefore liable to flooding (especially in Bihar). Technical standards, regulations and design guidelines for embankments are in place, but not always followed up during implementation. Safety standards for embankments (return periods) are still not defined using a genuine risk approach, comparing costs and benefits.
- Non-structural measures necessarily complement structural measures, as is well understood by all key stakeholders. However, flood forecasting, early warning and community preparedness are far from satisfactory. Community disaster management plans are still not mainstream practice. Land zoning is not actively implemented as part of flood management as legislation is still not enacted in most States.

This report provides a strategic framework for preparing integrated flood management plans. The framework follows the internationally accepted flood risk approach. An indispensable tool for such approach is a mathematical model to simulate flood hazards from source (rainfall) via pathway (river and floodplain) to receptor (people and their assets). It is only through such tool that effectiveness of measures can be assessed after which fruitful combinations can be built into a basin wide flood management plan.

Our study showed that it proved to be quite feasible to run a complete 1D/2D hydrodynamic model of the entire lower part of the basins (covering some 25,000 km^2 with approximately 100,000 calculation points). Runtime was in the order of 20 min. on a desktop computer. The advantage of running a dynamic 1D/2D model instead of first running a 1D model and then estimating the flood extent through GIS is that it much better includes the storage effect of the flooding itself during a flood event.

To bring about improvements in current flood management practices, the following recommendations have been formulated:

Flood Risk Analysis
Perform risk analysis at *the basin level* to obtain flood risk maps under current conditions and under scenarios of climate change. Such analysis should use a state-of-the-art mathematical model for hydrology and hydraulics. In order to derive validated model results the data on hydrological parameters, elevation, land use and infrastructure should be checked on consistency. In many cases a joint probability analysis needs to be performed in order to derive the appropriate return periods. Failure modes of embankments need to be researched and reservoir operation modes studied. Exposure and vulnerability data should also be made available and validated with community surveys. Fragility or damage functions for various assets as well as agricultural crops can be used from generic (Indian) sources or should be adapted for local conditions in case of significant deviation from the country average.

It is recommended to include possible climate change effects on the flood hazard. Ideally, downscaling of global climate models should be conducted for each basin or state, as has been performed in this study for the two states. Performing such a study might not be feasible for each project. Then, a factor for quantum of increase could be established so all future projects in that area can use those numbers.

Flood Risk Evaluation
Discuss the resulting flood risk maps among stakeholders to evaluate the acceptability of the risks and to decide if new measures are needed. Evaluation can be done based on predetermined safety levels (such as 1:25 year return period for agricultural areas and 1:100 year for urban areas), or on a full-fledged economic cost-benefit analysis. Also community needs and conditions need to be taken into account because there can be other than purely economic reasons for establishing a safety level.

Selection of flood mitigation measures
The entire gamut of measures, both structural and non-structural, needs to be taken into consideration for choosing the appropriate strategy. Ideally, the combined measures should reduce the hazard, limit the exposure and reduce the vulnerability. It should be kept in mind that there always will be a residual risk for which appropriate (government) intervention is required in the form of emergency response and relief funds. There is no general recommendation to prioritize measures, since each river basin has different physical as well as socioeconomic characteristics. Again, economic analysis as well as stakeholder consultations help making the right decisions. Mainstreaming measures with other policy domains (e.g. urban planning, watershed management, irrigation development) can greatly enhance their feasibility.

In the Indian context, most if not all possible types of measures have been introduced already at least somewhere sometime. The experiences and practicalities have been discussed extensively in this report. The enormous diversity in measures and conditions in which they can be taken precludes generic recommendations or guidelines. However, a multi-criteria analysis, based on the sub-basin studies, provides some guidance to prioritize measures in a river basin flood management plan. The table below shows the scores of each type of measure on four different criteria: i) flood reduction effectiveness, ii) investment size, iii) BC Ratio and iv) time scale needed for implementation. Scores are given on a scale of 1 to 5, where 5 denotes a good score and 1 a bad score.

Table 9 Multi-criteria analysis for Flood Mitigation Interventions

Intervention	Flood reduction effectiveness	Investment size	BC ratio	Time scale*	Overall rating
Flood warning	None 0	Low 5	Very high 5	Short term 5	15
Community Preparedness & Disaster Management	None 0	Low 5	Probably high 4	Short/medium 4	13
Embankments	Medium 3	High 2	High 4	Medium term 3	12
Crop protection	None 0	Low 5	? 2	Short/medium 4	11
Watershed management	Medium 3	Medium 3	? 2	Long term 2	10
Urban and rural drainage	Medium 3	High 2	? 2	Medium term 3	10
Dams and diversions	Medium 3	Very high 1	Medium 3	Long term 2	9

*: short term < 3 years; medium term 3-5 years; long term > 5 years

A first conclusion from the table is that none of the measures reach the maximum score of 20, but neither of them have a very low score. Apparently all have strong and weak points, resulting in final scores between 9 and 15.

The multi-criteria analysis presented here shows highest scores for non-structural measures Flood Warning and Community Preparedness & Disaster Management. Although they do not reduce the floods themselves, they score very good in terms of low investments and relatively quick results. Embankments, Crop protection, Watershed management and Urban & Rural Drainage have average scores between 10 and 12, but for different reasons. Embankments do reduce floods and often have good BC ratios, but they require substantial government funding and implementation takes many years. Crop protection does not reduce floods but requires little investment. On the other hand, its implementation requires appropriate market conditions which will take time to develop. Watershed management could significantly reduce floods, but its implementation will be a long term process. Urban & Rural Drainage is capable of substantially reducing inundations but requires high investments and results will be visible in medium term only. Dams and diversions have a lower score. Although they can significantly reduce floods, they require massive government funding and implementation will take many years.

In summary we recommend:

- Urgent measures first: these include all kinds of repair and emergency measures, in order to avoid major problems in the next flood season.

- Short term measures: implementing measures which can reduce flood impacts in the coming years and do not require large investments (such as adjustment of reservoir operation rules, improved flood forecasting and warning and community preparedness plans).
- Medium to long term measures, which require some kind of study and /or DPR approvals. This includes upgrading embankments, new dams and diversion projects, watershed improvement, land use zoning etc. For embankments the concept of a dike ring should be adopted, which provides a standard safety for the entire area that is enclosed by the embankment.

5.2 Proposals to integrate IFM under CC into CWC's DPR requirements

5.2.1 Evolution of the Existing DPR Requirements

The Guidelines for Submission, Appraisal and Clearance of Irrigation and Multipurpose Projects, 1989 were prepared by the Project Appraisal Organisation (PAO) of the CWC on the basis of the recommendations of the National Conference of Irrigation and Water Resources Ministers held in July, 1986. A revision of the Guidelines was issued in 2010, which would streamline the review procedure to avoid that projects would be pending too long before receiving investment clearance from the Planning Commission.

According to these Guidelines the concerned State Government needs to submit to CWC a preliminary report in the initial stage. The project proposal is examined and, if found acceptable, the CWC conveys *'In Principle'* consent to the State Government for preparation of the Detailed Project Report (DPR). During DPR preparation the State Government requests necessary clearances from the Ministry of Environment & Forests based on an Environment Impact Assessment and, if Scheduled Tribe population is involved, clearance is requested from the Ministry of Tribal Affairs based on a Resettlement & Rehabilitation (R&R) Plan.

The DPR thus prepared is submitted to CWC, which finalizes the cost, BC ratio, internal rate of return and other important technical components after which the State Government obtains concurrence of the State Finance Department for the finalized cost. In States where central design and planning organizations do not exist, the CWC checks the designs also. Thereafter the project proposal is put up to the Advisory Committee for clearance. For projects in the Ganga basin the above appraisals and recommendations for clearance are undertaken by the GFCC.

5.2.2 Preliminary and Detailed Project Report

The preliminary report is prepared after collecting the necessary information, if needed through surveys and investigations. Checklists are provided by the Guidelines that contain information required for initial assessment of soundness of the project proposal. The preliminary report is to be quickly scrutinized by CWC within a time frame of 18 weeks. Once a report is found acceptable, an 'In Principle' consent of CWC shall be given for DPR preparation which has a validity period of 3 years. In case investment clearance is not accorded to this project within this validity period, the In Principle consent will suo-moto lapse.

Items for Preliminary Report

- General Data and General Planning
- Inter-State and International aspects
- Geological investigation
- Seismic investigation
- Foundation investigation
- Construction material survey
- Hydrological and meteorological investigations
- Hydrology
- Drinking water requirements
- Irrigation planning
- Plans for other intended benefits
- Environmental and Ecological aspects

The DPR is prepared by the State government in accordance with applicable Indian Standards and Guidelines, and submitted to CWC after detailed surveys and investigations. It must be ensured that duly completed check-list, salient features and all relevant details as well as maps and annexures, as required by the aforesaid Guidelines are contained in the report and estimates are comprehensive as well as up-to-date. The clearances obtained in respect of Environment Impact Assessment and Forest and R&R Plans, shall be appended with DPRs and implied costs shall be duly accounted for in the estimate. During examination of the DPR, observations are listed and communicated to the State governments. After attending to these observations the State government send compliances to CWC. Subsequently, the final estimate is firmed up from the details based on finalized designs and details of civil and hydraulic structures.

Once the techno-economic viability of a Project Proposal is established, a comprehensive note and check-list, duly finalized by PAO (CWC) is circulated among the Members of Advisory Committee of MoWRRD&GJ for consideration and clearance of the DPR. State government officers associated with the project formulation/design are invited to the Advisory Committee meeting. After examining the viability of the project the Advisory Committee will take a decision during the meeting. The projects found acceptable by the Advisory Committee shall be recommended for investment clearance by the Planning Commission and inclusion in the Five Year Plan/Annual Plan.

Normally, the appraisal period of the DPR is completed within 6 to 12 months after DPR submission, depending upon the response of the concerned State in respect of the observations of Central Agencies and submission of all pending clearances. If they are not furnished within one year, the project shall be treated as returned.

In reality, many bottle-necks used to crop up causing delays in getting clearances from line Ministries by the State Governments. As a result, a number of project proposals remained in the pending list of CWC even for more than the plan period. By the time compliance to the observations was given by the State Government the project estimates would be irrelevant and needed modification. In spite of the streamlining through the Modifications from 2002 and 2010, the DPR approval process still often takes a long time due to noncompliance of all aspects by the state governments. It is suggested that a River Basin Organization (RBO), who will be empowered to accelerate clearances on a faster phase would be the ideal solution to these unduly delays. Or alternatively, a Project Preparation Cell in each WRD with officers who are trained in making compliances in their respective domains, could speed up the process to get the DPR approval in time.

5.2.3 Brief appraisal of the check list

The very exhaustive checklist reflects the guidelines and runs into 18 pages, covering 23 main clauses with a set of sub-clauses in each main clause. The main clauses are indicated below:

Check list items for DPR

(i) Location	(xii) Flood Control and Drainage
(ii) Category of the project	(xiii) Navigation
(iii) Planning aspects	(xiv) Hydro-power
(iv) Inter-state and inter-national aspects	(xv) Plants and Plant planning
(v) Surveys	(xvi)Foreign Exchange
(vi) Geological aspects	(xvii) Financial Resources
(vii) Foundation Investigations	(xviii) Cost Estimates
(viii) Material Surveys	(xix) Revenues
(ix) Hydrological and Meteorological Investigations	(xx) Benefit Cost Ratio
(x) Land acquisition and resettlement of displaced persons	(xxi) Environmental and ecological aspects
(xi) Detailed Designs	(xxii) Colonies and Buildings
(xii) Irrigation and Command Area Development	(xxiii) Public Participation and cooperation.

As can be seen from the above list the guidelines focus largely on the planning, investigations/surveys and design of the engineering aspects. The guidelines also address project-specific environmental aspects, cost, benefit and economic analysis. There is little coverage on the basin planning and community aspects. It is therefore advisable to expand these guidelines with specific elements mostly relevant for Integrated Flood Management.

5.2.4 Suggested measures for integration of DPR Guidelines in IFM under climate change

In order to be better able to judge the appropriateness from an IFM viewpoint of major investment projects for which DPR approval is requested, it is felt important to improve the current guidelines. But besides framing such improvements, which would apply on a project-by-project basis only, it is equally important to have a basin wide IFM plan. In fact, such a plan should be a pre-requisite before DPR approval is given.

IFM Planning

To prepare an IFM Plan, base work is required for a river basin, which could typically best be done through an RBO (see Section 4.5.2). Alternatively, a task study organisation could be created within CWC to prepare these base works. In brief, such work would include:

- An inventory of all existing, under construction and proposed structural interventions, describing their location and salient features. These projects, together with existing flood control measures such as embankments, should be presented in the basin map.
- Preparation of flood risk maps for different situations and scenarios, based on a flood model of the basin. Such model needs to be calibrated and validated with up to date hydrological data (examples are given in the modelling reports for both study basins, Vol. 5a and b).
- For all projects with significant impact on the river hydrology, such as reservoirs and diversion projects, such impact during the monsoon season should be precisely ascertained. For reservoirs the existing or planned operation rules before and during floods need to be studied, in order to assess the most appropriate rule curve for flood cushioning. A flood cushion of 15% of the live storage may be recommended.
- Possible improvements in the basin-wide flood forecasting network as well as the forecasting method (numerical models) need to be identified.

- Climate change impacts on flood hazards should be studied using downscaling methods for instance as used in our project or similar. Present annual maximum rainfall intensity series can thus be adjusted by an appropriate factor for a future scenario year, say 2040.
- Disaster preparedness activities in the basin, including cyclone shelters, raised platforms in flood prone areas, flood proofing activities , flood zoning, need to be mapped out.

Updated CWC guidelines
The CWC guidelines need to be improved for the preparation of DPR for Flood Control projects in the viewpoint of Integrated Flood Management under Climate Change. Following suggestions are given:

- In addition to the existing guidelines, a proposed intervention should be analysed with respect to its flood risk consequences using the river flood risk model described in the previous section on IFM planning. Model runs without and with the proposed project will show the flood levels and flood extension in the basin for various return periods. The adequacy of a proposed flood control can thus be checked and needful improvements identified. These need to be specified in the DPR, for which the project proponent is responsible. By using the downscaled climate change projections for the basin, also the performance of the project under climate change can be assessed, showing the level of robustness of the project.
- The existing guidelines for the environmental impact assessment are to be continued, with improved coverage of flood inundated areas, watershed status, sediment generation and ground water quality and status.
- Guidelines for economic analysis need to be upgraded, to avoid current deficiencies in calculating future costs and benefits (see section 5.3 in this Chapter).
- The existing guidelines need to include the community perceptions, their aspirations, their views about the floods, their coping mechanisms, their views about the flood control measures and with a brief profile of the socio-economic structure.
- The guidelines need to address all the institutions concerned with flood management (including forecasting, rescue and relief operations) and their interactions with the proposed intervention need to be mapped out.

These suggestions are recommended to be discussed further in an expert group so as improve the guidelines for Flood Control Project in the context of IFM under climate change.

5.3 Proposed strategy for economic analysis

It proved difficult to perform economic analyses on most of the proposed projects in the two basins because essential project details were not documented in the project documentation. Furthermore, there are limitations of the Benefit Cost Analysis method currently in use for approving flood management schemes (see Phase 1 report Annex G, pages 7-12). Most important limitations in the current method and subsequent recommendations are:

- The BC ratio is calculated on the basis of annualized costs and benefits and does not take into account the time factor and the trend of production during the life of the project. Thus, it does not explicitly reflect the society's preference for present consumption over future consumption.

Therefore it is recommended that costs and benefits are discounted at an appropriate rate to determine the net present value (NPV) of the project.

- The use of flood damage data over the last ten years tends to overlook the possibility of significantly higher damages due to a flood of a magnitude that has not occurred during the last decade. *Instead, it is recommended to calculate the benefit as avoided Average Annual Damage (AAD) using the entire damage probability function (see section 4.3.2 and Figure 15)*
- When benefits are calculated only in terms of avoided damage based on past records, this underestimates the future economic growth that may arise from the proposed flood control project. For instance, embankment protection could lead to double- and triple cropping. *It is therefore recommended to include a scenario of future economic development that takes into account the incremental agricultural benefits from flood management.*
- The current system only includes direct damages and relief expenditures. Although it is not easy to quantify, the indirect damages and losses due to flooding are an important impact on society. One can think of the loss of wages due to unemployment during flooding, increased time and cost of commuting as transportation routes get disrupted and damaged, etc. *It is recommended to include such indirect damages in the calculation, for instance by using a percentage of direct damage.*
- The current estimation of damages after a flood is inaccurate and incomplete (see also 2.6). Method of damage reporting differs between states and sometimes between years. *It is recommended to use national standardized methods according to the Guidelines for Post Disaster Needs Assessment (PDNA) issued by the Global Facility for Disaster Risk Reduction (GFDRR, 2010).* Major improvements are listed in Box 12.
- There is no provision for a sensitivity analysis in the current method. *It is recommended to perform a sensitivity analysis by applying: i) a rise in investment costs; ii) a rise in O&M costs, iii) a delay in implementation, iv) lower crop prices.*

A specific challenge in assessing the economic optimum for risk management is the monetary valuation of human life. Some people consider it unethical to put a price on human life. However, arguably, not taking the economic value of human life into account leads to a lower (economic) damage and thus results in a lower safety of the considered system. Several methods of valuation of human life exist. Some approaches relate the value of human life to the investment made and to the number of prevented fatalities. These approaches are therefore called comparative approaches. Contingent valuation is often used in economics to value services or entities for which prices cannot be obtained from the market. A survey can reveal how much people are willing to pay, e.g. for safety measures. Such a study makes it possible to calculate the value of a statistical life by comparing the willingness to pay and the expected number of fatalities (Jonkman et al., 2003). Also a macro-economic valuation can be used, expressing human life value in proportion to a person's potential economic production. The consequence of this approach is that the value of human life in a poor country is considerably lower than in a rich country. This may seem strange and unethical, but it actually accentuates one advantage of the economic optimization of safety, that is, the proposed investments in safety are affordable in the context of the national economy (Vrijling & Van Gelder, 2000). It is therefore recommended that:

- *A method suitable for the Indian economic, social and cultural context should be selected for accounting human loss of lives due to floods.*

These recommendations will improve the BC method currently in use and does not need substantial additional data. However, the appropriate calculation of avoided AAD does require a well validated flood risk model (for an example of a calculation using our developed model, see Vol. 2 Section 4.3).

Box 12 The following tasks and improvements are suggested for PDNA

1. Crop damage should include loss of inputs.
2. Crop damage should include (i) stage of the crop at the time of flood, (ii) crops completely destroyed and (iii) crops damaged but re-planted / re-sown.
3. Crop losses in terms of money should be estimated by using farm harvest prices.
4. Crop yield rates should be derived from crop cutting experiments.
5. Remote sensing techniques may be used to provide a sample check on the extent of cropped area affected by floods.
6. State Government should conduct economic survey to collect data on damages to household goods.
7. The monetary value of lost cattle should be estimated. With regard to loss of human life, an appropriate method for valuation should be determined.
8. Double counting of unrepaired public utilities damages from earlier years should be avoided.
9. Damages to Central Government properties should also be included in the consolidated figures of damages at the State, National and other levels.
10. Central government should arrange exploratory studies and sample surveys to assess the indirect flood damages in order to set norms for including them in future PDNA's.
11. Damage data should be aggregated at basin and sub basin scale additional to district level data.
12. The District Statistical Office should supervise damage data collection at the village and block levels and prepare estimates.
13. The State Directorate of Economics and Statistics should compile and process damages at State level.
14. The Central Water Commission, with an Economic Unit added to it, should compile damage data at the National level. Time schedules for submission of reports at various levels should be specified and adhered to.
15. There should be a periodical review of the methodology of the data collection, compilation and its publication.
16. The CWC should aid and encourage research in the methodology of flood damage assessment.
17. Approval of State Annual Plans for flood control should be made contingent of submitting flood damage data.

5.4 Requirements for addressing agriculture in IFM planning

The agricultural conditions in the Burhi-Gandak and Brahmani-Baitarani basins are very challenging due to frequent flooding in these basins causing heavy losses to the farmers. Through this study, it is evident that there is no exact solution to tackle the flood by the farmers primarily due to lack of innovative farming practices and unavailability of appropriate infrastructure in the flood prone areas of these basins. Hence, farmers need appropriate infrastructure, knowledge and information on innovative farming practices that can help them minimize the flood induced risks and improves their livelihood.

The key recommendations from this study is that mitigation measures and strategies should be through introduction of new technologies (e.g., changes in the cropping patterns, use of flood tolerant crop variety, introduction of flood forecast and early warning systems, improvement of water management systems, etc.), strengthening of agricultural value chains and creating a demand base for the agricultural products, engaging public and private sectors, improving the policy and regulatory environment and reaching the scale required for return on investment. They can thus help improve the socio-economic conditions of the farming communities in these basins. Flood mitigation measures and strategies need to be carefully designed and targeted to specific area. However, to ensure a larger impact, measures and strategies should be relevant across the districts and modified based on specific condition. Listed below are feasible specific flood mitigation measures and strategies which can address agriculture in Integrated Flood Management Planning (IFM).

Flood risk-mitigation practices: Mechanisms for processing and dissemination of flood forecast and Early Warning System (EWS) need to be strengthened so that accurate information can reach various stakeholders on time during various critical periods of the crop growth cycle. Strengthening the relationship with telecommunication firms and designing cheap and efficient mechanisms for information dissemination are, therefore, essential. It will be important to mobilize ICT providers, Community Information Centres and the Meteorological Department for collaboration.

Furthermore, community level storage systems at household and community level need to be developed in the flood prone areas of the basins so that farmers can store grains and seed. Construction and maintenance of storage houses can be through involvement of private institutions with mechanisms to generate income. There is also a need to identify mechanisms for household level protection of inputs during natural disasters.

Region and crop-season specific and alternate livelihood interventions: Interventions should be season and location specific, taking into consideration vulnerability, risk, value chain characteristics, and market prospects. Interventions may include selection of suitable crops that can withstand flood condition, as well as capacity building and awareness on alternate livelihood options that are relevant to a particular area. However, taking into consideration the population distribution in the two basins, interventions that try to strengthen the linkage and value chain of specific produce from farm to market may have to target several groups of farmers across the districts areas. The volume of produce will be important to garner the interest of private sector.

Seeds: There are several High Yielding Varieties (HYV) and flood tolerant varieties developed by public sector institutions and these are available in the market. Private sector organizations multiply these and distribute them in addition to imports and sale of various seed varieties. These seeds, while available in the market, need to be brought to the notice of farmers through field trials and training programs. The private sector should collaborate with the public sector to leverage the use of existing infrastructure facilities for distributing flood resilient seeds to the farmers in the two basins.

Soil and fertilizer management: Elevated bed agriculture, proper testing of soil and better soil management techniques are required in all the districts of two basins to optimize production.

Stakeholder interventions: Private seed firms are active in the country and have distribution networks in each district of the two basins. Private companies should utilize the existing public sector infrastructure for strengthening the seed sector and provide suitable seed varieties to the farmers in the flood prone areas. Public private collaboration is required in the areas of research and development for flood resilient seeds, breeder seed production, foundation seed development, and seed certification. The lead private seed firms can be associated at different levels for this.

Training and capacity building: Training and awareness is an important component for the successful implementation of the suggested flood mitigation measures and strategies. Training of various types is required for various stakeholders. At the farmers' level, awareness and knowledge development on the benefits of crop diversification and adaptive practices through training workshops and field demonstrations is recommended. Considering the access and distance between the districts, demonstrations should be carried out in each region along with farmers' tours. Capacity building of agriculture extension workers with the support of existing public sector research institutions is required to strengthen the support provided to farmers.

Financing agribusiness investment: Financing various stakeholders including input providers and agribusiness firms who are key links in the supply chain is required to strengthen the sector in terms of making it more flood resilient. Private players, who have presence in the district regions, are appropriate as no investment is required to develop a new network.

Introduction of agriculture insurance: Agriculture insurance is also a one of very useful flood mitigation measures for the farming communities. Hence, government would make available the agriculture insurance to the farmers at a subsidized rate so that poor vulnerable farmers can also purchase the insurance premium (see Box 13).

Box 13. Framework for regulation of crop insurance in India

Crop Insurance covers risks of anticipated yield loss of various crops. Almost the entire Crop Insurance business comes from government Schemes. These Schemes operate on the principles of 'Area Approach'. State governments issue notifications containing names of crops, areas eligible for insurance, rates of premium etc. at the beginning of each cropping season. Coverage is compulsory for farmers taking crop loans from Rural Financial Institutions (RFIs) for cultivation of crops, i.e., loanee farmers. Non-loanee farmers can also insure their crops under the same schemes. The main schemes available to farmers in respect of crop insurance are National Agricultural Insurance Scheme (NAIS), Modified National Agricultural Insurance Scheme (MNAIS), Weather Based Crop Insurance Scheme (WBCIS), and Coconut Palm Insurance Scheme (CPIS). All these schemes come under the purview of Government of India.

In most cases subsidy in premium is available to small and marginal farmers, ranging from 10% of premium (for NAIS) up to 75% in the case of CPIS. Some state governments offer higher subsidy. A network of financial institutions viz. commercial banks, regional rural banks and cooperative banks, spread across the country play the role of intermediaries.

Schemes of Ministry of Agriculture & Farmers Welfare, Government of India to develop agricultural sector

The abovementioned recommendations can be addressed through various schemes introduced by Government of India in order to develop the agricultural sector and welfare of farmers. These schemes have been divided into three categories namely, Centrally Sponsored Missions, Central Sector Schemes, and State Plan Scheme as given in Box 14.

Box 14: Schemes of the Government of India to Develop Agricultural Sector

A. Centrally Sponsored Missions

Under this mission there are five programs: National Food Security Mission (NFSM) to increase the production of rice, wheat, pulses and Coarse Cereals; National Mission on Sustainable Agriculture (NMSA) to make agriculture more productive, sustainable, remunerative & climate resilient; National Mission on Oilseeds and Oil Palm (NMOOP) to expand area under oilseeds; National Mission on Agricultural Extension & Technology (NMAET) to disseminate information and knowledge to the farming community; and Mission of Integrated Development of Horticulture (MIDH) to promote holistic growth of horticulture sector.

Box 14 (Cont.)

B. Central Sector Schemes

There are five programs under this scheme:, National Crop Insurance Programme (NCIP) to provide insurance coverage and financial support to the farmers in the event of crops failure; Integrated Scheme on Agriculture Cooperation (ISAC) to provide financial assistance for the activities of cooperatives; Integrated Scheme for Agriculture Marketing (ISAM) to promote creation of agricultural marketing infrastructure by providing backend subsidy support to State; Integrated Scheme on Agriculture Census, Economics & Statistics (ISACE&S) to collect/ compile data of operational holdings in the country; and Secretariat Economic Service (SES) to provide support and services to the employees/ officers of the Department of Agriculture & Cooperation.

C. State Plan Scheme

Under this scheme there is the Rashtriya Krishi Vikas Yojna (RKVY) programme to incentivize the States to increase investment in Agriculture and allied sectors to achieved 4% growth in agriculture sector.

In addition one more scheme has been launched by Government of India called *Pradhan Mantri Krishi Sinchayee Yojana (PMKSY).* The overarching vision of this mission is to ensure access to some means of protective irrigation to all agricultural farms in the country, to produce 'per drop more crop', thus bringing much desired rural prosperity.

All the schemes are constantly reviewed and evaluated at National, State and Zonal levels and taken up during meetings with States and during Zonal and National Rabi/Kharif season Conferences to identify the deficiencies in the implementation of the schemes. The deficiencies so identified are taken up with the State Governments concerned for remedial measures, modification of the schemes or its guidelines, for effective implementation.

5.5 Legal requirements for river basin organizations

Water Resource Management and interventions under it is mostly done for defined administrative units (say, Village, Block, District and State levels) under the existing legal regime. There are enactments like the Brahmaputra Board Act, 1980 and the Damodar Valley Corporation Act, 1948 which are mandated to plan for the respective river valleys and for promotion and operation of schemes for flood control in the rivers but they do not have an integrated river basin approach and has not been allowed to grow into a river basin authority.

The States have not responded to the legal space for River Boards created under the River Boards Act, 1956 and this has meant that the Act has fallen into disuse. The River Boards Act, 1956 also does not provide for any river basin planning.

There are a range of formal and legally backed Institutions within a river basin and also engaged in specific water management activities but there is no mechanism that can help coordinate these at the basin level both for water management generally and flood management in particular. Today a legal foundation for a river basin development and management plan for inter–State river basins is needed. This requires that a new legal framework for regulation and development of inter –State rivers and river basins be put in place.

The *Draft River Basin Management Bill, 2012* of the Government of India has proposed establishing a River Basin Authority for regulation and development of waters of an inter-state river basin or any specified part thereof and further makes it clear that different Authorities shall need to be established for different inter-state river basin. The Bill also provides space for creation of a separate River Basin Authority for a sub- basin within an inter-State river basin. The Bill proposes a two-tier structure for a River Basin Authority. Every River Basin Authority shall have to consist of an upper layer being a Governing Council and a lower layer being the Executive Board charged with the technical and implementation powers for the Council decisions to succeed. The Governing Council has extensive membership and representation including Chief Ministers of the co-basin States.

A legal foundation for a River Basin Master Plan for inter–State river basins can help achieve the protection, improvement and sustainable use of the water environment across the basin. Such a river basin master plan can be the singular guidance tool and basis for the River Basin Authorities to perform their powers. The Draft River Basin Management Bill, 2012 thus provides that a River Basin Authority shall ensure that a River Basin Master Plan is produced for the inter-state river basin under its jurisdiction.

The lead taken by Rajasthan in coming up with a legally backed state level River Basin Authority in 2015 may be followed up by other States including Bihar and Orissa. This could help introduce binding laws and regulation on the basis of the basin and sub-basin wise plans in the State.

5.6 Proposals to mainstream community needs into IFM

It is important to ensure the last mile connectivity in information and early warning dissemination to ensure its effectiveness. It needs institutional strengthening and capacity building at sub district (talukas) and Gram Panchayat level to ensure that it benefits the communities. To reinforce the pillar of community based approach for flood management the following steps are needed for mainstreaming community needs into IFM:

1. Consultation during flood management planning: Even though designing and implementing structural mitigation projects is the mandate of the WRD to which the community can provide only limited contributions, it is important to consult them to understand their needs, problems, concurrence, and ownership.
2. DM in local level planning: Leveraging the Panchayat Raj Act, Gram Sabha should consider DM activities while formulating development projects. Local flood maps need to be consulted and development activities need to consider flood risk zones. Communities need to be properly informed about the flood risk and provided advisory support for livelihood adaptation. Training and capacity building of local administrations should facilitate integration of DM and development planning during Gram Sabha meetings.
3. Preparedness: Encourage Community Based Organisations (CBOs) and NGOs to work among the community on DM activities. This includes keeping the local DM plan and task force active and emphasizes their roles and responsibilities during various phases of DM.
4. Response: Conduct mock drills in the communities, awareness development on dos and don'ts during flooding and post flood. Public announcement system and local sign board for flood warning and flood zones are required in flood prone villages.
5. Recovery: Training DM task force in rescue and relief operations, including first aid, hygiene and sanitation, safe drinking water, etc.

5.7 Proposal for integrated environmental conservation in IFM planning and RBO

Environmental assessments are ideally applied at two levels in flood management. These are the basin flood management planning stage and the project design and implementation stage. The environmental assessment at the planning stage is the Strategic Environmental Assessment (SEA).

Environmental Impact Assessment (EIA) is applied at the time of transferring a basin flood management plan into specific projects (WMO, 2013).

As can be seen in Figure 29, SEA is ideally suited to be used at the river basin scale of an IFM programme. SEA is a comparatively new method of environmental assessment, for which there is no statutory or administrative requirement in India.

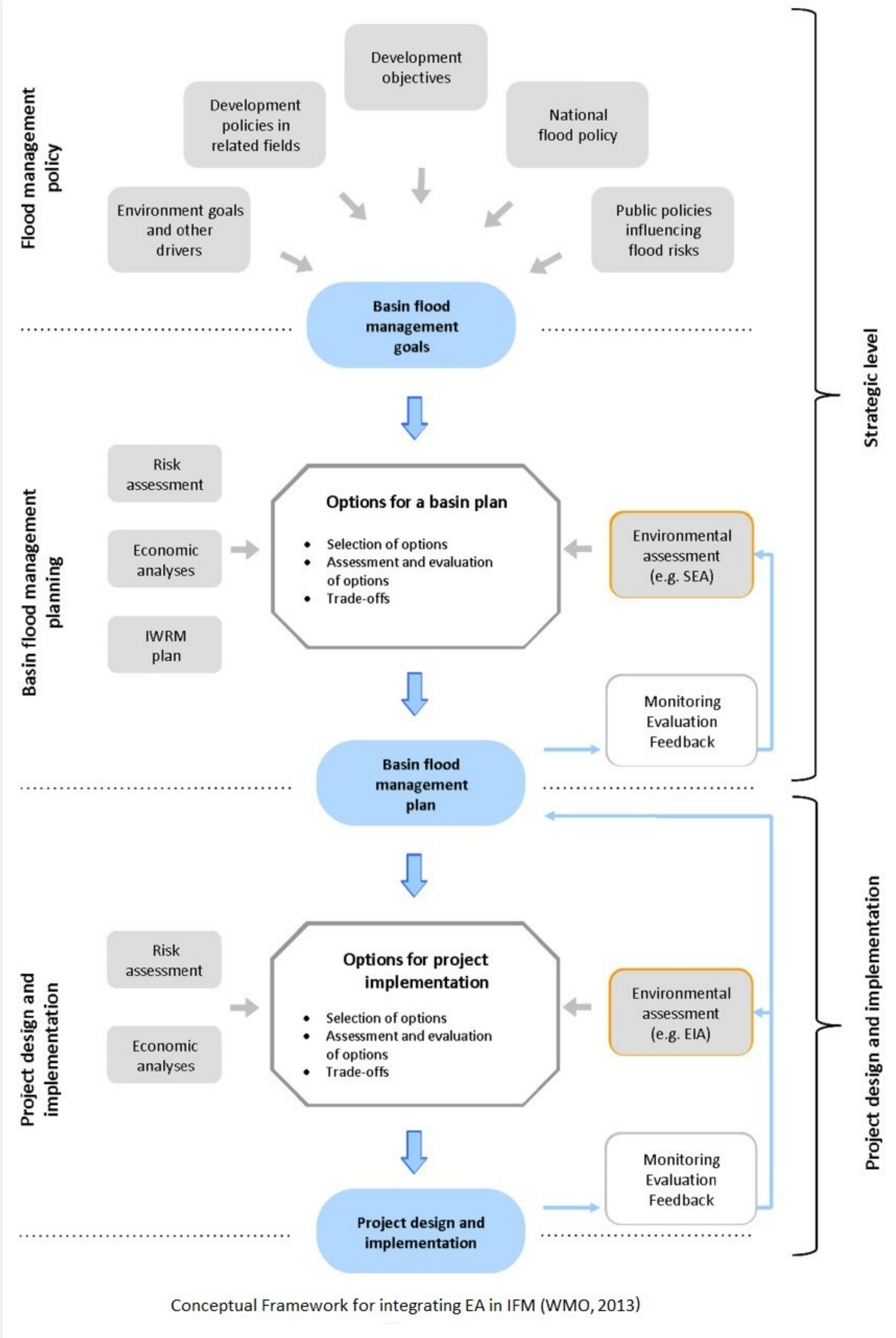

Figure 29 Conceptual Framework for integrating Environmental Assessment in IFM (Source: WMO, 2013)

SEA provides an opportunity to integrate environmental, social and economic considerations into strategic decision-making. It also acts as a scoping process for potential impacts of the flood mitigation measures, which enables more efficient use of resources during later stages when an EIA has to be prepared. It can also help in integrating the operations of related departments. For instance the Environment & Forest Department (EFD), the Town and Country Planning and Water Resources Department (WRD) are three separate entities with the first managing forests and natural resources conservation at national level, while the second is in charge of land use and zoning at the State Level and the third of structural flood measures. A SEA can help to include forest and natural resources conservation, land use planning and water management in IFM and bring the three Departments together. Other sectoral players which should contribute to the SEA process are the Revenue and Panchayat Departments, National Highway Authority of India, Indian Railways, Road and Building Department, Agricultural Department, etc.

At the level of individual projects, EIA can be used and has a legal regulation as EIA was made part of the Indian law through the EIA Rules of 1994. Originally River Valley projects including hydro- power, major irrigation and their combination including flood control were listed under the Schedule (GoI, 1994). New rules, issued in 2006, replaced those of 1994 and do not explicitly mention flood control measures any more (GoI, 2006). However, some departments require an environmental study as part of the administrative procedure for approval of projects. CWC has made it mandatory to either have environmental clearance or EMP (Environmental Management Plan) as may be applicable, for any irrigation or hydro-electrical structure proposed on a river. This is an administrative requirement. However, no environmental studies are required for embankment or related works (GoO, 2014).

Although SEA is not yet legally founded, it could be an ideal planning tool to bring the much needed integration of IFM at river basin level. Participation of the stakeholders is an important aspect of the method and should not only bring different government departments together, but also institutes, NGOs and civil groups should participate.

5.8 Recommendations for further study and follow-up

5.8.1 Study on embankment breaches

As has been mentioned earlier, embankment failures leading to breaches are frequently occurring phenomena. Although there seems sufficient knowledge regarding the geotechnical aspects of such breaches, laid down in the various Standards and Guidance documents, there still remain several knowledge gaps. These include sociological factors (incidences of purposely cutting embankments) as well as physical process of inundation due to a breach (flow velocities, speed of rising water, scouring effects etc.). Both knowledge fields are essential for prevention of future disasters as well as for guiding evacuation, rescue and relief operations.

5.8.2 Flood forecasting

The flood models developed under the projects can be very useful for flood forecasting in the two river basins. The SOBEK modelling suite as used in the project is well suited to be applied in forecasting. However, the current SOBEK river basin models are set-up for strategic assessment of flood risk mitigation measures. Any modelling system set up for strategic assessment needs some converting to become suitable and usable in flood forecasting. This also accounts for the SOBEK models developed for the Burhi-Gandak river basin and the Brahmani-Baitarani river basin. For these specific models additional activities focussing on the flood forecasting objective should be implemented:

i. Provide (near) real-time input of rainfall, reservoir operations and outflows, tidal levels, and inflows from other basins, e.g. Mahanadi river basin;

ii. Include forecasting focused on rainfall, downstream water levels (either Ganges River levels or sea levels for the Brahmani-Baitarani river basin), and possible operational control of dams and structures;

iii. Increase the detail of the model schematization in areas most flood or damage prone;

iv. Improve the quality of the elevation model for those targeted areas flood extent forecasting is useful.

Focussing on the first two activities could provide a basic flood forecasting system relatively quick. Improvement of the forecasting quality could then be part of a follow-up phase.

5.8.3 Ganges climate change study

Climate change will not only affect the flow patterns of the Burhi-Gandak river basin, but also the larger river basin of which the Burhi-Gandak river basin is part. The water level of the Ganges River influences the drainage capacity of the downstream part of the Burhi-Gandak River. Therefore it is recommended to carry out a climate change downscaling assessment for the entire Ganges river basin as well.

5.8.4 Uncertainty analysis and scenario studies

The substantial rise in flood hazard due to climate change, as projected in this study, warrant follow up studies in order to assess the uncertainties associated with these projections. Furthermore, in view of the long time horizons of 2040 and 2080, scenario studies are recommended with respect to the development in population numbers, economic development and land use changes.

Chapter 6 The legacy

This study introduced a risk approach to flood management in India by providing models for two sub-basins in flood prone states. In terms of complexity these sub-basins are representative for many other rivers in India, hence the modelling approach can be replicated, for instance with the assistance of CWC modelling capacity, which has been strengthened under this project (see 6.2). Besides this the legacy of this project includes two peer review papers, enabling key results to be visible and retrievable for the scientific community (see Appendix B and C) as well as stakeholder involvement at all levels (section 6.1). Data that has been collected is made available for future use and an Integrated Flood Management Information System under an open GIS platform can be used for these and other river basins in India (section 6.3).

6.1 Stakeholder involvement at all levels

During the course of the project many meetings and discussions were held that contributed to the understanding of Integrated Flood Management. These meetings were conducted at all levels: from the grassroots level, via the District and State levels up to the National level. The meetings were arranged accordingly, such as small meetings at State and National offices, state level workshops, Focus Group Discussions, household level interviews and field visits. Table 10 provides a brief summary of the most important events. In this way we have reached well over 600 people in the two States and many officers from all the relevant agencies and organisations. Of course this will not immediately lead to the adoption of an integrated approach for flood management. But it does illustrate our efforts to involve stakeholders at all levels of society. Without these interactions no real integrated flood management planning can be done.

Figure 30 Focus Group Discussion Pandua Village

Figure 31 Meeting at CWC Office, Bhubaneswar, with Chief Engineer, Mr. A S P Sinha

Table 10 Summary of stakeholder involvements

Activity	Description
Introductory project meeting 5 March 2014	The Team Leader of the PATA Team made a presentation on the 5th March at CWC. Fifteen Senior Officers of CWC based at Delhi, the CE (Lower Ganga Basin Organisation CWC), Patna and one Senior Officer from GFCC, Patna were the audience in addition to the Senior Project Officer ADB, and the PATA Team Members. Valuable interactions and discussions were held to enlighten the study approach. The study approach, the objectives, challenges and other focus areas of the study were presented.
Inception Report presentation 1 May 2014	The draft Inception report was presented by the Consultants at CWC for CWC (15 senior officers), ADB and GFCC. Before that the Director (cc), CWC and one of the counter-part officers of CWC gave a detailed account of the expectations of CWC from this Phase II study. The presentation invoked knowledge exchange based interactions.
Field visits Bihar June 2014	During field visit to Bihar in June 2014 many meetings were held during which the project set up and issues pertaining to flood management were discussed. This included meetings with : Joint Director FMIS, WRD Bihar; Joint Director, Hydrology, WRD, Bihar; Engineer-in-Chief (Central), WRD, Patna; Joint secretary, WRD, Bihar; Superintending Engineer, Monitoring , WRD, Patna; Superintending Engineer, Central Water Commission, Patna; Special Officer, BSDMA, Patna; Technical Officer, NIC, Patna Centre; Technical Officer attached with Joint Director (Agriculture) Govt. of Bihar; Assistant Engineer attached to office of the Chief Engineer, WRD, Muzaffarpur; SDO, Waterways under the Chief Engineer, WRD, Muzaffarpur
Field visits Odisha July 2014	During field visit to Odisha in July 2014 many meetings were held during which the project set up and issues pertaining to flood management were discussed. This included meetings with: Executive Director and Scientists, ORSAC; Chief Engineer (Irrigation), WRD, Odisha; Superintending Engineer/basin director, WRD, Odisha; Deputy Relief Commissioner, Revenue and Disaster Management Department, Odisha; Assistant Engineer, WRD, Odisha-Dhanaswar/Samal; Deputy Collector Emergency and Additional District Majistrate-Jajpur; Principal Secretary, Ministry of Agriculture, Odisha; Director (Agriculture and Food Production), Ministry of Agriculture, Odisha; Additional Chief Executive, Chilka Development Authority; Chief Engineer, CWC (Mahanadi and Eastern Rivers Organization); Superintending Engineer CWC (Coordination); Deputy Director, Department of Rural Development, Odisha; Engineer in Chief, PWD, Odisha; Chief General Manager, OSDMA; State Project Officer, UNDP; Deputy Relief Commissioner, OSDMA; Officer in the Unit of the Special Relief Commissioner, OSDMA.
State Level Workshops 14 October 2014 20 October 2014	Two State Level Workshops were held during the month of October: Patna, Bihar (14 October 2014) The workshop was attended by various stakeholders and was convened by the Project team members Bhubaneswar, Odisha (20 October 2014) Various stakeholders from government departments and District level elected representatives participated in the workshop. The workshop was convened by the Project team members. An extended report of both workshops is provided in Vol 7. Quarterly reports
DFID mission November 2014	The DFID Mission, covering two days had discussions with the consultants, with the Executive Engineer at the Chief engineer's office, with the Chief General Manager of OSDMA; as well it covered three important site visits to flood affected areas.
Focus Group Discussions December 2014	Two Focus Group Discussions were held in Odisha: 29 December 2014: Nunupur village in Jajpur district. Around 25 people participated. 31 December 2014: Pandua village in Keonjhar district. Around 20 people participated.
Focus Group Discussions January 2014	Two Focus Group Discussions were held in Bihar: 5 January 2015: Kalyanpur village of Samastipur. Around 20 people participated. 7 January 2015: Lodhipur village of Vaishali. Around 15 people participated.
Household survey February/March 2015	During the months of February and March 2015 two household surveys were conducted in the two states. In total around 500 households have been visited and interviews taken.

Roundtable workshop 27 August 2015	A Roundtable workshop has been held on 27 August 2015 in New Delhi. It was chaired by the National Water Mission Director Mr. Nikhilesh Jha (IAS). Around 30 persons participated, including officers from NWM, CWC and State governments, Chairman of GFCCC and team members.

Figure 32 State Level Workshop Odisha October 20, 2014

Figure 33 Discussions about identifying sub-projects over Akupada Barrage

6.2 Increased modelling capacity at CWC

During the course of the project the international experts in the field of hydrology and hydro-dynamic modelling have worked intensively with the staff of the Central Water Commission (Directorate CC and Directorate P&D). Transfer of knowledge was focused on the development of hydrological models and 1D/2D flood inundation models for the two focus basins (Figure 34). This resulted in the preparation of such models and subsequent execution of model runs for the project at the CWC premises. Topics included:

- Assessment of flood hydrographs
- Analysis of evaporation data
- Analyse frequency of storm events
- Analyse reservoir rule curves (Rengali Reservoir)
- Validation hydrological data based on nearest neighbour double mass
- Homogeneity tests of hydrological time series
- Determination return periods by extreme value analysis and depth-duration-frequency analysis
- Orography analysis
- (Sub)catchment delineation

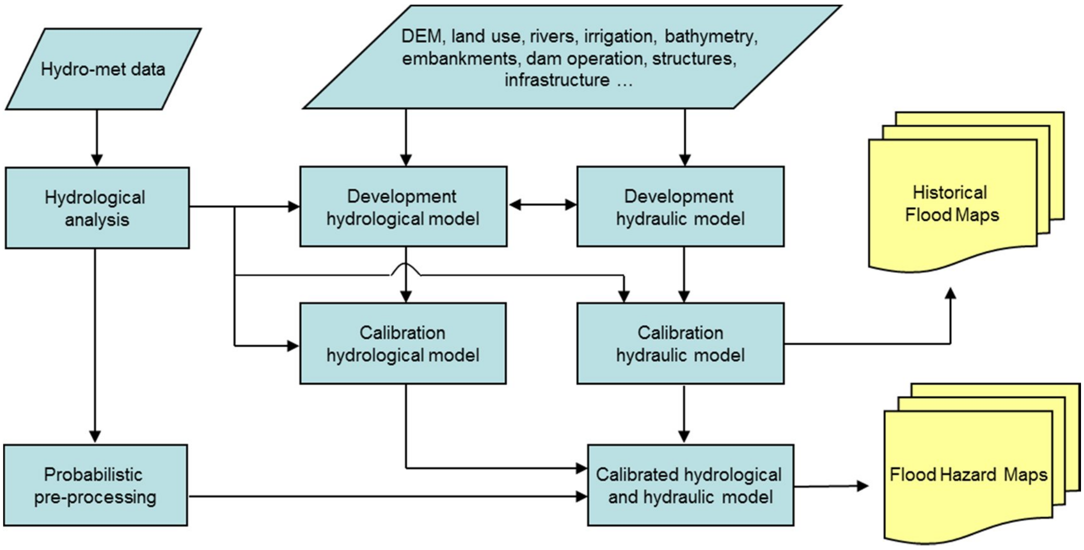

Figure 34 Steps in the development of flood hazard maps through modelling

- Set-up of the 1D/2D SOBEK hydrodynamic model (river schematisation, cross sections, structures, boundary conditions, Digital Elevation Model)
- Calibration and validation of the models
- Prepare framework of analysis (return period selection, measures and projects, indicators for evaluation)
- Post-processing (GIS analysis for damage computations for each scenario and strategy).

This on-the-job training proved to be highly useful for consolidating modelling experience at CWC. Details of the modelling exercises are given in Vol. 5 'Modelling Report'.

Furthermore, a 4- days training course was given at CWC on the use of the 1D/2D SOBEK model. The objective of the SOBEK training course was to transfer knowledge on SOBEK model development and its use to CWC. Topics included i) model schematization, ii) 1D open water, iii) 2D modelling. In total 15 participants successfully followed the course. The participants were from the following Directorates of CWC: Hydrology, Flood Management, Planning & Development, Climate Change, Coastal Erosion, monitoring, morphology, River Management Coordination. Also a Young Professional from the National Water Mission participated in the course. More details of the SOBEK course can be found in Vol. 8 'SOBEK Training Report'.

A decision was made during a meeting on 26 September 2014 under the Chairmanship of Chief Engineer (P&D), CWC at Sewa Bhavan, RK Puram, New Delhi to use the SOBEK software for 1D /2D modelling. Under this project a Basic Service Package worth 3,250 Euro was provided at CWC at no cost. The SOBEK Hydrodynamics-Hydrology Basic Service Package contains:

1) Right of use of the fully validated distribution "SOBEK Hydrodynamics-Hydrology" for 4 user.
2) One year maintenance and support on Service Level 1 with:
   a) Update and upgrade subscription.
   b) Online support via web and phone.
   c) Total of 8 hours single user support per year.

CWC received the SOBEK package on the 1st of March, 2015.

6.3 Models available for two sub-basins

For the two sub-basins calibrated and validated models are now available for use by the State Governments of Bihar and Odisha. These models include hydrology and dynamic flood simulation, which can be used to perform more detailed analysis of different measures and strategies.

6.4 Data Repository and IFMIS

The team has collected a huge amount of information for hazard, exposure and community data required for the modelling and other project components. The available data has been reviewed and assessed by the experts for their use in this study. While the data without any gaps are considered for further processing, the data with critical information gaps has been highlighted and subsequently filled with data from alternate sources using appropriate sources/ methods. A meta-database was prepared to store metadata information such as vintage, source, resolution, and other feature attributes. All the data has been stored on a CD-ROM that accompanies this report. A special volume has been prepared as a *data compendium* (Vol. 4), that describes the data as well as several data processing activities which were needed to use the data for analysis.

As part of the present assignment also an *Integrated Flood Management Information System* (IFMIS) has been developed under QGIS software as a desktop-based application that can be used to view and analyse flood hazard data along with other base layers such as basin boundary, river network, land use, population, etc. collated into an open source GIS application. In this study, one of the key aspects is to present flood hazard/risk maps for both Burhi-Gandak and Brahmani-Baitarani basins. Use of QGIS is found advantageous because it is a powerful open source based GIS application that supports compilation of data efficiently and presents user-friendly display, data management and analysis options. In addition, it supports data in a number of formats and facilitates the users to organize data using additional libraries and plug-ins.

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APPENDICES

Appendix A Compliance with the ToR

Deliverable	Chapter or section in Final Report
D1 Performance review current FM strategies	Main Report Chapter 2, section 2.2 Performance Review of current FM strategies
D2 Outlined strategic framework for FM for 2 sub-basins	Main Report Chapter 4 Strategic framework for integrated flood management
D3 Outlined plans IFM for 2 sub-basins	Report Volume 2 Draft Basin Flood Management Plan for Brahmani-Baitarani Report Volume 3 Draft Basin Flood Management Plan for Burhi-Gandak
D4 Proposals to integrate IFM under CC into CWC's DPR requirements	Main Report Chapter 5, section 5.2
D5 Guidelines for IFM planning at two sub-basins	Main Report Chapter 5, Section 5.1 Conclusions
D6 Two peer-reviewed research papers: 1. Climate Change paper 2. Return period paper	Main Report Appendix B and C.
D7 Progress reports, workshop reports and awareness program	Report Volume 7 Quarterly Reports
D8 Hydrology scenarios for flood and hydraulic modelling	Report Volume 5 Modelling Report
D9 Detailed analysis of flood scenarios and management options	Report Volume 5 Modelling report
D10 Climate change projections for two sub-basins	Main Report Chapter 3 The impact of climate change on flood hazards. Report Volume 2 Draft Basin Flood Management Plan for Brahmani-Baitarani Report Volume 3 Draft Basin Flood Management Plan for Burhi-Gandak
D11 Climate change scenarios for the hydrological and hydraulic modelling	Report Volume 2 Draft Basin Flood Management Plan for Brahmani-Baitarani Report Volume 3 Draft Basin Flood Management Plan for Burhi-Gandak
D12 Review of climate change inclusion in national flood warning	Main Report Section 4.5.3 Strategies for mainstreaming CC scenarios in state and national planning
D13 Strategies for mainstreaming CC scenarios in state and national planning	Main Report Section 4.5.3 Strategies for mainstreaming CC scenarios in state and national planning

D14 IFM GIS-based information system	Report Volume 4 Data compendium
D15 Review of cost-effectiveness and CBA of flood management approaches	Report Volumes 2 and 3 Draft Basin Plans, section 5.3.1 Review of cost-effectiveness and CBA of flood management approaches
D16 Review of economic impacts of floods	Main Report Section 2.6 Review of economic impacts of floods
D17 Proposed strategy for data collection and analysis for CWC guidelines	Main Report Section 5.4 Proposed strategy for data collection / economic analysis for IFM
D18 Review of current institutional arrangements for the 2 sub-basins	Main Report Section 2.8 Review of the current institutional arrangements Report Volumes 2 and 3 Draft Basin Plans, section 6.1 Current institutional arrangements
D19 Proposal for appropriate institutional strategies and requirements for IFM	Main Report Section 4.5.1 Appropriate institutional strategies and requirements for IFM
D20 Organizing consultation sessions for government staff and others	Report Volume 9 Consultation Session Report
D21 Review of current legal regulatory arrangements for IFM	Main Report Section 2.3 Review of current legal arrangements
D22 Proposals for appropriate legal framework for IFM	Main Report Section 4.5.1 Proposals for appropriate legal framework for IFM
D23 Legal requirements for river basin organizations	Main Report Section 5.6 Legal requirements for river basin organisations
D24 Review of community flood issues and needs	Main Report Section 2.4 Review of community flood issues and needs
D25 Identification of pilot projects to increase flood resilience	Report Volumes 2 and 3 Draft Basin Plans, section 5.4.1 Pilot projects at community level
D26 Community needs to support IFM plan for sub-basins	Report Volumes 2 and 3 Draft Basin Plans, section 6.2 Community needs to support IFM plan / Proposals to mainstream community needs in IFM
D27 Proposals to mainstream community needs into IFM	Main Report Section 5.7 Proposals to mainstream community needs in IFM
D28 Detailed agricultural systems review	Report Volumes 2 and 3 Draft Basin Plans, section 5.1.5 Detailed agricultural systems review
D29 Strategies for agricultural systems to address flood and drought	Main Report Section 4.4.13 Strategies for agricultural systems to address floods
D30 Requirements for addressing agriculture in IFM planning and RBO	Main Report Section 5.5 Requirements for addressing agriculture in IFM planning and RBO
D31 Review of environmental impacts of flood management strategies	Main Report Section 2.7 Review of environmental impacts of flood management strategies
D32 Proposal for integrated environmental conservation in IFM	Main Report Section 5.8 Proposal for integrated environmental

planning and RBO	conservation in IFM planning and RBO
D33 Review current practice of embankment construction	Main Report Section 2.6 Review of current practice of embankment construction
D34 Geotechnical analysis of slope stability	Main Report Appendix F Geotechnical analysis of slope stability
D35 Suggestions for improved design of embankments	Main Report Section 4.4.6.2 Suggestions for improved design of embankments
D36 Strategies for integrated flood control and drainage	Main Report Section 4.4.8 Urban Drainage Design
D37 Pre-feasibility designs and costings for urban and rural drainage	Main Report Appendix G. Design of urban water drainage systems Reports Volumes 2 and 3 Draft Basin Plans section 5.2.4 Urban and Rural Drainage
D38 Recommendations for drainage design	Main Report Appendix G. Design of urban water drainage systems

Appendix B Peer Reviewed Paper 1

Downscaling GCM data for climate change impact assessments on rainfall: a practical application for the Brahmani-Baitarani basin

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Abstract

The delta of the Brahmani-Baitarani river basin located in the eastern part of India frequently experiences severe floods. For flood risk analysis and water system design, insights in the possible future changes in extreme rainfall events caused by climate change are of major importance. There is a wide range of statistical and dynamical downscaling and bias-correction methods available to generate local climate projections that also consider changes in rainfall extremes. Yet, the applicability of these methods highly depends on local availability of meteorological observations. In the developing countries data and model availability can be limited, either due to the lack of actual existence of these data or because political data sensitivity hampers open sharing.

We here present the climate change analysis we performed for the Brahmani-Baitarani river basin focusing on changes in four selected indices for rainfall extremes using data from three performance-based selected GCMs that are part of the 5th Climate Model Inter-comparison Project (CMIP5). We apply and compare two widely used and easy to implement bias correction approaches. These methods were selected as best suited due to the absence of reliable long historic meteorological data. We present the main changes we can retrieve from the available data – likely increases in monsoon rainfall especially in the Mountainous regions and a likely increase of the number of heavy rain days. In addition, we discuss the gap between state-of-the-art downscaling techniques and the actual options one is faced with in local scale climate change assessments.

Paper accepted by the Journal of Hydrology and Earth System Science (HESS) as discussion paper on 10 December 2015.

Appendix C Peer Reviewed Paper 2

Review of Design Standards for Flood Protection in the Brahmani-Baitarani River Basin in India

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ABSTRACT

In India, return periods of 25 and 100 years are currently being used for designing flood protection works (such as embankments) for protecting rural lands and urban/industrial areas, respectively. Since these standards were set in 1980 much has changed: India's population has almost doubled and per capita income increased with a factor of 5. This is sufficient reason to review flood design standards as they may not provide optimum safety. We used a risk approach and calculated current flood risks for a predominantly agricultural case study area as part of the Brahmani-Baitarani river-basin in Odisha. A combined hydrological-hydraulic model was developed together with a damage model to analyse the annual average damage. Results showed that more than 90% of the total flood risk would be controlled with embankments giving a protection level of once in 25 years. Upgrading the embankment system to that level would give an indicative benefit cost ratio of 5.8.

Paper submitted to Current Science on 22 December 2015

Appendix D Legal issues, concerns and opportunities

WATER AND FLOOD MANAGEMENT PRACTICE IN INDIA WITH SPECIAL REFERENCE TO BIHAR AND ORRISSA

- LEGAL ISSUES, CONCERNS AND OPPORTUNITIES

VIDEH UPADHYAY[18]

INTRODUCTION

The Government of India in the Indian Parliament has stated in the past that the two main objectives of the flood management programme so far undertaken in the country were (i) mitigation of floods with the help of construction of embankments, drainage improvements, building reservoirs, detention basins and afforestation etc., and (ii) mitigation of susceptibility of flood damage through regulation of economic activity in the flood plains, flood forecasting and disaster preparedness, town and village protection works.[19] Rashtriya Barh Ayog in its report submitted in 1980, inter-alia laid great emphasis on proper flood management by adopting both the structural and non-structural measures. The National Water Policy in 2002 and then again in 2012 has also emphasized, *"While physical flood protection works like embankments and dykes will continue to be necessary, increased emphasis should be laid on non-structural measures such as flood forecasting and warning, flood plain zoning and flood proofing for the minimisation of losses and to reduce the recurring expenditure on flood relief."*

The Associated Programme on Flood Management at the World Meteorological Organization –United Nations (WMO) defines Integrated Flood Management (IFM) as "a process promoting an integrated -rather than fragmented –approach to flood management. It integrates land and water resources development in a river basin, within the context of

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[19] As per the Statement of the Union Ministry of Water Resources in the Fourteenth Lok Sabha i.e the Parliament quoted in *First Report Of Standing Committee On Water Resources, Fourteenth Lok Sabha, Ministry Of Water Resources, Demands For Grants (2004-2005)* , August 2004

Integrated Water Resources Management (IWRM), and aims at maximizing the net benefits from flood plains and minimizing loss to life from flooding."[20]

It is useful to assess the legal instruments and provisions as they exist in India on the touchstone of the principles and the mandate of IFM. The present report in its first part reviews the current regulatory arrangements relating to the water and flood management practice in India with special reference to the legal regimes of Bihar and Odisha. Based on this review in the second part it identifies specifically the gaps and potential requirements for integrated planning and management for floods. Finally, in the third part it outlines the necessary legal arrangements to support the implementation of river basin organizations. The review and analysis is presented below.

[20] See *Integrated Flood Management: Concept Paper*, APFM Technical Document N. 1. The Associated Programme on Flood Management c/o WMO, Geneva 2004

I

REVIEW OF THE CURRENT REGULATORY ARRANGEMENTS RELATING TO WATER AND FLOOD MANAGEMENT PRACTICE IN INDIA

The Constitutional Context of Flood and Water Management

A key feature of Constitution of India is the existence of separate lists demarcating central (the Union List) and state responsibilities (State List). This demarcation restricts the role of the Government of India and the government itself has clarified its role in the Parliament on Flood Management on a few occasions in the recent past. For example, in a reply to a question in the Parliament the Government had stated:

> *"Flood management being a State subject, the schemes for flood control are planned, funded and executed by the State Governments themselves as per their own priorities out of their State plan funds which are made available to them through Planning Commission. The assistance rendered by Central Government is technical, catalytical and promotional in nature."*[21]

The Statement above recognizes that water is in the State List of the Constitution (Entry 17). The said 'Entry 17' says *"water, that is to say water supplies, irrigation and canals, drainage and embankments, water storage and water power …*" is a state subject - and thus it is only state legislature, which is competent to enact laws on these subjects.[22] The Rashtriya Barh Ayog (the National Flood Commission) also noted that even while the subject of flood control does not figure in the three legislative lists in the Constitution, two forms of flood control viz., 'Drainage and Embankment' are specifically mentioned in the State list and it concluded thus that the "primary responsibility for flood control lies with the states"[23] It is useful to note carefully the basic entry in the State list for water management -"*water, that is to say water supplies, irrigation and canals, drainage and embankments, water storage and water power …*" may again be noted. The National Commission for Integrated Water Resources Development constituted by the Union Ministry of Water Resources noted in its final report in 1999 the heavy engineering or 'structural' bias inherent in the said listing in the Constitution. In fact, when it comes to flood management strategies and control works, perhaps this alleged 'bias' represents the single biggest charge that the State governments have been facing over the years.

[21] Lok Sabha Starred Question No 78 *Regarding Damage To Cultivable Land Due To Floods* Answered On 06.12.2004 By The Minister Of Water Resources

[22] Entry 17 of List II (State List) of the Indian Constitution

[23] Report of the Rashtriya Barh Ayog, 1980, Ministry of Irrigation, Government of India.

However it is significant to note that the entry 17 vesting power with States is a qualified one and is "subject to the provisions of Entry 56 of List I" (the Union List), which states: '*Regulation and development of inter-State rivers and river valleys to the extent to which such regulation and development under the control of the Union is declared by Parliament by law to be expedient in the public interest.'*

It has been commented that the legislative competence of the State Governments under Entry 17 of the State List remains unfettered only because Parliament has not made much use of the powers vested in it by Entry 56 of the Union list.[24] The entry relates to 'Regulation and development of inter-State rivers and river valleys' and major rivers and tributaries are of interstate nature and most northern tributaries have international dimensions. The recently constituted Task Force recognising this aspect also commented that the Central Government has to be fully involved and fund the projects proposed on these rivers.[25]

While *inter-State rivers and river valleys* is under the Centre's jurisdiction 'land' is a subject in the State List under the Constitution and in planning reservoir projects, for flood relief or other exploitation of water resources, the primary requirement would be the approval of the concerned State Government to allow the construction of the reservoir with attendant submergence of land and relocation of affected people in the state.

Apart from the above, speedy acquisition and requisition of land, restriction and regulation of land use, including for flood plain zoning are critical for execution of an effective flood control programme and it is important to ascertain the legislative competence of the Union and the States in this regard. First, "acquisition and requisition" of land falls under the Concurrent list and thus both Centre as well as States can legislate on the said subject.[26] Besides, even though state list does not cover the subject of land use, which is important for dealing with measures like flood plain zoning, it is said to be within the States' legislative jurisdiction included in the broadly worded State list *"Land, that is to say, right in or over land, land tenures….land improvement and agricultural loans*"[27]

The Constitution also lays down a number of fundamental rights to every person and citizen and in particular 'Right to Life' guaranteed under it is of relevance for flood and disaster management. The right to 'pollution free water' and the right of access to 'safe drinking

[24] The provisions of Article 262 of the Constitution give the center power to deal with inter-state river disputes. While this Article was used to pass the Inter-State Water Disputes Act, the broader powers under Entry 56 have not been used by the centre.

[25] The TASK Force also added that as it is, no State in the North East has the resources to finance the major schemes for river valley development with aspects of flood management. These projects in the North East Region may be treated as centrally funded national projects like the DVC, Bhakra, Tehri, etc.

[26] Entry 42, List III under Schedule 7 of the Constitution of India.

[27] Entry 18, List II under Schedule 7 of the Constitution of India.

water' has been read as a part of 'Right to Life' under Article 21 of the Constitution of India.[28] After initially talking about the right to water in the context of pollution cases, courts have delivered a growing body of verdicts on the more fundamental concerns of access to drinking water and on the right to safe drinking water as a fundamental right.[29]

There have been suggestions recently in the country that 'Disaster Management' as a legislative subject should find a place in the *Concurrent* list of the of the Constitution thereby empowering both the Centre and the States to enact law on the subject. If this is to be done the subject could ideally be placed in the Concurrent list, thereby empowering both the Centre and the States to legislate on the subject. States can legislate for disaster management, including Flood control and management, to devise plans for disasters within the territorial jurisdiction of the States. This is exactly how the State of Gujarat has come up with its legislation, defining disasters as being limited to the boundaries of the State. However, to combat disasters that are widespread running across States (more than one) the Union should be in a position to come up with a law, in case that is needed as part of a national strategy.

The States have been very conscious of their powers on water management and the limits of the power of the central government as laid out under the Constitution of India. The statement of the Minister of Water resources of the Government of Bihar towards certain important aspects which were proposed in the Draft National Water Policy 2012 circulated by Ministry of Water Resources, Government of India exemplifies the point in very clear terms and is extracted below:

> "Water is a state subject under the Constitution of India. Bihar is not in favour of any Central Legislation or Central Institution for management and regulation of water resources which impinge on the rights of the state. There could only be a national framework on general policies on water, but these should not be of regulatory nature. Such a framework can be advisory in nature. The proposed draft of National Water Policy 2012 is not formulated with due considerations to the "State Specific Needs". I submit that the National Water Policy should specially frame institutional systems and apparatus with a focus on "State Specific Needs".[30]

Community Participation in Water Management: A Constitutional Mandate

The Constitution also empowers both the rural and the urban Local self Governance Bodies to carry out 'water management' at local levels and this opens up a legal space for

[28] This has been possible because of a liberal and activist interpretation of the fundamental right to life by the Supreme Court as well as the High Courts of the country in series of cases before them.

[29] These cases include Wasim Ahmed Khan v. Govt. of AP, 2002 (5) ALT 526 (D.B.); Mukesh Sharma v. Allahabad Nagar Nigam & Ors., 2000 ALL. L.J. 3077; Diwan Singh and another, v. Th e S.D.M. and other 2000 ALL. L.J. 273; S.K. Garg v. State of UP. 1999 ALL. L.J. 332; Gautam Uzir & Anr. v. Gauhati Municipal Corpn. 1999 (3) GLT 110.

[30] See full text of speech of Shri Vijay Kumar Chaudhary, Minister, Water Resources Department, Bihar in the National Water Resources Council Meeting, 2012

community flood management all across the country. The point deserves a closer appreciation. Part IX and IXA of the Constitution were incorporated by the now famous 73rd and 74th Amendments to the Constitution of India that were brought into effect in 1993.[31] The 73rd Amendment of the Constitution had cast a Constitutional imperative on all the State Governments to come up with appropriate Panchayat Raj Act detailing meaningful democratic devolution of functions, functionaries and funds. Specifically, it empowers States to endow Panchayats with such powers and authority to enable them to function as institution of self-government and goes on to list 'Drinking water', 'Water Management', Minor Irrigation' and Watershed Development' as subjects under the jurisdiction of Panchayats.[32] In a similar vein the 74th Amendment to the Constitution of India requires that "the Legislature of a State may, by law, endow the Municipalities with such powers and authority as may be necessary to enable them to function as institutions of self-government" [33] The "matters that may be entrusted" to the Municipalities include "Water supply for domestic, industrial and commercial purposes", amongst others.[34]

Both the 73rd and 74th Amendments to the Constitution inspired changes in the existing State level Panchayats, Municipal Corporation and Municipal Council laws so as to bring them in line with the mandate under the Constitutional Amendments. To be sure the Constitution, while visualizing panchayats as institutions of self-government, subjected the extent of devolution of powers and functions to the will of state legislatures. However, the statutes governing the PRIs in the states, although they devolve functions to panchayats, are worded generally, and specific items of responsibility or activities under the broad functions are not indicated. If the letter and spirit of the 73rd Amendment are to be realized through the respective state Acts then the states must supplement the stated twenty-nine functions in the 11th Schedule of the Constitution with detailed functional responsibilities, and identification of functionaries and funds for them.

[31] Consequent upon the 73rd Amendment in 1992, Article 243G of the Constitution provides that the Legislature of a State may, by law, endow the Panchayats with such powers and authority as may be necessary to enable them to function as institutions of self-government with respect to the preparation and implementation of plans for economic development and social justice including for matters listed in the Eleventh Schedule. Article 243W has provisions similar to Article 243G with respect to Municipalities regarding matters listed in the Twelfth Schedule.

[32] The list can be seen under the Eleventh Schedule to the Constitution of India.

[33] See Article 243W of the Constitution of India. relating to Powers, authority and responsibilities of Municipalities. It adds that such a law may contain provisions for the devolution of powers and responsibilities upon Municipalities with respect to : (i) the preparation of plans for economic development and social justice; (ii) the performance of functions and the implementation of schemes as may be entrusted to them including those in relation to the matters listed in the Twelfth Schedule.

[34] See the Twelfth Schedule of the Constitution of India. Other related matters that may be entrusted to the Municipalities include Urban planning including town planning, Planning for economic and social development; Public health, sanitation conservancy and solid waste management; Safeguarding the interests of weaker sections of society, including the handicapped and mentally retarded; Slum improvement and up-gradation and Urban poverty alleviation.

REVIEW OF THE LEGAL REGIME AT THE STATE LEVEL WITH SPECIAL REFERENCE TO BIHAR AND ORRISA

A review of the legal regime seeking to address various aspects of flood management drives home the point that different States have different laws, dealing with whole range of issues, from land use planning, compulsory evacuation of land in case of floods, suitability of lands for construction of flood works, remission and suspension of land revenue in case of agricultural calamity caused by floods, to levying of betterment contribution for recovering the cost of flood control work.

Key Irrigation, Drainage Laws with implications for flood management

The Irrigation laws of most States address the issue of floods, in some way or the other. All the state legislations vest the State machinery with the duty to identify the areas that can be potentially affected by floods and thus requiring drainage or embankment works. The State has been provided with powers to acquire the land in case it is satisfied that such work is required, subject to the procedural safeguards, like notice to the affected people, enquiry into the objections or compensation for losses suffered as a result of survey work & execution of the scheme.

***The Bihar Irrigation Act, 1997*:** In 1997 the State of Bihar enacted the Bihar Irrigation Act, to consolidate the law relating to irrigation, embankment, drainage, levy and assessment of water rates, betterment contribution and matter connected[35]. The definition of drainage works, includes flood embankments[36]. The Act provides for preparation and execution of schemes for drainage works, including those for protection from floods, or erosion by a river, and embankment works, which may be taken up by the state government whenever it appears necessary.[37] The Act has provisions whereby the State government may prohibit formation of encroachment on the river, stream or natural drainage course. The State is also empowered to remove the encroachments so formed. The Act empowers the Divisional Officer to execute works for removal or alteration of any embankment or any obstruction which endangers the stability of a public embankment or the safety of any town or village, which is likely to cause loss of property by interfering with the flood drainage or general drainage.[38]

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[35] By virtue of this Act the Bengal Irrigation Act, 1876, Bengal Embankment Act, 1882, Bengal Drainage Act, 1880, Bihar Public Irrigation and Drainage Act, 1947 were repealed in the State of Bihar.

[36] Section 2(K) Likewise the term irrigation works includes Drainage works.

[37] Sec 16-17.

[38] The Act also provides for applications for the construction of any public embankment by any person to the Executive Engineer.

The Orissa Irrigation Act, 1959: The definition of "drainage works" under this Act is wide enough to include works for protection of lands from floods and erosion.[39] Similar to other State laws this Act also empowers the government to prohibit or remove obstructions to any river, stream or drainage works.[40] The Act provides for classification of irrigation works (inclusive of drainage works) for the levy of water cess and for the maintenance and repairs of such works.[41] Damage to or interference with the irrigation work, or diversion of the current of a river, spring, stream or canal and where there is a flood embankment[42], is an offence punishable under the Act.

The Orissa Public Embankment Construction and Improvement Act, 1951: This Act provides for construction and improvement of public embankments for the prevention of floods in Orissa. The term embankment has been defined to include all types of flood control structures. There is no provision in the Act for acquisition of land, survey work or payment of [rest of sentence is missing]

Other Drainage Laws with implications for Flood Management: The responsibilities of Municipal bodies with respect to proper drainage assumes importance in respect of flood management, if the area damaged or likely to be damaged by floods, falls within the domain of a Municipality. Here it is useful to look at the *Asansol Municipal Corporation Act, 1990.* The Act makes it obligatory for the Municipal Corporation to make provisions for the construction and maintenance of drains and sewerage works and drainage works[43]. The Corporation is required under the law to prepare a Draft Development Plan for Asansol in consultation with the District Planning Committee. The said draft development plan shall provide for schemes for future land use control by way of filling up of insanitary water courses, provision of drainage network and outfalls, protection of land surface through which sub-soil water sources are re-charged[44]. Similar provisions can be seen in the *Delhi Municipal Act 1951*. In this context the provisions of the *Patna Municipal Corporation Act, 1951,* can also be seen which contain elaborate provisions regarding the construction and maintenance of drains in the municipal areas. The Act empowers the Chief Executive Officer to control all municipal drains belonging to or vesting in the Municipal Corporation[45], he is required to maintain and repair the drains, construct new drains when authorized by the Corporation[46]. He may cause the municipal drains to empty into any place and may dispose off the sewage

[39] Sec 4 (6).

[40] Sec 7-9.

[41] Sec 30 read with S 4(16)

[42] Sec 39, 40 (3).

[43] Sec 87(1) (b)

[44] Sec 258 (e)

[45] Section 305 of the Act.

[46] Section 306 of the Act.

at any place. Further, his permission is mandatory for erecting a new building, wall or structure or for construction of street or railway over a municipal drain[47]compensation. [48]

Regulating Land Use in Flood Prone Areas: Some Legislative Examples

As mentioned above for acquisition and requisition of land both the centre and the state have the power to enact laws. Flood plain zoning inevitably entails restriction of land use and this power lies within the legislative competence of the state. The Rashtriya Bhad Ayog has also pointed out in this regard that 'since local conditions differ from area to area and, therefore, flood plain zoning is essentially is a local problem, it needs to be dealt with by the state govt. and the Centre need not come in to the picture.' Restrictions of land uses are typically mandated under the state legislation and one example of this in a Municipal context is the ***Bihar Restriction of Uses of Land Act, 1948***. The Act empowers the state govt. to declare any land to be a 'controlled area' and prohibits any person to 'erect or re-erect any building, or make or extend any excavation, or layout any means of axes to a road in a controlled area, except with the previous permission of the controlling authority in writing'.[49]

Requisition and Speedy Acquisition of Land for Flood Control

Establishment of dams, embankments and drainage works require huge areas of land. The area requiring flood control work may or may not be in government's possession, however the same can't be an obstacle in undertaking any such work. There is a central enactment empowering the Centre & State governments to acquire land for any public purpose, namely Land Acquisition Act, 1894. Most State laws, like Bihar Irrigation Act, 1894, Orissa Irrigation Act, 1959, Assam Embankment and Drainage Act, 1954 dealing with establishment of dams, embankments including flood embankments have references to Land Acquisition Act, for the purpose of acquiring land. To make the process speedier, the Act vests special powers in the District Collector to take immediate possession of any land in cases of emergency.[50] The Supreme Court and High Courts have endorsed these special powers. The Apex Court has held in a case that while departing from the normal procedure and invoking special provisions for acquisition, the District Collector should record his reason for such departure and only then he can make use of these special provisions[51].

[47] Section 310 of the Act.

[48] The Act however provides for the recovery of cost incurred in construction or improvement of any public embankment in part or full from beneficiaries, which can be recovered as arrears of land.

[49] See Section 2 to Section 6 of the Bihar Restriction of uses of Land Act, 1948

[50] Section 17 (1) of the Land Acquisition Act, 1894. For example, the Railway Administration can acquire immediate possession of any land, in case of sudden change in the channel of any navigable river, for maintenance of traffic or for the purposes of making thereon a riverside or *ghat* station. Similarly the collector can acquire possession of any land when the government feels it is necessary for maintenance of any drainage work.

[51] Collector of Monghyr and Others etc. V. Keshav Prasad and Others AIR 1962 SC 1694

Here it is pertinent to mention the Bihar Amendment[52] to the Land Acquisition Act 1894, wherein flood erosion has also been listed as one of the emergencies during which the District Collector can take possession of the land immediately after the declaration that such land is required for public purposes under the Act[53].

The above Acts enable the state officials with wide powers during emergencies like floods. There are no specific qualifiers built into these Statutes and judicial review is also circumscribed to a great extent. Besides, they also lay down an essentially "may" regime, leaving ample scope for administrative discretion. However, it cannot be said there is no check on administrative discretion; the administrative agencies are required to act in a fair, just, and reasonable manner. The Patna High Court, in a case[54] where the land was acquired for flood affected people but these flood affected people were rehabilitated elsewhere, had held that if the purpose for which the land is to be acquired is not fulfilled then the acquisition is held to be incomplete. In such a case section 48 of the Act is attracted and persons whose land is the subject matter of the acquisition are liable for compensation even if the proceedings are not completed. These provisions can help enable the administrative agencies to act diligently in fair manner during or post flood situations, though its sparse use in the Indian context is especially notable.

The Legal Position on Construction of Flood Works

In the post independence period India has witnessed expansion in the scale of development an all types of flood control projects. A close look into a specific State laws dealing with Flood Control Works would be useful to understand the nature of legal obligations cast on the government in this regard.

The *Orissa Hydro Electric Projects & Flood Control Works (Survey) Act, 1961* provides for survey and investigation of suitability of lands required for the establishment of flood control works. The Act defines "flood control work" to include all works and constructions for the purposes of controlling floods[55]. No other State has enacted such a specific legislation. However, the respective Irrigation and Drainage laws of the States having provisions for construction of dams and embankments do provide for identification of areas, where such works are required. Besides, even the Orrisa 1961 Act is not couched in mandatory language. The State is not under an obligation to carry on the survey or investigation, every time a flood control or hydro-electric work is undertaken. Such surveys are done "whenever it appears to

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[52] As mentioned earlier Land acquisition is concurrent list subject. The States can adopt the Land Acquisition Act, 1894 with some modifications and amendments.

[53] Section 17(2) of the Land Acquisition Act, 1894 (Bihar Amendment). The said provision was incorporated by virtue of Bihar Amendment Act, 1961.

[54] Ram Krishan Singh and Others V. State of Bihar AIR 1995 Patna 73

[55] Section 2 (c) of Orissa Hydro Electric Projects & Flood Control Works (Survey) Act, 1961

the state government that for the purpose of any hydro-electric project or flood control work it is necessary to carry on survey or preliminary investigation in respect of lands in any locality to ascertain the suitability of such land…..”[56] The notifications specifying the locality where such surveys are taken are to be notified publicly also (Apart from the official gazette.) After the surveys are completed, if the government proposes to execute the flood control or hydro-electric project, it is required to publish the description and situation of the project, along with the details as to the areas likely to be benefited or adversely affected. Any person can file his suggestions or objections to such proposal within the specified time to the District Collector. As per the Rules framed under the Act, apart from the Orissa gazette, the description of proposed works are published at the notice boards of the office of the Collector, the Sub-Divisional Officer, the Panchayat Samiti and the Gram Panchayat within the limits of which any land is likely to be benefited or affected by the proposed work.

Apart from ascertaining the suitability of lands, it is also important to see the possible impact of such projects on the environment. The *Environment Impact Assessment* [57] regulations issued under the Environment Protection Act, 1986 make it mandatory to obtain environmental clearance from the Ministry of Environment, Forests & Climate Change (MoEF&CC) for undertaking a new project or expansion or modernization of an existing project in certain specified industries[58]. “The river valley projects, including hydel power, major irrigation and their combinations including flood control” are among the specified projects[59]. Further, the project authorities are also required to intimate the location of project site to MoEF&CC while initiating any investigation and survey. This provision strengthens the control of Centre over the development activities in States and also ensures that there is uniformity on procedural aspects across all the States.

Betterment Fees and Enhanced Land Revenue due to Flood Control Works

In certain States, there are legislations providing for the levy of betterment contribution from the owners of lands who are benefited by flood protection works constructed by the government, as for instance the ***Bihar Irrigation & Flood Protection (Betterment Contribution) Act, 1959***, *AP Irrigation (Levy of Betterment Contribution) Act, 1955*. The Bihar Act defines “flood protection work” to include embankments, groynes, spurs, dams, barrages, sluices and other work for the protection of buildings from floods erosion, constructed or maintained by the State Government. Interestingly, the Act makes a distinction between the flood protection works in rural and urban areas. In rural areas if the cost of the

[56] Section 3.

[57] Issued on 27th Jan 1994.

[58] 29 Industries listed in Sch I to the Regulations.

[59] Entry 2 Sch I of the EIA Notification dated 27th Jan 1994.

flood protection work is less than INR 5 lakhs then no betterment contribution is to be charged. In the AP Act this is as low as INR 1,50,000.[60]

The fact that benefits accruing due to flood control works on a land would lead to greater revenue assessments is also made clear by certain State Land Revenue Regulations. For example the Assam Land and Revenue Regulation 1886 makes clear that "water courses and embankments shall be considered attached to the land for the benefit of which they were originally made."[61] With an identical provision the Manipur Land Revenue and Land Reforms Act 1960 also makes this aspect clear.[62]

Rehabilitation of Flood Affected People and Absence of Specific Provisions:

The present legal regime deals inadequately with the rehabilitation of people affected by flood. The *United Provinces Acquisition of Property (Flood Relief) Act, 1948*, however, deserves mention, as it provides for requisition of land and property so as to provide for the village sites and houses for flood-affected people. Having said that, even this Act, is inadequate, as it deals with provision of houses only, and overlooks other aspects like livelihood and development. It is also notable that details with respect to such relief works have not been elaborated like the criteria to determine who is a flood affected person and how should the houses be allocated to those people. ***The Bihar and Orissa Natural Calamities Loans Act, 1934*** follows a similar scheme. The Act enables the State Government to grant loans to the owners of buildings, which have been damaged or destroyed by natural calamities[63]. As per the Act the affected owner[64] is required to submit an application to the collector[65]. The Collector, after proceeding in the prescribed manner[66], may grant the loan applied for, if he is satisfied that the applicant is an affected owner[67]. Before granting the loan the Collector is required to determine whether the applicant is an affected owner, need

[60] It could not be immediately ascertained as to whether the State has increased this cost limit though the figures presented here seems to be low in present context.

[61] See Regulation 111 of the Assam Land and Revenue Regulation 1886

[62] See Section 51-H of the 1960 Act.

[63] See preamble to the Act.

[64] The Affected owner has been defined as the owner of a building, which has been damaged or destroyed, by an earthquake or other natural calamity. (Section 2.a)

[65] Section 3 of the Act.

[66] As per the *Bihar and Orissa Natural Calamities Loans Rules, 1934*, the collector when considers that the grant of a loan to any applicant is prima facie desirable, he shall, make an enquiry or cause an enquiry to be made by a government servant or by an non-official agent for the purpose of verifying the particulars required.

[67] Section 4of the Act. (Rule 2)

for the loan, adequacy of the security paid, total amount to be advanced, details of the repayment, among other things[68].

Flood Plain Zoning Regulations

Generally speaking, the flood plain should not be used for residential purposes or building construction, or for public & social institutions, like schools, hospitals etc. However, agriculture especially cultivation of seasonal crops may be permitted.

National Water Policy 2012 says that *“There should be strict regulation of settlements and economic activity in the flood plain zones along with flood proofing, to minimise the loss of life and property on account of floods.”*

In order to restrict these activities and regulate the use of flood plains the State of Manipur, has enacted a specific act for this purpose namely *Flood Plain Zoning Act, 1978.* The Manipur Act empowers the State to notify and demarcate the flood plain area after proper survey and prohibit or restrict the use of land therein. The Act also provides for the constitution of an authority, namely Flood Plain Zoning Authority. The Authority is responsible for carrying out the surveys of land and rivers and classify the land with reference to relative risk and permitted land use and publish them for reference. A similar flood plain Zoning regulation has been more recently passed by the State of Uttarakhand in 2012. Rajasthan also has such a law but that has remained on paper and not being implemented on the ground. Other states, which include the major flood prone states of Assam, Bihar, West Bengal, Odisha and Uttar Pradesh, have made no enactment.

The States have not responded with regulation for flood plain zoning so far even though a plea to do so (along with a model Bill) was made by the Union Government almost 30 years ago. The limits of the persuasive role of the Central Government get clear on the response of the States to the Flood Plain Zoning Bill. The Bill drafted and circulated to the States in 1974 by the Government of India and again in 2000 has failed to elicit any good response. Only three States have specific law in this regard and even there the implementation of the law hasn’t happened.

Legally Mandated Famine Relief Funds

Certain State laws provide for the establishment and maintenance of relief funds to be utilized on occasions of serious famine and distress caused by floods or other natural calamities in the State, such as *AP Famine Relief Fund Act, 1936,* ***Orissa Famine Relief Fund Regulation, 1937,*** *the Bombay State Famine Relief Fund Act, 1958.* Under all these laws it is incumbent

[68] Rule No. 4 under the *Bihar and Orissa Natural Calamities Loans Rules, 1934*

upon the State to establish a famine relief fund. Such funds are required to be utilised only for the relief of famine and distress caused by serious floods and other natural calamities. The Orissa Regulation specifically adds that the fund can also be used "for construction or repair of embankments after serious floods."[69] The 1936 AP Act specifies that if the fund exceeds forty lakhs (four million) rupees[70], the government may utilize the excess to meet expenditure on protective irrigation works and other works for the prevention of famines. Under the Orissa Regulation this limit is as high as INR one crore (ten million)[71], further the amount can be utilized *inter-alia* for protective irrigation works, prevention of famines, grant of loans under the Agriculturists Loan Act, 1884, grant of loans to institutions, undertaking to advance loans for building fire proof houses.

The accounts of the fund are required to be made at the end of each financial year. The A.P Act also provides that if the accounts so made up show that the balance in the fund falls short sixty lakhs of rupees, the deficiency shall be made up from the revenue of the State[72]. While the Orissa Regulation mandates that the every year the State government shall place an amount of eight crores and seventy-five lakhs of rupees to the credit of the fund and the said expenditure shall be a charge on the consolidated fund of the State[73].

Another Act, which deserves mention here, is the *Bengal Famine Insurance Fund Act, 1938*. The Act provides for the establishment and maintenance of a fund called the Bengal famine Insurance Fund. The expenditure from the fund are required to be incurred on the relief of famine and relief of distress caused by serious floods, natural calamities among other things[74]. The initial contribution to the fund is required to be made by the State. The Act also specifies the initial amount required to be contributed by the State to be 12 lakhs[75]. Further if the accounts of the fund made up at the end of the year show that the balance at the credit of the fund falls short of twelve lakhs of rupees, the deficiency shall be made up by contribution from the revenues of the State[76].

Apart from the specific Famine Relief Fund Regulation, the ***Orissa Municipal Act, 1950*** also contains provisions regarding relief measures, which may be taken up by the Municipality in

[69] Section 5(iii) of the Orissa Famine Relief Fund Regulation, 1937

[70] Sector 5.

[71] Proviso to Section 5 of Orissa Famine Relief Fund Regulation, 1937

[72] Provided that if the deficiency exceeds five lakhs of rupees, it may be made up in annual instalments, the amounts of each instalment, except the last being not less than five lakhs of rupees (Section 7)

[73] Section 7 (2).

[74] Provided that, if at any time, the total amount of fund exceeds twelve lakhs of rupees, the State government may utilize such excess to meet expenditure on protective irrigation works for the prevention of famine and floods. (Section 5 of the Act).

[75] Section 4.

[76] Section 7 of the Act.

case of famines and serious distress[77]. The ***Asansol Municipal Corporation Act, 1990*** also lists giving relief to and establishing and maintaining relief works in the time of famines or scarcity for destitute persons[78]. However the same is a discretionary power of the Municipality.

Town and Country Planning, Building Regulations and Flood Control Measures

The laws relation to building operations assumes importance as they regulate or prohibit the building operations on certain areas that may be susceptible to recurrent natural calamities. In this context the provisions of the ***Patna Municipal Corporation Act, 1951*** can be considered. Under the Act the Municipal Corporation has been empowered to direct the Chief Executive Officer (CEO) to draw up[79] schemes providing for matters, such as, prohibition of building operations permanently or temporarily when by reason of the situation of the land, where the erection of buildings would be likely to involve danger or injury to health, standard plan for division of land into buildings sites[80]. The Act also empowers the State Government to make rules for various purposes including[81], regulation or restriction of the use of land as sites for building, regulation and restriction of building and alterations or additions to building, regulation of construction of wells, ponds, tanks etc. The Rules may specifically provide that no insanitary or dangerous site should be used for building. The above-mentioned provisions may ensure that the areas prone to floods are not allocated for building purposes. **The *Asansol Municipal Corporation Act, 1990*** empowers the Municipal Corporation to regulate all building operations and regulation of building uses. The Corporation is required under the law to prepare a Draft Development Plan for Asansol in consultation with the District Planning Committee[82]. The said draft development plan shall provide for regulation and restriction of sites for construction of buildings, huts or structures for the purposes of safety[83]. Likewise *The Uttar Pradesh (Regulation of Building Operations) Act, 1958* provides for the regulation of building operations with a view to prevent haphazard development of urban and rural areas. The Act also provides for preparation of master plan showing the existing and proposed location and outline of the various land uses like buildings, residential sections,

[77] Sec 411 of Orissa Municipal Act, 1950.

[78] Sec 88 (1) (a)

[79] The Municipal Corporation may draw up such scheme if under the provisions of the *Bihar Town Planning and Improvement Trust Act, 1951*, a portion of the master plan for Patna or a scheme within the framework of the master plan has been allotted to the Corporation for execution or an improved scheme prepared by the Corporation has been duly approved by the State and if the State Government requires the Corporation to prepare such scheme, the Corporation shall, within six months of such requisition direct the CEO to draw up scheme(s).

[80] Section 228 (f) and (h) of the Act.

[81] Section 253 (1) (a-c),

[82] Section 258 of the Act.

[83] Section 258 (f) of the Act

industrial areas etc.[84]. This becomes relevant in flood management when master plan is prepared for the flood prone areas. For carrying out any material change in the site plan such as erection, re-erection of buildings in the regulated areas declared under the Act, the person interested is required to make an application to the prescribed authority under the Act.

[84] Section 10-A of Uttar Pradesh (Regulation of Building Operations) Act, 1958

II

ASSESSING GAPS AND POTENTIAL REQUIRMENTS IN LAW FOR INTEGRATED FLOOD MANAGEMENT

Notwithstanding the Centre's role in flood disasters and on inter-state dimensions since the legislative competence on the structural measures for flood control has been seen to be an exclusive responsibility of the states (as 'embankment' and 'drainage' have been state subjects under the Constitution), different states have dealt with the subject with their own preferred emphasis on certain aspects of flood management. As the review above shows states have already enacted laws with provisions to deal with matters connected with flood control works. A review of the legal regime seeking to address various aspects of flood management drives home the point that different States have different laws, dealing with whole range of issues, from land use planning, compulsory evacuation of land in case of floods, suitability of lands for construction of flood works, remission and suspension of land revenue in case of agricultural calamity caused by floods, to levying of betterment contribution for recovering the cost of flood control work. This shows that there exists a very useful legal space in terms of laws that already exist which can be utilized for better flood regulation in the country. The fact that states also have laws, some of which date back to colonial times regulating various aspects of flood management and control has been almost hidden from the public discourse on floods. Even while the states have provisions in various laws that could be utilized to deal with flood management there is a need to integrate the disparate laws addressing the range of issues for a unifying legal perspective for flood management in India.

A Working Group on Flood Management & Region Specific Issues of the Planning Commission constituted for the 12th Five Year Plan also notes that as the subject of flood management falls within the purview of the State Governments "Therefore, project-specific planning and their implementation is to be ensured by the State Governments. However, the present structure of the State level flood control departments needs to be revamped to discharge their role as prime flood managers in the State." Clearly there needs to be greater political and legislative will to give effect to plans on flood management as we move ahead.

Some of the key gaps and constraints in the legal regime that exists in States including in Bihar and Orissa are presented point-wise below:

- Legal provisions on various aspects of flood management in different states including states of Bihar and Orissa exist but they are spread very unevenly across the States. Some of the best practices, in terms of enactment of useful legal provisions in one

State, have not led to adoption of similar provisions by other flood prone States. Since the legislative competence on the structural measures for flood control has been seen to be an exclusive responsibility of the states, different states have dealt with the subject with their own preferred emphasis on certain aspects of flood management. Even while Bihar and Orissa have provisions in various laws that could be utilized to deal with flood management there is a need to integrate the disparate laws addressing the range of issues for a unifying legal perspective.

- There is a mismatch between institutional powers and obligations and this is exemplified by the fact that while on one hand the relevant laws vest substantial discretion with authorities to take all possible measures in times of floods and empowering them to do so, on the other this is qualified by the fact that all the measures he "may" (thus may not also!) take which mean that there are no enforceable obligation that he is committed to in times of such emergencies. Since the responsibilities of authorities in times of Flood are not couched in mandatory terms the correlative rights with the flood affected people is of limited value.

- The legal regime on control of land use has been found wanting. Only three States have Flood Plain Zoning Acts but they haven't been given any operative effect. There are general laws in some states that could be invoked for regulating land use in flood prone areas but these legal spaces also haven't been utilized. Besides, lack of independent Land Use policy has meant that proactive policy approaches to land use in urban and agriculture areas has been missing.

- There are series of general legal instruments with implications also for flood control as in speedy acquisition/requisition of land, suspension of land revenue in times of agricultural calamity and in irrigation and drainage laws but the presence of these instruments has not meant that flood management issues are considered in planning being done for other activities.

- Flood insurance and financial incentives for incorporating flood considerations into personal / institutional behaviour are still blind-spots in the existing legal regime and are critical law reform areas that need to be taken up urgently.

- The existing legal regime on building control regulations does not specifically provide for considerations for environmental planning and control generally and also specifically to minimize flood damage within the housing and building regulations.

- Under the present legal regime most of the important aspects of flood management have been vested in the State officials, like identification of areas suitable for flood works, initiating the schemes for such works, requisition and acquisition of lands. While the laws dealing with structural measures have some space for involving people especially by way of inviting comments or objections and mandating service of notice to those affected, the laws with respect to relief works for the victims of natural calamities vest complete powers with the State officials for any works that they may be proposing to undertake.

- A disaster management mechanism has recently been mooted through the enactment of the Disaster Management Act, 2005. The Act provides for National Plan and Department Wise Plan but does not speak about local plans. This is a critical omission because the limits of technical expertise need to be internalized with the potential reach of native intelligence. This intelligence needs to be tapped for devising approaches to management of disasters and thus policies and laws for flood management need to provide space for such intelligence to be counted.

- While some States have specific laws that enable public authorities for entry, inspection and survey for flood control works; in other states such rights vest in public authorities through general laws.

- Laws relating to various aspects of flood management have provisions for conflict resolution and for right of the aggrieved person to appeal to higher authorities. However, typically all the important measures that should be taken during or before a flood are left to the discretion of the authorities, without casting any mandatory obligation to necessarily take such measures in flood emergencies. This has implications in terms of both limiting the significance of formal dispute resolution as legal liabilities cannot be easily placed and also limiting the possible reach of Judicial review (i.e of Courts) on such aspects.

- Generally speaking, the involvement of Stakeholders in decisions making on flood management in all area and levels have been inadequate. This is notwithstanding constitutionally and legally mandated role of the Panchayat Raj Institutions and the Municipalities. Besides the involvement of the local people most likely to be affected by floods has been thought to be more on execution of Schemes at local levels and there is little space for them to intervene in the Planning process.

III

TOWARDS A LEGAL FRAMEWORK FOR RIVER BASIN PLANNING AND FOR RIVER BASIN AUTHORITIES (RBAs)

It is important to note that the first institutional reform suggested by the Working Group on Flood Management & Region Specific Issues of the Planning Commission constituted for the 12th Five Year Plan for effective flood management in the country includes expeditious setting up of River Basin Authorities. In fact way back in 1976, the Government of India had constituted the high level Rashtriya Barh Ayog (National Commission on Flood), which had emphasized that comprehensive or integrated basin-wise planning is necessary for flood protection and control instead of pressing on any one physical measure in a piecemeal manner like a dam or embankment. It is also notable that in 1978, a working group on flood control had emphasized that flood affected states should prepare master plans for each river basin.[85] In this context the as the Working Group for the 12th Five Year Plan itself adds: “The issue of setting up of River Basin Authorities has been raised by the Expert Committees long back. However, action in this regard is yet to be taken both by Central as well as State Governments.”

The National Water Policy 2012 under the subject of flood control and management says thus: “*There should be a master plan for flood control and management for each flood prone basin.*” It adds the following on the subject of river basin organisations:

> “Appropriate river basin organisations should be established for the planned development and management of a river basin as a whole or sub-basins, wherever necessary. Special multi-disciplinary units should be set up to prepare comprehensive plans taking into account not only the needs of irrigation but also harmonising various other water uses, so that the available water resources are determined and put to optimum use having regard to existing agreements or awards of Tribunals under the relevant laws. The scope and powers of the river basin organisations shall be decided by the basin states themselves.”

The rationale and the mandate for river basin organisations have thus been clear. It is imperative to have a close legal perspective on the subject which is presented next.

[85] With respect to embankment, the group asserted that “ while embankments constructed so far has giving the desired protection to the large areas at comparatively low cost, their consequent long term affects on the river regime are yet to be evaluated. New embankment schemes should be taken up with caution”.

Inter State River Waters need a Legal Framework for River Basin Planning

The Constitution of India has vested powers on the Parliament of India for the "Regulation and development of Inter State Rivers and river valleys to the extent to which such regulation and development under the control of the Union is declared by Parliament by law to be expedient in the public interest" by virtue of Entry 56 of List I of the Seventh Schedule to Article 246 of the Constitution. It was in pursuance of this power that the Parliament had enacted the River Boards Act, 1956 (Act 49 of 1956). However, no single River Board was constituted under this Act and law has remained a dead letter.

The States have not responded to the legal space for River Boards created under the River Boards Act, 1956 and this has meant that the Act has fallen into disuse. This is largely due to the fact that in Section 4(1) of the Act, the exercise of power of the Government of India to establish a River Board was dependent on a request received from the State government and no State Government ever made a request under the said section of the River Boards Act, 1956.

The River Boards Act, 1956 also does not provide for any river basin planning. In fact integrated planning, development and management of water resources of the river basin were not contemplated at the time of enactment of the River Boards Act, 1956. The common accepted term for institutions like the River Boards today is River Basin Authority where the word 'basin' is important as it is the hydrological unit that underpins the institution. It is instructive to note that even the term 'Basin' does not figure under the River Boards Act, 1956.

Today a legal foundation for a river basin development and management plan for inter–State river basins is needed. This requires that a new legal framework for regulation and development of inter –State rivers and river basins be put in place. It was in this backdrop that the Government of India constituted a Committee to study the activities required for optimal development of river basins, in which River Basin Organizations (RBOs) and preparing master plans.[86] The Committee proposed the Draft River Basin Management Bill, 2012 under the aegis of the Ministry of Water Resources, Government of India.

The Draft River Basin Management Bill, 2012 proposed establishing a River Basin Authority for regulation and development of waters of an inter-state river basin or any specified part thereof and further makes it clear that different Authorities shall need to be established for different inter-state river basin. The Bill also provides space for creation of a separate River Basin Authority for a sub- basin within an inter-State river basin. The Bill proposes a two-tier

[86] This committee was headed by Justice Tejinder Singh Doabia with the key objective of studying the problems faced by RBOs in India and suggest changes required in making them operational. The committee submitted its report in November 2012. The committee was also expected to suggest changes required in the existing River Boards Act of 1956.

structure for a River Basin Authority. Every River Basin Authority shall have to consist of an upper layer being a Governing Council and a lower layer being the Executive Board charged with the technical and implementation powers for the Council decisions to succeed. The Governing Council has extensive membership and representation including Chief Ministers of the co-basin States.

A legal foundation for a River Basin Master Plan for inter–State river basins can help achieve the protection, improvement and sustainable use of the water environment across the basin. Such a river basin master plan can be the singular guidance tool and basis for the River Basin Authorities to perform their powers and functions under the Act. The formulation and implementation of the river basin master plan can potentially make all water use and land uses in the inter -State basin compatible with the principles of integrated river basin management. The Draft River Basin Management Bill, 2012 thus provides that a River Basin Authority shall ensure that a River Basin Master Plan is produced for the inter-state river basin under its jurisdiction.

The present approach of inter- state river water disputes being addressed by the Tribunals under the Inter States River Water Disputes Act, 1956 has had its own problem of long delays and other related difficulties. A proactive approach to disputes resolution is needed today. Under the Draft River Basin Management Bill, 2012 where any dispute or difference arises between two or more Governments interested with respect to any recommendation given by the River Basin Authority or the refusal or neglect of any Government interested to undertake any measures in pursuance of the River Basin Master Plan or Schemes, amongst other things, the Governing Council of the concerned River Basin Authority shall follow persuasion, conciliation and mediation as means to resolve disputes. [87]

Towards Intra-State River Basin Authorities

The Chief Minister of Orissa in an important speech before the National Water Resources Council in 2012 said that "For sustainable use of water resources, we have prepared River basin plans of all river basins and started a River Basin organisation (RBO) on pilot basis in one of the River basins. Water allocation for use of various sectors has been prioritized in the State Water Policy. This may be appropriately addressed at the national level."[88] While the Chief Minister refers river basin plans and organisations at the state level he said that this is being done on a pilot basis alone. Another state meanwhile has taken up the lead in setting up an intra-state river basin authority.

[87] The Draft River Basin Management Bill, 2012 empowers the Governing Council to require the Governments interested to adduce all facts and evidence as, in its opinion, may be necessary for the determination of disputes.

[88] See the deliberations of the 6th Meeting of National Water Resources Council (NWRC) held on 28th December, 2012, New Delhi.

The state of Rajasthan has come up with an important legal initiative in 2015. It has enacted the *Rajasthan River Basin and Water Resources Planning Act, 2015* establish an authority to be known as the Rajasthan River Basin and Water Resources Planning Authority to exercise the powers conferred under the Act. It empowers this State level Authority to perform the following powers and functions, amongst others:

> "(a) to recommend to the Council the Integrated State Water Resources Plan proposed by Water Resources Planning Department of the State Government;
>
> (b) to recommend to the Council water resources projects proposed by Water Resources Planning Department of the State Government on the basis of the basin and sub-basin wise plans;
>
> (c) to ensure that the Integrated State Water Resources Plan and water resources projects proposed by Water Resources Planning Department of the State Government are in conformity with the economic, hydrologic and environmental viability and where relevant, are in consonance with the State's obligations under inter-state agreements and awards of water dispute tribunals;
>
> (d) to ensure that the Integrated State Water Resources Plan and water resources projects proposed by Water Resources Planning Department of the State Government are in conformity with concept of Integrated Water Resources Management..."

On major reason for setting up State level legally empowered river basin authority deserves to be closely noted. A Committee of the Central Water Commission said in 1996 that "The States should ensure inter- departmental co-ordination amongst the various State Govt. agencies to avoid adverse impact of executed schemes on flood" while emphasizing the need for implementation of the recommendations of the *Rashtriya Badh Ayog* (National Flood Commission*)* [89] In most of the States, State Flood Control Technical Advisory Committees have representatives of Ministry of Shipping, Road Transport & Highways as well as the Ministry of Railway as their members and the adverse effects of the flood control works being taken up by the States are discussed therein. However, it is not clear if a mechanism exists wherein the works proposed by Ministry of Railway and Ministry of Shipping, Road Transport & Highways are discussed with the representatives of the Irrigation/Flood Control Departments of the State Governments. There is necessity of a regularly functioning mechanism for coordination between the States' Irrigation & Flood Control Departments, States' Public Works Departments, Railways and Highway authorities.[90] There is a need to

[89] See the recommendations of the Task Force under the Chairman, Central Water Commission constituted by Ministry of Water Resources, Govt. of India vide their letter No. 7/3/94/ER/755 dated 30th September, 1996.

[90] The Task Force of the Central Water Commission in its final report in 2004 has said that as the State Flood Control Technical Advisory Committees (TAC) have been setup and are meeting periodically in most of the States, the representatives of Railways and Highways authorities can point out any adverse effect on their works due to proposed works or existing works during the states TAC meetings. All agencies implementing construction of roads, bridges etc. must obtain clearance of the concerned state department dealing with flood management, before undertaking the construction of such works.

develop facilitative frameworks and forums that enable these departments to come together. This is where the idea of a legally backed state level River Basin Authority makes for a good sense.

The lead taken by Rajasthan in coming up with a legally backed state level River Basin Authority in 2015 may be followed up by other States including Bihar and Orissa. This could help introduce binding laws and regulation on the basis of the basin and sub-basin wise plans in the State.

Key Pointers and Recommendations on River Basin Authorities may be summarised point-wise as below:

- Water Resource Management and interventions under it is mostly done for defined administrative units (say, Village, Block, District and State levels) under the existing legal regime. There are enactments like the Brahamaputra Board Act, 1980 and the Damodar Valley Corporation Act, 1948 which are mandated to plan for the respective river valleys and for promotion and operation of schemes for flood control in the rivers but they do not have an integrated river basin approach and has not been allowed to grow into a river basin authority.
- The States have not responded to the legal space for River Boards created under the River Boards Act, 1956 and this has meant that the Act has fallen into disuse. The River Boards Act, 1956 also does not provide for any river basin planning.
- There are a range of formal and legally backed Institutions within a river basin and also engaged in specific water management activities but there is no mechanism that can help coordinate these at the basin level both for water management generally and flood management in particular.
- Today a legal foundation for a river basin development and management plan for inter–State river basins is needed. This requires that a new legal framework for regulation and development of inter –State rivers and river basins be put in place.
- The Draft River Basin Management Bill, 2012 of the Government of India has proposed establishing a River Basin Authority for regulation and development of waters of an inter-state river basin or any specified part thereof and further makes it clear that different Authorities shall need to be established for different inter-state river basin. The Bill also provides space for creation of a separate River Basin Authority for a sub- basin within an inter-State river basin. The Bill proposes a two-tier structure for a River Basin Authority.

- A legal foundation for a River Basin Master Plan for inter–State river basins can help achieve the protection, improvement and sustainable use of the water environment across the basin. Such a river basin master plan can be the singular guidance tool and basis for the River Basin Authorities to perform their powers.

- The lead taken by Rajasthan in coming up with a legally backed state level River Basin Authority in 2015 may be followed up by other States including Bihar and Orissa. This could help introduce binding laws and regulation on the basis of the basin and sub-basin wise plans in the State.

Appendix E-1 Examples of flood modelling for IFM

Mekong River Commission: Flood Management and Mitigation Program -Structural Measures and Flood Proofing (Cambodia, Laos, Vietnam, Thailand)
The project introduced Integrated Flood Risk Management (IFRM) in the four riparian countries of the Lower Mekong Basin, i.e. Cambodia, Lao PDR, Thailand and Vietnam for the preparation of structural works for flood risk reduction (reservoirs, diking schemes, river improvements and diversions). The first step involved the proper assessment of flood risk by using a mathematical model. Secondly, the possible measures for risk reduction were identified. The third step involved the evaluation of the effects and impacts of the different types of measures and development of a strategy for flood risk management. In the fourth step, IFRM plans were developed on the basis of this strategy. The plans included a specific set of measures and projects for the reduction of flood damage risk in a certain area. In the final step implementation of these measures and projects was prepared.

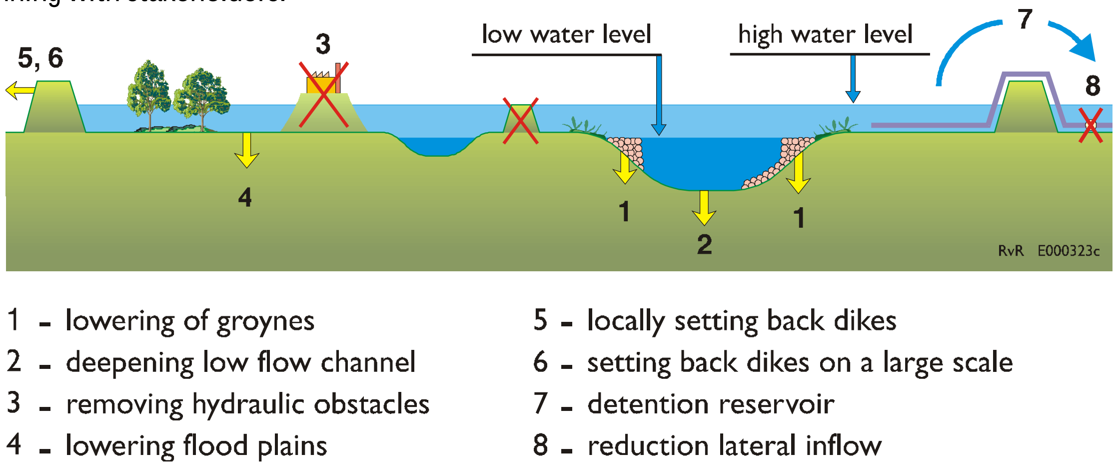
Ho Chi Minh City Flood and Inundation Management Project (Vietnam)
Flood prevention has been one of the biggest preoccupations of Ho Chi Minh City authorities in recent years. Residents must confront flooding every year during the rainy season. Causes of flooding include flood tide, heavy rainfall, high discharges of upstream rivers, insufficient capacity of the drainage system, low ground elevations of the city and land subsidence, spatial planning, policies and regulations, lack of public awareness and participation. The HCMC Flood and Inundation Management Project prepared an integrated strategy and implementation plan for Flood and Inundation Management (FIM) in HCMC and related areas. The various measures were analysed using a mathematical model. Computer simulations were also used to forecast the effects from sea level rise and land subsidence. Finally a Cost-Benefit Analysis was performed for the most promising measures.

Darwen and Blackburn Flood Risk Management Strategy (UK)
In 2008 a Flood Risk Management (FRM) Strategy was prepared for the River Darwen and River Blakewater, along with their associated tributaries. The Strategy sets out the sustainable management of flood risk to people, property and the environment over the next 100 years in the Upper Darwen and Blakewater catchments. The river features a steep valley with narrow flood envelopes and a constrained channel with many culverts of varying size and condition. The catchment delivers fast flows and a rapid on-set of flooding. The existing standard of protection is uncertain and there is little information on informal defences. Mathematical modelling was used to identify the flood risks, where and when defences are likely to fail, block or overtop and whether there is justification to continue to maintain, enhance or undertake capital works, giving a prioritised programme for maintaining flood defence assets.

Andhra Pradesh Cyclone Hazard Mitigation and Integrated Coastal Zone Management Project (India)
The overall objective of the project was to provide a system that minimises impacts due to cyclone natural disasters, and enhances sustainable development of the coastal zone. The project provided the AP Planning Department with a number of planning tools and products for dealing with the consequences cyclones in coastal Andhra Pradesh and for implementing ICZM. An automated Real Time System (RTS) was set up making use of a storm surge model, a rainfall model and a wind hazard & damage model under the dedicated software to generate forecasts for the early warning system.

An extensive GIS database contains geographical as well as statistical data such as population statistics, transport infrastructure, settlements and towns, flood hazards, status of natural resources and land use, both for the use in the RTS as well as ICZM. The GIS formed the backbone of an Expert Decision Support System to use for ICZM. A Strategic Action Plan for implementation of ICZM practices was prepared together with staff of the Government of Andhra Pradesh.

Room for the River Rhine (the Netherlands)
After two near floods in the 1990s there was renewed attention to flood protection, not in the least because of fears that climate change could significantly increase high river discharges. But instead of raising the embankments it was calculated through mathematical modelling that giving more room to the rivers would substantially lower flood levels and sustain a more attractive environment. Room for the Rivers was officially adopted by the Dutch government to achieve the required safety level for the river systems. Later it also became the guiding principle for climate change adaptation along the major Dutch rivers.
The implementation of the new Room for the River policy required difficult choices at the local level and it was thought essential to involve local stakeholders in finding optimal solutions. Both national and regional authorities, municipalities and individual citizens proposed around 700 local measures that could help in reducing the water levels. Each of these measures would have secondary impacts and different costs. In order to handle such a huge amount of information a special tool was developed, the planning kit ‘Room for the River’, which proved to be successful in supporting joint planning with stakeholders.



Appendix E-2 Best practices of community involvement in flood control and management

There are many community practices that have learned to cope with flooding. In Bihar and Assam States several good examples can be found how communities live with flood. Traditional practices and communal knowledge in Bihar are mentioned in volume 6b "Community Survey Report BB". In Assam traditionally stilted houses are constructed by communities to cope with high soil moisture content and recurring floods. Similar communal practices can be seen in South East Asian countries, particularly in the Lower Mekong region. Recent years population growth and market forces has witnessed more intense human activities in flood prone areas causing increased risk to people and assets.

Community involvement in flood management is relative new. Because flood management needs a basin wide approach, involving communities in flood control and management requires an organised approach, which is attempted by international organisations. This can be illustrated by several initiatives from South East Asia

One of the most notable efforts in involving communities in flood risk management is executed by the Mekong River Commission (MRC). It has emphasised the importance of such involvement based on its experience working in the four member countries (Cambodia, Laos, Vietnam and Thailand). With the support of several UN organisations it improved community based early warnings, e.g. through community owned "Flood Information Billboards" and through emergency response contributions to national flood risk reduction initiatives.

A pilot project on "Community Approaches to Flood Management" was implemented in Bangladesh, India and Nepal. The Associated Programme on Flood Management (APFM) – a joint initiative of the World Meteorological Organization (WMO) and the Global Water Partnership – introduced the community level approach to IFM in selected villages in the three countries. Community Flood Management Committees were formed with defined roles for the pre-, during and post- stages of a disaster. The experience showed the need for political will to link the community approach to the regional and national level in order to make it sustainable[91].

ADPC, the Asian Disaster Preparedness Centre, has conducted a regional workshop on Best Practices in Disaster Mitigation during which a series of papers where presented, highlighting community initiatives in various countries. The papers described the participatory approach of community based urban flood mitigation in Bangladesh, mitigating flood risk in Cambodia, experiences of community based disaster mitigation in municipal ward 34 of Kathmandu city; and community based approaches to landslide disaster reduction in Sri Lanka. These papers mainly emphasized community initiatives and involvement in mitigation activities[92].

[91] (Anonymous, 2004, Synthesis of manuals on community flood management in Bangladesh, India, and Nepal, Asia Pacific J. Env. Dev., 11(1&2), 2004, pp. 1-39)

[92] Best Practices in Disaster Mitigation, Regional Workshop on Best Practices in Disaster Mitigation, Bali, Indonesia, September 24-26, 2002

Appendix F Geotechnical Slope Stability Analysis

The present criteria by CWC, GFCC, BIS Codes and NDMA make the recommendation for detailed slope stability analysis only for embankments with a height of more than 6 m. For smaller embankments, the criteria concludes that if the riverside and country side slopes are followed as per guidelines it is sufficient to establish that the slopes are stable. It also stipulates that the country side slope is to be maintained from the top of the embankment up to a point, where the cover above the hydraulic gradient line (HGL) is 0.60 m. However based on this study, it seems appropriate that the criteria should make a unified recommendation for detailed slope-stability analysis for all types of embankments, irrespective of their height.

During the course of this operational research study, it was noticed that the state governments follow the criteria for geo-technical slope stability analysis as per the appropriate methodology, of course for higher embankments, covering the non-overflow sections of dams. But we recommend that they should follow this methodology for the smaller river embankments also to establish the appropriate slopes instead of using arbitrary slopes, like 2H:1V.

During this study, such systematic geo-technical slope stability analysis encountered in Odisha for the Sankhabanga dam for the non-overflow section, which is an earthen embankment of about 22 m high. The slope stability has been carried out in a systematic manner, as briefly discussed below:

A. Tabulation of Relevant Data as below:

1. level of the top of the embankment	243m
2. Prevailing Natural ground level	221m
3. Deepest River bed level	218m
4. Full Reservoir Level	240m
5.Top width of embankment	6m
6. River Side slope	3H:1V
7. Country side Slope	2.5H:1V
8. Length of Horizontal filter from downstream toe inwards	35m
9. Cohesion of the soil of the embankment	2.4 t/m^3
0. Cohesion of foundation material	5.4 t/m^3
11. Angle of the internal friction in embankment soils	25 degrees
12. Angle of internal friction in foundation material	12 degrees
13,Dry weight of the soil in the embankment	1.8 t/m^3
14. Submerged weight of the soil in the embankment	1.2 t/m^3
15.Dry weight of the foundation soil	1.80 t/m^3
16. Coefficient of permeability of soil in the embankment	$1x10^{-4}$ m/sec

B. Establishment of the phreatic line

This is carried out by Kosenv's base parabola method as per accepted analysis of relevant equations of parabola and the phreatic line is established.

C. Checking of the stability of the embankment

This is analysed by considering its cross section at a location where its height is the maximum. The shear resistance of the embankment is computed by using relevant equations, considering the weight of the material above the phreatic line, such weight below the line (submerged weight), the cohesive properties of the material in the foundation and the internal friction angle of the material in the embankment. This is compared with the horizontal disturbing force due to the water. The ratio of the shear resistance and the horizontal forces by water is termed the Factor of Safety which should be not less than 1.30. If the Factor of Safety is more than this value the embankment safety is established, with the assumed slopes of the embankment.

(in the Sankhababga case in Odisha, it was ascertained that with assumed section with slope of 3H:1V and 2.5H:1V for the river side and country side slopes, respectively, the factor of safety was noticed to be 6.48, which is very safe and conservative)

D. Stability of the upstream slopes, (under sudden drawdown condition).

This is analysed by separating the river side embankment by a vertical line from the outer edge of the top of the embankment (on the river side). The Horizontal force on this separated section of the embankment, (in the river side) is computed by the set of equations established, using the weighted density at the centre of the embankment triangular section on the river side. This horizontal force acts along the base under the river side slope. Then the shear resistance developed at the base at river side of the embankment is estimated using the equation developed for estimating this shear resistance. Subsequently, the Factor of Safety is given by the ratio of shear resistance and the horizontal force. This factor of safety should be more than 1.5. If the factor of safety computed is more than 1.5, the river side slopes are stable under the sudden drawdown conditions. (Based on the perusal of the computations and discussions held by the experts of this study the Sankhabanga dam has realized a factor of safety of 2.24, which is acceptable). Likewise, the analysis for the river side slopes is further explored by estimating the average shear stress at the base of the river side slope. From this the maximum shear stress estimated along with its location within the body of the river side embankment. Then the unit shear resistance is estimated at this location of maximum shear stress. Then the factor of safety at this location of maximum shear stress = Unit Shear resistance/Maximum shear stress. The factor of safety should be more than 1. If the factor of safety established at the point of maximum shear stress is more than 1, the slopes are stable. (in the computations studied for the Sankhabanga embankment in Odisha, this factor of safety realised is 1.84, which is greater than 1). If the above two analysis (at the base of the embankment at the river side and at a point of maximum shear stress in the river side embankment) bring out the required Factors of safety of 1.5 and 1 respectively, then the river side slopes are stable in all conditions of horizontal forces.

E. Stability Analysis for the Country side Slope.

Just like the analysis of river side slope, a vertical line is drawn to separate the country side portion of the embankment. This vertical line is drawn downwards from the outer edge of the embankment top (in the country side). This will result in the triangular section of the embankment in the country side.

First, the stability analysis is carried out along the base of te country side embankment. The horizontal force is computed under steady seepage conditions. The important input in this computation is the weighted density of the triangular portion of the embankment at the centroid. Then, the shear resistance provided by the mass of the embankment at its base is estimated. Then as per usual norms, the factor of safety is the ratio of resistive force to negative horizontal force. This factor of safety needs to be at least 2. (In the Sankhabanga embankment, this factor of safety realised is 2.45). As in the case of the river side, here also, the stability analysis is carried out at a point of maximum stress. From the average shear stress at the base, the point of maximum stress is found out. Then the actual shear stress which is the maximum is estimated. Then the unit shear resistance at this location is estimated based on the mass of the triangular section of the country side embankment. The factor of safety then is = Shear resistance/Maximum Shear stress. This should be at least equal to 1. (in the Sankhabanga country side embankment, this factor of safety estimated was 1.73). The above two stability analysis at the base and at the point of maximum stress, if provide acceptable factors of safety, the country side slopes are stable and safe.

F. Stability check of the Foundation

The horizontal stress on the foundation is first estimated considering the dry density of the embankment material. This is because the maximum compressive force and stress will be exerted by the embankment on the foundation in dry state. Then, the total horizontal force is computed in the country side slope, where it is generally the maximum. For this computation the equivalent weight of the dry material in the embankment is used. From this force, considering the area of the foundation, the compressive stress is computed at the base of the embankment. Then the total shear force is estimated along the country side slope using the appropriate equation. From this shear force the average shear stress is computed at the base of the country side slope.

Then, it is a question of tracing a point along the line inward from the toe of the embankment at the country side, where this average shear stress becomes a maximum. Thus the average and maximum shear stress are established at the base of the country side slope and at a point in the embankment body in the country side.

Then, the shear resistance of the foundation soil below the country side slope of the embankment is estimated in two parts; one is unit shear resistance below the toe of the country side and the other unit shear resistance developed at foundation level. Then the average of these two shear resistances is estimated.

The overall factor of safety against shear is the ratio of the average shear resistance to average shear stress; this should be greater than 1.5 (In the Sankhabanga embankment the overall factor of safety of the foundation has been estimated to be 1.51).

Then the factor of safety at the point of maximum shear stress is computed. The maximum shear stress has been already computed from the average shear stress; the maximum shear resistance is further estimated at the location of maximum shear stress. The factor of safety at location of maximum shear stress=Maximum Shear Resistance/Maximum shear stress. This should be not less than 1 (For Sankhabanga embankment foundation, the factor of safety realised is 1.20)

G. Findings

1. The State WRDS have the capability to perform slope stability analysis

2. They do the slope stability analysis only for very high embankments.

3. The criteria need to recommend slope stability analysis for all embankments irrespective of their heights. This will be unified criteria. Nowadays software has been developed for slope stability analysis and as such the analysis will not be difficult.

4. The properties of the soil and other material used in the embankment and in the foundation need to be very precisely estimated for slope stability analysis.

As such, the WRDs need to have state of the art laboratories with appropriate apparatus for carrying out the tests on various materials for estimating various properties; or else they need to have tie-ups with appropriate state/central material testing laboratories.

5. The slope stability analysis will bring out the precise need of the slopes of the embankments

6. in addition to stability analysis, proper revetments to protect against erosive action of River need to be provided; to improve the shear strength of the embankment soils, the growth of short rooted vegetation has been recommended by the CWC Handbook on flood control, Anti-erosion, river training, which needs to be put in to practice.

Appendix G Design of urban water drainage systems

A. Drainage Investigations

Investigations for drainage works can be divided in to three types depending on the objectives and level of investigations required. These are, reconnaissance, preliminary and design surveys. Since problems at each site may be different, the extent of investigations needed should be carefully considered. It is necessary to prepare a check list for large problem areas to include all works to ensure that the data required are obtained in an orderly manner.

The *reconnaissance* will be utilized to develop the concepts like a tentative plan for improvement, location of the proposed drainage system including structures, preliminary cost estimates, the benefits and preliminary economic analysis.

The *preliminary investigations* will indicate the location of the areas in need of improvements, a possible comprehensive plan for the improvements, the design criteria to be adopted and preparation of preliminary designs.

The *design oriented investigations* are required for the preparation of construction plans and specifications. The major data required will be identified and collected. These data are: topographic map of the problem area, soil map, information on extent, frequency and seasonal flooding in the problem area, precipitation records, location of main and lateral drains, delineation of drainage areas of main and lateral drains, longitudinal profile and cross sections along the proposed alignment, brief geological investigations for forming an idea about the stability of proposed drainage channels, identifying the details of bridges, culverts, pumping stations, aqueducts and the required hydraulic studies, construction specifications for all items of works and firmed up estimation and costing

In achieving the above data, after the field reconnaissance, discussions with government authorities and citizens and carrying out topographical surveys as per requirement (like contour survey, alignment survey with longitudinal and cross section profiles, detailed spot surveys at proposed pump houses, and outfall area) are taken up. Concurrently, the experts will identify the alignments of the needed laterals, main collector drains and the location of outfall drains, based on the reliable contour survey maps. If lifting of water is required, the location of pump house or pump houses (in case of multi-level lifting) will be identified and located.

B. Design of storm water drains

The design of a storm water drain has been given, in CPHEEO "Manual on Sewerage and Sewage Treatment" MoUD, Government of India.

I. A minimum diameter of 150 mm is adopted as per recommendations in case drains are proposed to be pipes.

II. If pipes are not used, recommended standard rectangular or trapezoidal sections could be used. There are eight types of rectangular sections and five types of trapezoidal section of RCC drain in the Storm Water Drainage Schemes (these recommendations are followed in Muzaffarpur, as ascertained through discussions with town authority).

III. Compute the catchment area from the delineated catchment area maps for different laterals and the main drain.

IV. Estimate the storm water discharge rate, which is a function of
- Intensity and duration of rainfall
- Characteristics of catchment
- Time required for flow to reach the drain

V. Decide the storm frequency to be adopted as per design criteria determined. The storm frequency is an important factor to be considered; storm water drains are not designed for storms of rare occurrence such as once in 25, or 10 or even 5 year return periods; The frequency for which the drainage has to be designed depends on the importance of the area to be drained. CPHEEO Manual has suggested the frequency of flooding in the design of storm water drains as follows:
- Residential areas
  - Peripheral areas: twice a year
  - Central and comparatively high priced area: once a year
- Commercial and high priced area: once in two years

(For this report the storm frequency has been adopted as "twice a year" for the design of storm drains for Muzaffarpur city)

VI. The contributing catchment area is obtained from the contour map. The total drainage basin under consideration is generally divided into two parts:
- Built up area = A percentage of total town area depending upon the town (In the case of Muzaffarpur, this has been determined to be 70% of total area of the city)
- Open area = (100-percent of built up area=30% of total area for Muzaffarpur)

VII. Determine the imperviousness factor. The above areas may contain footpaths, roads, garden and parks; for the above two categories of the catchments the imperviousness are recommended to be:
- The imperviousness of the built up area = 70% i.e. impervious factor 0.7
- The imperviousness of the open area = 20% i.e. impervious factor 0.2

Therefore total weighted average imperviousness (Im) of the total area will be

Im = ((0.7x70) + (0.2x30)/ (70+30)) = 0.55 (for Muzaffarpur city)

VIII. Determine the rainfall intensity based on the data of the nearest rain gauge station. (The rainfall intensity (I) has been determined from the records of the nearest rain gauge station. This is 18mm/hr (1.8 cm/hr) for 1-hour rainfall. This has been adopted for the case of Muzaffarpur City in the Burhi-Gandak Basin.)

IX. Next it is required to estimate the time of concentration, for each delineated catchments. (The time of concentration for this scheme for Muzaffarpur city has been taken as below):
- Time within house premises as 15 minutes
- Time from internal drain to main drain with 700 m length of internal drain in each area with a velocity of 0.5 m/sec = 700/60/0.5 = 23.3 minutes

- Time to flow in main drain assuming 2000 m length and velocity as 1.5 m/sec = 2000/1.5/60 = 22.22 mins

The Time of concentration (Tc) = 15 + 23.3 + 22.22 = 60.52 mins = 1 hour and the Critical intensity of rainfall (Rainfall intensity for a time equal to the time of concentration) = I*2(Tc+1) = 1.8*2 (1 + 1). (in cm/hr)

X. Compute the design discharge from this rainfall intensity, which will be equal to the product of critical intensity of rainfall, the catchment area and a run off factor. The run off factor is assumed based on experience, which could be assumed to be 80%. Now this discharge is to be carried away by the drains of appropriate shapes and dimensions.

XI. Next assume a typical section of the drain. Estimate the discharging capacity of the assumed section of the drain. If this discharge carrying capacity is more than the design discharge computed in the above step, then the section is firmed up. Discharge capacity is calculated as a product of the cross section area of the drain and the velocity. The velocity computation is performed using Manning equation, while assuming Manning's roughness values for RCC and smooth plastered surface as 0.013. The maximum permissible velocity for RCC and plastered over brick surface is generally taken to be 3m/s and the minimum velocity is kept as 0.6 m/sec.

XII. Then if for the assumed rectangular or trapezoidal section the discharging capacity is more than design discharge, that section is firmed up. Over the level of water (during discharging the design discharge), the free board is fixed, which is generally in the range of 15 to 25 cm depending upon the prevailing ground level and site conditions of inundation.

(Final values have been taken from "Storm Water Drainage Scheme for Muzaffarpur Town" as shared by Muzaffarpur Municipality (Nagar Nigam). The report has used the following:

- Freeboard: 15 cm
- Roughness coefficient: N=0.013 for plastered brick and RCC drains
- Side slope: 1:½
- Area of rectangular section of RCC drain = 2.625 m^2 (max).

Appendix H. Framework for Flood Early Warning

Principles

The main idea behind forecasting for early warning, such as a Flood Early Warning System (FEWS) is that the time to detection of the hazard is increased. Traditionally, warnings are generated when a certain natural phenomenon is detected. The time between the detection and the actual hazard generally can be short. By using a modern forecasting technique, natural phenomena (such as wind, air pressure, rainfall, inflows, downstream water levels) are simulated and forthcoming hazards can be detected well in advance, thus increasing the lead time for warning and response. This is visualized in the figure below:

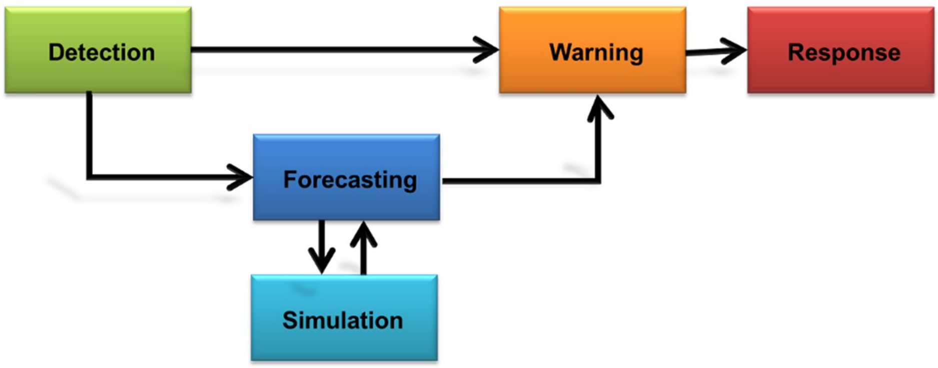


Figure Forecasting can increase lead time for warning and response

The simulated response of a forecasting system will indicate whether or not a hazard might be approaching. Thresholds can be set on water levels, precipitation intensity, wave height, soil saturation etc. When the forecast value crosses the threshold, the simulated phenomenon can be considered a hazard and warnings can be sent out. Often multiple thresholds are defined, for instance *Floodplain flooding, Flood watch, Flood warning* and *Severe flood warning*.

The main goal of an EWS is to prevent hazards from becoming disasters. By providing end-users with meaningful warnings, these have the opportunity to take risk mitigating actions, such as moving assets to higher ground, laying sandbags, and preparing for evacuation. Warnings should ultimately be provided by local authorities because they know the local conditions and vulnerable people and assets. However, it is beyond the capability or capacity of local governments operate a unified, multi-channel, nationally standardized for delivering warnings to their citizens. This is the responsibility of the national government; in this case the Central Water Commission, who collects hydrological data and receives weather forecasts from the IMD.

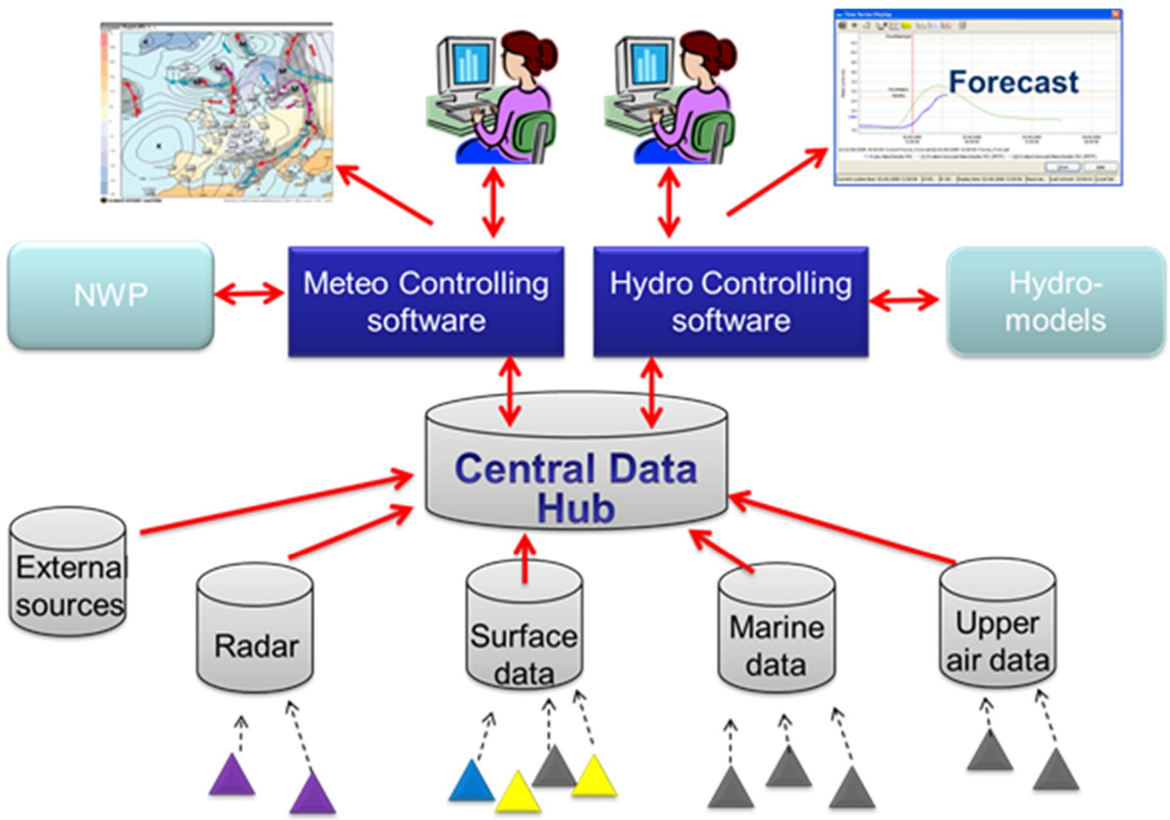
In general, warnings should be issued when properties and live are at risk. In some cases events can have a long lead-time, such as floods caused by long rivers where the flood wave can be observed several days in advance. A flood forecasting system, using hydrological, hydraulic or regression models to calculate the progression of the flood wave, offer timely information that can be used to generate warnings. For other hazards, such as flash floods with shorted lead-times, in general no forecasting is possible. Therefore in these situations warnings are directly coupled to real-time observations upstream. Systems providing these warnings are generally called Community-based EWS and are managed locally. These EWS will only work when there is sufficient lead-time between the trigger and the occurrence of the event. There are also other methods to notify end-users of potential threats, such as Flash Flood Guidance systems.

Components of a Flood Early Warning System

A Flood Early Warning System consists of:

- Observation network (incl. external data sources, such as satellites, GTS (WMO) data, etc.)
- Data transmission network
- Data processing and archiving
- Forecasting (weather, rivers, marine, etc.) using models and expert knowledge
- Warning dissemination

Ideally, there is a Central Data Hub that receives all required data for preparing weather forecasts as well as hydrological and marine forecasts. This is depicted in the figure below:



Staff strength

Typically a flood forecast system requires the deployment of three groups of experts: i) Operators and managers of observation network; ii) IT and communication staff and iii) Forecasting staff. The actual size of a forecasting organisation depends on the size of the country or region for which the flood forecasts need to be given. In general, the majority of the staff will be engaged in operation and management of the network (60-70%). Some 20-30% are actually preparing the forecasts and 10-20% are supporting staff for IT and administrative work. Actual size of the staff needed depends further on staff skill levels and the level of automation of the various processes.

Appendix I. Comments Matrix

Comments on Draft Final Report

Comments from ADB on version 31-08-2015	Comments / action taken
Frontispiece Please consider replacing cover photo to represent an image from one of the focal basins that were studied. The frontispiece should seek to highlight a key/emerging issue of Flood risk and thus be more relevant to the overall scope of the study;	New photo inserted
Abbreviations Please only use commonly accepted/standardised abbreviations. ADB Handbook of Style and Usage (http://www.adb.org/sites/default/files/institutional-document/31385/hsu.pdf) (previously provided to Firm) may be used as reference. Check capitalization - e.g. DRR – Disaster Risk reduction, IFMP - Integrated Flood management Plan etc Units – Please follow standard SI units (eg. Unit for kilometer is km not Km). Ensure consistency is maintained throughout the report and appendices (e.g page #4)	Done
Paragraph numbering Paragraphs at present are not numbered. Please revise throughout the Report.	MS-Word does not have automatic paragraph numbering.
Executive Summary The ES in its current form is poorly presented – both from an English language/grammar perspective and also and perhaps more importantly content. Please re-write and present the revised ES in a manner which highlights the innovation bought by this study to the sector, emphasizes the operational relevance of the scope of work and presents strong rigour and the science applied to flood risk management which is relevant and practical to policy makers/scientists/researchers and development planners. Avoid starting sentences with 'And"…. 1st bullet point starting: "as per our model calculations……." The last reference to recommendations of the National Flood Commission in 1980 being to the point implies that the data analysis conducted 35 years	 Has been updated Done Last sentence removed.

later through this TA hasn't contributed much more than this. Please revise this bullet point; A tremendous amount of research and study has been conducted during the TA period and the ES does not adequately showcase this. Please re-write.	
Chapter 1 Section 1.1 – Under overall objectives of the study please direct the reader to the relevant volumes where the study objectives have been met. Please change the period for Phase 1, which was completed and approved in Feb 2014.	A special section 'Guide for the reader' is included. Section 1.4, page 3 of Main Report Done
1.3 Reporting - please include titles of the two research papers in the list after Volume 9.	Done Section 1.3, page 2 of Main Report
Chapter 2 Title should read: Review of existing Flood Management Initiatives in India, (change the title in contents sheet accordingly).	Done
Section 2.1 Para 3 - sources for Bihar presented in this para need to be sourced. This applies throughout the report where data and figures are quoted an appropriate reference must be provided. Please check grammar and tenses used in this chapter and throughout the text. A thorough edit is recommended of this chapter the DFR as a whole.	Done
2.2 – Ensure the titles of the committees listed are in consistent with their actual titles given by the government. Also check for some spelling mistakes (such as <u>Minsters'</u> Committee on Floods and Flood Relief-1972) Second para page 5 – begins "This having said…" – language is incorrect. Please revise.	The titles of all the 9 items (Committees /Working Groups/ Commissions) are verified and consistent with the titles given by the Government. These have been adopted from the IWRS site and have been already mentioned so in the Phase-I study, which stands approved. Section 2.2, Page 5 of Main Report Done Done
2.6 Review of Economic impacts to Floods - this section is not complete. However it should be noted that significant background study and investigation was conducted here during Phase 1. The Firm is therefore requested to ensure this section is not a repeat of Phase	Section inserted Section 2.6, Page 11 of Main Report

1 investigations but seeks to build on work done earlier – not a repeat of the same content. For this chapter and subsequent ones a fundamental missing component is a failure of the firm to illustrate points with clear examples from the Basins studied. Please revise the report to address this lapse please. It is obvious to the reader that sections of the report have been written by different authors. There is a need for the report to be consistent in its presentation and style. We therefore request the Firm to ensure the reports are proofread and revised accordingly.	Examples are included in the main text where considered relevant Done
2.8.2 Please re-write the description of the CWC in a manner in which the content may be understood. Also at present this section merely lists the functions of the CWC and does not seek to address the capacity issues referred to in the sub-heading which precedes it. Please revise to ensure the Report provides a critical analysis of institutional capacities.	Done Section 2.8.2, Page 15 of Main Report
Chapter 3 The material presented under this subheading needs to be supplemented at the start of the chapter to the parameters of the cc work and overall scope. The approach and methodology adopted needs to be mentioned. Then the results may be presented in summary but with sufficient explanation of the main points which have been obtained through the modelling and other exercises. The reader at present is not provided with sufficient introductory and background information which are required to be presented in the main report. Again it is clear that this section has been written by another expert and the writing style and presentation is thus different. The Firm is requested again to ensure a thorough language check is done prior to finalization which addressed this and aids overall readability of the document.	Done Done
Chapter 4 This chapter may be significantly improved by relating the theory presented with examples from the Indian context which seek to substantiate the arguments presented. Similarly examples critiquing Central and State Government initiatives should also be provided here.	Examples from the two basins have been included: Main Report: Box 7 Page 34, second para Page 35, third para Page 36, first para Page 37, third para Page 42, second para Page 44, third para Page 45, whole Page 47, first para Page 49, last para Page 50, second para Page 51, section 4.4.7 Page 52, fourth para Page 53 first para Page 55, Section 4.4.12 Page 57,

	last para Page 57, third para Page 63, third para Page 68.
All figures should be correctly sourced where relevant. Similarly references to relevant Phase 1 outputs and studies may also be included here.	Done
Please supplement the text with examples form the Basins under study. This helps contextualize the report and also avoids presentation of material in an abstract manner.	Results from model studies of both basins have been included in the Main Report to illustrate the effectiveness of measures.
Page 34 last para beginning: 'Nevertheless, also criticism is vowed ?)….." this sentence makes no sense. Ps re-write.	Done
Section 4.4.6 Embankments- please supplement with photo examples of overflowing/wave overtopping etc.	Done
In this chapter and the others there are several important recommendations being made to Central and State Agencies. The way this is currently presented is that it is lost in the text. Please revise and include either a separate chapter with recommendations and directives to the agencies involved or else an Action Plan/Guidance Document to Indian practitioners which may be included as a separate Volume. This comment follows similar guidance from MOWR to the Study Team at a recent Steering Committee meeting.	We have included a table with Recommendations and Action Plan with reference to potential actors. Pages xiv to xix of Main Report Chapter 5 provides recommendations
4.4.12 Emergency response Opening sentence needs revision - sentence incomplete?	Done
5.1 Conclusions This section provides some very relevant and practical recommendations for MOWR/CWC. There is good scope to present these recommendations in a manual/action plan form for MOWR/CWC staff. This may also form the basis of the Final workshop to be held in October.	We have included a table with Recommendations and Action Plan with reference to potential actors. Pages xiv to xix of Main Report
(i) Research Paper: "Downscaling GCM Data for Climate Change Impact assessments on rainfall: a practical application for the Brahmani-Baitarani Basin". Please confirm whether this paper has been reviewed and endorsed by GoI/MOWR/CWC. If CWC staff Mr. S.K Singh is an author he will need to ensure clearance for publication is initiated. Please specify intended journal for publication and dates for this. Who will take responsibility for acceptance of	The Paper has been discussed with the Co-authors Mr. M.P.Singh (Chief Engineer-P&D, CWC and with Mr. Sanjay Kumar Singh, Director-I &CAD, CWC). They have reviewed and provided some inclusions in the draft paper. This paper has been submitted as a discussion paper to be reviewed for the journal "Hydrology and Earth System Sciences (HESS)"

publication etc. after contract period ends. Acknowledgements - please note this TA is cofinanced by ADB and DFID. Not just DFID as noted in this section. Kindly revise.	 Done
(ii) Volume 4 Data Compendium Report Please include a section in the report on efforts made to ensure the data collected as part of the TA may be accessed by users groups etc. I.e. attempts for open sourcing.	Section "4.6 Accessing the collected data" has been included. Section 4.6 on Page 42 of Volume 4.
(iii) Flood risk Modelling and Mapping Why is this titled Component 1? Isn't this for the Buhri Gandak? Please be consistent with report titles etc. Presentation of this report needs to be re-worked to follow presentation style in other volumes/reports. Please revise.	Report has been revised
(iv) Flood risk Modelling and Mapping - Brahmani- Baitarani Presentation of this report needs to be re-worked to follow presentation style in other volumes/reports. Please revise.	Report has been revised
(v) Volumes 3 and 4 - Basin Flood Management Plans Both Basin Plans contain a lot of very important information and data which will be very useful for the State Governments. However as currently presented in both volumes there is a lot of descriptive material and less analysis presented. Please revise by including brief summary paras at the end of each section which highlight the key issues and messages required for basin management.	A new section 7.2 has been added in both volumes 3 and 4 "Towards a River Basin Flood Management Plan" in which a summary of the key interventions is provided in the form of a multi-criteria analysis. Section 7.2 on Page 88 in Volume 2 and Section 7.2 on Page 74 of Volume 3.
(vi) Volumes 6 Community Survey Report: Burhi Gandak (Part 2) and Volumes 6 Community Survey Report: Burhi Gandak (Part 1) Both volumes demonstrate sound study and collation of relevant data. Both reports are however let down by the very general nature of the recommended measures presented at the end which form the crux of the report. The authors are requested to re-think the recommendations and provide specific actionable items which may be taken up by relevant central and state agencies.	Recommendations have been made more action- and actor specific.
Comments from DFID on version 31-08-2015	
1. The Executive Summary should make more substantial references to the basin level plans.	Bihar and Odisha basin plan results have been incorporated.

	This should be presented as a stand-alone document as far as practicable, including the insights from the community surveys.	
2.	The draft version does not include the legal and economic analysis (except a generic section). It is important that these two parts should be suitably integrated into the main recommendations that are being formulated.	Sections are inserted Section 2.3 on Page 7, Section 2.6 on Page 11, Section 4.5.1 on Page 64, Section 5.3 on Page 77, Section 5.5 on Page 82, Appendix D on Page A-7 of Main Report
3.	The climate modelling exercise should include a brief statement on the level of confidence attached to the predictions, if possible. This would help place the modelling results in better perspective from the management point of view.	A section of confidence level has been included. Section 3.2.3 on Page 24 of Main Report
4.	Page 31: "Additional considerations regarding flood safety may come from the community survey, which identify specific community needs and which could adjust the purely economic CBA result." This in an important observation, but needs elaboration and preferably a backing-up by field data or observations in more detail.	A sentence has been added that links CBA results with community preferences, which for our two basins are in agreement.
5.	Page 54: "The Climate Change Adaptation Strategies for local impact……". This is an important section but consider if the strategies can be more specific and actionable at the appropriate level.	The strategies would have to be developed for each basin depending upon the flood modelling outputs and the socio-economics of the extended inundated areas. A paragraph has been inserted at the end of the section.
6.	There should be a brief para in the early part of the report, mentioning the reasons for choosing the two sub-basins and why they may be considered representative of river basins in India.	A footnote has been inserted referring to Phase 1 study and representativeness.
7.	Appendix A (Compliance with ToR) is very useful. However it is noted that certain deliverables like D15 are yet to be included. It is expected that the final version will include all the deliverables.	All deliverables are included Appendix A on Page A-2 of Main Report
8.	The photo on the cover page of the main report does not seem very appropriate. Please consider replacing this with another photo or graphic which represents the theme of this study.	New cover photo included
9.	The report needs some proof-reading before the final version is presented. In particular, please be accurate in referred to key institutions (for example, the name of MoWR has been changed but not reflected in some parts of the report).	Done

10. Please add a disclaimer for DFID along with that for ADB.	Done

Comments from NWM (4 November 2015)	
1. The effect/impact of deforestation and erosion in the catchment areas in both river basins need to be incorporated as separate chapters. Siltation is one of the main problems in Burhi-Gandak Basin, Bihar due to prevailing terrain conditions in the upper catchment, which has caused heavy sediment load in the River. This also need to be suitably discussed/explained in the report	Complied (see Section 4.4.3, Page 39 of Vol. 1; Section 5.1.3.1 Page 44 of Vol. 2 and Sections 2.1.3 Page 5 and 5.1.3.1 Page 38 of Vol. 3)
2. The Buhi-Gandak River Basin, Bihar falls under earthquake Zone IV. Hence, it should be ensured that the structures constructed for flood control shall be conforming to National Building Code of India, 2005 (SP(7): 2005). Criteria for Earthquake Resistant Design of Structures (IS91983):1984) and Recommendations for Seismic Instrumentation for River Valley Projects (IS(4967):1968). Same action is proposed for Brahmani-Baitarani River Basin, Odisha	-Complied (see Section 4.4.14 Page 60 of Vol. 1)
3. The name of M Dinesh Kumar in the Title Page should be omitted	-Complied
4. In the list of participants given it should be in the order by NWM-MoWR, CWC, ADB, RMSI Consultants, IRAP Consultants and other consultants. A draft list is enclosed.	-Complied
5. Provide some examples of best practices of flood preparedness and modelling studies in other countries in order to get a better picture of its usefulness in flood management	-New Appendix E-1
6. Incorporation of international best practices concerning community involvement in flood control and management need to be reviewed and presented.	-New Appendix E-2
7. Capacity building programmes for the communities for promoting Integrated Flood Management.	-Complied
8. Role of PRI's in flood management.	-Complied
9. Provide a standard format for preparation of village level community based flood preparedness plan.	-Complied
10. Non-structural measures for flood control need to be analyzed.	-Complied
11. Need to understand certain behavioral patterns among the communities affected by floods, which often pose hindrance to the officials of	-Complied

government agencies carrying out flood relief works.	
12. Many of the processes occurring in the basin are already incorporated in the study, of which modeling one component is. The model was used to analyze the impact of climate change on basin hydrological processes. The impact of deforestation could be made use of in the report, rather than making refinements in the model.	--Complied. Additional text and sections on land use, watershed and deforestation has been given in Section 4.4.3 of the Main Report and Section 5.2.3.1 in both River Basin Flood Management Plans (Vol. 2 and Vol. 3).
13. Road map may be prepared for implementation of the recommendations in a Phase wise manner.	Phases have been indicated in matrix
14. The recommendation of flood return period of 1:25 years in rural areas needs to relooked. Increasing it to at least 50 years return period may be considered. For semi-urban are as 75 years of return period flood may be considered.	Reference is made to the Return Period Paper.
15. Presently flood forecasting is issued on gauge to gauge correlation Bramhani-Batarini Basin but automation of the hydrological stations is most important. Hence a specific recommendation should be need for online monitoring and automation of the stations.	Reference is made to Section 4.4.11 Flood Forecasting and Early Warning, in which the automation of the observation network in India by CWC is mentioned. Also in Table 1 a specific recommendation (4.1) is made on automated hydromet stations.
16. The report should incorporate the erosion map and representative data of sediment load from the upstream to downstream of the river channel. Drainage congestion is one of the main factor for the rivers flowing in Bihar which is causing floods from past, the report needs to be account this factors. Specific cropping pattern, plantation or other structural measures with design need to be recommended for erosion control in the river basin.	Unfortunately there does not exist an erosion map for the watersheds. Representative data on sediment load of the Burhi-Gandak has been presented in Section 2.1.3. A new section (5.1.3.1) has been written in both River Basin Reports on watershed management.
17. A specific recommendations for the dissemination of flood forecast related warnings through SMS on the mobile networks, will provide access to very large no of stakeholders in flood affected area compared to other media like TV, Radio etc. Basin/Sub-basin wise hydro-meteorological networks/station shall be established on modern technology and recommended to assess the rainfall-runoff as long-term measures. For flood mitigation measures mainly online systems like decision support system (DSS) need to be more effective.	Best practices have been added to section 4.4.11
18. International best practices through networking of the stakeholders on the system of dissemination of flood forecast warnings and feedback need to be implemented in a PPP mode may also be considered as one of the recommendation	Best practices have been added to section 4.4.11

Comments/Observations on Typography (from National Water Mission, Ministry of Water Resources, RD & GR):

Cover page Main Report and Volumes: The National Water Mission name has not mentioned in the cover page of the report, after name of the Government of India. There is need to be include National Water Mission. Also, with Ministry of Water Resources there is a need be include River development & Ganga Rejuvenation.

1. Content page no iii: in the contents of the report need be include Executive Summary as Content with page no ix-xiv.
2. Content page no v: References and Appendices- page numbers need be mentioned.
3. Abbreviations page no v: the following abbreviations need to be revised
    i) BB: Bramhani-Baitarani river basin need to be changed as Bramhani-Baitarani river basin in Odisha
    ii) MoEF: Ministry of Environment & Forests need be change as MoEF & CC- Ministry of Environment & Forests and Climate Change.
    iii) In abbreviations NWM-National Water Mission, CGWB- Central Ground Water Board, DDMA-District Disaster Management Authority not mentioned. So, there is a need to include these three abbreviations.
4. Units page no viii: The characteristics of the units are not mentioned like

MWh-Mega Watt Hour need to be mentioned as unit of Energy, m- Metre as unit of Length, cm-Centimetre as unit of Length, mm- Millimetre as unit of Length, Cumec- Cubic Metre per Second as unit of flow-discharge, km-Kilometre as unit of Length and Sq. Km.-Square Kilometre as Unit of Area.

5. The page no need to be revised like Executive Summary in the report page no need be changed from i-vi to ix-xiv.
6. In the entire report where Ministry of Water Resources (MoWR) is written, need to be replaced with River Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD & GR). Page no 2 Para 1.3. Report Vol 2. Draft Basin Flood Management Plan for Bramhani-Baitarani need to be amended as Draft Basin Flood Management Plan for Bramhani-Baitarani river basin in Odisha.
7. Page no 2 Para 1.3. Report Vol 3. Draft Basin Flood Management Plan for Burhi-Gandak need to be amend as Draft Basin Flood Management Plan for Burhi-Gandak river basin in Bihar.

These issues have been corrected.

Comments from DFID (2 November 2015)	
We have the following additional comments on these sections: Burhi-Gandak:	
1. There is no new analysis in this section. What is presented is a review. We appreciate that time was not adequate to do any fresh assessment; however in the absence of any comment on the methodology used for the previous computation (that has been reported), the section does not seem to add significant value. Clearly this is a lacuna in the documentation process (not necessarily attributable to the Consultant); if details of previous calculation are not available, it would not be possible to update the computation based on updated data – this can possibly be a recommendation. It is not very clear if the section on Burhi Ganga Noon Baya Ganga link is the author's own computation or taken from NDWA – may be clarified. We suggest that the Consultant makes comments along these lines. Do the two projects have exactly same BCR?	As was indicated in the report Vol. 2 on the Burhi-Gandak for the Masan dam and Akharaghat barrage no details of the projects are given in the Government reports, so that an updated BCR could not be provided. We have now clearly included this in the Main report (section 5.3) as a lacuna. Furthermore, we have included in the same section 5.3 a number of essential recommendations for improvement of the current method of BCR. A sentence has been added to make clear that the section on the BNBG link is extracted from NDWA. Yes, the two projects have exactly the same BCR.
2. Proposed guidelines to improve the present practice are provided. We notice the absence of demographic variables here. It is assumed that all damage is agricultural. Please provide some justification to this. The Excel templates have not been provided.	New text replaces the previous guidelines in Section 5.3.1. (Pages 60 to 62 of Vol. 3). This includes demographic variables and damages other than agricultural. No Excel templates required.
3. On financing options, no indicative budget availability is given and the discussion is rather general.	The scope of the study did not permit a more detailed study of the state and national budget allocations, which are subject to political rationalities beyond the domain of flood risk management. However, additional text is given in Section 5.3.1 (Pages 62, 63 of Vol. 3)and an additional recommendation in the Main Report is given (recommendation 2.2d on Page xvi).
Brahmani-Baitarani:	
1. It is not clear how flood reduction has been converted to avoided damage figure of Rs 100 crore or other values. In this section, calculations are not clear. Please make this explicit.	New text replaces the previous guidelines in Section 5.3.1 (Pages 72-75 of Vol. 2) and includes formulae to convert flood reduction to avoided damage.
2. Same as in 2 above.	New text replaces the previous guidelines in Section 5.3.1. (Pages 72-75

	of Vol. 2) This includes demographic variables and damages other than agricultural. No Excel templates required.
3. Same as in 3 above.	The scope of the study did not permit a more detailed study of the state and national budget allocations, which are subject to political rationalities beyond the domain of flood risk management. However, additional text is given in Section 5.3.1 Pages 76, 77 of Vol. 2) and an additional recommendation in the Main Report is given (recommendation 2.2d).

Comments from CWC (4 November 2015)	
Main Report Para 5.1:	
1. In the past, most of the embankments were designed for 1:25 return period flood depending upon the norms specified in relevant BIS codes as per the importance of the area proposed to be protected at the time. Now, a lot of activities/developments have taken place in those areas, leading to change of their categories of greater importance, from socioeconomic considerations. Therefore, the embankments in such areas may need to be designed tor a flood of higher return period, say, of 50 years or more depending upon the level of socioeconomic developments. The design of existing embankments may need to be revisited in accordance with the recommendations of 12th plan working group on flood management and region specific issues.	The Consultants have gone through in detail the above report of the Working group of the Planning Commission, during the course of the present study. The Final Report details revisiting of the design of each and every component of an embankment, as extensively brought out in the section 4.4.6 of the Main Report in the two sub-paras 4.4.6.1 (page 46) and 4.4.6.2 (page 48). The Consultants also discussed details of the embankment construction practices in section 2.5 (page 9) of the Main Report. Slope-stability analysis and embankment protection works like riprap/pitching is discussed in the Annexure F (page A-35) of the Main Report. The status of the embankments in the Brahmani-Baitarani basin is detailed in the sub-para 5.1.1 (page 34) of Volume 2. The embankments improvements required in the basin are discussed in the sub-para 5.2.3 (page 64), with relevance to the standard criteria and analysis of the present high flood levels adopted for the existing embankments in the sub-paras 5.2.3.1 (page 64) and 5.2.3.2 (page 66), respectively, in Volume 2. Similarly, the status of the embankments in the Burhi-Gandak basin is detailed in the sub-para 5.1.1 (page 31) of the Volume 3. Inter-alia, the short-term and long-term recommendations of GFCC for flood mitigation measures are detailed in the para 5.1 (page 30). Also under the sub-para 5.2.2 (page 49), the analysis of embankments as a promising measure of flood control in the Burhi-Gandak basin has been brought out.
2. Although embankments play a major role to stop spilling water from the river during high floods exceeding the channel capacities, their use in combination of possible channel improvement, say, by dredging at some critical reaches may prove to be more effective.	This measure has been added in Section 4.4.6.1 (page 46) of the Main Report.
3. Integrated reservoir release information system, particularly in case of cascade dams located in series in a river basin has not been brought out in	Although cascades are not in our basins, these may be relevant for other Indian basins. A sentence has been added on

the document	optimizing reservoirs operations in Section 4.4.11 in the Main Report.
4. The approach of flood plain zoning needs to be taken up with states addressing their concerns about large flood prone areas, particularly, in the States of Bihar, West Bengal, Orissa, Assam, U.P. and Andhra Pradesh. Thereafter, and implementable approach need to be worked out conveying the States about effectiveness of flood plain zoning in undertaking measures of flood damage reduction.	This issue has been dealt with in the Main Report Section 4.4.9 (Page 54) and Appendix D (Page A-7).
5. Local building bylaws should have stipulations for encouraging the people adhering to the laws and some disincentive/penalty for those not honouring the laws. In the States with large flood affected areas, for instance Bihar, stilt type buildings can be considered to be constructed at raised platforms, say, above High Flood Level to provide passage for floodwater and also to utilise the space by the people of the area effectively.	Flood proofing has been mentioned at several places throughout the report. A specific note to the use of local building bylaws has been added in Section 4.4.9 (Page 54). Community Report Section 5.3.1 (page 26 of Vol. 6a and page 24 of Vol. 6b) mentions incentive mechanism for adopting flood proofing constructions.
Main Report Para 5.2	
1. CWC has already issued the modified guideline for preparation of DPR for river valley projects in 2010 which may be incorporated	The recommendations for upgrading the Guidelines given in the Main Report have been based on the Modified Guideline of 2010.
2. Under para 5.1, Brahmaputra Board is mentioned as erstwhile. Since the Board still exists the word 'erstwhile' is not required at present. The appraisal of the schemes is not done by the Brahmaputra board. This may be corrected.	This has been corrected.
Para 5.3	
The current practice of flood damage assessment does not account for the loss of human lives due to floods. Therefore, this loss needs to be factored while assessing benefits of a flood management project.	Text and recommendation have been added in Section 5.3 (page 78) of the Main Report
Para 5.4	
The economic analysis given as page no. 70 must also include the Post Disaster Needs Assessment (PDNA) which is the area of concern where recovery efforts need to be concentrated. The methodology of flood damage assessment may be based on the procedure given in PDNA.	PDNA has been added in Section 5.3 (page 78 and Box 12 on page 79) of the Main Report
Para 5.5	
For effectiveness of the river basin management existing CWES (Central Water Engineering Service) needs to be converted into all India service for having common approaches among the states in a basin. Any	This suggestion is noted, but requires more discussion within the Government.

other institutional setup with such an integrated management may also be thought of.	
Para 5.6	
Peoples participation in flood management may be seen as a prospective tool and may be of great help. For this, the local bodies like Gram Panchayats or their group need to be associated in the IFM at all levels right from planning to execution and maintenance and supervision.	This has been mentioned in many parts of the reports, for instance Sections: 2.3 (page 7), 4.4.10 (page 55), 4.5.1 (page 64), 5.6 (page 83) and 5.7 (page 83) of the Main Report and also in the Volumes 6a and 6b (Community Survey reports).

Comments from CWC (5 December 2015)	
1. Based on the outcome of the study, actionable flood management plan may be made and prioritize the activities.	A new Section 7.2 is included in each of the Basin reports (page 88 Vol. 2 and page 74 Vol. 3), which present a multi-criteria analysis for prioritising measures.
2. Devise a framework for collecting and collating the flood damage data for flood risk assessment quantitatively and its relations with various structural and non-structural measures.	A reference is given to the GFDRR Guidelines for PDNA (Section 5.3 page 78 and Box 12 on page 79 of Main Report). Also mentioned in Recommendation 2.1. (page xv of Main Report)
3. Carry out flood plain zoning.	Floodplain zoning is mentioned at several places in the Main report. A detailed discussion is given in Section 4.4.9.
4. Start using the flood models developed under the project (SOBEK) for flood forecasting in the two river basins.	This suggestion has been incorporated. A new section 5.8.2 (page 85) has been included in the Main Report mentioning the follow-up activities that need to be done for using the models for flood forecasting.
5. Model calculation indicates that by providing 1:25 safety standard for rural areas around 90% of the average annual damage could be avoided. In this context it needs to be mentioned that for the schemes where only construction of embankment is proposed (in agricultural areas) for flood management, the return period of flood is considered as 25 year as per provision in IS 12094:2000.However, if embankments are proposed along with anti erosion works like Groyne etc. in agricultural areas, which is quite common case, these are to be designed for 50 year return period as per IS 8408:1994. Further, in view of present economic development scenario of rural areas as well as of urban areas, cost of damages involved by flood or submergence is very high. Hence cost benefit ration for greater return period may be positive. In respect of psychological point of view, safety from flood after construction of embankment, enthuses confidence in behavior as well as in economy of protected area. Hence for uniformity, design flood return period for flood embankment with anti erosion measures in rural areas may be adopted as 50 years. There is no point in designing embankments and revetment/pitching on embankment/river bank side or Groynes for different return period. Hence it would have been more prudent to carry out the flood risk assessment study for the 1:50 safety standard also.	When applying a safety standard for a protected area it should not matter how the embankment is constructed, be it with or without anti-erosion measures. It seems irrational to use a safety standard of 1:50 years for embankments with anti-erosion measures and 1:25 years for embankments without. With respect to code IS 8408:1994, there is an ambiguity in understanding. It is not clear whether the composite structure of embankments and anti-erosion is to be designed to protect the land from 1 in 50 year flood or else, the anti-erosion works only are to be designed to withstand such 1 in 50 year flood. If the former is correct, there is a difference/contradiction between the two Codes. As correcting the codes is beyond the scope of our ToR we recommend the constitution of an expert group by the Government to iron out unambiguous criteria in the Code. In this context it is cited that the sub-paragraph 4.4.6.2 of the Main Report (page 48), elaborately deals about the present criteria for the design of every component of an embankment along with the recommendations for improvements for the existing criteria. Additionally, the assessment of safety standards is based on economic sound measures as among others described in section 4.3.2. (page 35) of the Main Report.

		An economic assessment of safety standards implies that many different return periods are assessed. The fact that a 1:25 year safety standard could avoid around 90% of the average annual damages is a result of this economic assessment. From this we cannot and did not conclude that the economic optimum for all rivers is 1:25 year. This also depends on the cost of the measures. In Section 4.3 of Volume 2 (page 30) an example CBA is worked out for Jenapur area. In the case of Burhi-Gandak which has meandering river course it is important to have anti erosion structures to avoid breach of embankment rather than increasing the height of the embankment based on 50 year return period.
6.	In terms of flood hazard, climate change is expected to cause heavier rainfall events and can lead to significant increase in flood extent(in order of 25 % in 2040 and perhaps 30% in 2080 in case of Brahmani –Baitarni . In this regard it is to mention that it may be better to furnish a factor for quantum of increase in design discharge due to climate change above the calculated design discharge by conventional methods.	The idea posed with the comment is very interesting. In this study a dedicated climate change assessment for both river basins have been applied. This is described in chapter 3 of the Main Report. A dedicated climate change assessment allows for local perspectives on e.g. which climate models perform best, what emission scenario should be studied, and maybe local rain gauge data is of high quality to be used for bias correction. Due to the scale of the Indian river basins it is to be advised to carry out these kind of dedicated climate change assessments. Performing such studies might not be feasible for each project. Then, a factor for quantum of increase might be very relevant so all future projects in that area can use those numbers. The suggestion is included in the Executive Summary.
7.	As part of institutional arrangements, it has been proposed to create a project preparation cell for integrated flood management in each state WRD and at central level at CWC under chief engineer PAO consisting multidisciplinary team in the interim period till RBOs set up. It needs to be pointed out that at CWC HQ, a separate Flood Management Organisation exists which obviates the need of creating project preparation cell at center level. The field office of CWC are of basin wise, till setting of RBOs, these offices may given the active role along with state WRD for project preparation with a basin wise IFM approach.	Noted and agreed. The last paragraph in Section 4.5.2 of Main Report (page 68) has been modified to effect the necessary modifications.

8. It has been recommended to revitalize the existing RBOs or restructuring exiting organization such as National Ganga River Basin authority and GFCC into one RBO. It needs to be pointed out that presently no RBO is existing and National Ganga River Basin Authority and GFCC are also not RBOs and have been established for different functions and can not be merged into one RBO.	Noted and agreed. The first recommendation in the Table (in the Main Report under Legal and institutional recommendations, page xiv) is modified to effect the needed change.
9. The suggestions regarding changes in BC ratio analysis by including future economic growth, change in cropping pattern, indirect damages etc not appear to be appropriate as it can not be assessed properly.	It is indicated in the report to do so by using scenario analysis, which is a common method for accounting for future changes in flood risk studies.
10. One of the objectives of the study is to demonstrate that flood risks can be reduced through a broad mix of flood management measures, typical for Indian context, with specific considerations for climate change. It has been mentioned that as part of the Integarted Flood management(IFM) at basin level, several structural and non structural measures/strategies should be used. However, risk assessment study to arrive at a well balance optimal combination of measures has not find place in the report.	We showed that a combination of structural measures can reduce flood risk but not eliminate them. Therefore also non-structural measures are needed. In both Basin Reports (Section 7.2)and in the Main Report (Section 5.1 page 73)a multi-criteria analysis has now been included for prioritising among structural and non-structural measures. What is an optimal combination depends on the criteria which need to be agreed upon by the main stakeholders.
11. The study should also include the impact of climate change on availability of water resources vis-à-vis increasing demands of various sectors for future growth periodically with available state of the art technology.	The impact of climate change on availability of water resources is not within the scope of the study.
12. Actor(s) involved under para 3.1(b) (Climate Change Downscaling studies)should be NWM, MoWR, RD&GR instead of CWC and under para 3.1(c)(Preparation of Flood Risk map) should be WRD/NDMA/SDMA.	Has been changed.
13. Actor(s) involved under para 4.3 (Review of Reservoir operation rules) should be WRD/CWC.	Has been changed.
14. There is no mention of construction material used in the present embankment, their quality and recommendation regarding scope of using durable geo-synthetics material etc., for improving embankment's performance.	A vivid coverage of the construction materials used and their quality are now discussed in a new sub-paragraph in the Section 4.4.6.2 of the Main Report (pages 51 and 52), where the construction practices of the embankments are reviewed. The heading of this sub-paragraph is "Construction material and recommendations for the use of geo-synthetics"
15. The vulnerable location of the embankment details has been indicated. However, special breach and inundation studies have not been conducted. Recommendation for conducting	Noted. A section on Recommendations for further study (section 5.8.1) has been added (page 85).

breach and inundation studies to have better preparedness to face the situation for vulnerable locations for breaches/overtopping and mitigation of flood damage needs to be included.	
16. Framework for Flood forecasting and warning system and Recommendations regarding required staff strength and technology of Hydro-meteorological observation needs to be provided in the report.	A new Appendix H is prepared with a Framework for Flood Forecasting (Main Report page A-42).
17. The projections on change in rainfall indices of two river sub-basins have been studied and likely impact of flood hazards have been assessed. There may be change in the main river Ganga due to climate change therefore flood scenarios in Budhi-Gandak should have been developed after considering the impact of climate change on main river Ganga.	The comment posed is a very valid and relevant one. Of course climate change will not only affect the flow patterns of the Burhi-Gandak river basin, but also the larger river basin of which the Burhi-Gandak river basin is part. As water level of the Ganges River influences the drainage capacity of the downstream part of the Burhi-Gandak River it might have been assessed. However, it should be noted that in such case a new climate change downscaling assessment should have been carried out and a new hydrological and hydraulic model should have been developed. The Ganges river basin being approximately 90 times the size of the Burhi-Gandak river basin, such analysis was not feasible within the scope of services of this study.
18. Rainfall Runoff (RR) model and combined model both need to be explained separately.	The RR model for both basins has been described in Chapter 4 of the Volumes 5a and 5b. The hydraulic model has been described in Chapter 5 of both volumes. The calibration and validation of the combined model has been described in Sections 5.3 and further.
19. Framework for regulation of crop insurance may be provided in the report.	A new Box 13 in the Main Report (page 81) is added with main features of crop insurance regulations in India.
20. There are many typographical errors in the report which may be rechecked and corrected.	We rechecked.
21. The forcing factors for flood are rainfall in the catchment, the operation of Rengali dam and other reservoirs, coastal storm surges in the Brahmani-Baitarani basin. Thus, the risk of certain flood can be attenuated by proper regulation and releases prior to and during the flood event with proper flood forecasting. The vulnerability of flood can be managed to reduce risk considering the effect of barrage at Anandpur for Baitarani sub basin. The similar effects need to be considered for the basins under report.	The risk of a certain flood can indeed be attenuated by proper regulation and operation management prior and during a flood event. This comment is therefore very relevant and indeed it was assessed as one of the strategies for flood reduction. This assessment was carried out focussing on Rengali dam flood buffer optimization. Also the potential flood cushion of Balijhori Dam has been modelled. See Section 4.4.4 in the Main Report (page 42) and Section 7.2 in Volume 5b (page 79 of Modelling report

	BB).
22. The demands for upcoming industries and the proposed schemes are to be considered for estimating the flood hazards. For example, the discharge from Anandpur barrage at the rate of 165 cumec for Kharif in the monsoon can reduce flood hazard to certain extent. Likewise, effects of other schemes may be considered in the basins. The future demands like demands for industries, increasing population, proposed schemes, irrigation needs etc. have not taken into consideration while calculating flood hazards.	Demands of upcoming industries and increasing population indeed have an impact on the future flood hazards. Known proposed schemes that are in the pipeline and probably will be developed in the coming years have been taken into account. This has been described in Section 7.2 of both Volume 5a and 5b (pages 64 and 79 of Modelling Reports, respectively). Also in the basin reports Sections 5.1.2 and 5.2.1 of Vol. 2 and 3, respectively, a description of the proposed schemes can be found. The discharge from Anandpur barrage at the rate of 165 cumec is included as such known proposed scheme. It might be recognized that including future demands of upcoming industries not yet known to proposed schemes in the flood modelling framework is quite challenging. Apart from the uncertainty on how these demands will evolve, their combined water demand might still be relatively small in comparison to a 1:25 year flood event.
23. The probabilistic approach needs to be simulated with potential (extreme) events which may cause flood, cyclones and the worst combination of the both.	Correct. The project did exactly that; simulating potential extreme events of torrential rain, storm surge and their combination. This is mentioned in Section 7.4.2 page 88 of Volume 5b. In reply to this comment, Section 7.4.2. is extended to increase understanding of how the probabilistic approach is applied in this project.
24. There is no mechanism at present to coordinate the inter/intra basin level water management for flood and other such extreme events. Flood hazard adaption strategies at basin level need to be stressed upon.	The relevant paragraph in Section 4.5.2 (page 68) of the Main Report dealing with functions of RBOs is now expanded to include adaptation strategies and inter-basin coordination.
25. There remains a gap in the modeling to conclude the hydrological and hydrodynamic models. The full basin has to be calibrated for the rainfall runoff modeling and results should not be assumed as final by calibrating a part of basin.	The hydrological models and the hydro-dynamical models have been calibrated separately whenever this was possible. In case of the Brahmani-Baitarani basin the hydrological model of the basin upstream of Rengali dam was calibrated separately. The calibration of lower Brahmani-Baitarani basin was done with the combined model because we did not have sufficient flow gauging stations in the hydrological model area to do a stand-alone calibration for the hydrological model. This was also the case in the Burhi-Gandak basin, where we also

	did not have sufficient flow gauging stations in the hydrological model area to do a stand-alone calibration for the hydrological model. Instead, we calibrated the combined hydrological-hydro-dynamical model, since we could use the data of a number of gauging stations in the main river. We strongly recommend to extend the network of gauging stations and record the relevant data at a short time interval to be used in future upgraded version of the models.
26. The assumptions made in the rainfall runoff modeling, climate and other models should be properly documented.	The assumptions for the RR and hydraulic modelling have been documented in the Model Reports Vol. 5a and 5b (chapters 4 and 5). Assumptions for the forcing factors, such as climate change have been given in chapter 6 of both modelling reports. Assumptions for climate change downscaling are given in Sections 3.2 of the Basin Reports (Vol. 2 and 3).

Comments from Ministry of Agriculture (26 October 2015)	
1. Conclusions and recommendations of the study in terms of Integrated Flood Management (IFM) are noted.	Noted
2. With reference to requirement for addressing agriculture in IFM, key recommendations / interventions mentioned in the study are being addressed under all major programmes of Ministry of Agriculture & Farmers' Welfare including National Mission for Sustainable Agriculture (NMSA). Further, PMKSY also addresses issues related to strengthening of water bodies/structures, water conservation / management and watershed treatment which have relevance to IFM.	Schemes have been added to section 5.4. of Main Report (Box 14 pages 81, 82)

Comments from WRD Odisha 20 November 2015	
1. With respect to the different recommendations made basing on the model study, a blue print has to be prepared for implementation in a Phase wise manner	The Recommendations listed in the Table at the beginning of the Main Report (Executive Summary) now indicates the preferred phases for implementation of all recommendations.
2. The recommendation of flood return period of 1:25 years in rural areas needs to be re-examined. It has been pointed out that by providing the 1:25 safety standard for rural areas around 90% of the average annual damage could be avoided. Its confidence level may please be reassessed.	This is a valid comment. The comment asks specifically to reassess the confidence level where currently a deterministic approach has been applied. This method was chosen as the uncertainties in the full modelling chain – from rainfall runoff, HD and 2D hydrodynamic modelling to the economic assessment – includes many different scales of uncertainties. If all these uncertainties need to be quantified it would require many more simulations than currently run. When a basic approach would have been followed, e.g. three flood model results (e.g. 25,50,75 percentile) and three different damage assessments, then that would have resulted already in 9 simulations for 1 measure. For the 17 cases in the Burhi-Gandak basin this would imply an additional 136 model runs. The comment is certainly a valid one, however in view of the project - showcasing flood risk management approaches in two river basins – an extended uncertainty and confidence level assessment was deemed out of scope.
3. Presently, for Brahmani-Baitarani Basin gauge to gauge correlation is used for flood forecasting. Recommendation should be needed for online monitoring and automation of the stations.	Noted. Recommendation 4.1 now explicitly mentions automation of stations and improved data transmission.
4. Sediment load and its effect from the upstream to downstream of the river channel, drainage congestion and tidal effects etc. should be taken into consideration and incorporated in the report.	Sediment issues are mentioned in Section 2.2 (page 6) and 5.1.3.1 (new text) page 44 and 45 of Vol. 2. There is a special section on urban and rural drainage (5.2.4 page 68 Vol. 2) and tidal effects are included in the flood model (Section 6.7 page 73 in the Model Report Vol. 5b).
5. The modern design criteria for raising and strengthening river embankments may be attended to.	Reference is made to Section 4.4.6 page 46 of the Main Report (Suggestions for improved design of embankments), where also a new paragraph has been added on Construction material. In both Basin Reports a paragraph has been added to the sections on Embankments, which refers to the Main Report.
6. Specific cropping pattern, plantation to control the erosion be recommended for erosion control in the river basin along with erosion mapping.	Section 5.1.3.1 page 44 and 45 of Vol. 2 is dedicated to watershed management and is now further extended.

	Detailing cropping patterns for the basins is out of the scope of the project.
7. Basin/Sub-basin wise hydrometeorological networks/stations shall be established on modern technology and recommended to assess the rainfall runoff as long-term measures. For flood mitigation measures mainly online systems like decision support system (DSS) need to be more effective. Best practices through networking of the stakeholders on the system of dissemination of flood forecast warnings and feedback need to be implemented.	Noted. Please refer to Recommendation 4.2. page xv11 of Main Report. Also text is added in section 4.4.11 page 56 ,57on this issue. See also comment 16 van CWC.

Comments from NIH (November 2015)	
1. The study has been carried out using the SRTM DEM. In future studies higher resolution DEMs may be used (such as 10m Cartosat DEM or any other higher resolution DEM)	The Cartosat DEM as free downloadable from the Bhuvan Portal has been assessed on suitability for flood risk modelling. It was concluded that this Cartosat DEM was not yet suitable for that purpose. This is mentioned in Section 3.1.2 and 3.1.3. of Volume 5a and 5b (Modelling report). It was therefore considered to purchase higher resolution Cartosat DEM having a horizontal resolution of 10m and vertical accuracy of about 4m available with NRSC. However, it was observed that the cost of this high resolution Cartosat DEM data (vertical accuracy of 1m) would require around US$ 511,500 (only Brahmani-Baitarani river basin) that exceeded the budget available under the survey and data component in the present study.
2. Flood hazard mapping and required inputs for flood plain zoning should be provided considering the floods of various return periods and 2-D hydrodynamic modelling of areal extent, depth, velocity and duration of flooding, economic and other considerations. Such information would be helpful for the state governments for flood plain zoning.	Flood hazard maps have now been provided for each of the return periods for both the Brahmani-Baitarani basin and the Burhi-Gandak basin in Chapter 3 of Volumes 2 (pages 14 to 16) and 3 (pages 13-15), respectively. These show the flood extent and the maximum flood depth in meters at any of the grid cells of the 2D-grid of the SOBEK-model. Velocity and duration are not provided within this project since the damage assessment is done with applying damage curves which describe the relation between damage fraction and flood depth only. The model can provide overland flow velocities and duration of flooding once a more detailed schematization is implemented including the local drainage network and when more sophisticated damage functions are available.
3. The impact of flood situation particularly in Brahmani-Baitarani Basin due to cyclonic storm accompanied by torrential rain as well as with tidal surge should be studied *(for example super cyclone, which occurred on October 29, 1999; Cyclone Phailin, which occurred on October 12, 2013)*.	The project used a probabilistic approach to assess the impact of extreme events resulting in floods. This approach included tidal surge and extreme torrential rain, both separately and combined due to e.g. a cyclonic storm. This is mentioned in Vol. 5b Sections 6.4 (Rainfall), 6.7 (Sea boundaries) and 7.4.2 (Probabilistic approach using the Hong Kong method). Hence, the flood risk assessment of the Brahmani-Baitarani river basin includes the impact of tidal surge and extreme torrential rain on the flood situation.
5. It seems that the residual risk will be high in case of Brahmani-Baitrani Basin as mentioned in	Flood early warning, hazard mapping and floodplain zoning are indeed essential

the report that flood extent will largely governed by back water effect due to sea level rise in future scenario under climate change. For such a situation real time early flood warning system as well as flood hazard mapping and flood plain zoning should be brought out.	measures for integrated flood management. These are described in 4.4.9 and 4.4.11 in the Main Report.
6. It is mentioned that there will be 25% to 30% increase in flood extent in 2040 and 2080 respectively due to climate change. It appears to be high and hence uncertainty analysis of this increase in flood extent should be carried out. The factors like land use land cover changes may also be considered in the study. Further, the duration of flood and estimated population to be affected by flood should be assessed and mentioned for providing more insight in the decision making.	The comment focusses on the fact that for flood risk assessment in 2040 and 2080 also changes in land use land cover should be considered. Additionally, the estimated population to be affected in those reference years should be taken into account. Because of the long time horizon such issues are usually taken into account through a scenario analysis. Valid as the comment is, a scenario analysis for socio-economic, demographic and LULC projections was outside the scope of the current study. The objective of this project was to provide a first estimate of what might happen in these two river basins due to climate change. A follow up analysis should preferably include LULC-changes, and population scenarios. This has now been included in Section 5.84 page 86 of Main Report ("Recommendations for further study and follow-up")
7. If the rainfall data for estimation of floods of various return periods has been downscaled at daily interval; then, the rainfall estimated for various return periods (computed from the daily rainfall) should be converted into hourly annual maximum rainfall for the given return period based on the pattern of SRRG data of a SRRG lying in the study area for severe storm(s). Otherwise, u*sing the annual maximum rainfall series based on daily data for frequency analysis would provide lower estimates of floods of various return periods.*	Practically, at the time of the setup and calibration of the simulation models, no usable hourly rainfall data were available. Instead, daily rainfall data has been used. It can be discussed if the usage of hourly rainfall data would yield a higher estimate of the computed flood extent. The computed flood extent is in fact the result of the cumulative rainfall for a certain simulated period. The time scale of flooding and the reaction time of a flood extent are much longer than one hour. It is unlikely that a single hourly high rainfall event is directly reflected in the flood extent. We agree that a row of high hourly rainfall events would probably influence the flood extent, but in that case the shift towards the use of daily rainfall data is also a good representation.

Comments from WRD, Bihar (2 December 2015)	
1. Legal and institutional recommendations 1.1 Create or revitalise RBOs for IFM policy and strategy development a. WRD agree with the view. State govt. should be represented in the newly framed RBO b. Agreed c. Project preparation cell already exists under Chief Engineer, Hydrology. This organisation need to be linked with CWC; so that CWC norms might be followed.	Noted Noted The Recommendation 1.1 and the last paragraph in Section 4.5.2 (page 68) of Main Report is now modified to reflect the required changes in the light of this comment as well as the comment # 7 from CWC pertaining to Project Preparation Cell
1.2 Improvements in legal framework for IFM a. Bihar govt. is under way to frame its own State Water Policy under umbrella of National Water Policy 2012. State Flood Plane Zoning bill is not implantable in in Bihar as it will obstruct pace of development due to high density of population. b. Not related as stated above c. Not related as stated above	Noted. The Recommendation is generic and addresses all States in India. As such it may be not applicable for Bihar.
1.3 Institutional coordination Bihar has already implemented SOP for flood	Noted
1.4 Organisational strengthening a. Agreed b. Agreed, WRD Bihar is planning to fill existing vacancies c. Agreed. WRD, Bihar is strengthening field staff by providing modern equipments and technology	Noted
1.5 Capacity building/training in IFM a. WALMI and FMISC under WRD, Bihar is already working for capacity building. b. As stated above.	Noted
2. Economic recommendations 2.1 Country-wide standardization of damage assessments a, b, c are not related to WRD	Noted
4. Recommendations on flood risk mitigation measures 4.5 Improve rural drainage to reduce waterlogging problem b. As per requirement WRD, Bihar continuously improving drain network system.	Noted
4.6 Improve flood cushioning in the basin a. Not related to WRD, Bihar b. WRD, Bihar and MWRD, Bihar are working in this area	Noted
4.7 Improve urban drainage a. Not related to WRD, Bihar b. Already properly maintaining department existing water related infrastructure.	Noted
5. Community level recommendation	

5.1 Include communities in major flood management interventions a. Carried by WALMI, Bihar and Disaster Management Department, Bihar. b. as stated above.	Noted (WALMI, Bihar and SDMA carry out awareness and capacity building activities at institution and community level. However, we recommend to have community involvement in major flood management project which can be in the form of consultation/public hearing before project formulation, involvement of communities in maintenance of flood control structures like sluice gate desiliting, including them in the flood committees of WRD, involving them in monitoring of embankment (during normal time and during flood), etc. These are further explained in the section 5.6 “5.6 Proposals to mainstream community needs into IFM” (page 83 of Main Report)
5.2 Introduce/revitalize disaster preparedness in vulnerable communities a, b, c, d is not related to WRD, Bihar but Govt. of Bihar agreed with mentioned recommendation.	Noted
5.3 Protect livelihood to increase resilience a, b, c, d is not related to WRD, Bihar but Govt. of Bihar agreed with mentioned recommendation.	Noted

Comments from WRD, Bihar (14 December 2015)	
1. The river Burhi Gandak originates from Chautarwa Chaur near Bisambharpur in the District of West Champaran in Bihar and flows through the districts of East Champaran, Muzaffarpur, Samastipur and Begusarai. It outfalls into the Ganga near Khagaria. The River Kosi originates at an altitude of over 7000 m above MSL in the Himalayas. The upper catchment of the river system lies in Nepal and Tibet. It enters the Indian territory near Hanuman Hagar in Nepal. It joins the Ganga river near Kursela in Katihar district. The distance of outfall of Burhi Gandak and Kosi in river Ganga is too far to affect each other. This needs to be re-examined.	The original text of Section 2.2 in Vol. 3 (page 5 and 6) was a bit confusing. It has been adjusted.
2. Kosi and Burhi Gandak can't be treated as a single channel because of the reason stated above.	See above. Text has been adjusted.
3. Return period is an important parameter in flood design, considering the recent study on the climate change a specific suggestion on return period should be incorporated in the report. Suggestion on adoption of return period according to type of structure should be given as per current practice adopted in developed countries.	Return period is indeed an important parameter in flood control design. Reference is made to the special paper on Return Periods which has been written by the Study team, in which also current practice in other countries is reviewed. The impact of Climate Change is discussed in Section 3.3 of the Vol. 3 report and flood maps for different return periods are presented in Section 3.1.
4. Model analysis on Burhi Gandak river should be done considering the effects of its tributaries also.	The tributaries of the Burhi-Gandak River have been included in the SOBEK model analysis, namely Non, Thalhi, Nuna , Baghmati, Chaknada, Santi, Bainti, Chanha, Jamwari.
5. The report mention, 19 rain gauge stations in the catchment, out of which seven are being maintained by the IMD and the remaining twelve are maintained by the State Government of Bihar. However in practice State Government of bihar have only eight flood forecasting site namely Lalbegiaghat, Sikadarpur, Samastipur, Roesar, Khagaria, Dalsingh Sarai, Shiv Ghat, Dadaul Ghat. Data from these station should be considered in analysis.	This has been corrected in the Section 2.1.2 of Vol. 3 and in Section 2.2 of Vol. 5a. It is mentioned in Section 5.3.3 (page 47) of Vol. 5a that 8 rain gauge stations have been used in the modelling analysis: Chanpatiya, Lalbegiaghat, Ahirwalia, Muzafarpur, Samastipur, Rosera, Khagaria, and Simara (in Nepal). Data from these stations was considered in the analysis.
6. The report should also include the guidelines on adopting both tangible and intangible losses due to flood while calculating Benefit/Cost ration in DPR for flood related works.	Section 5.3 (pages 78,79) of the Main Report includes a recommendation for adopting indirect losses and a recommendation for adopting loss of life in the B/C ratio